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INDUSTRIAL MANAGEMENT

by

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PREFACE

This book has been written with the hope that it will be useful to students of industrial management, whether they are actively engaged in the management of industrial enterprises or learning the fundamentals for the first time.

The text and problem materials contained in this book have been used effectively in teaching industrial management to students of business administration, engineering, and liberal arts during the past twelve years. Moreover, a considerable portion of the contents is based on actual business and consulting experience of the authors. The principles are not untried theory, but have been formulated and recorded after successful application in many different types of manufacturing industries.

This textbook differs from others on industrial management in these respects:

1. *Scope.* The subject matter is confined to topics of immediate and vital concern to persons who must direct the work of others in manufacturing enterprises.
2. *New Material.* A considerable portion of the subject matter presented has not appeared in organized textbook form prior to the publication of this volume. This is particularly true of the parts dealing with the Management of Physical Property, Production Control, and Cost Control.
3. *Unit Treatment.* In recognition of the fact that all topics of industrial management are closely related, the entire book has been organized so that the related aspects of any one topic in the field of industrial management are presented as a unit. For example, the subject matter of motion study is treated in two separate chapters; one chapter discusses the principles of motion study as they pertain to the organization and layout of the physical plant, in Part III, and the other chapter as they pertain to the effective use of manpower, in Part IV.
4. *Problems.* Each of the six main parts of the text is followed by problems which require solution. These problems are incorporated in this text in the sincere belief that the student of management gains a real understanding of management principles only when required to make application of them.

ACKNOWLEDGMENTS

No textbook is ever wholly the work of one or two people. It is the result of years of experience, association with others, combinations of ideas, and nearly always special debts are due particular persons who make particular contributions. Seldom is a person wholly competent to do a first-class job in every aspect of a broad subject such as industrial management. The authors are indebted to many persons for contributions to this text.

A special debt of gratitude is due to Mr. Loring M. Thompson, formerly instructor in Industrial Administration and Research Assistant in the Bureau of Business Research at Northeastern University, for his tireless effort in organizing and developing materials contained in Parts I, II, and III of this text. His collaboration in the research, organization, and preparation of these parts of the text made possible a more complete and competent treatment of the subject matter contained in them.

Space prevents mention of all the others who have contributed to the completion of the manuscript. The following, however, deserve special thanks and comment: Mr. Thomas Harris, Director of Occupational Services, Boston Y.M.C.A., Huntington Avenue Branch, for preparing materials on selection and testing of employees; Mr. H. H. Kerr, District Representative, and Mr. Gilbert H. Tapley, Assistant District Representative, Training Within Industry, War Manpower Commission, District No. 1, Boston, Massachusetts, for their kind assistance in making available special materials on quick industrial training programs for war industries; Mr. H. W. Heinrich, Assistant Superintendent, Engineering and Inspection Division, The Travelers Insurance Company, Hartford, Connecticut, and Mr. Robert Clair, Supervisor, Industrial Safety Education, Liberty Mutual Insurance Company, Boston, Massachusetts, for information on safety engineering; Mr. Frederic V. Hetzel, author of *Belt Conveyors and Belt Elevators*, for permission to reprint his tables for solving material-handling problems; Mrs. Lillian Gilbreth and Mr. Allan H. Mogensen for permission granted to use materials on motion study principles; and Mr. Warren Ganong of the Northeastern University faculty for his suggestions contained in the chapter on Time Study.

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Many of the diagrams and pictures used to illustrate the text would not appear except for the courtesy of business and industrial organizations whose names appear as *courtesy lines* wherever appropriate.

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ASA S. KNOWLES
ROBERT D. THOMSON

Boston, Mass.
December, 1943

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INDUSTRIAL MANAGEMENT

PART I

INTRODUCTION

The six parts of this text deal with different, but closely related subjects of industrial management. While an attempt has been made to have each part a separate unit, the reader must bear in mind constantly that each of the six parts is merely a segment of the whole book. Any one of the subjects of management can be best understood when one knows something about all the others, but unfortunately all the topics cannot be presented at one time. Consequently, in reading this text particular attention must be given to making the topics of industrial management fit together as a unit.

Part I, which is the introduction to the text, consists of two chapters. The first focuses attention on the significance of management in an industrial democracy, and who should profit from a study of management; the second chapter presents an over-all view of the scope of activities involved in carrying out management functions. More specifically, these chapters cover the following:

1. **The study of management.** This is intended to be an introduction to the subject of industrial management. It is designed to acquaint students with "the first principles of management" and to stress their significance in relation to the study of all management problems.

   Attention is called in this chapter also to the importance of the study of management for students of business administration, engineering, and liberal arts, as well as others; and since most successful businesses are a reflection of the capacities of persons who have inherent qualities for leadership and direction, an attempt is made to show how management is in reality an art which has direct bearing on a great many occupations and professions.
2. **Budgeting — an over-all view of management.** In order to grasp basic management principles, one must have a clear understanding of the total range of the subject matter of the field. The study of budgeting is a means of accomplishing this because it embraces all the branches of activity involved in organizing and controlling an industrial enterprise. In many respects, *budgeting is synonymous with management* since both are concerned with the system-

atic, intelligent planning and control. Moreover, all management decisions must be sound from the budget standpoint, as well as technical standpoint.

In particular, Chapter II acquaints students with the classifications and interrelations of budgets together with techniques for developing budgetary procedure and control. Special attention is given to budget reports which deal with the control of the fundamental purpose of a manufacturing enterprise — finished goods.

The discussion of budgeting as an introduction to this text, therefore, provides an opportunity to obtain a knowledge of fundamental management principles and at the same time to get an over-all view of many of the objectives sought through application of management principles.

CHAPTER I

THE STUDY OF MANAGEMENT

Management is unique among the arts and sciences. The need for management is universal and the application of its principles determines to a large degree the success of any undertaking. A home must be well-managed before it can be neat and attractive; an industry must be well-managed in order to prosper.

A manager must possess both knowledge of the thing he is managing and skill in the application of management principles. *Industrial management* is the profession of planning and controlling the use of men, materials, money, and machines for production. The industrial manager, therefore, must possess a broad knowledge of business and industry, as well as a complete understanding of basic management principles which have application in the solution of manufacturing problems.

Unlike other professions, that of industrial management must never become too highly specialized. If it does, it ceases to become management in the full sense of the word; management is concerned with the harmonious coordination of all the parts of a business to the end that all its parts function smoothly as a unit. Many of the arts and sciences are continually being subdivided into highly specialized branches. Each is so complicated that a lifetime can be devoted to its study. A mechanical engineer may become a specialist in power plants, aircraft structures, or ventilation in order to become more proficient in some one thing and thereby command a high salary. Similarly, men may devote their lives to becoming specialists in particular branches of law, chemistry, merchandising, art, and music. Contributions of all of these experts are indispensable to progress in modern industrial society. There is a great need also in an industrial society for specialists in particular phases of industrial management to give purpose and direction to specific aspects of a production program — methods, training, cost control, and so on.

Those who would become professional managers and rise to the top of their profession, however, must guard against specializing in any one branch of the management field, and must develop the faculty to see all of its branches as interrelated units. When persons who aspire to become members of top management confine their knowledge to only a few aspects of the thing being managed, they are at a loss in handling

those aspects of the work with which they are less familiar. They lack the broad knowledge necessary to control or manage the enterprise as a whole effectively. For example, when a sales manager is promoted to the position of general manager he must cease being a specialist in sales and obtain a more general knowledge of the entire business in order to control other activities such as research and production planning.

The more general and widespread a man's knowledge, the higher the managerial position he is qualified to hold, provided he is also able to apply management principles. If a man's knowledge is limited to machine tools, he may be qualified to be a foreman in a machine shop. If he knows something about the financing of a business, dealing with people, and also machine-shop practice, he may then be qualified to manage the entire machine-tool business. If he understands history, human nature, modern social and industrial problems, he may be qualified to manage the affairs of state, achieving a high position in the government of the nation.

At first the manager must concern himself with the management of less important things. The personal management of one's own affairs and activities is a starting point. This leads naturally to a trade or profession in order to earn a living. Some people are so constituted that they prefer to become specialists in one particular thing such as microbe biology or thermodynamics. To these people we owe our modern progress in science and invention. Others find that they prefer to deal with the more general aspects of many general topics, and if these people apply management principles, they are able to enlarge the scope of their activities, becoming responsible for departments, whole business organizations, and perhaps the affairs of the entire community. When they begin their careers they must have a somewhat specialized knowledge of one particular job, whether it be that of an office clerk, draftsman, bellhop, or lathe operator. They must prove their ability to manage themselves on minor jobs before they can go up the management ladder and assume the responsibilities of directing others. At each rung in the ladder they have the choice of staying and becoming specialists, or continuing to maintain a broader viewpoint and going up higher. For example, some instructors become proficient in their field and are promoted to professorships and perhaps the leadership of their departments. Others do not maintain an intense interest in one field only, but spread out their knowledge so that they see one field of knowledge in relation to others and qualify for general administrative positions. Both types are essential for a well-rounded academic organization.

No one profession has a monopoly on furnishing leaders. Engineers, lawyers, businessmen, musicians, and many others have contributed

to the progress of management and to the direction of society. Each contributor has been more than a specialist in one field only. He has supplemented a general knowledge with the advice of experts. His success in management is a result of an ability to use *management principles* in balancing conflicting opinions of advisor specialists in order to arrive at decisions which are advantageous to all concerned.

THE FIRST PRINCIPLES OF MANAGEMENT

The fundamental principles of management are universal and hence can be stated in many different ways as well as languages. For purposes of analysis, the following statements are given as guides to understanding these universal principles:

1. SEE THE SITUATION AS A WHOLE. IT IS FIRST NECESSARY TO OBTAIN A PROPER PERSPECTIVE.
2. PICK OUT THE MOST IMPORTANT ASPECTS OF THE SITUATION AS SEEN IN STEP 1.
3. DEVOTE TIME AND EFFORT TO THE ASPECTS OF STEP 2 IN PROPORTION TO THEIR IMPORTANCE.
4. ESTABLISH ROUTINES TO TAKE CARE OF CONSTANTLY RECURRING DETAIL.
5. ESTABLISH METHODS OF NEW PROCEDURE FOR THE ANALYSIS AND THE SOLUTION OF THE MORE DIFFICULT ASPECTS.

Application of First Principles throughout Text

This text covers the application of management principles in the organization, planning, and control of manufacturing. It assumes that students have a general knowledge of existing society, and understand the significance of industry in our social structure.

The most important aspects of manufacturing are indicated in this text by the part and chapter titles. It will be observed that the table of contents differs from that of other books on the same topic. Some aspects of the subject that are considered important by one author are not stressed by others, and vice versa. Probably expert manufacturers could not agree on the importance of various topics. This merely indicates the predominance of judgment involved in all management, whether it be organizing a book or running a town meeting. Some of the major topics in this text are unorthodox, but they were developed in an effort to obtain a comprehensive approach in accordance with the first principles of management listed above.

In general, the length of the chapters indicates the time and effort that the beginning student should spend on each topic. Some of the topics are cumulative — they continually recur in successive chapters.

and hence are built up as the book progresses. Others can be learned only from practice, rather than discussion. The chapter on budgeting applies to every other problem discussed in the text. Hence, importance is not indicated by the number of pages alone, but rather by the general emphasis throughout.

In many of the chapters, forms are suggested for the handling of routine details. The finished goods budget report (Fig. 6, page 23), for example, facilitates communication between the storekeeper and the planning department and specifies certain definite information which should always be supplied. The blank columns on the card remind the storekeeper what is required and also promote neatness and accuracy so that it is not necessary for him to think these things through each time he makes a report.

The general outline of any chapter is a pattern which may be followed to guide a conference discussion on the topic problem. To illustrate, the chapter on Job Evaluation discusses in successive order the steps in developing a job-evaluation program. When the development of a job-evaluation program is under consideration, a conference leader should be able to reach an understanding more smoothly and quickly if the discussion of the group is directed according to this outline.

IMPORTANCE OF SOUND INDUSTRIAL MANAGEMENT

There is no field of knowledge for which a greater need of understanding exists today than that of industrial management.

Manufacturing industry is one of the main streams of the lifeblood of our nation. Upon its existence depend the livelihoods of millions of people. To them industry is the sole means of support and they prosper in proportion to its success or failure. No longer are there frontiers — homesteads and free lands to which workers may turn in time of need or when they become dissatisfied with their lot. Instead, they are shackled to their jobs and have little chance of working out their salvation except through selling their services to an employer.

In fact, the number of persons in this category — those dependent upon industry for their livelihoods — is sufficiently large that the welfare of the entire nation is becoming increasingly dependent upon continued industrial prosperity. This is reflected in the fact that when one industry curtails operations, the neighboring industries suffer; and also in the agricultural communities, for if the farmers cannot sell to industrial workers at prices which pay their costs of production, they in turn cannot continue to buy the goods made by the industrial workers, such as farm machinery and home appliances.

Industry to exist, however, must operate at a profit. There must be a sufficient return on the capital invested in industry both to warrant its continued investment and to attract new quantities. Unless this profit is forthcoming, not only will existing industrial plants cease operation, but also there will be no expansion and growth in the community itself.

The profitable operation of industry is dependent upon good management. This means more than knowing just the principles underlying the managing of a manufacturing enterprise. It requires an understanding of their application so that each branch of the business is a part of an efficient working organism, each function properly conceived, coordinated, and executed. It demands discrimination in selecting the things to be done and the people to do them. It demands the elimination of the unnecessary and the inefficient, and a constant striving to preserve and improve the devices of demonstrated value and usefulness.

The attainment of these ends requires both competence and courage in management — rare qualities which are born only of knowledge and experience, backed by sound judgment.

It requires, in addition, what Oliver Sheldon calls "a social responsibility."

> It is occasioned, [he says] rather by its control of men than its application of technique. The student of economics does not bear the same responsibility as the manager who applies his economics. Whether management knows much or little of its own science, its responsibility remains unaffected. The responsibility of management resides in the fact that the industry which it directs is composed of human as well as material elements. Furthermore, that responsibility is enhanced by the fact that industry exists for the satisfaction of human needs. Management has, therefore, a responsibility not only to the human element within industry, but also to the human element which industry serves.
>
> Consequently, in considering the social aspect of management, there are two broad divisions; firstly, the relation of management, as an integral and directive force in industry, to the general body of the community; secondly, the relation of management to the human element engaged in industry. In the one, management bears the responsibility of industry as a whole, since it holds the reins of industry; in the other, it bears the responsibility of its own service to those whom it directs.
>
> In its relation to the community, management is representative of industry as a whole. For management is, as it were, the helmsman of a giant schooner, which it steers, amid winds and waves, towards the harbour of its communal end. This is the fundamental purpose of management.[1]

[1] Oliver Sheldon, *The Philosophy of Management*, Sir Isaac Pitman & Sons, Ltd., London, 1930, pp. 72, 73.

WHO SHOULD STUDY INDUSTRIAL MANAGEMENT?

In the light of the foregoing, there will be few who will not acknowledge the importance of good industrial management in our present social order. As a field of study, however, it is of special concern to all students whether their major interest be business administration, engineering, or liberal arts.

The *student of business administration* who plans to become an industrial administrator must understand the principles underlying the organization, operation, and control of the manufacturing enterprise; and even if he has no plans for a career in industry, a well-rounded business education must include an understanding of the business principles by which the industrial structure of the nation is kept alive. For this latter type of student, great benefit will be derived also through an understanding of the problems of economical production. To cite a few examples — the salesman who can understand his firm's manufacturing problems becomes a better, more dependable salesman; moreover, the cost accountant who does not understand inventory, production control, and shop management is handicapped; and few are the businesses in which the principles of production efficiency cannot be applied.

The study of industrial management for the *student of engineering* is no less valuable; there will be few engineers, regardless of their special branch, who will not be concerned with manufacturing processes of industry. Increasingly, the engineer in industry is being called upon to perform work for which a technical background alone is insufficient. There is also required a knowledge of the principles underlying organization, planning, and controlling production from the angle of good management.

The engineer who is concerned with technical research and design, as well as the factory engineer, will also profit by a general understanding of industrial-management principles. Even though he may never be called upon to assume management responsibilities, he needs a background which will give him a sympathetic understanding of the requirements and limitations which managers place upon him and his work. He needs to understand the problems which new designs create for production managers and even for sales managers, so that he can balance technical perfection with the limitations imposed by production and sales requirements. This broader viewpoint will make it easier for him to get along with his associates in other departments and therefore become a more valuable man to the company. In addition, he will be developing the qualifications for promotion to higher salaried managerial positions.

Moreover, the study of management is extremely valuable to those engineers who have little or no interest in factory production. A striking example of this is found in the work of the civil engineer whose job is that of construction. His services are greatly enhanced through understanding the principles of efficiency in plant layout. Moreover, in planning, estimating, and controlling operations, the principles of material handling, cost finding, and production control are no less valuable to him than to engineers who concern themselves solely with manufacturing businesses.

Merely because industrial management is a profession does not mean that it should be overlooked by the *student of liberal arts.* Management is one of the most important arts which man has developed, and industry is of prime importance in our existing social structure. In the past an education has been considered liberal if it acquainted the student with the great thinkers and civilizations of other years, but it cannot be said that a modern student has been given a "liberal" background of the most important knowledge if he knows nothing of the organization and conduct of contemporary industrial society.

THE ART OF MANAGEMENT

Profitable business firms and well-managed institutions are usually the reflection of some one or more persons possessing superior management ability. Most people have the ability to perform some task well, but only a few have the attributes which qualify them for the art of management. This art of management has its foundations deep-rooted within the individual. It requires an ability to initiate, direct, and control, and, even more important, the capacity to win and hold the respect and loyalty of fellow workers.

Unfortunately many people do not appreciate that management plays an important role in life — that ambitions, work attitudes, and ultimate success have their foundations in personal-management ability. These people cannot plan and control wisely their own expenditures of energy, and they spend endless effort futilely, ever wondering why it is so. However, they are no more unfortunate than those who are content to accept life as it comes, making no attempt to have a more venturesome or a more profitable existence, except as necessity may require. In fact, there are few people who have either the willingness or the courage to change the path of life when even they know too well that it has been ill chosen. Surprisingly, these same people will condemn the executive personnel of a business for adopting a similar attitude, but fail entirely to appreciate that their own life situation hinges on management policies as much as does the conduct of a business.

Successful businesses have long-range, short-range, and even daily management policies which must be formulated, adopted, and tried — so have successful individuals. Business managers must adopt policies of purchasing, inventory control, inspection, and sales promotion and in a like manner individuals must have plans for education, earning a living, home life, travel, and recreation. In both cases, these are the framework of general management policies — steps toward ultimate goals.

The action of a business in a given situation at a given time must depend upon its short- and long-run policies. So, too, individuals must act in the short or long run in accordance with their management policies. Similarly, business failures are nearly always due to faulty management or to none at all. The reasons may be stated as insufficient working capital or an inadequate sales volume, just as success may be indicated by good profits and a sound financial condition; but these are only the results of management policies as the failures or successes of the individual are indications of personal-management ability.

It is not surprising, therefore, that the well-managed business is a reflection of a person, or persons, who have inherent qualities for leadership and direction. These persons so entrench themselves in their work that the line of demarcation between their personal success and that of their work is not easily discernible. Both unite to produce a portrait of success in the *art of management.*

CHAPTER II

BUDGETING — AN OVER-ALL VIEW OF MANAGEMENT

Budgeting and records are found in practically every business organization. Records give a detailed account of what has happened in the past. Budgeting plans future activities. Nothing is more important to sound management than systematic planning based on previous performance and business judgment. In the small business, the proprietor may formulate plans in his own mind and execute them without ever writing them down, but in larger business organizations it is essential that *plans* be written down in advance item by item so that they may be discussed, revised, and later compared with actual performance.

The term "business policy" refers to the general aims and procedures which management intends to follow in carrying on the business. It is necessary that these policies be clearly defined and understood so that the actual conduct of the business may be based upon them. General statements of policy by themselves, however, are not sufficient; plans must be made to implement and carry them into effect. This is done by means of the budget. It is in the budget that general policies are given definite, concrete expression. It is in the budget also that we may look for the *exact interpretation* of general statements of policy.

Budgeting itself is not concerned with technical, engineering details; these are left to the specialists in their respective fields. Of course, when a budget is used to obtain productive and financial coordination between the departments, this often points the way to technical improvement of processes or procedures. For example, the budget considers appropriations for such an item as lighting. If the lighting costs of two similar departments show considerable difference, this calls for a justification or a reduction of the higher cost. Thus financial review will indicate opportunities for both technical and financial improvement.

Budgeting Defined

Defined in general terms, budgeting is planning the conduct of a business. This definition includes both the over-all planning for the whole business, and the detailed planning of the operations in individual departments. Budgeting is not an isolated topic in the field of industrial management. On the contrary, *the term "budgeting" is more*

nearly synonymous with "management" than any other single chapter title in this text. "Management" implies *systematic and intelligent planning and control.*

"Budgeting" as treated in this chapter deals with the procedure for bringing together all the separate plans which must be made for a business for the purpose of financial review, coordination, and control. It enables each individual expenditure to be made more wisely because its relation with all other expenditures may be reviewed. The technical details involved in planning particular activities are treated under separate topics in successive chapters. For example, the principles involved in planning material-handling systems in relation to plant layout are considered in the chapter on Material Handling, but the procedure for coordinating the plans of all the departments is introduced in the present chapter.

The topic of budgeting is introduced at the beginning of the study of management because all management decisions must be sound from the budgeting standpoint as well as from other technical standpoints. A man who is an expert in any other specific branch of management such as material handling, production control, or work simplification should also understand budgeting. Budgeting embraces the whole field of management; all supervisors, executives, and even technical designers must be concerned with it. No business can continue to exist if it is not successful from the financial and productive standpoint, and all those who have a hand in its management need to become budget conscious in order to ensure this success.

A successful business enterprise and a high standard of living for the community can be achieved only by careful and systematic planning. Technical and engineering planning is of the utmost importance, but it must always be coordinated with financial planning (budgeting) in order to become a valuable contribution to a business and to the community.

By-products of Budgeting

While the primary purpose of a budget is planning, there are several by-products of good budgeting which should be recognized and utilized. These include (1) knowledge of the business, (2) establishment of procedures which automatically make for discipline, and (3) provision of information useful in measuring the efficiency of supervisors. Each is discussed in further detail below.

Knowledge of the business. It is impossible for executives to make careful and accurate plans for a business without becoming intimately acquainted with its details. By constantly making predictions and then checking them against actual performance and explaining any

discrepancies, those connected with budgeting gain a knowledge which can be obtained in no other way. Costs which are out of line lead the financial officers to investigate the technical processes where the costs arise, and consequently to become better acquainted with the technical aspects of the business. On the other hand, the engineer whose designs must be passed upon by the budget committee is forced to recognize the financial aspects of his activities. The budget enables top executives to keep in touch with the details of the business, and the heads of individual departments to understand the relations between their own and other departments.

Discipline. When men have to plan their own work, there is an incentive to accomplish the established objectives. This is missing when work requirements are merely dictated by those in higher authority. While it is not usually possible to use this incentive in connection with the wage earner, it does serve a necessary and valuable function among those in managerial positions. Working in cooperation with associates and superiors, they set their own goals, and the process of budgeting and checking results enables each to know whether he is earning his salary without being told.

It is poor psychology for top management to set up budgets for subordinates to follow. When department heads are required to estimate the future costs of their departments, they will make every effort to live within that estimate in order to justify their own competence.

Measure of efficiency. Budgets and budget reports give top management a valuable measure of the efficiency of supervisors. When department heads can make plans and then direct workmen to complete them successfully, there is evidence that they understand both the work and supervision. The comparison of budget information with operating results provides data of value to those who rate foremen, department heads, and others. This is considered in further detail in Chap. XXI.

CLASSIFICATION OF BUDGETS

Most business organizations are too large to permit the detailed planning of the entire business in one budget. It becomes necessary to use a master budget that summarizes all the plans and shows how they affect the business as a whole; and details are relegated to various specialized budgets. The major classifications of these specialized budgets are considered below. Any number of subordinate budgets may be made under each one.

Selling-expense budget. The selling-expense budget covers the various expenses involved in marketing a product — advertising, salesmen's

expenses, transportation, storage of goods, delivery. Selling expenses are sometimes considered along with the sales budget, and in other cases a separate budget is drawn up.

Production budget. The purpose of the production budget is to assure finished goods to meet the demands of the sales department. The term "finished-goods inventory" is practically synonymous with "production budget" because it is the quantity of finished goods on hand which must be maintained at the proper size in relation to sales. If the inventory becomes too large, a financial loss results from many reasons — deterioration, changes in style, spoilage, and storage charges. If the inventory becomes too small, there is danger of losing sales because no goods are available. The sales budget indicates the rate at which stock will be removed from the finished-goods inventory, and the production budget must set a production quota that maintains the inventory at its proper size.

Manufacturing-capacity budgets. In order to manufacture goods it is necessary to have a factory building, machinery, men, material, and supplies. The budgets for all of these fall into the general classification of manufacturing capacity, that is, the ability or wherewithal with which to manufacture. The purpose of these budgets is to ensure an adequate amount of materials and labor to meet the requirements of the production budget. There follows a further discussion of the major budgets within this group.

Physical-property budget. Physical property includes the buildings, machinery, and equipment which constitute a relatively permanent investment. They are things which are not purchased and used up, but items which become part of the permanent structure of the business.

Materials budget. Material refers to the things from which the product is made. For example, in making a wooden product, wood is purchased, processed, and sold as the finished product. The material, wood, passes through the manufacturing processes and in so doing becomes the finished product. In distinction to physical property, it does not become part of the business, but passes through it, and a continual supply is necessary to keep the business in operation.

Supplies budget. Supplies are needed to carry on manufacturing, but they do not become part of permanent physical property, nor do they leave the factory as part of the finished product. Supplies are consumed by the manufacturing operations in the factory, and new supplies must continuously be made available. A typical example is the oil necessary to lubricate machinery.

Labor budget. A manufacturer must have an adequate force of workmen in order to carry on his business. These men must be available at the time when they are needed; they must have the skills

required to perform the work; and provision must be made to pay for their services. As a group they must be cooperative with the foremen and with each other. The labor budget is complicated by the fact that it is not always good policy to dismiss men when there is no work immediately available for them, and also that their very presence requires management to provide certain services for them, such as washrooms, luncheon facilities, and insurance.

In manufacturing organizations where it is desirable to keep employees on the pay roll regardless of the volume of work to be done, industrial managers can use productive and idle-time labor budgets for control purposes to great advantage. These permit making estimates of production costs in the light of (1) the amount of labor time paid for which results in salable products, and (2) the amount paid which results in nothing productive from the standpoint of the purposes for which the industry is organized. In other words, this is a comparison of relative costs of productive and idle time of labor. When properly analyzed, these costs make clear to management just what it is paying labor to do, and the way is cleared to take steps necessary to adjust conditions in order to obtain the greatest possible return per dollar of pay-roll expenditure. The analysis of these costs is most meaningful only when it is accompanied by an analysis and comparison of the overhead costs — which are closely related to the pay-roll expenditures — supplies, power, and other overhead costs which are affected by changes in the volume of production.

Departmental budgets. Departmental budgets are usually subordinate to the other major types of budgets discussed in this section, and may contain parts of several different budgets. A productive departmental budget would probably list labor, materials, supply requirements. The various requirements of all the departments are then summarized in the different specialized budgets.

Research budget. In order to keep the product design and manufacturing processes up to date it is necessary to devote part of the income to research. This provides for materials, supplies, man power, and equipment with which to carry on research work.

Purchase budget. There is a difference between planning the amount of raw materials, manufacturing supplies, etc., that will be needed during a budget period, and planning the time and the amounts in which to purchase them from outside sources. The purchase budget must meet the requirements of the manufacturing-capacity budgets, and also consider purchasing policies — where to make purchases, frequency and size of purchases, timing, delivery, and so on.

Financial budget. It is the financial aspect of a business which determines its success or failure. Fine performances in other individual

parts of a business are of no benefit if they are not coordinated so that the business makes money, or is at least able to keep enough cash on hand to meet its current obligations. This is spoken of as "maintaining a cash balance."

The financial budget must provide an adequate cash balance at all times. If this balance becomes too low or is eliminated, bank loans are secured in order to keep the business in operation — to meet pay rolls, bills, and other current obligations. If the cash balance becomes larger than necessary, some of it may be paid to the owners as dividends or reinvested in the business.

INTERRELATION OF BUDGETS

One of the keynotes to the success of a business is maintaining a proper balance between the different parts. The size of any one part, by itself, is no indication of success or failure. For example, a business with a large volume of orders to fill is usually thought of as successful, but the finished goods must be available to fill the orders before any profits can be made. Another example is the necessary balance between labor supply and material supply. Both must be available in the proper proportions for manufacturing. In budgeting one of the principal objectives is the maintenance of a proper relation between all the divisions of the business.

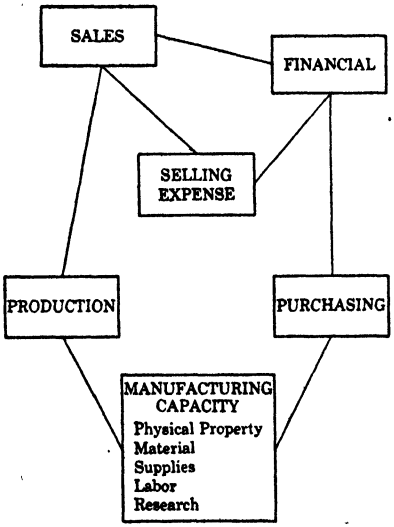


FIGURE 1. DIAGRAM SHOWING STEPS OF BUDGETARY PROCEDURES IN RELATION TO ONE ANOTHER

It is impossible to make a budget for just one part of a business without making a budget for the remainder of the business also. A sales budget, for example, cannot be made without also planning (budgeting) the activities of the production department. A cash budget cannot be drawn up without also knowing the plans of the collection and purchasing departments.

The general relation between the parts of a manufacturing business, and consequently the relation between the budgets for these parts, is shown in Fig. 1. The diagram has the pattern of a circle rather than a straight line because it is impossible to start at any one point and make plans in which the planning to be done at other points is not a factor. Every departmental budget will both influence and be influenced by the others.

Each budget for the major parts of a business shown in Fig. 1 must aim to keep a balance between the parts on either side of it. For example, the proper balance between sales orders and finished goods has already been discussed. It is the function of the production budget to maintain this balance. If any one of these major budgets fails to maintain its own balance, the business is in danger in the same way that a person is in danger if any one part of his body, such as the stomach or lungs, is either oversupplied or undersupplied with the things it needs.

The major classifications of budgets, the things they control, and the things they must balance are shown in Fig. 2. It will be noted that each budget must be a balance between the thing controlled by the budget above it, and that controlled by the budget below it.

Budget	*Thing Controlled*	*Balance Between*
Financial	Cash	Income — Expenditures
Purchase	Expenditures	Cash — Manufacturing capacity
Manufacturing capacity	Ability to manufacture — labor, materials, supplies, physical property	Purchase orders — Production
Production	Finished-goods inventory	Manufacturing capacity — Sales
Sales	Income	Finished goods — Cash

FIGURE 2. THE MAJOR CLASSIFICATIONS OF BUDGETS

The relation between the budgets in the group termed "manufacturing capacity" is still more complicated. Here each one must be in balance with the others in the group as well as those coming before and after, namely, purchasing and production. Materials, labor, physical property, supplies, and other manufacturing-expense items must all be available in the correct proportions for the manufacture of goods. An adequate labor supply is worthless without materials, and manufacturing machinery (physical property) is of no value if men cannot be obtained to run it. The budgeting of materials, for example, must consider (1) the ease and readiness with which materials may be purchased, (2) the material requirements of the other factors of production — men and machines, and (3) the size of the finished-goods inventory (production budget).

Procedure for budgeting. In order that budgeting may be performed with a minimum of time and effort, it is necessary to establish standard

procedures which are adapted to the situation in the individual manufacturing company. There are no rigid rules which can be applied to all companies, but some one routine should be established for each of the following questions:

1. In what order should the different budgets be made?
2. What should be the length of the budgeting period?
3. Who should do the budgeting?

Order of making budgets. There is no perfect order in which budgets can be made. As shown in Fig. 1, the relation between budgets is circular — each one affects the others and is also affected by the others. However, budgets must be made one at a time, so it is necessary to start somewhere and do preliminary work on one without knowing exactly what the others will be. Later, when the others are completed, it may be necessary to go back and revise the first one.[1]

Usually the best approach is to begin with a preliminary estimate of the sales budget and plan the remainder of the organization around this estimated volume of sales.

Who should do it. The responsibility for budgeting should be centralized in one of the top financial executives. This officer usually has the title of controller, treasurer, vice-president in charge of budgeting, or some similar title. He must act as a central agency for the collection of data and the preparation of all budgets. Using the detailed budgets prepared by each department, he must draw up a master budget and submit it to the board of directors for approval, and then control the expenditures authorized by the budget and check upon variations from the budget amounts.

As many subordinate executives as possible should be connected with the preparation of the preliminary estimates, if for no other reasons than the knowledge and disciplinary aspects previously discussed.

Time considerations. Most business firms have a budget period which they consider best adapted to their particular needs. This may be a year, month, quarter, or thirteen periods of four weeks each. At the beginning of the budget period the budgets are drawn up for the period, and at the end the budgets are checked with actual performance and new budgets drawn up, and this cycle continuously repeated.

[1] The same type of problem is encountered in selecting the order of topics for this textbook. Any one topic can be best understood when the student knows something about all the others, but all the topics cannot be presented at one time. This chapter, for example, is included at this point to acquaint students with the management field as a whole. It is recommended that the student read it again when the book has been completed. No order of presentation can be perfect, but an attempt has been made to select the best one.

No one budget period should be rigidly followed for all the various types of budgets needed in a business. The time period for which a budget can be made for any one section of a business will depend upon the frequency with which decisions have to be made. A budget for physical property may extend over a period of many years. On the other hand, if there are constant changes in the design and sales volume of a product, as would be the case with women's hats, then it would be impossible to prepare a detailed materials budget very far in advance.

Even in the light of the above discussion, the standard budget period should not be eliminated, for it is still necessary to have *one* definite period for the master budget of the business as a whole. This period should be the one that is most easily coordinated with the various periods for which the detailed budgets are prepared. For example, a business with a year as the budget period might revise the physical budget every quarter, and make a general master budget every year. The inclusion of a time schedule by quarters on the purchase-budget forms will enable them to be tied in with the yearly budget period and also be used for short-time planning.

CONTENTS OF BUDGET FORMS

The simplest possible budget is merely a statement of proposed activities or expenditures; usually the time and amount are also noted. Illustrative of this is this budget of a salesman's time.

SUREFIRE SALES COMPANY

BUDGET OF SALESMAN'S TIME

Name..... Date filled out.....

Period covered .....

Time	*Event*
8 : 00 A.M.	Call at Jones, White, and Company
8 : 30 A.M.	Meet Mr. Robinson in the lobby of the Mayflower Hotel
9 : 30 A.M.	Telephone Mr. Davis
9 : 35 A.M.	See Messrs. Alderidge, McDavitt, Lyard, and Safford at Southwestern Manufacturing Company
11 : 30 A.M.	Visit Public Library to see announcements of new contracts
12 : 00 Noon	Luncheon conference with Mr. Fisher of the Walnut Service Corp.
2 : 00 P.M.	Visit 125 Broad Street to make estimates for Burton and Gibbs
3 : 00 P.M.	Attend funeral of J. G. Moulton
4 : 30 P.M.	Call at Tabor and James Company

While a simple form such as the above is much better than nothing, there are many instances when the effectiveness of planning may be improved by recording other pertinent information on the plans to be recorded on the budget. Since this information will be considered while making and reviewing the budget, space is reserved for it by means of designated blanks on the printed budget sheet. *The particular information to be required on any one form will depend upon the circumstances surrounding its use.*

As with all the forms presented in this text, the particular illustrations and column headings used should not be accepted by the reader as suited to all industries and firms. No one best form exists for every enterprise. On the contrary, those shown in the text are intended only to illustrate the principles being discussed. All forms to be used in actual practice should be tailor-made to fit the particular practical situation. Forms should not be lifted out of the text without alteration, but used as guides in developing others which are adapted to the special conditions surrounding their application.

The major types of information which may be recorded on budgeting forms are discussed below. It is unlikely that all the topics will be included on any one budget form. The budgeting process itself should not be unduly complicated by gathering and recording data of no interest in connection with the particular plans being made. Nothing

DEPARTMENTAL BUDGET

Department..... Budget for..... (period) Production Quota.....

Department Head.....

Item	*Unit Cost*	*Number*	*Total Cost*	*Per Cent of Total*	*Cost during Previous Periods*	*Difference*
Materials						
Supplies						
Direct labor						
Ind. labor						
Other overhead						

FIGURE 3. TYPICAL FORM OF DEPARTMENTAL BUDGET

reveals poor management more than standard forms with a lot of blanks that are never filled in. From the list which follows, those things directly connected with the plans to be made should be selected and spaces provided for them on a standard form. A typical form is shown in Fig. 3.

1. **Item.** This term refers to the names of the things which are being planned. It will be found at the top of the column in which they are listed. In a budget for the purchase of different sizes of pipe, the different sizes to be purchased would be listed in the item column. "Item" refers to the name, rather than the quantity or the price.
2. **Unit cost.** This is the cost per article or piece, pound, ton, yard, or gallon — whatever unit is ordinarily used in quoting prices.
3. **Amount or quantity.** Usually the principal concern in budgeting is not what items to plan for, but what amount or quantity. To illustrate, if we are budgeting the production of shoes for the coming month, it is much easier to decide which styles and sizes to make than to decide exactly how many of each model should be made.
   Budgets which are subject to revisions provide columns for the original estimate and for the probable number of revised estimates.
4. **Value.** This is the total value of the item, found by multiplying the unit cost by the quantity.
5. **Percentages of total.** The per cent that each item is of the total may be recorded in order to have a definite statement of the relative importance of the item. This is found by taking the sum of the total quantity or value of all the items, and dividing this sum into the amount of each item. The calculation is illustrated in the table below.

CALCULATION OF PER CENTS OF TOTAL

Item	*Unit Cost*	*Quantity*	*Value*	*Per Cent of Total Value*
A95	$0.13	20	2.60	12
A97	0.15	42	6.00	28
C19	0.60	25	13.00	60
			21.60	100

6. **Historical and current information.** This may include previous and current performance, costs, sales. For example, on a production budget, the quantity produced during past periods and the rate of production in the present period might be listed. Strictly speaking, such information is not part of a budget, because it is a record of the past rather than a plan for the future. It is entered on the budget form so that plans for the future may be quickly checked against previous performance.
7. **Estimated accomplishment.** This will be some measure of results to be obtained from the proposed expenditures or activities. For example, if

production expenses are being considered, accomplishment may be measured by units of output, or expenses by sales. Expected profits are also used to measure the value of proposed activities.

8. **Accomplishment in terms of effort.** This involves calculating a ratio or a rate, such as pounds of product per dollar of expense, or the percentage of profit to be obtained from each dollar of sales. These ratios and rates are particularly useful in measuring the relative effectiveness of expenditures which differ in size. For example, the selling expenses and also the sales in a large city will be much greater than those in a small village, so that it is difficult to judge whether each dollar spent in the city accounted for as many dollars of sales as each dollar spent in the village. However, when the sales per dollar of expense are calculated for both, the comparison is readily made, and serves as an index of what the expenditure will accomplish.
9. **Amount of revisions.** When original estimates are revised, the size of the change may be recorded as well as the original and revised figures. This is done to focus attention on the difference between them.
10. **Time schedule.** Some budgets contain plans which are to be executed at one particular date or within a certain period so that a detailed time schedule is not necessary. When one budget contains plans which are to be executed at different times, a detailed time schedule is necessary. A budget for a year, for example, might show the monthly schedule for expenditures, production, and so on.
11. **Cumulated amounts.** When a time schedule is included, the amounts may also be cumulated to show the amount spent up to and including any one time as well as the particular amount to be spent at that time (Fig. 4).

MONTHLY AND CUMULATED AMOUNTS

Item	*Jan.*	*Feb.*		*March*		*April*	
	Amount	*Amount*	*Cumulative Total*	*Amount*	*Cumulative Total*	*Amount*	*Cumulative Total*
A	5	6	11	4	15	5	20
B	30	35	65	27	22	32	12

FIGURE 4. BUDGET FORM SHOWING COLUMNS FOR MONTHLY AND CUMULATIVE AMOUNTS

12. **Difference between estimated and previous amounts.** This comparison is used when it is desired to focus attention upon the size of proposed changes. It brings to notice the expected differences between the future and the past and tacitly suggests that those planning the change should be able to explain its cause. For example, if a department head must list the difference between budgeted and previous telephone expenses,

he is not encouraged to increase the budget so that it will cover some of his personal calls. Even though the reason for the difference must be recorded, it indicates the possibility of his being asked for an explanation, and helps top management keep expenses under control with a minimum amount of disciplinary action.

13. **Other plans affecting the particular budget.** The plans for any one part of a business will be influenced by the plans for the other parts. For example, the production budget is inextricably linked with the expected sales and consequently the sales estimates are often placed on the production budget. The interrelation of cause and effect between budgets has been already treated (pages 16–17).

Budget reports. One phase of budgeting is planning what will be done in the future; another phase is checking old plans with what has actually occurred and explaining any differences. This checkup helps management understand just what is taking place in a business, and promotes more accurate future estimates. Frequently a separate form

MONTHLY FINISHED-GOODS BUDGET REPORT

Month 1 Year 1943 Dept. H Signed A.S.K.

Item	(*1*) *Production Quota*	(*2*) *Initial Inventory*	(*3*) *Actual Production*	(*4*) *Production Quota against Actual Production*	(*5*) *Closing Inventory*
106	400	200	405	5	240

FIGURE 5. SUGGESTED FORM FOR ABBREVIATED MONTHLY FINISHED-GOODS BUDGET REPORT

is used for reporting the comparison of estimated with actual performance, and this report also serves as a factor in making the budget for the next period. The principles involved are illustrated by the discussion of a typical report, the "Finished-goods Budget Report," which is shown in Figs. 5 and 6 and is discussed in the following paragraphs. Before considering the details of this form the terminology used in the several column headings and the principles underlying their use need explanation.

MONTHLY FINISHED-GOODS BUDGET REPORT

Month 1 Year 1943 Dept. H Signed ASK

Item	(*1*) *Expected Sales*	(*2*) *Unfilled Orders Beginning of Period*	(*3*) *Actual Sales*	(*4*) *Production Quota*	(*5*) *Actual Production*	(*6*) *Production Quota against Actual Production*	(*7*) *Unfilled Orders — End of Period*	(*8*) *Unfilled Orders — throughout Period*
106	100	190	110	290	180	110	120	10

FIGURE 6. MONTHLY FINISHED-GOODS BUDGET REPORT FORM SHOWING COLUMNS FOR UNFILLED ORDERS

Finished-goods budget report. The details of a finished-goods budget report will depend upon the nature of the business, which will probably fall into one of the two following classifications:

1. **Manufactures for stock.** Industries which keep a stock of finished goods on hand, so that the products may be taken from the shelves and shipped to customers as soon as orders are received.
2. **Manufactures on order.** Industries which make up goods only when orders have been received. In this case the customer must give his order and then wait for the goods to be manufactured. Usually the product is of a specialized nature, and minor changes in the design are made for each customer, so that it is not possible to manufacture a standard design independent of the specifications supplied by each customer. This is the case with emergency products, such as pumps and turbines.

These two classifications are not mutually exclusive, but industries tend to fall into one or the other.

When a company manufactures for stock, those who plan production endeavor to keep a sufficient number of finished goods on hand so that all orders may be filled as soon as received, and yet not increase expenses by maintaining an inventory that is larger than necessary. The proper size of the inventory is a balance between losing orders because no finished goods are on hand, and incurring unnecessary expenses by maintaining a large inventory. These expenses include the costs of storeskeeping, protection, and losses due to obsolescence and deterioration. In addition, large inventories tie up working capital, that is, money which could be spent otherwise to obtain more materials and labor to manufacture more goods is not available until the present finished goods are sold.

The finished-goods inventory acts as a cushion between production and sales. It is necessary because it is impossible to coordinate production and sales so that goods are ordered at the same time their manufacture is completed. In the final analysis the production budget must be geared to the sales budget, but it is also affected by the inventory. The inventory is an intermediate cogwheel which has an important effect. Also, if the existing inventory is too large, the amount to be produced in the next period is correspondingly lowered by this excess size of the inventory. If the inventory is normal at the beginning of the period, the amount to be produced and estimated sales will be the same. When the inventory is dangerously low, however, the production budget will be larger than sales estimates.

Unfilled orders are the opposite of an inventory. Industries which operate strictly on a job-order basis cannot have finished-goods inventories because they do not make anything until an order has been received, but they may have an "inventory" of unfilled orders which will be one

of the major factors in setting the production quota for the next period. Of course, the planning of production will be influenced by the orders which are expected during the period, but before these future orders can be filled, those already on hand must be taken care of. Whereas future orders may be refused if production facilities are not available, orders now on hand represent a definite commitment or promise by the company which cannot be broken without serious loss of reputation.

There follows a discussion of two sample forms for the "Finished-goods Budget Report." The first one contains a minimum of information but may be desirable for simplicity. It is shown in Fig. 5 and contains the following information:

1. **Production quota.** This is the amount to be produced which was entered on the production budget at the beginning of the period, and it is included on the budget report form which was planned before the period started so that the actual achievement might be compared with that which was planned.
2. **Initial inventory.** It is always important to control the size of inventories. The inventory of finished goods at the first of the period is listed on the report so that any changes may be noted. In a job-order business this column would be headed "Unfilled Orders — Beginning of Period" and the orders listed which were on hand at the beginning of the period.
3. **Actual production.** This column is used to record the actual amount produced during the budget period.
4. **Production quota against actual production.** This column calls attention to variations between the planned and the actual amount of production.
5. **Closing inventory.** This figure will be used in setting the production quota for the following period. The heading would be changed to "Unfilled Orders — End of Period" for a job-order business.

The form discussed above summarizes the productive activities of the budget period and provides information which is needed to combine with sales estimates for making the next production budget. Many times it is convenient to enter all pertinent information on one card, so that the final quota may be set after referring to only one combined report.

A sample composite report is shown in Fig. 6 and contains the following information:

1. **Expected sales during period.** This figure is taken from the sales budget as it existed at the beginning of the budget period, and was used as one of the guides for setting the production quota. It is recorded again on the budget report so that it may be compared with the actual production and sales during the period.
2. **Unfilled orders — beginning of the period.** The orders which were on hand at the beginning of the period are recorded in this column. If the company manufactures for stock, the inventory would be listed instead.

3. **Actual sales.** The actual sales are listed so that they may be compared at the end of the manufacturing period with the estimated and actual production.
4. **Production quota.** (already defined)
5. **Actual production.** (already defined)
6. **Production quota *vs.* actual production.** (already defined)
7. **Unfilled orders — end of period.** This is the number of orders received but not filled, so that they must be included in the plans for the production during the next period. (Final inventory would be used if the business manufactured for stock.)
8. **Orders remaining unfilled throughout the entire period.** This is one of the most important columns on the entire report because it contains those orders which were on hand at the beginning of the period and scheduled for production but not produced during the period. This represents a further analysis of the previous column, "Unfilled Orders — End of the Period," isolating the orders which have been held up at least one entire production period, and so deserve first consideration in scheduling work of the production of the next period.

   In a business which manufactures for stock, the counterpart of this column would be "Inventory Retained throughout Period" and would contain the finished goods which were in stock at the beginning and had not been sold. Large entries in this column indicate either that production of the item should be suspended or additional efforts made to sell the goods.

QUESTIONS

CHAP. I. (THE STUDY OF MANAGEMENT)

1. Explain the meaning of the "art of management."
2. What is the "social responsibility" of management?
3. What are the first principles of management?
4. Why is industrial management important to the continued prosperity of the United States?

CHAP. II. (BUDGETING — AN OVER-ALL VIEW OF MANAGEMENT)

1. Why is budgeting a good topic to study to get an over-all picture of the scope of industrial management?
2. What are the by-products of budgeting?
3. Define budgeting.
4. What are the advantages of budgeting procedure?
5. Why are finished-goods budget reports used?
6. List and explain briefly the major classifications of specialized budgets used in manufacturing industries.
7. What headings may appear on budget forms?
8. What is meant by "cumulated amounts"?
9. What is the procedure for drawing up budgets?
10. How are budgets interrelated?

PROBLEMS

Problem 1

Draw up a plan of budgetary procedure for a business with which you are familiar. Make a chart diagram of the steps involved.

Problem 2. Penny-Packer Finishing Company

FINISHED-GOODS BUDGET REPORT

On the basis of the following information, complete the finished-goods budget report card for the month of August.

	Production Quota	*Estimated Sales*	*Actual Production*
Part No. 168A	8,300	8,400	7,900
174B	10,000	9,500	9,000
1,726H	410	410	425
182C	1,200	12,500	13,400
2,701DH		300	310
2,702DH		400	360
2,703AH		460	500

Standing orders for account of stockroom:

Part No. 2,701DH	500
2,702DH	410
2,703AH	490

Actual sales as reported at the end of the month by the sales department to the production department:

Part No. 168A	3,270 Aug. Delivery
	2,730 Aug. Delivery
	2,660 Aug. Delivery
Part No. 174B	4,610 Aug. Delivery
	2,903 Aug. Delivery
	3,104 Sept. Delivery
Part No. 1,726H	410 Aug. Delivery
Part No. 182C	2,792 Aug. Delivery
	8,164 Aug. Delivery
Part No. 2,701DH	260 Aug. Delivery
2,702DH	430 Aug. Delivery
2,703AH	510 Aug. Delivery

No orders remained unfilled at the beginning of the period. Standing orders for account of the stockroom are treated as customer orders for budgeting purposes. The Penny-Packer Company determines its estimated sales at the beginning of the month; actual sales and the quantity delivered to stock are recorded at the end of the month when the amounts to be entered in the remaining columns are computed.

Problem 3. The New London Company

FINISHED-GOODS BUDGET REPORT

The New London Company is a job-order plant which manufactures on receipt of customer orders only and does not carry inventories of any of the products it makes. In order to be certain that delivery dates specified by customers are met, the New London Company has introduced finished-goods budget reports as a manufacturing control procedure. The various departmental reports for the manufacturing period just ended reveal the following information in relation to four standard items manufactured:

Item	*New Orders Received*	*Production Quota*	*Actual Production*	*Unfilled Orders, Beginning of Period*
0231	150	170	185	20
0232	20	210	145	190
0245	15	90	60	75
0261	235	235	95	0

Show a completed budget report for this company and comment on the following:

a) What facts are of primary importance to management as revealed by the completed form?

b) What steps should management take in the light of these facts?

Show how a new form will look at the beginning of the next manufacturing period.

Problem 4. The Wanamaker Chemical Corporation

PRODUCTIVE- AND IDLE-LABOR TIME BUDGETS

The Nu-sift grinding department of the Wanamaker Chemical Corporation operates 1800 hr. per budget period when it is producing Nu-sift at full capacity. Ten men are employed in this single department who are paid 70 cents an hour. These men are experienced at their work and are not laid off when the production volume declines. They are guaranteed 180 hr. work each, during every budget period, regardless of the quantity of orders received for Nu-sift.

At capacity operation under present conditions, the department can grind 165,600 lb. of Nu-sift per budget period and the rate of output per hour is uniform regardless of the per cent capacity production. Nu-sift must be used within a few days of its manufacture or it will deteriorate and, therefore, it cannot be stocked for future orders.

At the opening of the budget period, the Wanamaker Corporation has advance orders for 99,360 lb. of Nu-sift. It is believed that additional orders can be secured immediately if the cost of Nu-sift per 100 lb. can be lowered. In this way competition can be met more satisfactorily by making a reduction in the cost of idle time and additional savings in costs can be effected. The cost of operating the grinding department at 90 per cent capacity is shown below: (The variable expense items are charged at a constant rate regardless of the number of hours of operation.)

Wage cost: Productive time	$1134.00
Idle time	126.00
Supplies: $0.836 per prod. hour	1354.32
Other variable expenses @ $0.20 per prod. hour	324.00
Fixed expenses: Total $1412	
Productive time	1270.80
Idle time	141.20
Total	$4350.32

An analysis of the plant conditions and facilities for manufacturing Nu-sift leads the management to conclude that the rate of production can be increased 50 per cent if a bonus of ½ cent per pound is paid the men for the increased production, in addition to the wage they are guaranteed.

a) Prepare an estimate of the cost of grinding 100 lb. of Nu-sift when the men are paid at the guaranteed rate of pay for capacity production, and the cost when the proposed bonus is paid for the same quantity.

b) What will it cost to produce the Nu-sift for which the Wanamaker Corporation has orders at the opening of the budget period (1) when no bonus is paid, (2) when a bonus is paid?

c) Itemize your estimated cost to show each element of cost, classified as to productive and idle time.

d) State the reasons why there is or is not a saving under the bonus plan.

e) The present market price for Nu-sift is approximately 10 per cent above the Wanamaker cost of manufacturing. Do you think the savings in cost of manufacturing Nu-sift would give the Wanamaker Corporation a great competitive advantage?

f) What are the advantages of showing expected idle-time labor costs in any proposed budget of labor costs?

Problem 5. The Greymere Hotel

BUDGETING LABOR REQUIREMENTS

The Greymere Hotel is a 6-story commercial hotel located in a metropolitan city near the shopping and business centers. It has been built for 4 years and is thoroughly modern. It contains 400 rooms. Each of 350 rooms has its own bath, 50 rooms being designed for use as suites of 2 or 3 rooms. In either case, a suite has two baths. The hotel operates a dining room to accommodate approximately 100 persons; a coffee shop for serving breakfast over the counter, and seating 40 people; a guest laundry; and a bar, as well as a cafeteria for its help.

All lobby shops and stands are operated on a concession basis. The hotel operates its own bakery which is located just above the kitchen.

Hotel guests are served by six elevators, all of which operate from eight o'clock in the morning until ten o'clock in the evening. At all other hours, only three elevators are in use. The service end of the structure is served by a freight elevator which is used to carry supplies from the basement storerooms to the kitchen and bakery. The bakery is located above the kitchen. All supplies and provisions stored on the premises are controlled by the steward's department.

The hotel is not equipped to handle large banquets and conventions and does not intend to cater to this type of business.

Because of poor management, the business has yielded no profit for 3 years. A new manager has been chosen to take over the establishment. He has been given complete authority by the owners to undertake a thorough reorganization which involves a complete change of personnel. Careful investigation leads the new manager to believe that the total personnel required to operate the hotel on the basis of an expected occupancy of 80 per cent of capacity should not exceed 250 in number. Hotels are normally staffed by both male and female workers. The management appreciates that staff requirements will fluctuate with the volume of business, but wishes to have an estimate of the number of men and women needed as a skeleton organization to render the type of service normally expected by commercial travelers making a city commercial hotel their headquarters.

The manager appreciates that expected income and labor costs would ordinarily be deciding factors in the number of persons that might be hired. For purposes of budgeting, however, it is deemed necessary to make a temporary setup of the personnel required to operate the hotel. For this purpose, no attempt is to be made to estimate the probable labor costs.

Personnel will be needed to staff the major departments and subdivisions listed below. In order to assign personnel properly, it will be necessary to complete the lists of employees given under each of the subdivisions and decide upon the number to be employed in each category.

Front Office
  Manager, assistant managers, room clerks, mail clerks, cashiers, information clerks, etc.
  Accounting Department:
    Accountants, auditors, bookkeepers, timekeepers, etc.
  Telephone operators
  Service Department employees (bellboys, elevator boys, porters, etc.)
  House detectives, night watchmen, nurses
Dining Room
  Waiters, bus boys, etc.
  Coat-checking employees
  Cashiers
Steward's Department
  Stewards, storeskeepers, coffee men, salad men, dishwashers, glass washers, etc.
Kitchen
  Chefs, butchers, scullery-division employees, oyster and cold-meat men, pastry-division employees, firemen, pot washers, freight-elevator operators, kitchen porters, etc.
Cafeteria for help
Housekeeping Department
  Housekeepers, chambermaids, bath maids, housemen, linen-room workers, cleaners, etc.
Laundry workers
  Counters, washers, shapers, folders, etc.
Engineering Department
  Chief engineer and assistants, etc.
Maintenance Department
  Carpenters, electricians, etc.
Coffee shop
  Attendants, etc.
Bar
  Head bartender and assistants, waiters, etc.
Valet service
  Valets for gentlemen
  Maids for ladies

a) What personnel setup would you recommend as that needed to start operating the hotel?
b) Upon what factors will the success of the Greymere Hotel depend?

NOTE: It is recommended that a standard reference on hotel management be consulted. (Boomer, L. M., *Hotel Management Principles and Practice*, Harper & Brothers, New York, 1938.)

PART II

MANAGEMENT OF PHYSICAL PROPERTY

Few managers can be experts in all phases of plant organization and management. The true management viewpoint must be a broad one and therefore all managers need to avoid time-consuming details. Where detailed information is needed in order to reach decisions, the manager must rely upon the advice and counsel of specialists in various fields. One phase of management responsibility where this is particularly true is that of deciding the technical considerations which have to do with the selection of physical property. The plant engineer and maintenance specialist who will be concerned with installations and repairs should supply the plant manager with the detailed information he needs in deciding upon the purchase of particular machinery, equipment, buildings, and services. Every manager, however, needs to have some general information about these matters in order to render sound final judgment on the recommendations and reports of technical staff members. Otherwise, he may not only decide unwisely, but also may appear unintelligent in discussing technical matters. The information the manager needs to know reduces itself to some basic principles.

In order that the student of industrial management may have a grasp of the scope of management problems involved in the selection and coordination of physical property for effective use, he needs to have an understanding of the following:

1. **Principles of selection of physical property.** There are some fundamental concepts which have broad application in the selection of physical property. These are:
   a) The order to be followed in the selection of physical property.
   b) Principles which underlie the effective use of the capacity to be provided in the completed industrial plant.
   c) Determination of how much any given organization should undertake to manage by way of plant size and ownership of property.

   Each of the foregoing serves primarily as background material and information which is useful to the plant manager in approaching the subject of physical-property selection.

2. **Plant location.** The first step in the management of physical property is the selection of the plant site. This selection must be made in terms of factors which will make the location of the plant advantageous from the profit standpoint.
3. **Selection of machinery and equipment.** Having decided where to locate the industrial plant, the next responsibility of the management is to select and install the machinery and equipment which will make possible the operation of an efficient plant organization. The manager needs to have background information on some of the technical aspects of the selection and installation of plant machinery and equipment in order to render sound decisions. The details regarding machinery and equipment which are installed, however, should be delegated to technical specialists and the manager in turn should pass upon their recommendations.
4. **The selection of factory services and buildings.** When the machinery and equipment necessary to carry out the manufacturing process have been selected, it then becomes necessary to (1) select service equipment to implement production, and (2) provide a factory building in which to house both the productive machinery and these services. The principles underlying the selection of factory services and buildings need to be considered in connection with the selection of other kinds of physical property.
5. **Cost patterns of physical property.** When all the physical property selected is combined to be put into operation it creates certain cost patterns. If these are anticipated at the time the property is selected, the original selections can be made more wisely. Top management must understand the cost patterns which may result when added units are put into operation and the units are combined. The management needs to know also the characteristics of fixed and variable costs in terms of increasing and diminishing returns, capacity points, and profitable limitations.
6. **Management of maintenance.** In the selection of all physical property — machinery, buildings, equipment, services — it is important to give attention to the problems of maintenance which are likely to arise when it is installed. The amount of maintenance and kind of maintenance which the property selected may require may make its selection undesirable. Plant managers everywhere desire above all else to have a plant that is in a wholesome working condition. This demands maintenance work be preventive as well as remedial, and costs which arise from maintenance machinery and equipment be kept at a minimum. The final chapter of Part II deals with maintenance-management considerations and presents a suggested plan of maintenance control.

CHAPTER III

PRINCIPLES OF SELECTING PHYSICAL PROPERTY

Industrial management is not the design of the product which is to be manufactured. This is done by technical research men. Neither is industrial management the design of the individual machinery and equipment used in manufacturing the product. It is design in the sense that an important phase of the work is the selection, organization, and arrangement of the physical property needed for manufacturing, as well as the supervision of the labor force. Motors, lathes, and furnaces must be designed by electrical, mechanical, and chemical engineers, but after these intermediate products have been perfected, they become the raw materials from which the industrial manager designs his factory.

In the eighteenth century, the forerunners of modern industrial managers were not concerned with the design of production floors. They needed only to hire laborers who provided their own simple hand tools, and to see to it that they kept busy until the work assigned them was done. In contrast with this, one of the biggest problems of present-day management is the selection and arrangement of expensive machinery and equipment — the design of the production floor — which is a very important intermediate step between the design of the product itself and its manufacture in large quantities.

THE ORDER OF SELECTION

In selecting the physical property for a manufacturing plant it is impossible to select any one item without considering it in relation to the remainder of the equipment which will be or has already been selected. It is senseless to buy a hydraulic press without making sure that the building facilities to house it exist, or that adequate housing can be constructed economically. On the other hand, the design of the factory building should be predicated upon the particular requirements of the manufacturing processes and machinery it is to house.

The factors to be considered in purchasing any one piece of physical property include not only its general value and performance characteristics, but also the extent to which this one piece of property fits into the entire manufacturing organization.

The whole manufacturing enterprise is nothing more than the sum of all the individual purchases, and since no one purchase should be made without knowing what the others are, selections of physical property must be made one at a time. It is necessary to pick out some point at which to begin. First, the manufacturing enterprise should be considered as a whole, then the individual parts should be tentatively selected. Those which are important factors in the selection of other types of property should be determined first so that an entire, efficient enterprise may be set up with a minimum number of readjustments.

The most efficient order in which physical property should be selected will vary with the individual manufacturing plant. The following is the tentative *order of selection* which should be made for major types of property in industries which are starting to organize from scratch.

1. Machinery and equipment to be used in the manufacture of the product.
2. Machinery and equipment to be used in servicing the manufacturing operations. This includes material-handling equipment, storeskeeping equipment, power-plant equipment, and maintenance equipment.
3. Selection of the factory buildings necessary to house the manufacturing process and auxiliary equipment used to provide various services.

On the basis of these major classifications it is possible to develop a more detailed order-of-selection list. A sample follows:

ORDER-OF-SELECTION LIST

Manufacturing machinery and equipment. This includes machines actually used to make the product. These may be lathes, milling machines, heat-treating ovens, mixing vats, or looms, as well as the jigs and fixtures used in connection with production setups.

Manufacturing service machinery and equipment.

Material-handling Devices. Under this heading are included the material-handling devices used to move the material from one step of the process to another. Typical of these are lift trucks and monorail conveyor systems.

Storeskeeping Equipment. This equipment will include the racks, bins, shelving, and equipment used in storage.

Power-plant Equipment. The installations of equipment needed to operate the power plant include boilers, compressors, pumps, automatic-draft equipment, coal bins.

Maintenance Equipment. This list should include the following if used exclusively for maintenance purposes: lathes, electric saws, planers, anvils, carpenters' tools, and plumbers' tools.

Other factory services. The other factory services to be listed include air-conditioning equipment, insulation, conduits and piping, communication systems, and employee facilities.

Buildings. The final step is the selection of a type and kind of building best adapted to housing the above-listed items.

The foregoing list is well adapted as a method of procedure for organizing a new industry. Where an organization is to be fitted into an existing building the principles of order of selection still hold, but must be modified in application by the limitations imposed by the building structure — type, size, and construction.

In selecting physical property, top management is concerned with general coordinations. Details of plant organization must not be considered at this point, but will be worked out by specialists in this field, who will advise top management. The more special work of organizing the physical plant is treated in Part III. For purposes of the present discussion, it is assumed that these can be satisfactorily worked out so that the major principles in property management may be treated as a unit.

In general, the specifications for types of machinery and equipment at the top of the list are determined by the nature of the product to be produced, and specifications for services at the bottom of the list are established by the nature of the remainder of the manufacturing plant.

The productive machinery is listed first because the most important consideration in its selection is the quantity and quality of the product which will be manufactured, rather than the other parts of the entire manufacturing organization. The selection of the productive machinery, in turn, determines the specifications which must be met by the material handling, power equipment, maintenance, and housing. Those items which are at the top of the list may be thought of as relatively "independent" parts in the design of a new manufacturing enterprise; the selection of those at the bottom of the list is more "dependent" upon what selections are made for other parts of the enterprise.

Several other characteristics of the order-of-selection list may be noted at this point. As a general rule the unit size of the items at the top of the list is smaller than those at the bottom. Productive machinery, such as lathes, milling machines, or looms, is smaller than boilers and factory buildings. Of course, the quantity of the smaller units is greater, but the importance of deciding whether or not to buy each additional unit is of less significance. A management problem of whether or not to buy a new boiler is more important than one of buying another lathe or loom and deserves proportionate study and consideration. Furthermore, the time required to design and manufacture a unit of the lower items on the list is greater than for those which are at the top. The greater quantity of those at the top of the list facilitates mass-production methods, whereas this is not true for boilers and factory buildings. Perhaps efficient management should be placed at the very bottom of the list because it is necessary for all the items above, and it requires the greatest time to "produce."

Accumulation of factory-service requirements. The method by which factory-service requirements may be accumulated is shown in Fig. 7. The checks in the column headed Manufacturing Machinery and Equipment indicate the requirements which accompany its ownership and operation. Most of the requirements are primarily physical in nature — power, maintenance, supplies — but nevertheless necessitate financial expenditures. Check marks on the chart opposite building, maintenance, power, and material handling indicate that as soon as productive machinery is purchased these factory services must also be provided. In the majority of plants this is done by purchasing and operating the physical property needed to produce the factory service required, although some services, such as power, may be purchased in a form ready for immediate use, and in other cases the physical property for producing the service may be leased. The question of whether to purchase services from the outside or to own or lease the physical property is considered on pages 49–51. The present discussion assumes that the physical property necessary for producing the services is owned and operated by the same management.

Material handling is the second item on the order-of-selection list, so the factory-service requirements of the material-handling equipment are checked in the next column; these requirements include the other factory services such as housing, maintenance, and power. Vertical columns are devoted to the remaining factory services according to their sequence on the order-of-selection list, and the expense items of each service are checked off. The complete chart shows that the specifications for any one factory service may be derived from the cumulative requirements of other factory services as well as those of the productive machinery, which is another way of saying that each item on the order-of-selection list is a factor in the requirements of the factory services listed below it.

It is important to note that a lower item on the order-of-selection list may also be a small factor in determining the requirements of services which are placed above it. The machinery of the maintenance department, for example, will consume a small portion of the total power. The maintenance department may also be asked to repair the building, and the heat for the building may be a by-product of the power plant. However, each of these requirements is only a small portion of the total requirements of the upper service, otherwise the order-of-selection list would be modified.

The chart shows the most typical manner in which factory-service requirements are interrelated. The total requirements for any one factory service named in the stub at the left of each horizontal line are found by adding up the requirements indicated by the checks on

	Manufacturing Machinery and Equipment	*Material-Handling Equipment*	*Storeskeeping Equipment*	*Power Equipment*	*Maintenance Equipment*	*Other Factory Services*	*Building*
First cost	√	√	√	√	√	√	√
Operating expenses (Labor)	√	√	√	√	√	√	√
Supplies	√	√	√	√	√	√	√
Building expense	√	√	√	√	√	√	
Other factory services	√	√	√	√	√		
Maintenance	√	√	√	√			
Power	√	√	√				
Storeskeeping	√	√					
Material handling	√						

FIGURE 7. CHART SHOWING ACCUMULATION OF FACTORY SERVICE REQUIREMENTS

that horizontal line; in addition there may be relatively small requirements from services further down on the order-of-selection list, and these must be estimated when prior tentative selections are made according to the order-of-selection list.

If the check marks are replaced by the costs of meeting the requirements they indicate, the total of each column would be the sum of the costs of providing (making available) the factory service named at the top of the column. It is important to note that costs cannot be entered into each column in succession at the same time and in the same way that the requirements are cumulated, because the cost of any one factory service will be influenced by the total demand for that service, so that all the requirements must first be known. For example, the cost of providing power for the productive machinery cannot be determined solely on its power requirements. The cumulated power requirements, including those of all the other factory service, must first be found, and selection of the power-plant equipment based on this total volume. The unit cost of producing power will vary with the size of the power plant which is constructed, and after this has been decided, the cost of providing the power for each of the other departments or services may then be found.

The costs of owning and operating any one piece of physical property cannot be determined until the property for the remainder of the plant has also been selected.

CAPACITY UTILIZATION

From the standpoint of the owners of a business, the final test of its management is, Can the business be run at a profit? From the social or community viewpoint, the ultimate test of management is the usefulness of the goods and services it renders to the community through production. In time of war the need for maximum production becomes paramount. The objectives of both the owners and the community can be satisfied only by the efficient utilization of manufacturing capacity.

The ownership of property which is not used fully within the limits of potential capacity indicates poor judgment in its selection, and profits are reduced in proportion to the cost of the amount of capacity which is unused. The old adage applies: "A chain is no stronger than its weakest link." The extra cost of the stronger links is thrown away. The capacity of a manufacturing plant does not depend solely upon the capacity of its parts, but also the way which management puts together these parts. An ideal combination of machinery and equipment leaves no one part with capacity in excess of the others, assuming all machinery and equipment are in good working order.

The principle of capacity utilization may be expressed as follows: In selecting physical property the industrial manager must be careful to avoid expenditures for productive capacity which cannot be used because it is not in balance with the capacity of other machinery and equipment already existing or to be installed.

Limitations on Effective Use of Capacity

It is difficult to design and arrange a manufacturing plant where all machinery and equipment will be operated constantly at maximum capacity. Chief among the many reasons why machinery and equipment must be idle are the following:

1. The difficulty of predicting the exact times which may be required to perform new manufacturing operations.
2. Unavoidable delays — repair schedules, emergency repairs, employees absent from work — which may hold up the production of some parts of the product while others are produced according to schedule.
3. The desirability and often necessity of having some reserve capacity to handle rush work, to provide for emergencies, and to anticipate future expansion.

Existing Capacity Affects Each Additional Purchase of Machinery and Equipment

In striving to achieve capacity utilization, management must appreciate that it is always necessary to consider the purchase of additional physical property (machinery, equipment) in relation to its coordination with existing or future facilities. There is little advantage in purchasing an expensive piece of equipment because of exceptional operating characteristics — speed, strength, efficiency — except as it may be tied in with the remainder of the manufacturing plant. The price paid for added capacity may be just so much wasted investment.

PROCEDURE FOR OBTAINING CAPACITY UTILIZATION

Management's approach to the problem of capacity utilization depends upon whether a new plant is being organized from scratch or whether modifications are being made in size and capacity of an existing plant. Each of these is considered in order.

When Designing a New Plant

Following the order-of-selection list (see pages 38 and 39), tentative selections of productive machinery are made. These selections determine what factory-service equipment will be required, and consequently the total cost of owning and operating the productive machinery.

Factory services included in cost curve. When making cost curves for the selection of production machinery, the overhead costs — material handling, power, housing — that are necessary for the operation of the machinery should be included in the cost curve. This is in keeping with the list of cost items in Fig. 7.

It may be necessary to estimate some of these costs because they will vary with the total quantity of the service required, as explained in Chap. VII. Even though estimated, the overhead costs should be added to the cost curves of the physical property because differences in overhead requirements of various machines may be the deciding factor in the selection.

As the different types of physical property are selected in sequence down the order-of-selection list, the costs of the remaining factory services (lower items on the list) should be added. The cost curve of material-handling equipment, for example, will include charges for maintenance, power, and housing — the remaining lower items on the list. The cost curve of the last items, such as housing, may also include a small charge for services which are above them on the list, as explained on pages 40–42. However, purchase cost, taxes, insurance, and depreciation will constitute most of the physical-property charges connected with the building; maintenance for the building is largely labor rather than equipment costs, and steam for heat is a by-product from the power plant.

Costs subordinate to performance. After the decision to purchase productive machinery has been made, the primary consideration in the selection of factory-service equipment is that of meeting the requirements of the productive machinery so that its full capacity may be utilized. Differences in the cost curves of factory-service equipment should receive secondary consideration, entering into the selection only when all possibilities satisfy the physical specifications for power, housing, and so on; that is, those which accompany the ownership of the equipment and which are higher up on the order-of-selection list. For example, a major breakdown in the power plant during a busy season would jeopardize the life of the entire business, and more than neutralize any savings obtained by cutting costs on the power-plant equipment. (Attempts to save in the initial purchase price of any machinery and equipment may prove to be costly in the long run.)

The estimated costs of factory services should be considered before deciding to start the business, or before deciding what productive machinery to purchase, but once either of these decisions has been made, the primary factor in the design of the remainder of the plant should be to provide the auxiliary property necessary to put these decisions into full effect.

Designing Changes in an Existing Plant

The most frequent selections of physical property made by management are additions and replacements in plants that are already operating. They are usually concerned with the smaller units that are near the top of the order-of-selection list — lathes, stamping machines, industrial trucks. The larger units at the bottom of the order-of-selection list, such as boilers and buildings, are more expensive and once selected are relatively permanent. Consequently, they become the limiting factor in minor alteration of an existing plant. Changes on the production floor are made to obtain capacity utilization of the more permanent and expensive factory-service facilities.

Existing, unutilized factory-service capacity reduces cost of owning new machinery. Cost curves to be used in the selection of additional physical property for an existing plant will always include the following items: purchase cost, taxes, insurance, and depreciation. In addition, the following expense items may be included: material handling, maintenance, power, and housing. The extent to which any one of the second group is included depends upon whether or not additional expenditures are necessary to obtain it. For example, if the power plant of a factory is operating at 70 per cent capacity, the power for an additional lathe will involve little or no additional expenditure for power. On the other hand, if the addition of the extra lathe would also necessitate investment in additional power-plant equipment, then the cost of owning and operating the lathe is increased accordingly. Similarly, if unused floor area is available, the lathe will not increase housing costs, but if another building must be constructed to house the lathe, the costs of owning include a large housing expense.

Cause and effect relationship reversed. The cause and effect relationship of the previous section is reversed. Originally this factory-service equipment was selected to provide capacity utilization for the production floor, but after the building has been constructed and the boilers installed, changes on the production floor must fit into the pattern established by the large expensive units which are at the bottom of the order-of-selection list. If this is not possible, then the problem is one of designing a new plant rather than altering an old one. Many industries reach a point where it is better management to start all over again with a new, modern factory in a new location rather than continue with makeshift modification of an antiquated factory.

Other Applications of Principle of Capacity Utilization

1. Size of enterprise in relation to market. In designing a manufacturing plant to make a product for which there is an existing demand, the business should be large enough to meet the volume demanded by

the market. Otherwise, competing producers may gain a foothold and capture the entire market for themselves.

2. Product design. A similar standard of quality should be followed in making all parts of the product. If an automobile has an engine which is mechanically perfect, and the body is fitted with poor upholstery, sales will fall off and the expense of designing and making the engine is wasted.

3. Marketing and advertising expenses. Productive capacity in the form of factories and equipment is of little value if the product of the latter cannot be sold. Expenditures for marketing and advertising are necessary in order to utilize fully the investment in production facilities.

4. Utilization of natural resources. The industrial pattern of a nation should be predicted upon the raw materials that are readily attainable. The natural raw materials "set the stage" and the prosperity of a nation depends upon the extent to which its natural advantages are utilized.

5. Plant location. Finding the most desirable community for the location of an industrial plant is really a matter of selecting a community that has services — transportation, materials, markets, labor — that may be utilized by the business without undue additional expenditures for these services. Once an industry has located in a community, unutilized community services may be used to advantage when making alterations or expansions.

6. Personnel administration. It is just as important to utilize effectively the training, experience, and ability of personnel as the productive capacity of physical property. Both the selection and placement of personnel should be influenced by the ability of the company to make full use of the services which its employees can perform and must be paid for.

7. Production control. Part V on Production Control continues the application of capacity utilization to the operation of physical property after it has been purchased.

8. Control of costs. When considering revisions of existing procedures or machinery, the decisions are often based on calculations of costs that will be saved by the new process. For example, if part of the maintenance work is to oil the bearings of machinery, then the installation of self-oiling bearings should result in a considerable time-saver in the maintenance work. The value (cost) of this time saved is frequently calculated by multiplying the total man-hours required to oil the machine during its lifetime by the hourly wage rate. Such a calculation is not always justified because the time saved by eliminating the oiling cannot be put to another equally productive use. The same

situation occurs when the savings in power consumption of a new machine are calculated. This theoretical saving will show on the expense account only if either (1) the fixed costs of the power plant may be reduced proportionally, or (2) the power which has been saved can be used by other machines.

In other words, there is no actual saving merely because there is no longer any need for a factory service which has already been paid for.

HOW MUCH TO MANAGE?

The vast majority of industrial organizations start from small beginnings. The prominence accorded large, well-known firms with impressive capacities for production and assembly of manufactured products should not blind the student to the importance of the thousands of smaller companies that are also an integral part of our industrial picture. The smaller concerns are often more profitable; the mere size of a firm is not in itself an indication of worth-whileness to the community, of profitability, or of good management.

One of the primary decisions to be made by management is how much it should attempt to manage. Should it be content with the control of only a single manufacturing process, or should it own and control the manufacturing facilities of an entire industry? While there may be certain definite advantages to be obtained from size, size by itself does not ensure success, and it always multiplies the management problems to be handled. Particularly in the initial stages of growth, the management of a manufacturing concern needs to be cautioned about assuming responsibilities which may place the organization in a financial strait jacket.

Successful management requires the happy combination of knowledge of the thing being managed, and ability to apply management principles. The larger the size of an organization, the more difficult it is for top management to have a complete understanding of the manifold problems that exist, let alone making effective application of management principles to them on a broad scale. Although it is true that in the large plant full-time specialists may be assigned to different phases of the work, it is still necessary for top management to pass upon the recommendations of these specialists and assume responsibility for themselves or the owners [1] in making decisions that are based upon only a general knowledge of the situation.

[1] Management and owners are nearly always the same in the small enterprise. In the medium-sized and large enterprise they are more apt to be separated. Individuals and stockholders who have invested money in the business leave its management to professional specialists.

There are many means by which an independent shop can manufacture a valuable product and yet assume a minimum of financial obligations. Examples are found in several areas of responsibility: (1) buildings and machinery can be rented; (2) power and other services can be purchased from local service agencies rather than being produced on the premises; (3) arrangements can be made to procure semifinished raw materials; and (4) advanced sales volume may be attained through an established distributor.

By using these devices to keep the scale of operations for which it is entirely responsible at a minimum, management gains the following advantages:

1. **Minimum capital investment.** To own a plant requires a substantial additional capital investment. When a manufacturing concern owns the plant it uses and its management makes expansions in operations as needed, generates the power required, and does its own selling, more financial capital is needed than would be required otherwise. To obtain these funds, it is necessary either to sell stock, thereby sharing ownership and possibly management with outsiders, or to borrow money. Even if the money needed may be borrowed at reasonable interest costs, the interest charges and the principal payments must be met whether the business is successful or not.
2. **Reduced risks of ownership.** When management does not own all the property it uses, it is freed from the risk of loss of property which cannot be replaced, even though it may be compensated for by insurance; losses caused by obsolescence — changes in style or unexpected new developments in machinery and equipment — are also avoided. In addition, the rental contract may provide that the owner shall maintain the property in good repair, thereby relieving the user of the dangers of loss from inadequate and improper maintenance.
3. **Management need not spread itself thin.** The control of any one small part of a manufacturing organization may require the services of specially trained personnel. Where such a part is not sufficiently large to keep special personnel busy all the time, it may be better business to hire an outsider for this purpose. For example, the potential dangers inherent in the use of elevators justifies paying for elevator-maintenance service. It is not worth while for a small plant to hire a full-time elevator specialist, but more economical of managerial time and money to have the elevators cared for by an outside expert.
4. **Flexibility.** A firm that owns all its property is forced to operate along essentially the same lines year after year or else dispose of the property at a loss. It is not free to shift quickly and economically to a more desirable geographic location as is the firm that only leases its quarters. Further, when the machinery and equipment are owned advisable changes in the style or nature of its product to meet market demands cannot be made.

To be balanced against the advantages of keeping the financial size of a firm — the amount to be managed — at a minimum, there are the following benefits from enlarging management responsibility:

1. **Obtain complete control.** If a concern rents property, hires management services periodically, or purchases semiprocessed raw materials, in reality it surrenders the opportunity to run its own affairs. It is the owner, or full-time manager representing the owner of a business, who has the deepest interest in its welfare. Provided he has the necessary ability, he is in a much better position to run the business successfully than service agencies whose equipment or part-time services are hired. A manager ties his hands if he must consult with a landlord every time he wishes alterations in his building, or with his supplier every time he wishes a modification in a semiprocessed raw material.
2. **Economies of coordinated division of labor.** Our present-day mass production is predicated upon the division of labor. The work is broken up into simple elements, so that each man may spend his full time at one particular task only, developing specialized skill, and thereby permitting more work by all. In a very small organization there are so many different types of work to be done that each person must perform a variety of tasks, preventing the economies of extensive division of labor. In a larger firm, these economies become possible, particularly if the management is skillful in coordinating the work performed in the various departments. Specialization can be developed not only among the workmen, but in the design and operation of physical property — buildings, machinery, and equipment. A rented building will probably be a general-purpose one adaptable to many different industries and consequently not possessing special features desirable in any one particular industry. The ownership of all kinds of physical property — building, machinery, and equipment — permits freedom in adopting special features for more efficient production.
3. **Organization permanency.** A firm which is well established and owns its facilities commands more respect from both employees and customers than one which is in a position to alter its activities or go out of business with the next shift of the wind. Employees look for steady employment so that they in turn may establish their homes on a more permanent basis, and customers of industries whose products require service or replacement parts are careful to purchase from established and reliable producers.

OWNING VS. LEASING

The how-much-to-manage problem amounts to more than deciding upon the size of the enterprise and whether to own or rent buildings, machinery, and service. Its solution requires also an understanding of these matters: (1) If a decision is made to own the property to be used, should it be built new or existing buildings, machinery, and

equipment purchased? (2) If the property is leased, should the lease agreement be a gross lease or a net lease?

Building new. When machinery, equipment, and buildings are designed and built by the manufacturer, he achieves these advantages:

1. His physical property meets his particular needs.
2. Alterations in his property may be made quickly and conveniently because no landlord has to be consulted.
3. His physical property can be designed to facilitate the manufacturing process.
4. Because the property will be constructed under his direction, he can be certain of the accuracy of the design and of the quality of materials used in construction.
5. Maintenance work will be facilitated because his maintenance staff will be familiar with property which it has seen erected and had a hand in building.

Buying existing property. When a manufacturer decides to house his plant in some building which already exists and to buy standard machines and equipment manufactured by others he will need to balance judgment on the following in deciding upon a path of action:

1. Standard equipment manufactured by other manufacturers may prove to be more serviceable and cheaper in cost than anything that can be made in the shop.
2. Secondhand equipment which is in good condition may prove to be as useful as new equipment at a great saving in initial cost. This will be helpful in keeping down overhead expense. (Not infrequently buildings may be purchased at great savings, and with little cost they may be altered to meet particular needs.)
3. The manufacturer needs to recognize that when secondhand or used property is purchased, the cost of altering and repairing buildings, as well as reconditioning motors, may more than offset any savings to be achieved through bargain purchase prices.
4. Except as secondhand and used property is in good condition, the cost of maintaining it may also defeat its value in use.

Gross and net leases. When industrial property is rented, it is customary for the manufacturer to make a lease arrangement with its owners. Many types of machinery and equipment are not to be obtained except on a lease basis. This is particularly true of service equipment such as blower systems, elevators, and some types of manufacturing equipment. Where the new market for machinery and equipment is limited the manufacturer needs to have regular income from rentals in order to continue in business and make developments and improvements in his product.

In renting factory buildings, the types of lease to be obtained are primarily a matter of individual bargaining with building owners. It is necessary for the manufacturers and the owners to decide which of the costs of occupying and using the building each is to pay. For example, an agreement may be made whereby a manufacturer agrees to pay all the costs of alterations, repairs, and maintenance, giving the manufacturer a flat sum per year to cover his costs of interest on his investment, depreciation, taxes, and fire insurance. Typical of the leases to be made in this connection are so-called gross leases and net leases.[1]

Gross Lease. In the gross lease, the owner or lessor agrees to meet all property charges regularly incurred through ownership. These include taxes, insurance, interest, repairs, maintenance, depreciation, water, heat, and light.

Net Lease. Under this type of lease, the manufacturer who uses the building agrees to pay a rental stipulated and in addition all property charges such as taxes, insurance, and interest.

If management has the time, knowledge, and ability to supervise all of the factory services which remain under its control in a gross lease, it should obtain such a lease in order to benefit from its management ability. It retains more complete control of the entire enterprise. It is in a position to coordinate all its activities economically and profitably. On the other hand, if the management of repairs, maintenance, and heat would become an added burden, then it is wise to obtain a net lease, permitting management to devote its entire time to the efficiency of direct productive effort. There are, of course, any number of intermediate arrangements that incorporate features of both the gross lease and the net lease.

[1] *Appraisal Terminology*, 2d ed., Report of the Education and Research Committee, American Institute of Real Estate Appraisers, 1938.

CHAPTER IV

SELECTING THE SITE — PLANT LOCATION

The migrations of United States industry during the past quarter century and the studied care with which many firms now select locations indicate the importance progressive managers attach to the selection of the plant site as essential to the conduct of a profitable manufacturing enterprise.

Because many profitable industries have chance locations, some industrial executives have tended to underestimate the role of plant location in industrial management. The record reveals, however, that manufacturing industries often fail as a result of poor location. The successful firms with chance locations only demonstrate that there may be in reality several excellent sites for any given type of manufacturing enterprise, and that, in addition, a sizable portion of industry has its origin in particular local circumstances. The existence locally of raw materials, other firms making similar products, as well as local product demand, may contribute toward the success of any given enterprise, but this does not deny the possibility of greater success if a location were determined scientifically.

Unfortunately, many plant managers pay little heed to location until competitive disadvantage calls attention to the present site as a factor in unprofitable operation. It is just as important for manufacturers, whose present plant locations are advantageous, to be on the alert to keep them so, lest resources become depleted or markets shift. Also industries having special privileges (patent monopolies) or those of a quasi-public nature (public utilities) must heed the location problem. Both have an obligation to the public to operate as economically as possible.

THE FOUNDATIONS OF INDUSTRIAL SOCIETY

If management is to make the study of plant location truly productive of increased earnings, it must first understand those *factors* which are fundamental in determining the degree to which industry may be expected to prosper in various sections of the country or the world, and, in turn, whether or not these sections deserve management consideration from a profit-making standpoint. These are:

Geographic factors:
- Soil
- Climate
- Topography
- Raw-material resources
- Power resources

Social factors:
- Characteristics of the people as affecting labor supply and markets for the product
- State of organization and development of learning
- Governmental regulation and subsidy

Industrial factors:
- Transportation
- Communication
- Financial facilities
- Complementary and competing industries

These factors are shown in chart form in Fig. 10 following page 64. A brief discussion of their relationship reveals the extent to which natural and social environment have direct bearing upon the industrial development of any given area. Space permits mentioning only the most significant facts. These follow:

Geographic Factors

Soil. Soil has a direct bearing upon the type of activity which will be undertaken by any area or section of the country in its early development. A fertile, nonrocky soil offers opportunities for agricultural pursuits and attracts industries which utilize agricultural products or cater to agricultural needs. Infertile soil forces people to seek other means of gaining a livelihood such as fishing, trading, or manufacturing. Within any given community, factory buildings are erected on low-cost ground wherever possible in order to keep manufacturing overhead expenses (taxes, interest on investment in land) at a minimum.

Climate. The development of modern systems of heating and air conditioning has lessened the importance of natural temperatures and humidity as factors in determining the location of an industrial plant. Indirectly, however, climate still has great influence on the industrial activity of any section or region. This is in its effect on the worker. A cool, invigorating climate develops the best type of industrial worker. He must work to provide shelter, food, and clothing, whereas the inhabitants of very warm climates, such as tropical areas, are less

efficient as industrial workers. They lack the incentive to provide shelter and clothing, and food is much more easily available. By temperament they are not so energetic as the worker who lives in cooler climates and by nature do not adapt themselves so readily to indoor occupations.

Topography. A hilly, rough, and rocky countryside does not lend itself readily to agricultural pursuits and usually has very little industrial activity except as a particular place may be blessed with mineral deposits or some natural resource to support a given type of industry. Mountain barriers, plateaus, and large rivers often have a retarding influence on industrial development. Any one or a combination of these makes for difficulties and expense of transportation and communication, thereby preventing competition with areas that are more readily and inexpensively accessible. These same factors may also have a retarding influence on the growth of population, and, consequently, restrict local markets for possible local industries.

Raw-material resources. Many industries have their origin in the production and utilization of specific raw materials (ores, minerals) and, therefore, are located in their midst, unless topography forbids. Extractive industries must be located at the source of raw material. Other industries which utilize these materials may obtain great advantage by locating at or near the source of supply. There is advantage in certainty and quickness of supply as well as a saving in transportation costs. The tremendous concentration of industry near the ore deposits of the United States Great Lakes region is evidence of the importance of this factor.

The advantages of locating manufacturing industries near raw materials must be balanced with the advantages of locating near markets.

Power resources. The sources of energy for turning wheels of industry have had a very decisive influence in plant location and the development of industrial centers. Until the coming of the steam engine, both water and wind power were widely sought as sources of power supply.

Water power has caused many industries to locate on riverbanks, and more recently hydroelectric power has had a similar influence. Currently, however, steam-turbine power plants, which are located near or on the premises of the industrial user, have decreased the relative importance of both water and hydroelectric power as factors in plant location. High-tension lines erected to transport power from large-scale hydroelectric plants to industrial users everywhere were hailed as sources of cheap power supply and a means of minimizing the importance of power as a significant factor in plant location. Thus

far, however, the costs of erecting and maintaining these lines have prevented achievement of the desired goal. Power still continues to be a significant influence in the attraction of industry.

Social Factors

Characteristics of the people as affecting labor supply and markets for the product. The labor supply has long been an important consideration of plant location. Industries everywhere are anxious to procure intelligent and effective workers; for many, no consideration is more important in the selection of a location than the availability of the right type and amount of labor. Experience has demonstrated that geography has a definite influence on labor quality. Furthermore, labor is less mobile than machinery. It is easier to move industrial facilities to places where workers live than to uproot workers from their homes.

All manufacturing exists to supply markets with goods which people will buy. There is no point in manufacturing a product unless people think it is useful or desirable, and have the purchasing power to obtain it. Manufactured products can be sold only when the thinking and living habits of the people are such that they can be persuaded to include these products in their pattern of living. Quite naturally, therefore, the characteristics of the people in different localities influence the market as to quantity and type of product which may be sold in any given area.

The advantages of market considerations need to be compared with the advantages of locating near raw materials. A manufacturer can keep in touch with the pulses of his markets when he is located near them. Sometimes industrial centers offer peculiar marketing advantages because buyers tend to gravitate toward them. When the buyer can visit the manufacturing plant he is brought into closer contact with the producer and designer. This enables the manufacturer to improve his customer relations and improve his service.

State of organization and development of learning. New industries, as well as the development and expansion of those already established, hinge on research and investigation to develop products and improve methods. Moreover, the profitable operation of industry is dependent on a constant supply of educated and trained men. To provide both of these, educational institutions and research agencies are needed. They will be found where industry or agriculture is successful; that is, where economic and geographic resources and conditions are favorable there will be sufficient wealth to establish educational institutions and research laboratories, but where they are unfavorable, these facilities will be appallingly lacking. Seldom does industry flourish without the support of organized education.

Governmental regulation and subsidy. Increasingly, state and national governments are creating agencies to direct and control every kind of business. Manufacturing industries are particularly affected by laws regarding the safety of employees, compensation for accidents, unemployment and other taxes; laws governing use of buildings, fire prevention and protection; rates of transportation; licenses, patents, limitations on the use of raw materials, hours of labor, and so on. When these added costs and limitations become burdensome to the extent that the existence of the industry is impaired from a profit-making standpoint, the manufacturer must seek a location in an area more favorable in these respects. Moreover, manufacturers seeking new locations give these matters advance consideration.

Governments influence the development of industry still further by means of subsidies. Tariffs exist to protect manufacturers against foreign competition, and often outright grants are made to permit both the establishment and continuance of particular manufacturing enterprises. Government subsidy affects plant location, therefore, in that industries exist in places which would be regarded as unprofitable under normal competitive conditions.

Industrial Factors

Transportation. To expand beyond its local environment and in some cases to exist at all, industry must have access to means of transportation. It is necessary to obtain raw materials and market finished goods. In the early history of the United States an industrial-plant site on a stream or the coast was needed in order to have easy access to potential markets and raw materials. Industries today are no less influenced in their location by transportation. In the choice of a site, attention is given to the availability and frequency of rail, water, air-transportation service, and trucking service.

The term "transportation" implies the existence also of storage, handling, and service facilities; and industries are attracted to those localities where these are readily available at reasonable cost. (Both topography and climate may have a retarding influence on the development of transportation facilities.)

Communication. The continued successful operation of an industrial plant requires that management be informed on market situations with respect to raw materials, finished goods, supplies, and prices. At one time topography, climate, or other factors prevented easy communication, placing industry at considerable disadvantage; and it was only natural, therefore, for industry to congregate in industrial centers to keep closely in touch with trends. Communication is a factor of lesser importance at present because modern facilities have

become both widespread and reasonable in cost. In fact, it is more important as a factor in encouraging industrial decentralization.

Financial facilities. Industry cannot exist and grow without funds to be invested in its development. These are obtained most readily from banks which are sympathetic to financing manufacturing enterprises. Some banks do not make industrial loans. Moreover, free capital is not to be found in a frontier society and it is to be expected that industry will locate in settled areas rather than frontier communities. In some cities and towns industrial-development finance corporations exist to attract industries needing capital loans for establishment or expansion.

Complementary and competing industries. Some manufacturers select locations which are near complementary industries, that is, those which produce materials and supplies used in connection with their own manufacturing processes. From the plant-location standpoint, this tends to encourage the centralization of industry. On the other hand, forces are at work which encourage decentralization. Competing industries located near one another may be handicapped by custom, making it difficult to initiate new manufacturing procedures; companies may have to compete against each other for workers; moreover, there may be a tendency for labor troubles to spread easily among plants.

An illustration of the influence of locational factors. The influence and significance of economic geography may be well illustrated in a brief résumé of the industrial experience of the New England area of the United States.

It was the influence of geographic conditions that turned the attention of many early New England settlers toward manufacturing pursuits. The New England climate, soil, and topography were found to be unfavorable to extensive agricultural development except in restricted areas. The people themselves were the industrious, thrifty, enterprising sort who make successful industrial workers, and they had to find an immediate means of livelihood or transport themselves elsewhere. The basic need of keeping alive and providing shelter against the climatic extremes of the New England weather sharpened their wits. They naturally turned to the development of skills and crafts by which they could produce things to exchange with peoples in other sections. Natural resources existed in New England in the form of wood, stone, and fish, and manufacturing industries centered around their utilization developed. Shipbuilding, quarrying, and related enterprises were the early ones, followed by those in the textile, boot-and-shoe, and machine-tool fields, utilizing the skills of workmen and mechanics coming to the United States from areas in the old country where these industries were already established.

A further impetus to the development of manufacturing was found in the natural water and wind power of the area, while the rivers and ocean made for free trade among the colonists and easy access to world markets and needed raw materials.

The New England industrial area eventually became supreme among United States manufacturing centers because of a variety of circumstances. It had the advantage of an early start coupled with Yankee ingenuity, inventiveness, and capacity for trade. It was encouraged by public authorities anxious to foster its development. It profited from the Napoleonic wars when European manufacturers were shut off from the United States; and from the development of the West with its ever-growing market for manufactured goods. Concurrently, the United States agricultural South was eager to send raw cotton and other staples to the New England mills in exchange for their manufactured goods. Finally, both during and following the Civil War period, New England industries entrenched themselves through combination and further growth and expansion. Their momentum, size, and abundance of capital, combined with the possession of ample skilled craftsmen, served to continue their growth until after the turn of the century.

As the United States extended its territory westward and discovered the rich ore and mineral deposits, and in particular coal for fuel, the very same economic and geographic factors which forced early colonial settlers to become craftsmen and laid the foundations for New England's industrial growth, served also to contribute to its industrial decline. Except for skilled labor, New England's resources were too few to give it an indefinite continued natural advantage in comparison with other fast-growing United States manufacturing industrial areas. With the expansion of Western markets, many industrialists found advantage in locating near them, while at the same time they profited from easy access to raw materials. Not only did migration take place, but new industries located in these areas as the center of United States population shifted to the western portion of the country. Notable among these migrants were the boot-and-shoe, machine-tool, and automobile industries. Moreover, the agricultural decline of the South as a result of the Civil War gave rise to a new industrial South, and the once firmly entrenched New England cotton-textile industry sought relief from high wages and taxes, as well as savings in raw-material transportation costs by locating near the sources of supply of raw cotton.

Today New England's primary advantages may be briefly summed up as follows:

1. It still profits from the advantage of an early start and retains those industries that originated there and that continue to operate at a profit.

2. It offers the advantage of highly skilled labor, some of which cannot be duplicated in other parts of the country.
3. It provides a good location for industries manufacturing products that require highly skilled labor and that have a high unit value, and, therefore, are capable of absorbing a high transportation cost to market centers.
4. New England in itself is a large market and must be expected, therefore, to retain a number of establishments that find this to be a major or primary market area.
5. It attracts workers as a recreational area.

New England businessmen are aware of both its industrial situation and of current trends. They have turned the tide in New England's favor. It is now generally appreciated that New England has lacked the diversification needed to minimize the shock of declining activity in a single industrial field. In the face of diminishing job opportunities, organized agencies are seeking to attract new industries as well as to hold established firms that offer the needed diversification. Unless industries are sought and held that can profit from the advantages New England can offer, the efforts of these agencies will be of little avail in the long run. Figure 8 shows a typical piece of promotional literature distributed by a progressive New England industrial city.

THE MANUFACTURING DISTRICT

Unique among present-day influences shaping the pattern of location of United States industry is the manufacturing district. In reality it is an industrial real-estate enterprise located in an urban industrial center. Land which is advantageously situated from the standpoint of accessibility to raw materials, markets, and labor supply is procured by enterprising citizens and held for development as a privately operated modern industrial community — a city within a city.

Reputable manufacturers are sought out and invited to buy or lease industrial property — land and buildings — in the area. The primary inducements used to attract these manufacturers are low-cost dependable services and financial assistance.

The Central Manufacturing District of Chicago is outstanding for its reputation of success as such an area. The services provided by its owners and management include: rail service to all lines serving Chicago, warehouse space, banking facilities (The District National Bank), fire and police protection, watchmen service, heat, light, gas, and water. All of these services and others are at hand at reasonable costs to users, because they are provided not for one firm, but for all.

The Chicago Central Manufacturing District has demonstrated that selecting a location within its limits is good business. The district

SAVINGS . . . *through distributing to New England from* WORCESTER

Geography and logic establish Worcester as distribution center

SAVE in your distribution methods by lowering the costs of getting your goods into the hands of your customers. New England presents a sharply defined market area—only 2 per cent of country's area—yet 8,000,000 consumers. *Worcester is the center of this highly concentrated consuming area.*

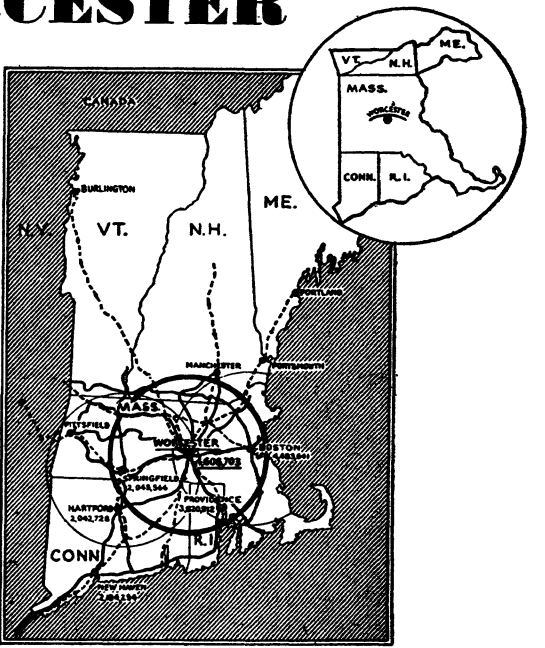
Concentrated population

One N. E. stock by inventory control

The greatest wastes in New England distribution are caused by needless stocks of goods, due to lack of inventory control; by back-hauling, misdirecting, and *excessive handling* of merchandise. Interest and freight charges, due to these causes, are costing millions of dollars in New England alone.

The solution

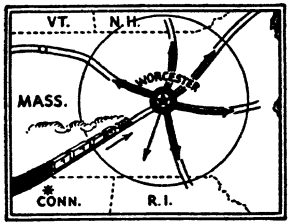
The solution is simple—WORCESTER—the point in this area where least back-hauling is necessary; where a single large stock can daily (or more frequently) supply your retail outlets; where the best transportation facilities are available.



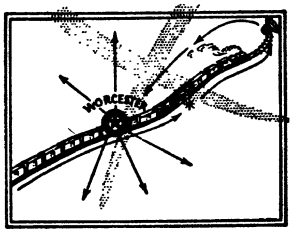
The distorted map (inset) is scaled to the relative market value and purchasing power of the states

Spot your merchandise at Worcester

—here the back-haul and the forward haul balance—here your market centers are equi-distant—here you eliminate costly delays—here your freight bill is at a minimum.



*Indicates the maximum elimination of back-hauls.



*Indicates wastefulness of distribution from seaboard.

It Steals Your Profit

to haul your products through or past Worcester to a seaboard distribution center.

The back-haul freight bill of New England distributors is enormous. *Add* to this, wasteful time delays. Stocks which unnecessarily spend from two days to a week in freight cars contribute in lost trade and increased charges.

1. The red lines on the large map show highways radiating from Worcester to form a vast transportation network. Your goods reach *all* the important centers in half a day's time.
2. The black lines indicate the three big New England railroads which serve Worcester (see map). Trains speed overnight to all important centers. Warehousing facilities are numerous.
3. The large map indicates that any distributing plan which reaches the *buying power* of the New England market must base its center in Worcester. Fifty-mile radius populations are shown.
4. It is to your advantage to learn the complete story. At your request we shall send a competent representative to confer with you.
5. Your individual problem will be analyzed carefully and a complete report submitted.

INDUSTRIAL BUREAU

***The* WORCESTER CHAMBER *of* COMMERCE**

4,608,703 people in a 50 mile radius of **Worcester, Massachusetts** has a metropolitan population of 305,000

Courtesy of the Worcester Chamber of Commerce

FIGURE 8. TYPICAL PIECE OF PROMOTIONAL LITERATURE USED FOR INDUSTRIAL DEVELOPMENT PURPOSES

Note. The original of this illustration is printed in red and black. In this reproduction in legend 1 for "the red lines" read "the solid lines" and in legend 2 for "the black lines" read "the broken lines."

contains plants of many leading national and international organizations. Typical of its foresight and planning are the statements contained in the two following paragraphs quoted from "Speaking for Ourselves" by Richard Hackett, Manager of the Chicago Central Manufacturing District, appearing in the Silver Anniversary edition of the Central Manufacturing District Magazine.[1]

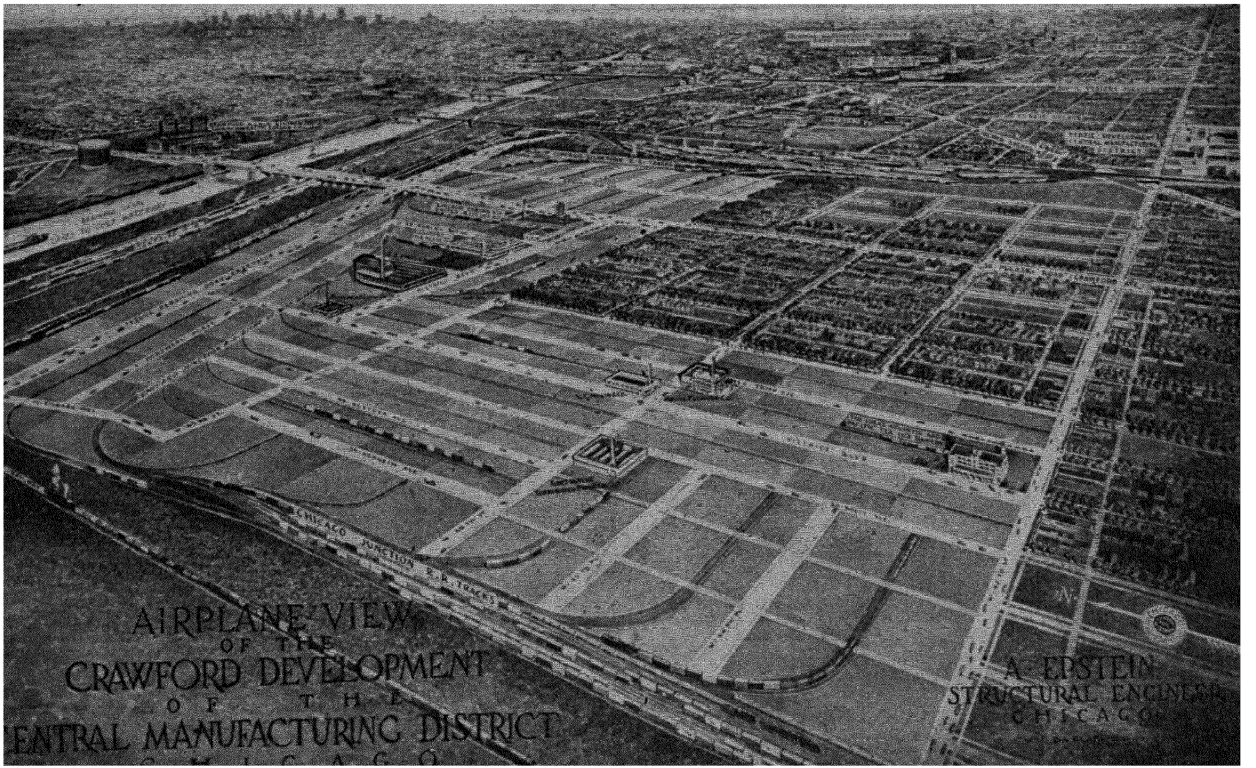
> . . . not only did the District anticipate the physical requirements of industry but the Trustees also included, in its bid for residents, the offer of financial assistance. Herein lies one of the principal differences between our scope of relations with industry and those of most other industrial real estate owners or agents. In properly accredited cases we finance as much as 80% of the amount required to acquire land and structures. This offers the further advantages of a complete transaction within the knowledge only of the signatory parties, and without exposure to the guile of opportunists or resort to outside sources of capital. It allows a company, also, the immediate possession of needed facilities without drain upon capital assets or cash reserves.
>
> All of which, interpreted, means we have land, services, and powerful financial resources available to accommodate industry, according to individual needs. There is land for such as wish to consummate outright purchases. They are privileged to erect their own structures within the provisions of the normal codes. For those whose operations are served best by multiple story construction we have sites among others of their kind, and for those to whom straight line production is dictated by economy we can offer other locations wherein low land unit costs enable expansion without surcharge. If, after a land purchase, an industry desires the District to design and erect a suitable building, either for immediate or amortized payment, we have an experienced staff of structural engineers and architects to plan and supervise the work in which we assume the full responsibility.

Figure 9 shows an airplane view of the Crawford development of the Central Manufacturing District in Chicago.

TECHNIQUE OF PLANT LOCATION

Plant-location problems arise from two sources: (1) manufacturers seeking to locate a plant for the first time and (2) manufacturers already established seeking new locations. In seeking solutions to either problem, it is necessary to compare the relative advantages of one community with another. In both instances special operating economies are sought and they are in reality only phases of the same problem. In seeking information to determine whether a present location is advantageous, or to select a site for an entirely new enterprise, top management may follow a variety of paths. Chief among these are: (1) it

[1] January 25, 1941, Vol. 25, No. 1.



Courtesy of Central Manufacturing District

FIGURE 9. AIRPLANE VIEW OF THE CRAWFORD DEVELOPMENT OF THE CENTRAL MANUFACTURING DISTRICT, CHICAGO
This photograph shows plants already located and tentative schematic arrangement of sites and service tracks.

may use its own staff to conduct an investigation to determine what area or locality offers the best advantages for profitable plant locations. (2) It may do very little investigating through its own organization and utilize information compiled and disseminated by one of several industrial-development agencies seeking to attract industries to particular areas and communities. (3) The data sought may be gathered jointly by representatives of the industry concerned and various industrial-development agencies seeking to attract it. (4) The management may employ specialists as consultants who will make a report of their findings. (5) Top management may rely entirely on its own trade association for specific recommendations.

In actual practice it is not uncommon to find any one or a combination of these methods employed in the solution of a single location problem. It has been found, however, that an independent investigation is somewhat risky because it is so easy to overlook significant considerations.

Regardless of the means employed to obtain the information essential to solving the problem, the steps in its solution will be these:

1. **The factors of plant location.** Those charged with recommending desirable locations for a proposed or existing plant must analyze carefully the factors of plant location.
2. **Factors of concern to a particular industry.** Through careful investigation and study it must be decided which plant-location factors have a direct bearing on the particular problem, that is, which are of greatest importance to the specific industry and what is their order of relative importance.
3. **Survey of likely areas.** Information must be sought on various sections of the country to discover which can most nearly meet the predetermined requirements. The communities or areas which appear most promising must be analyzed in detail. For this purpose, information must be sought on every aspect of the community.
4. **Selection of a community.** When the data with respect to the areas under consideration have been completely compiled, they must be correlated and compared statistically to show specifically how well each of the communities studied measures up to the requirements, that is, which is best, second best, and so on.
5. **Checking the results.** By way of supplementing the information obtained in regard to the communities deemed most desirable, local manufacturers of the communities studied should be consulted to learn more specifically the nature of local conditions.

Good management demands not only that each of these steps be followed in sequence, but also that specific techniques and considerations applicable to each be made a necessity. A brief discussion of each follows:

The Factors of Plant Location

Figure 10 following page 64 shows the factors of location already discussed (pages 52–59). These factors are subdivided into three major classifications: (1) those which determine the most suitable area or section of the country; (2) those pertaining more particularly to a specific location — city, suburban, or rural district; and (3) factors influencing the selection of the plant site itself.

In addition, the chart includes under the head of "Complementary and Competing Industries" those considerations which tend to encourage or discourage locations in industrial centers — areas where like or similar industries tend to congregate.

Choice of city, town, or rural district. The small industry usually finds advantage in renting loft space in urban areas where it can obtain its many needed services which it cannot yet afford to provide itself. The choice of a city, suburban, or country location may depend upon the type of building needed or process arrangement; a factory requiring a single-story building covering several acres cannot afford high land cost of urban areas and, therefore, must seek a country location. Similarly, the manufacturer who requires special services found only in the metropolitan or urban area, and who also needs an extensive plant property, will probably be best situated in a suburban locality. In general, when allowed free choice, one may expect to find small industries in the city proper (usually in rented areas), medium-sized and large industries in the suburban localities, and very sizable or extensive plants outside in the country.

Significance of location factors constantly changing. A study of the factors influencing plant location over a considerable period of time reveals a constantly changing emphasis in the influence each may exert at any given time. Not only has human invention lessened the significance of some factors, but also by natural trends of events some have ceased to operate. For example, the introduction into textile mills of automatic humidifying equipment has lessened considerably the importance of the climate in the location problems of this industry. Similarly, the introduction of special labor-saving machinery has rendered less potent the existence of craft skill as an essential requisite of a community.

In the United States there are still many factors for which the original reason of location no longer exists. Time and circumstances have rendered them obsolete and no pressing reason has as yet forced a reestablishment of the firm. Those industries which originally sought the advantage of water power find this a poor justification for their location today when ample power may be purchased from local utilities

at reasonable rates. It is important for managers of industry to recognize that location advantages change and if possible avoid the practice of locating a new plant near established ones on the assumption that due consideration has been given recently to location. Not infrequently, the original advantages sought are no longer of great significance in the achievement of profitable manufacturing operations.

Factors of Concern to a Particular Industry

The determination of the specific factors of greatest importance to industries seeking locations may be accomplished as follows: (1) They may be determined solely from the industry's own experience; (2) they may be arrived at after consultations and exchanges of opinion with similar or related firms; (3) they may be obtained from various trade associations whose recommendations will represent a consensus of the entire industry; (4) specialists or consultants may be asked to conduct an investigation and make specific recommendations.

The factors designated as those applicable to the location problem under consideration must then be listed in order of their relative importance. Figure 11 shows the plant-location factors listed in order of importance for several classifications of manufacturing industries.

Survey of Likely Areas

To make a survey of various sections to determine the extent to which they offer advantages as a location for particular industries, it is important that those charged with the responsibility make a

Reasons	*Food Industries*	*Textile Industries*	*Lumber Industries*	*Machinery Industries*	*Leather Industries*	*Chemical Industries*
Markets	1	2	1	1	3	1
Labor	4	1	2	2	1	3
Transportation	3	4	3	3	6	2
Materials	2	6	4	6	4	4
Available buildings	6	3	5	4	2	5
Power and fuel	7	5	7	8		7
Near related industries	8		8		5	8
Living conditions	5	7	6	7	7	6
Financial aid		8		5	8	

NOTE: The figures noted under the various industry headings show the relative importance of each reason given for that particular industry. These data are for the United States as a whole.

FIGURE 11. REASONS FOR PLANT LOCATIONS BY INDUSTRIES

From "Industrial Development for a Community," prepared by Policyholders Service Bureau, Metropolitan Life Insurance Company, New York, 1932.

thorough investigation. This demands that the communities selected as possessing possible advantages must be examined most carefully and in great detail. The type of information to be sought is set forth in the following recommended community-survey pattern: [1]

A. The community
   1. Government efficiency and effectiveness
   2. Conditions that have caused industries to leave
   3. Advantages and disadvantages of existing industries
   4. Adequacy of public services — fire, police, water, sewerage
   5. Living conditions — housing, recreational, school, hospital, and church facilities

B. Labor
   1. Present status and trend of population in the community and surrounding territory
   2. Types of labor available for employment in various trades
   3. Wages paid labor in comparison with that in similar communities
   4. Attitudes, unionization, and conditions of labor

C. Markets
   1. The local market
   2. Distance and traveling time to principal marketing centers

D. Transportation services
   1. Railroad passenger and freight service, sidings, etc.
   2. Bus line and trucking facilities
   3. Air and water transportation (port facilities)

E. Power sources, service, rates, etc.

F. Tax rates and assessments

G. Existing factory buildings
   1. Sizes, conditions, and possible uses

H. Raw materials
   1. Types and quantities
   2. Transportation costs

I. Banking facilities

Space does not permit the presentation of complete illustrations of the detail which must be sought in relation to the above items but there follow selected samples showing the arrangement and scope of information that must be compiled if the results of the analysis of the community are to have real usefulness.

Figure 12 shows the tabulation of workers available for employment taken from a community survey. The manufacturer seeking a new location needs to know more than just how many persons are unemployed in the community. He needs to have specific information of their type and number; he also wants to know where the workers live

[1] Asa S. Knowles, "Getting the Industry Best Suited to the Community," *The American City*, January, 1939.

and whether they can be obtained at a reasonable cost. In like manner manufacturers who seek locations need to have complete information on available buildings. Figure 13 shows the best arrangement of the detail required for this purpose.

The agencies which may be of assistance in compiling information pertaining to developing communities are these: (1) local government officials, (2) local chambers of commerce or boards of trade, (3) regional development agencies, (4) local development agencies, (5) local real-estate brokers, (6) local manufacturers, (7) state labor unemployment boards, employment offices, (8) various research agencies which are devoting attention to industrial migration and development.

AVAILABLE SHOE MANUFACTURING WORKERS

Type of Work	*Male*	*Female*
Wood heelers	38	
Stockfitters	12	
Cutters:		
Trimming	13	
Block	5	
Stitchers:		
Goodyear	3	
Vampers	2	2
Shoemakers	4	

FIGURE 12. TABLE SHOWING TYPICAL INFORMATION NEEDED FOR INDUSTRIAL DEVELOPMENT PURPOSES

Selection of a Community

In order to make wise use of the data compiled on various communities for industrial-location purposes, a comparison should be made of their offerings. This will show how well each meets the location requirements desired. A comparison of tabulated lists of information can be given real meaning only if the factors sought have a numerical value, that is, a maximum number of points possible for each factor. It is impossible to score each community under consideration on the basis of actual offerings as found.

There follow in the next page in Fig. 14 examples showing the total maximum scores to be obtained for three communities in Massachusetts, and the number of points assigned to them after careful study of data revealed by surveys of them made for industrial-development purposes by the Bureau of Business Research at Northeastern University.

The range of points used in Fig. 14 is selected more or less arbitrarily. It is important to have a total point scale that permits fairly careful

AVAILABLE FACTORY BUILDING

Information Sheet

(Picture of Property)

Location:
Town: Jacksonville — Lot No. 270
Street: Williams — Plan: 204

Sale: Yes ☐ No ☐
Rent: Yes ☐ No ☐
Price: $65,000

Tax Rate: $42.25
Assess: $55,000
Mtge: $18,000

Distance from:
Boston 40 miles
Portland 70 miles
New York 240 miles
Springfield 140 miles

Age: 26 yrs.

Previous use:
Cotton Textiles

Condition: Good

Owner:
A B C Realty Co.

Property Description:
Name: Rand Mill
Land: 250′ × 190′
Bldg: Main building 75,000 sq. ft.
Other: Garage
Office building

(See reverse side for layout plan)

Service Facilities:

Material Handling:
No special equipment

Transportation:
R.R. siding — B. & M. R.R.
Length — whole side building
Distance from R.R. station ¼ mile
Trucking — 3 lines

Building: (details of construction)

Type: Three story

Construction:
Heavy mill, timbers 14″ × 14″ first floor; 12″ × 14″ second and third floors; material: longleaf hard pine

Floors:
Area — 25,000 sq. feet each
Safe load: 175 lbs. per sq. ft.

Walls:
Brick: 2′ thick on first floor, graduating 4″ on each floor
20″ second, 16″ third

Windows:
Factory well lighted
Sash material: wood
Condition fair

Ceilings: (Height to Beams)
First floor — 11′
Second floor — 10′6″
Third floor — 10′

Stairs:
Number — 2
Fireproof construction

Elevators:
Number — 1
Fireproof shaft

Water.
City supply — good
Ample for process

Fire Protection:
Sprinkler system
Private hydrants — city supply

Power:
Water power — none
Steam plant — for heat only
Gas — yes
Public utility — yes, municipal plant
Rates — special contract

Heat:
Steam plant:
Cost estimated $1500
$2000 per year

Other:
Plant yard enclosed
Fence (new)

Special:
Mortgage may be taken over by purchaser

Notes, Broker Listings, etc.:
All local brokers

Date:
10-1-39

FIGURE 13. FORM FOR RECORDING INFORMATION ABOUT AVAILABLE FACTORY BUILDINGS USEFUL TO MANUFACTURERS SEEKING AVAILABLE BUILDINGS FOR A NEW LOCATION

Food Group

Advantages	*Possible Points*	*Points Given Cities* (1)	(2)	(3)
1. Markets	800	400	750	700
2. Materials	700	350	300	350
3. Transportation	600	500	400	400
4. Labor	500	250	450	350
5. Living conditions	400	400	400	350
6. Available factory buildings	300	200	0	0
7. Power and fuel	200	150	200	150
8. Near related industries	100	50	75	50
	3,600	2,300	2,575	2,350
Correlation = Points given cities / Possible points		63.9%	74.9%	65.3%

Leather Group

Advantages	*Possible Points*	*Points Given Cities* (1)	(2)	(3)
1. Labor	800	700	700	750
2. Available factory buildings	700	700	0	550
3. Markets	600	600	400	600
4. Materials	500	500	200	500
5. Near related industries	400	400	100	400
6. Transportation	300	300	300	250
7. Living conditions	200	200	200	150
8. Financial aid	100	50	100	50
	3,600	3,450	2,000	3,250
Correlation = Points given cities / Possible points		95.8%	58.3%	90.3%

FIGURE 14. RELATIVE PLANT LOCATION OPPORTUNITIES OFFERED INDUSTRIES IN THE FOOD AND LEATHER GROUPS BY THREE CITIES IN MASSACHUSETTS

Based on three surveys of communities in Massachusetts for industrial development purposes. Northeastern University, Bureau of Business Research.

measurement. A scale of 500 can be split up more equitably among several factors than a scale of 50; of course the same scale should be applied to all cities or areas under consideration.

Checking the Results

Even though community surveys may be made on a very thorough basis, it is very easy to overlook essential information. In this connection management has found it helpful to seek supplementary data from manufacturers located in the various communities under consideration. In so doing they have sought answers to questions similar to the following that were recommended for this purpose by the New England Council:

1. Are taxes, both local and state, fair and reasonable? If not, what should the community do to decrease or more equitably distribute the tax burden?
2. Are the public services maintained by the community necessary, adequate, and reasonable in costs?
3. Are local sources of industrial financing adequate? If not, what are the needs?
4. Is there a scarcity of buildings suitable for modern manufacturing purposes, or a shortage of houses for workers? If so, what is the local situation as to building-construction costs — materials, labor, taxes — and how does it compare with that of neighboring communities?
5. Are there local shortages of labor? If so, what types? How is it suggested that these needs be met?
6. Do industries feel that they are unduly handicapped by local or state regulations?
7. Do manufacturers believe that the community understands and appreciates the extent to which its economic life depends upon the continued growth and prosperity of its industries? Do they find the community prepared to cooperate with them in solving local industrial problems?

THE BATTLE FOR THE SMOKESTACKS

The past two decades of American industry have witnessed considerable change in its national organization. Recognizing the profit-making advantages of wisely chosen plant-location sites, industry has been "on the move." The increasing intensity of competition has resulted in a survival of the fittest, and in the struggle many manufacturers have sought to overcome handicaps of disadvantageous locations.

The migration of these industries has created a series of unemployment problems for the communities from which they have moved. Not only have the latter had to awaken to the need to attract new industries to replace those lost, but also to hold those still remaining.

Their situation has been made even more difficult by adverse business conditions and serious unemployment problems from time to time in other communities not industry conscious heretofore. This has called to the attention of the business leaders of the latter the need of attracting industry to assist in reducing tax burdens. Still other areas, such as the southern and western portions of the United States, have sought to establish industry to rehabilitate their economy. The net result has proved to be a battle for industry among the different sections of the entire country.

Special agencies are now operating to accomplish these ends: regional development bodies (such as the New England Council, industrial-development commissions, local industrial-development committees,

and public-utility companies) are bending every effort to hold present industries and attract new ones. Similar organizations are established in southern and western portions of the country as well as in separate states; and since each depends upon its success for existence and support, the competition is very keen — one attempting to outsell the other.

These trends have aroused considerable interest in the scientific location of industrial plants, however, and made possible substantial and worth-while contributions to the literature and experience of the field. Among the advantages are these: (1) Guess work has been eliminated in appraising industrial possibilities of various communities. (2) Areas and communities have analyzed their industrial assets and by criticizing themselves constructively have sought effective remedies for their disadvantages that heretofore have caused an exodus of industry, thereby stopping needless migration. (3) Much data has been compiled on the needs of specific industrial groups and this has been interpreted by management in the light of community offerings. (4) There have been formulated definite plans of procedure by which industry can seek new locations with confidence in ultimate success. (5) Communities have been shown how to attract industries, hold present ones, and make their communities generally more inviting to both existing industries and those seeking new locations.

It must be pointed out, however, that the activities in this direction have not been without specific disadvantages to both industry and the nation as a whole. The following are outstanding:

1. A number of groups of towns and cities have set about attracting industries by offering free enticements (tax exemptions, free sites, free rent) and have encouraged the growth of "fly-by-night" establishments which remain in each community only long enough to profit from temporary advantage, moving to the next "grab bag" when this has disappeared.
2. Many industries have been attracted to communities not best suited to their needs, and their location problems have not been remedied.
3. Migrations between areas or sections of the country have upset conditions both in the areas from which industries have moved and created special problems for the areas into which they migrated. Not infrequently towns and cities have been forced to spend sizable sums of money to expand water or sewerage systems to take care of industries too large for the community. In addition, new industries have often attracted migratory labor, creating problems of housing and sanitation for the public officials.
4. The competition for industries between sections and communities of the country has created an ill feeling and prevented many communities from facing the entire problem on a basis of what is best for the manufacturer is best for the country as a whole.

There is need for a clearinghouse to supervise these migratory tendencies. Industry should be located where it will have greatest advantage because this will benefit both the manufacturer and the general public. (When industry cannot succeed, it merely creates a problem of unemployment and great sacrifice of valuable assets.) An impartial tribunal for industries to weigh the advantages of various sections and to advise industries seeking a change of location would be to the interests of both manufacturer and the nation as a whole. An industrial location in itself cannot revive a dying organization, nor can it be a substitute for poor management; moreover, there are often other considerations, such as military needs, which require a specific type of industrial development. All of these factors should be given consideration and industrial locations made a matter of cooperation among industrial management, the public, and a special advisory government agency.

Both industry and the community have a recognized stake in the industrial organization of the United States. Hit-or-miss methods must be abandoned in favor of definite planned procedures for industrial development.

CHAPTER V

SELECTION OF MACHINERY AND EQUIPMENT

Few managers can be experts in every phase of plant organization and management. The true management viewpoint must be a broad one and therefore all managers need to avoid time-consuming details. Where detailed information is needed in order to reach decisions, the manager must rely upon the advice and counsel of specialists in various fields. One phase of management responsibility where this is particularly true is that of deciding the technical considerations which have to do with the selection of machinery and equipment. The plant engineer and maintenance specialist who will be concerned with installations and repairs should supply the plant manager with the detailed information he needs in deciding upon the purchase of particular machinery and equipment. Every manager, however, needs to have some general information about machinery and equipment in order to render sound final judgment on the recommendations and reports of technical staff members. Otherwise he may not only decide unwisely, but also may appear unintelligent in discussing technical matters. The information the manager needs to know reduces itself to some basic principles.

The following paragraphs[1] present a check list of the principles which the plant manager should use in making his decisions regarding the selection of machinery and equipment and the provision of plant services. This is merely the background which is needed to work with his technical specialists and to reach intelligent decisions. The detailed study of each of the topics presented below is a task for the technical specialist. The manager must appreciate that the primary function of this general technical knowledge is to pass upon the specialists' findings.

Performance Characteristics

The purchaser of the machine should know the mechanical performance expected of it in terms of power, speed, direction, and distance. Manufacturers of machinery have available for purchasers

[1] Students who are totally unfamiliar with the terminology of machinery should use the discussions which follow as topical guides for further reading. (Suggested readings are listed in the bibliography at the end of the text.)

curves showing the performance of various models regularly manufactured. On request they will design special equipment to meet individual needs. The operating characteristics of all machines may be grouped under the following classifications:

Output. There should be no question about the ability of the machine to perform the mechanical task required. The most efficient operating output is usually below capacity, and an ample allowance provides flexibility for rush periods and business expansion.

Fuel or power requirements. Besides the financial consideration of fuel or power requirements, it is important that the correct fuel be delivered to the machine at the proper time and in the correct quantities. Data for these requirements will be furnished by the manufacturer of the machinery and equipment under consideration and should be checked with the available fuel or power supply at the point of installation.

Efficiency. The mechanical efficiency of a machine measures the energy put into it — mechanical, electrical, or chemical — against the power which the machine delivers. This will always be less than 100 per cent, since energy cannot be created by the machine itself, and some of the energy put into it is needed to operate it. The mechanical efficiency should not be confused with the "financial efficiency" in terms of dollar expense against dollar value of work done. A machine with a high mechanical efficiency may nevertheless be very expensive to operate. However, when operating costs are approximately the same, the efficiencies of different machines over the probable range of output become an important factor in selection.

Frequency of adjustments, oilings. When machinery requires frequent attention, its reliability depends upon the presence and reliability of an attendant who is familiar with its individual characteristics and can give it the proper care. Other considerations being equal, it is desirable to have machinery which requires as little attention as possible, since minor adjustments and needed periodic oiling are easily postponed and hard for the management to check upon until it is too late.

Accessibility of parts for adjustments and repairs. The mechanic's time and skill required to make adjustments or repairs when working on a machine depend not only upon the particular part that requires attention, but also upon the ease of getting at this part. If there are other parts that must be removed and replaced with difficulty, a small repair job soon becomes a major operation.

Availability of replacement parts. When machinery contains standard fittings, such as screws and gears, the problem of replacements is greatly simplified. From this standpoint it is safer to purchase standard

designs from large, established manufacturers. Special models produced by small shops are frequently "orphaned" in the sense that the manufacturing or parent company may go out of business and hence replacement parts cannot be obtained. Many large concerns maintain extensive service and supply departments that can be depended upon to make almost continuous operation of a machine possible.

Freedom from breakdown. It is impossible to tell how quickly and frequently a machine will break down until the accidents actually occur. In selecting machinery which is built for particular uses the purchaser must depend upon the general reputation of the producer and his own knowledge of the materials of which it is made as well as the design of the machine being purchased. The reliability of standard equipment can be determined from reports of organizations where it is installed.

Tolerances and allowances. The power, dependability, and durability of a machine are determined in part by the accuracy with which the parts are machined and fitted together. However, the time and labor spent on machining operations increases tremendously with small increases in the accuracy with which the work must be done. The designer of the machine must balance these two factors and specify definite limits within which the measurements of the finished product is to fall. For example, if a shaft and bearing are both roughly 3 inches in diameter, the machinist does not try to make both of them exactly the same diameter. The drawings will specify a small allowance, say 0.0019 inch, as the minimum difference between the two diameters. But the machinist cannot make the shaft exactly 2.9981 inches and the bearing exactly 3.0000 inches. He is given a tolerance of 0.0012 inch for both jobs, that is, the dimension of the shaft must be between 2.9969 inches and 2.9981 inches and that of the bearing between 3.0000 inches and 3.0012 inches. Thus when the parts are assembled the difference between the diameters may be as little as 0.0012 inch or as much as 0.0043 inch. Parts within the limits specified above may be assembled at random, but some combinations will give closer fits than others. The quality of the machine might be improved by requiring greater accuracy and care in selecting the parts to be assembled together, but this would incur higher production costs.

MACHINERY TERMINOLOGY

For general purposes of talking intelligently and making comparisons in the selection of machinery, the manager needs an understanding of terms that are commonly used to define the parts found in most machines.

A machine is a device to transmit or modify a force or motion for the purpose of doing some definite, useful work. For example, a water wheel takes the force from the moving water in the stream and modifies it so that it will turn a grindstone. Other machines take mechanical, electrical, or chemical energy and deliver a motion which accomplishes some desired work, such as drilling, cutting, turning, or lifting. Every machine is made up of parts which transmit or modify power, and a base or frame to hold these more active parts. There must also be smaller parts which fasten the others together, and devices to control the operation of the machine.

The parts of machinery about which every manager needs to have general information are discussed briefly in the following paragraphs. Only those parts are illustrated which are difficult to visualize from the word descriptions.

Base or frame. The moving parts of a machine must be attached to a base or frame that serves the important function of keeping the moving parts in proper alignment. For example, the frame between the shafts of two gears must provide rigid support for the shafts so that the gears remain in mesh. If the frame should become "sprung," so that the gears fail to mesh, the machine cannot operate.

The frame of a machine must be able to withstand both (1) internal and (2) external shocks. Internal shocks arise from the contact of the moving parts with each other and with the frame. Sometimes they are of sufficient intensity to require special foundations to absorb vibration which would be detrimental to surrounding property. External shocks arise from the contact between other objects and a machine in motion, or from shocks which come from surroundings.

Fastenings. Some sort of fastening device must be used whenever one part is to be rigidly attached to another. *Screws and bolts* are widely used fastening devices. There are many standard forms to meet the requirements of various installations, and adherence to these facilitates repairs and flexibility.

Keys. Keys are used to prevent movement between a shaft and the member — gear, pulley, or wheel — mounted upon the shaft, so that neither the member nor the shaft can move without moving the other also. A keyway or key slot is cut in both the surface of the shaft and the surface of the hole in the member. The shaft and member are turned so that the keyways are opposite each other, and the insertion of the key keeps them in this position.

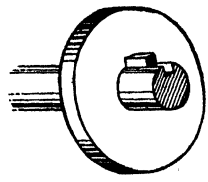


FIGURE 15. KEY

Pins. A pin used in connection with machinery is essentially the same thing as the pin used in connection with clothing — merely a shaft

or peg inserted through two parts to hold them together. In reality, the bolt, with its threads and perhaps a nut, is a refinement of the idea of the pin, but there are many instances where a simple pin is effective. A taper pin is one that tapers so that it may be wedged into the pieces it holds together. A cotter pin is one whose ends may be spread apart in order to keep it in place.

Either *riveting* or *welding* are frequently used where the fastening is to be permanent. A rivet is a pin with one head; it is inserted through the pieces to be joined so that the other protruding end may then be flattened out to form a second head. In the welding process heat is applied to the metal surfaces to be joined so that they fuse together and become one piece. In the past riveting has been more common, but recent developments in the field of welding have brought this method into popularity.

Bearings must be used when there is contact between moving parts. When the pressure is not great, there may be direct contact between the two surfaces, but high speeds or pressures call for the insertion of balls or rollers between the moving surface and the fixed one. A plain *journal bearing* is simply a hole into which a rotating shaft may be inserted. In a *cap bearing*, half of the bearing surface is in a removable cap. These bearings may be lined with brass or babbitt metal and the linings replaced as they wear out. When a journal bearing wears and becomes loose, there is no way of tightening it. The cap of a cap bearing may be removed, relined, and tightened.

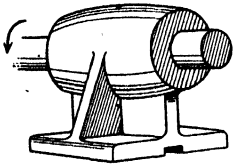


FIGURE 16. JOURNAL BEARING

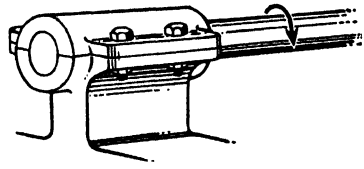


FIGURE 17. CAP BEARING

Friction may be reduced by the use of *ball bearings*, in which steel balls are placed between the bearing and the rotating shaft. For heavy loads at low speeds, rollers may be used rather than balls, constituting a *roller bearing*.

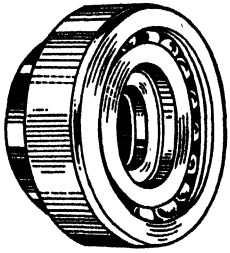


FIGURE 18. BALL BEARING

It is highly important that provision be made for *lubricating* all bearings. The following methods may be used: (1) *Hand oiling:* oil from the can is applied directly to the bearing. (2) *Drop-feed oiling:* a drop-feed oiler consists of a small oil reservoir with an adjustable needle valve which controls the rate at which oil drips into the bearing. (3) *Syphon oiling*, oil is carried from a reservoir to the bearing by a wick. This method is desirable for continuous-running machines only. (4) *Felt*

oiling: oil filters through a felt pad in the bottom of a reservoir and drips into the bearing. (5) *Pad oiling:* a pad from an oil reservoir is in contact with the shaft to be oiled. (6) *Ring oiling:* rings with a diameter about twice that of the shaft are hung on the shaft adjacent to the bearing, and splash oil into the bearing from an oil reservoir beneath it.

Belts and pulleys. Belts and pulleys are a simple and widely used method of transmitting power. Minor variations in the distances between the shafts may be compensated for by the slack in the belt, so that an expensive frame between the shafts is not necessary, permitting them to be attached to the walls or ceilings of the building. When stepped pulleys are used it is possible to obtain a variety of speeds by simply shifting the belt from one step to another.

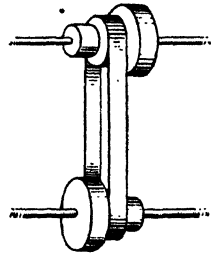


FIGURE 19. STEP PULLEYS

Whenever large belts are in rapid motion, there is danger of the belt breaking and whipping about the room, causing serious injury. Wire or rail guards should be placed about the belting to prevent this danger.

The motion transmitted by pulleys and belts will not be absolutely uniform, belts creep, and some slippage will always occur. For uniform motion and heavier loads, a chain must be used between two gears.

Gears. Gears provide a means of transmitting uniform motion and tremendous force between two adjacent shafts. The common types of

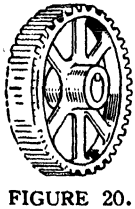


FIGURE 20. SPUR GEAR

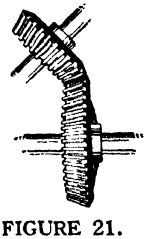


FIGURE 21. BEVEL GEARS

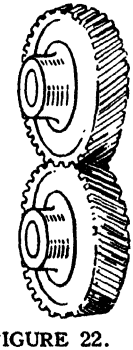


FIGURE 22. HELICAL GEARS

gears include the following: (1) *Spur gears:* spur gears transmit rotary motion between two parallel shafts. Teeth on the circumference of one shaft mesh with a similar gear on the second shaft. (2) *Bevel gears:* bevel gears are used when the two shafts are not parallel but intersect, or would intersect if extended. (3) *Helical gears* have the teeth cut at an angle across the edge of the gear rather than directly across —

at right angles with the face of the gear. This provides smoother operation for both spur gears and bevel gears. (4) *Worm gears* are used to transmit motion between two shafts which are perpendicular to each other and a short distance apart. (5) A *rack* is a bar with teeth on one side which mesh with the teeth of a gear. Rotation of the gear slides the rack.

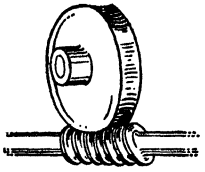


FIGURE 23. WORM GEAR

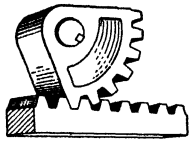


FIGURE 24. RACK

Clutches. A clutch is a coupling between two parts of a machine which enables the operator to connect or disconnect the parts at will. Positive clutches drive with no slippage, but cannot be operated when the shafts are moving. Friction clutches transmit the motion by means of friction between surfaces connected to the different shafts, so may be thrown in while one shaft is in motion, and slippage may occur.

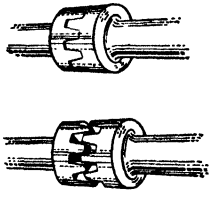


FIGURE 25. CLUTCHES

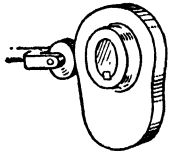


FIGURE 26. PLATE CAM

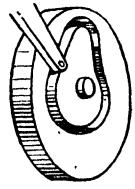


FIGURE 27. FACE CAM

A *cam* is a device for imparting varied or periodic movement to a machine part. A common type of cam is a modified wheel or a wheel with a projection on it, so that it gives intermittent motion to a rod which is in contact with it. Other types of cams are shown in Figs. 26 and 27.

Piping. While piping is not in itself a mechanical device, the use of piping in connection with machinery warrants its consideration here. The material used for piping depends upon (1) the fluid to be conveyed, (2) the temperature of the fluid, and (3) the pressure of the fluid. Steel is appropriate for high temperatures and pressures. Seamless brass pipe is expensive but desirable for hot-water lines and condenser tubing where corrosion must be avoided. Copper will not withstand high temperatures but is flexible and resists corrosion and chemicals. Lead, or lead-lined pipe, must be used for many acids.

Joints between pipes require careful consideration, particularly when high pressures are used. The simplest method of joining pipes utilizes threaded pipe ends and short threaded pieces called "couplings." On more expensive installations the ends may be brought together by tightening bolts which connect flanges at the ends of the pipe. When pressures are not excessive, welded joints are sometimes used.

CHAPTER VI

THE SELECTION OF FACTORY SERVICES AND BUILDINGS

POWER — LIGHTING — AIR CONDITIONING — MAINTENANCE — NOISE CONTROL — CONDUITS — COMMUNICATION — EMPLOYEE FACILITIES — BUILDINGS

The surroundings in which an employee works are an important factor in both the quality of work he does and his attitude toward his employers. Heat, ventilation, light, appearance of the room, noise — all these add up to an impression of attractiveness or repulsion which the worker subconsciously formulates in his mind. Not only is it impossible for the employee to work efficiently amid unfavorable surroundings, but in the long run these same surroundings also influence the quality of work through their effect upon the workers' health. In this connection it should be noted that most individuals are not sufficiently sensitive to, or critical of, ventilation and light to determine the conditions that are best in the long run for their individual health. Many men will work for years under insufficient light for their tasks without even thinking of making a complaint. Hence it becomes the responsibility of management to study the requirements for each process and make adequate provision for the health, safety, and comfort of the workers.

In some cases, the requirements of heat and air conditioning are also determined by the nature of the production processes and the product itself. For example, in textile mills, dry air is undesirable because of the large amount of static electricity it contains.

Provisions for power, light, heat, ventilation, and so on should be decided upon and selected at the same time the building itself is being designed or remodeled in order to secure the most economic installations.

POWER

Among the many services which should command the attention of management when the plant is being organized for production none is more important than power. The management considerations to be met in deciding upon provision of power service follow:

Cost Aspects of Power Supply

Whether or not it is economical and wise for an industry to attempt to provide its own power or buy its power needs in whole or in part

from a local utility is a management consideration which demands attention in the early stages of organizing the plant for production.

Industries have found advantage in a variety of combinations as follows: (1) ownership of a power plant with capacity to take care of all the power needs of the factory; (2) ownership of a power plant to provide for normal (average) needs supplemented by an arrangement to purchase peak-load requirements from a local utility; (3) ownership of a power plant to provide peak-load requirements only with an arrangement to buy the normal needs from a local electrical utility; (4) joint ownership of a power plant with another manufacturing concern whose needs complement those of the needs of the industry in question; (5) joint ownership of a power plant with a public-utility concern whose demands for service come at times when the industry does not require power. Which of these arrangements may prove best from the management viewpoint depends on answers to questions discussed in the following paragraphs.

The cost of operating a plant. The expenses incurred in the operation of a power plant are fixed and variable overhead costs — taxes, insurance, depreciation, maintenance, and fuel. The labor of attendants required is of minimum importance in comparison.

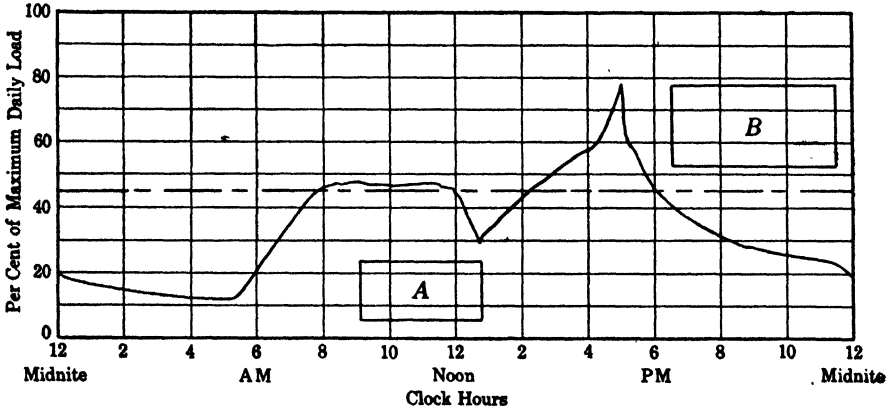


FIGURE 28. COST OF OPERATING A POWER PLANT

A large part of these costs must be met regardless of the degree of capacity utilization of the power plant. Consequently, if the plant is built to take care of maximum needs in a day or manufacturing period, and if this maximum requirement is of only a few minutes duration, the extra price paid for the additional plant size needed may be so great as to increase kilowatt-hour power cost. For example, if normal needs require a plant of size A (Fig. 28) and the peak-load size B (Fig. 28), the cost of the production of normal needs is nearly doubled.

The amount of operating expense — taxes, insurance, and so on — of a power plant depends upon the size and cost of its installed equipment and fuel consumption.

Comparison of purchase costs with production cost. The rates to be charged any industrial user of power are largely a matter of bargaining with local utilities. The cheapest rates are obtained when the industrial user can fill its needs in the off-peak period of electricity production. Electric utilities have peak loads of use of power produced for domestic and commercial consumption. The rates paid by these users are usually adequate to cover the costs of production for that period. The peak loads for the utility would correspond to those shown in Fig. 28. The productive capacity of the plant may be unused, relatively speaking, at other times, and therefore the sale of power at a very low rate is attractive because it provides extra revenue. This whole picture is shown graphically in Fig. 28. From 12 : 00 midnight to 6 : 00 A.M. and 8 : 00 P.M. to 6 : 00 A.M. are the off-peak periods when idle capacity can be bought cheaply. In recognition of these facts, top management needs to give consideration to (1) total cost of production of all its needs; (2) total costs by combining production of some of its needs and the purchase of off-peak capacity from electric utilities; and (3) total cost of purchasing from an electric utility all power requirements. If the decision is in favor of a whole or partial tie-up with a local utility, a written contract specifying all terms of cost should be obtained. In some instances manufacturing concerns and public utilities have erected plants jointly. This should be done only when the needs complement one another, that is, use of the capacity of the power plant by one when the other does not need it. An arrangement for joint operation of the plant should be agreed upon. Each uses its capacity and pays a separate operating manager of the power plant for its consumption of current and steam for heating, processing, and so forth. In general, however, manufacturing concerns should avoid the production of power for sale for use by the public in any way because it places the company's power production subject to public regulation and control. The principles of combining various sources of power to meet regular and peak loads is an application of the principle of Combination of Different Types of Property discussed in Chapter VII.

Dependability and convenience. When an industry is uncertain as to its exact needs or the size to which it must adapt production schedules to meet the needs of the organization supplying its power, the savings and cost of joint ownership may be entirely offset by disadvantages and inconveniences. In this connection there is danger of trying to overdo on saving.

Imponderables. Uncertainties as to growth of the industry which may be just getting under way may be a factor for deciding for or against a power plant adequate to meet all power service needs. Not to be overlooked either is a possibility that very low rates may be offered by local utilities as an inducement to get business when an industry is located in a community for the first time. The managers of the industry in question should look into the experience of other firms already established in the community and if there are good possibilities of increased rates, these increases should be reckoned with when making initial cost calculations.

Power Drives

The flexibility and efficiency of any process layout or individual workplace are dependent upon installed power drives. There are three types:

1. Single motor
2. Group drive
3. Unit motor

Each of these has cost advantages and disadvantages and has direct bearing on efficiency and layout of an industrial plant. The following are the important considerations in connection with each.

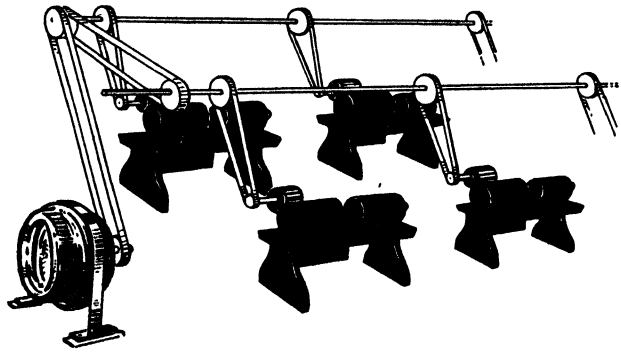


FIGURE 29. SINGLE MOTOR DRIVE

1. **Single-motor drive.** In a single-motor drive the power for the entire plant is derived from a large motor or perhaps a water wheel. This is geared to machines by shafting and belting. Both of these are costly and make for inflexibility in arranging machinery and equipment. Machines which require the most power must be located nearest the main shaft. Similar or like machines may need to be grouped for economy of power installation and operation. Valuable floor space may have to be given over to belting, shafting, and safeguards against injuries to people working in the plant. In some instances, the layout of the whole plant has to be geared

to the use of the single motor and savings thereby derived from efficiency in material handling or arrangement of storage facilities are completely sacrificed.

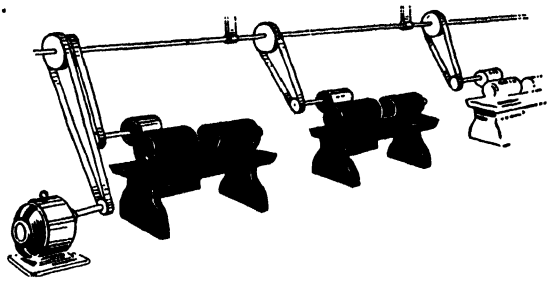


FIGURE 30. GROUP-MOTOR DRIVE

2. **Group drive.** This type of drive permits more economy of installation than the single motor. A limited number of machines which are similar or the same type receive their power from one motor. There is a savings of belting and cost of switches, and, also, the capital outlay for an individual motor for each machine is eliminated. The primary objection to the group drive is the cost of its operation. When several machines are powered from the same source and only one is to be used at a time, the power cost is the same for one machine as for several since all derive power from a single source.

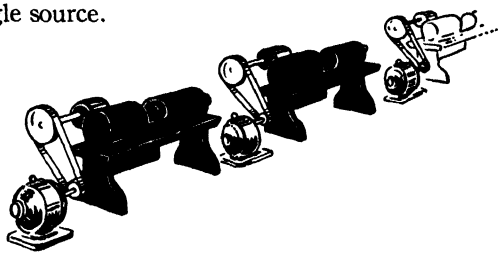


FIGURE 31. UNIT-MOTOR DRIVE

3. **Unit-motor drive.** When each machine has its own individual power source it is termed "unit-motor drive." Unit drives make possible the installation of machines without regard to shafting, special belting, and grouping. Furthermore, unit drives permit more economy in use of power because the power source of machines not in use may be turned off. Unit drive demands considerable capital investment, however, and it is possible that the cost of carrying charges on this may more than offset the extra costs of wasted power under either the group drive or the single motor.

LIGHTING

In providing artificial illumination, there are several factors which may be controlled, and the lighting setup adopted should be that combination of methods which best meets the requirements of the individual

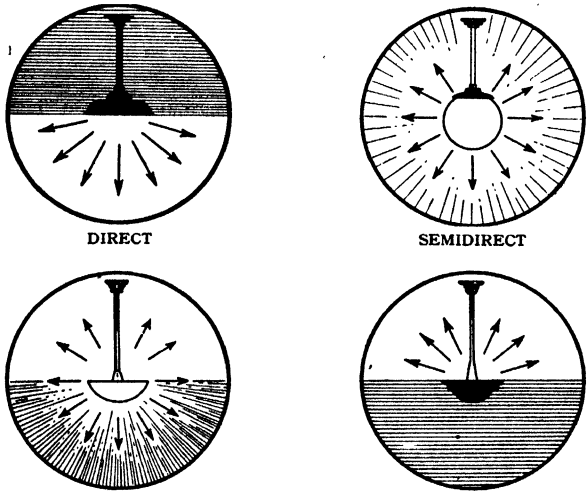
problem from both the technical and financial aspects. The variable factors to be considered in selection of lighting are as follows:

1. The lighting equipment itself.
2. The size, location, and quantity of the lighting equipment.
3. The surface characteristics — rough, smooth, or polished — and the color of the room and objects to be lighted.

The work area to be illuminated is usually a definite fixed element in the problem; it is only rarely that the work to be done is changed because of the difficulty of providing illumination.

Lighting Equipment

Lighting equipment is composed of a light source, usually some kind of bulb, and reflecting equipment to direct and control the light produced by the source. The whole unit is termed a "luminary." There are four major types of lighting equipment. These are illustrated in Fig. 32 and described as follows:



Courtesy General Electric Co., Nela Park, Engineering Dept.

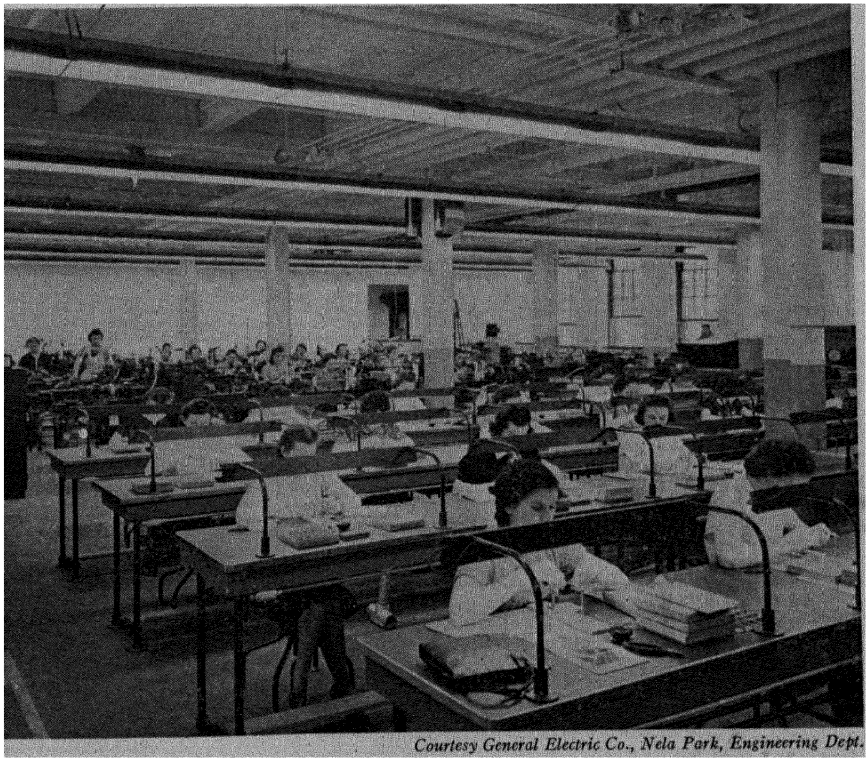
FIGURE 32. ILLUSTRATION OF LIGHT PRODUCED BY MAJOR TYPES OF LIGHTING EQUIPMENT

1. **Direct lighting.** In direct-lighting equipment, all the light from the source is directed straight to the working area, and the light which falls on other parts of the room is incidental only. This is the most efficient means of lighting any one area, but it must be installed so that glare and harsh shadows are minimized. Difficulties in this respect have led to the development of other types listed below.
2. **Semidirect lighting.** In semidirect lighting most of the light comes to the work area directly from the luminary, but some light also strikes the ceilings and walls and is reflected from them onto the working area. Glass

enclosing globes are a very popular type of semidirect lighting fixture. Unless the globe is of sufficient size to diffuse the light at the source, direct glare will not be eliminated.

3. **Semi-indirect lighting.** In this type most of the light is directed toward the ceiling from which it is reflected back to the work area, only a small portion going directly from the luminary to the work area.
4. **Indirect lighting.** All the light from the luminary goes to the ceiling and is then reflected about the room. The whole ceiling then becomes in effect the light source, and glare and harsh shadows are eliminated.

There are many variations in the light sources and reflectors used in any of the above classifications. In each case the reflector must be designed for the particular type of bulb used. The recently developed fluorescent bulb has advantages over the incandescent bulb in that it provides light of daylight quality and appreciably reduces the heat loss, but care must be exercised in providing proper reflectors.



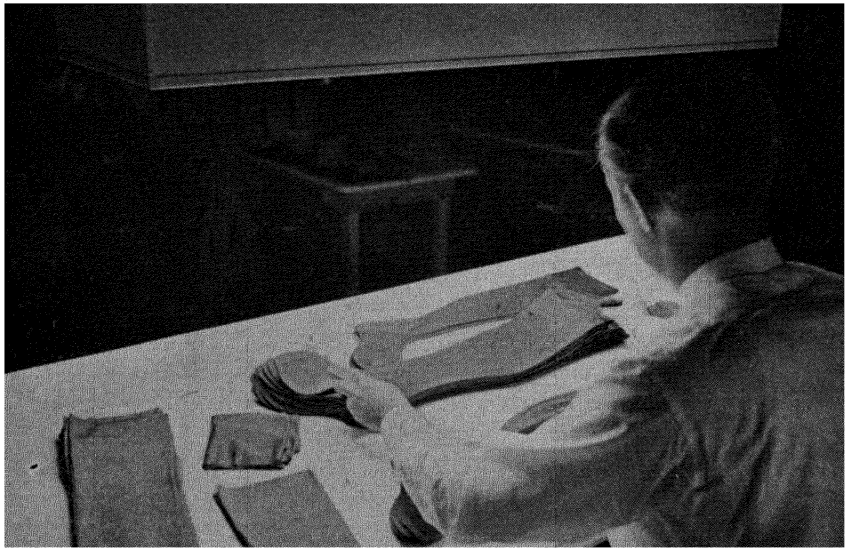
Courtesy General Electric Co., Nela Park, Engineering Dept.

FIGURE 33. ILLUSTRATION OF GENERAL AND SUPPLEMENTARY LIGHTING

Continuous rows of industrial fluorescent reflectors provide 40 foot-candles of general lighting in different factory areas, and the individual bench units in the foreground supply over 200 foot-candles of supplementary illumination.

Location, size, and quantity of lighting equipment. There are three different systems which may be followed in determining the location, size, and quantity of luminaries. These are as follows:

1. **General lighting.** The entire room is illuminated to approximately the same level of illumination. When particular work areas require more light than others, general lighting by itself becomes uneconomical or insufficient (see Fig. 33).
2. **Supplementary lighting.** Supplementary lighting is generally the most desirable system for illuminating purposes. The whole room is illuminated at a uniform level of at least 5 foot-candles, and supplementary lights provide the additional illumination at individual working areas (see Fig. 33).
3. **Local lighting.** In contrast with lighting the whole room, it is possible to illuminate only the individual working areas, using many units so placed that each shines only on one area. This method by itself is unsatisfactory because it produces an abrupt contrast with the remainder of the room, causing eyestrain, inefficient work, and a generally gloomy atmosphere (see Figs. 34 and 35).

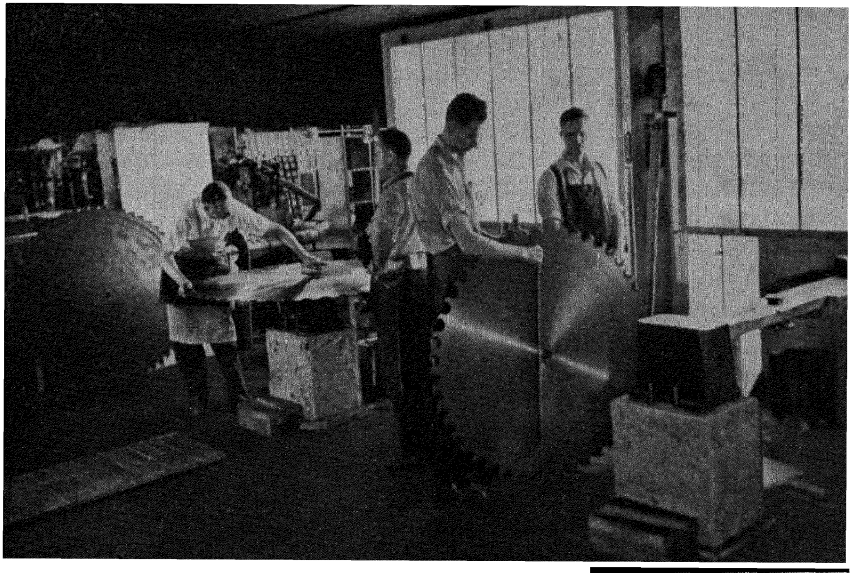


Courtesy General Electric Co., Nela Park, Engineering Dept.

FIGURE 34. ILLUSTRATION OF LOCAL LIGHTING

100 foot-candles of cool fluorescent daylight is provided on this hosiery pairing table by two 30-watt Mazda F lamps.

Surface of objects illuminated. A surface which is light in color and smooth or polished will reflect more light than a rough, dark-colored surface. The quality of illumination may often be improved by apply-



Courtesy The Austin Co.

FIGURE 35. "NORTH LIGHT"

"North light" — always considered essential for smithing operations on precision cutting tools — is manufactured and delivered to just the right places in the 5-acre room where Simonds Saw & Steel Company now produces all of its saws, machine knives, files, etc. The new windowless plant has "windows" like this, with fluorescent tubes behind translucent glass, at a number of locations right in the production lines at the point where smithing is required, so that the saws do not have to be handled to and from windows. Furthermore, smithing that used to require north daylight can now be done at any time of the day or night — an important feature in the Simonds plant which works three shifts a day.

ing a light-colored flat paint to the walls, ceiling, and even large pieces of machinery and equipment.

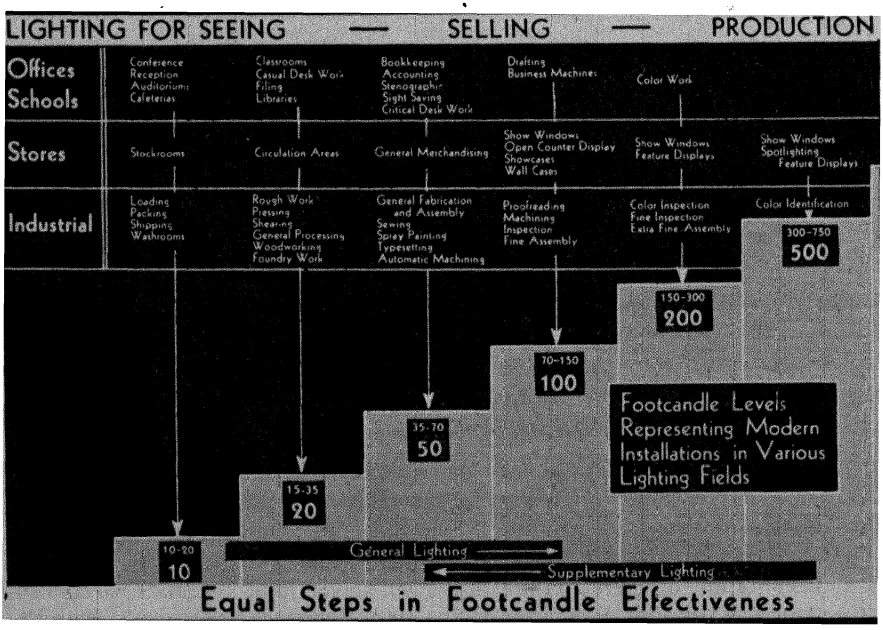
The field of industrial lighting is one in which many new technical improvements are rapidly being developed. All of these aim to provide illumination that will enable the work to be performed more efficiently and under conditions that are more attractive to the worker. In passing upon the desirability of any lighting system, its effectiveness should be checked against the following considerations or end products.

1. **Sufficient illumination for all operations.** The amount of illumination may be measured by an instrument called a "light meter" which reads in units called "foot-candles." The recommended foot-candles for various types of work are shown in Fig. 36.
2. **Elimination of glare.** Glare arises whenever light becomes so concentrated as to cause discomfort to the eyes. It may come directly from the light source itself, or be reflected from other objects. Surfaces which are smooth, light in color, and highly polished tend to reflect more light than

those with opposite qualities, and when they are located so that light strikes them and is reflected directly into the eyes of workmen, the glare may be just as bad as if the workmen were required to look directly at the light source. When an attempt to provide more light also results in increased glare, any benefits arising from the increased illumination may be more than nullified by the accompanying glare.

Glare which arises when the eye looks directly at the light source may be eliminated by (1) diffusing the light at the source — for example, enclosing a light bulb in a frosted globe, (2) placing a shield (or reflector) around the source of light, or (3) by changing the position of the light source. Glare arising from reflected light may be removed by (1) changing the surface of the reflecting object so that it absorbs more light, (2) changing the position of either the light source or the reflecting object so that the reflected beam does not strike the eye, or (3) diffusing the light at the source so that there is less concentrated light falling upon the reflecting object.

3. **Elimination of abrupt contrasts.** Abrupt changes in the level of illumination require adjustment within the eye that increase the time necessary for perception and also contribute to eyestrain. Not only should individual working areas receive the proper illumination, but there should be no violent contrasts between these working areas and the remainder of the room.



Courtesy General Electric Co., Nela Park, Engineering Dept.

FIGURE 36. RECOMMENDED FOOT-CANDLES FOR VARIOUS TYPES OF WORK

Quality of light. The spectral quality of light — that is, the color of the light itself, is generally of lesser importance than the provision of an adequate amount of light, although for tasks which involve color identification it becomes essential to have light which approaches daylight quality. In other cases, refinements in the quality of light add much to giving the workplace an atmosphere that is attractive to the employee.

Stroboscopic effects. When rapidly moving machinery is illuminated by a light that goes on and off very rapidly due to alternations in the current, it is possible that the frequency of the alterations and the speed of the machine may be such that the machine appears to be motionless, whereas it is moving at a rapid rate. This illusion, termed "stroboscopic effect," may be very dangerous for the operators of machinery. For example, a man might touch a saw which appears motionless and find that his fingers are missing.

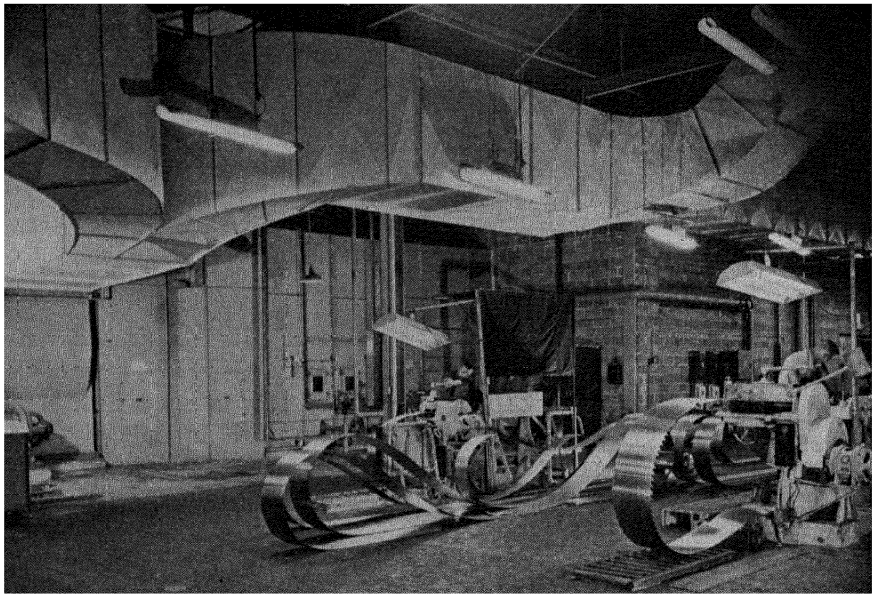
AIR CONDITIONING

The term "air conditioning" has replaced that of "heating and ventilating," bringing with it the idea that air may be cooled as well as heated, and the humidity and purity of the air may be controlled also. Because of the large amount of publicity that has recently been given air conditioning, it is important that in making selections of equipment management understand how much can be expected from it and the importance of operating it properly. Total air conditioning, or the complete control of the air in a building according to the ideal standards, can be achieved only in a building that is entirely shut off from the surrounding atmosphere, and one with provision for the condensation from cooler objects such as windows. The effectiveness of many installations is impaired because they are not properly operated, or because workmen open windows and thus create drafts that cancel any benefits from the mechanical apparatus. Figure 37 shows a modern air-conditioning installation.

Air conditioning aims to provide air that will be comfortable and healthful for the worker, and meet any requirements arising from the nature of the product and production processes. This involves control of the following characteristics of the air:

Temperature and humidity. Comfortable air cannot be produced by regulation of temperature alone, but by the joint control of both the temperature and the humidity of the air. The water vapor, or moisture, in air is an important component of the atmosphere and determines the characteristic which we call "humidity." The quantity of moisture which may be contained in air without forming mist or dew is dependent

on the temperature of the air; the higher the temperature, the more moisture it can contain. However, comfort conditions are not determined by the absolute amount of moisture in the air, but by the relative humidity of the air, that is, the ratio of the amount of moisture actually present to that which the air could contain at the given temperature. If the moisture content remains constant while the temperature changes, the relative humidity changes, and vice versa.



Courtesy The Austin Co.

FIGURE 37. AIR-CONDITIONING UNITS

Four large air-conditioning units like the one shown behind these skilled craftsmen, who are putting the final touches on wide band saws destined for a lumber mill, circulate 400,000 cubic feet of air per minute through the Simonds Saw & Steel Co.'s new windowless factory at Fitchburg, Mass. Conditions inside the plant are completely controlled, so that heat-treating, forging, grinding, and precision operations that heretofore required daylight can all go on together inside one 5-acre room.

Purity. In the absence of a specific source of contamination, there should ordinarily be no need of purifying the air. However, in industrial applications one of the prime needs for air conditioning arises because of the presence of dust, powder, or fumes which must be removed.

Circulation. Desirable conditions of temperature, humidity, and purity of air will not produce comfort unless there is circulation of the air. Still air immediately surrounding a human body soon becomes

uncomfortably warm and humid, and circulation not only brings fresh air in contact with the body, but also has a stimulating effect upon the worker. At the other extreme, rapid circulation produces undesirable drafts. Figure 38 shows a schematic drawing of a central-station air-conditioning system. Particular attention is called to the cleaning, humidifying, and reheating of the air.

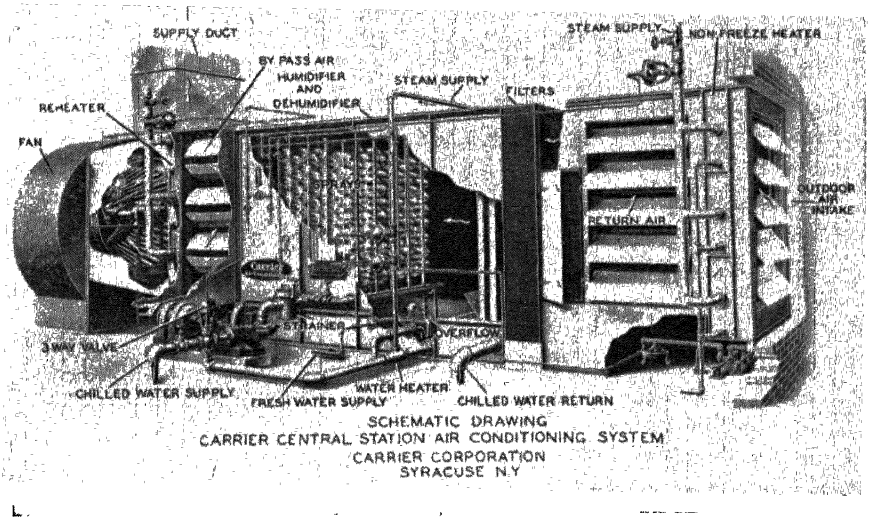


FIGURE 38. SCHEMATIC DRAWING, CARRIER CENTRAL STATION AIR-CONDITIONING SYSTEM

Comfort Dependent upon Many Factors

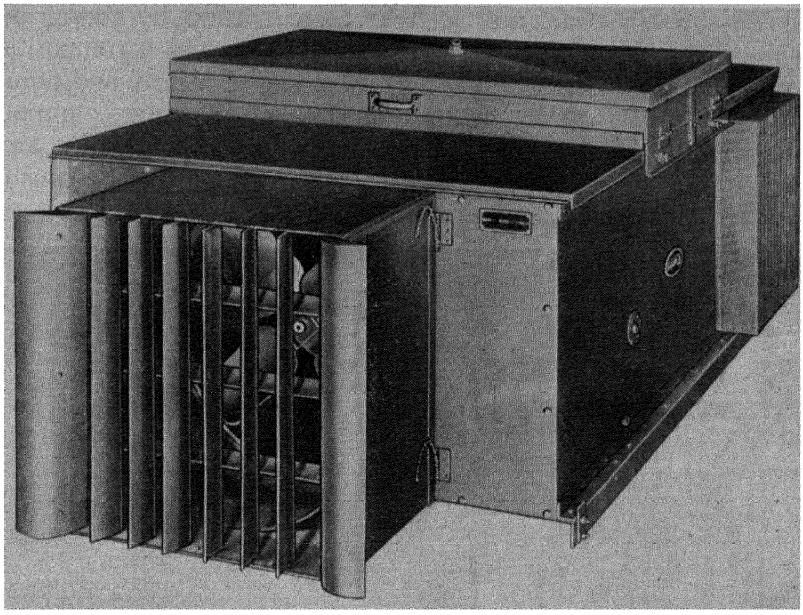
Even when the temperature, humidity, purity, and circulation may all be controlled, the provision of healthy and comfortable conditions for employees is not a simple matter. (1) Comfort conditions vary with each individual and are influenced by previous environments, racial background, and prejudice, as well as the present state of health and amount of clothing. (2) The comfort standards vary with the type of work being performed, those for sedentary occupations being different than those for active manual labor. (3) The number of occupants in a room increases the heat and moisture, and necessitates a consequent change in the mechanical treatment of the air for the room. (4) When there is a difference between outdoor and inside temperatures, a period of about 2 hours is required for people to become acclimated to the change. On summer days the change from the warm outside to an air-conditioned inside should not be too great, and rooms in which occupants will remain for a number of hours should be cooler than rooms with only temporary occupants.

Natural ventilation. Natural ventilation is still widely used, particularly in plants where the heat created by the processes themselves is more than enough to provide heat for the building. Circulation is obtained by admitting outside air into the lower part of the building and discharging it from the top through ventilators or monitor roofs. For the effective operation of this system, the vertical distance between the inlet and outlet should be as large as feasible, and the system should be controlled in accordance with the prevailing wind and weather conditions. Windows on the windward side of the building should be opened to admit air, which then becomes heated by the processes and occupants, and rises toward the ceiling where it is discharged to the leeward. When outside air is circulated in this way, the building is ventilated, but it is not air conditioned as there is no control.

Heating. In the past, factories have been heated by placing steam pipes or radiators on the walls of the room underneath the windows. This method is unsatisfactory from a number of standpoints: (1) The radiant heat makes it uncomfortably warm for those next to the radiators, while the occupants in the center of the room are cool because the heated air rises to the ceiling. (2) The heat is difficult to control — it is either on or off — and opening the windows produces an undesirable draft. (3) The radiators take up valuable space next to the windows. (4) There is no provision for the control of the relative humidity, resulting in excessively dry air during the winter months.

In modern installations, the means of heating is coordinated with other methods of conditioning the air. The first step in this direction is to enclose the radiator, reducing the direct radiation and directing the flow of the air that is heated. In systems of complete air conditioning the heating element is an integral part of the system which includes fans, ducts, air-cleaning, and humidifying devices. The heating coil itself is termed a "convector," and differs from the old type radiators in that a large secondary heating surface in the form of fins is attached to the pipes, forming a system of flues through which the air passes. The unit is designed to heat air as it passes through, rather than to radiate heat directly into the room.

Humidifying. There are several methods of adding to the moisture content of air: (1) Water spray — water is sprayed either directly into the air, or against a "target" so that the impact further breaks up the water particles and produces a more intimate mixture. (2) Steam spray — steam rather than water is emitted into the air stream to be humidified. This process is accompanied by an odor which is objectionable in offices, but is permissible in industrial installations. (3) Evaporation pan — a large surface of warm water is exposed to the air. Figure 39 shows a modern industrial humidifier.



Courtesy Carrier Corporation

FIGURE 39. MODERN INDUSTRIAL HUMIDIFIER

Dehumidifying and cooling. As warm air usually has a high relative humidity, most of the equipment designed to provide more comfortable air conditions performs the dual function of both cooling the air and reducing its moisture content. Air is cooled by passing it through a refrigerating coil, or by means of a cold-water spray. The cooling of the air also reduces its capacity to contain moisture, so that humid air loses some of its moisture content during the cooling process. It is sometimes necessary to reheat the air after it has passed through the water spray or refrigerator coils. Moisture may also be removed from air by means of absorbent materials.

Air cleaning. Before air-cleaning devices are selected it is first necessary to know the nature of the impurities of the air. Atmospheric dust consists of the solid, invisible impurities — bacteria, soot, and so on — found in atmospheric air (Fig. 40). Process dust is created by a manufacturing process and is usually present in large quantities that are plainly visible. Air filters are used for the removal of atmospheric dust, and dust collectors are employed in connection with the coarser process dust.

The first air filters were pieces of fabric which removed the particles that were too coarse to pass through the mesh of the cloth. These filters were difficult to clean and offered too high a resistance to the

air going through them, and so have been replaced by the air-mat dry filters and viscous filters. The air-mat filter uses a composition paper, and is particularly adapted to the removal of linty and fibrous dust. In industries where a large amount of atmospheric granular dust is present, the viscous filter is recommended. In this device, air is passed through steel wool or baffles which are coated with viscous oil film to which the dust particles adhere.

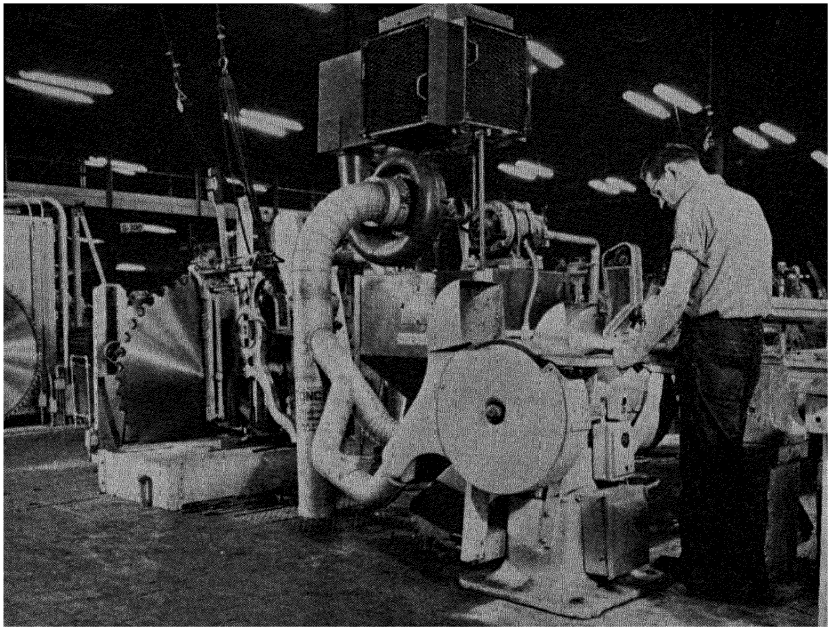


FIGURE 40. DUST REMOVAL UNIT *Courtesy The Austin Co.*

Dust and sparks produced by polishing machine knives on emery wheels never get out of control in the Simonds Saw & Steel Company's new windowless plant at Fitchburg, Mass. Provision is made for this by installation of dust-removal units just like this one wherever grinding or other similar operations are under way. The sparks are drawn right into the unit through ducts which serve a number of machines, and the air pulled in with them is recirculated after filtering through the screens at the top of the unit, which also serves several positions in the circular saw line, just alongside.

Dust collectors should be used whenever large amounts of process dust are to be removed. There are several different types operating on mechanical or electrical principles. In the air washer used for the collection of fly ash, the rising air is met by a spray of water. Centrifugal force is used to accomplish the removal of dust in the centrifugal-effect collector. The verticose-type collector contains no moving parts, but consists entirely of a series of baffle plates in a particular

arrangement, and is suitable for the removal of relatively heavy particles. In the electric dust precipitator the air passes through an electrostatic field in which the dust particles become charged and attracted to the electrodes. The efficiency of this type of collector is consistently high, but it will not remove carbon particles.

Circulation. Air which has been properly conditioned in other respects must be properly circulated before it is of benefit to the manufacturing process or the workers. Natural movements of the air must be controlled and supplemented with pressure differences created by fans. These may be part of a central system or located in individual air-conditioning units. The velocity of the air, the direction of the air stream, and the location of duct openings or individual units — all are factors in securing a circulation in all parts of the room without producing undesirable drafts.

When providing for the circulation of air, special attention must be given to the removal of objectionable dust or fumes coming from industrial processes (Fig. 40). The air should be drawn past the worker, over the process, and into the exhaust outlet which is usually some type of hood. Sometimes a separate room is used for the processes producing dust or fumes and special provisions made for exhausting the air from the whole room. Another device known as "inward air leakage" may be used when it is not necessary to remove dust from the process, but the dust must not be allowed in the surrounding air. The dust-creating device is enclosed and connected with an air exhaust so that air from the room leaks in rather than dust from the process leaking out into the room.

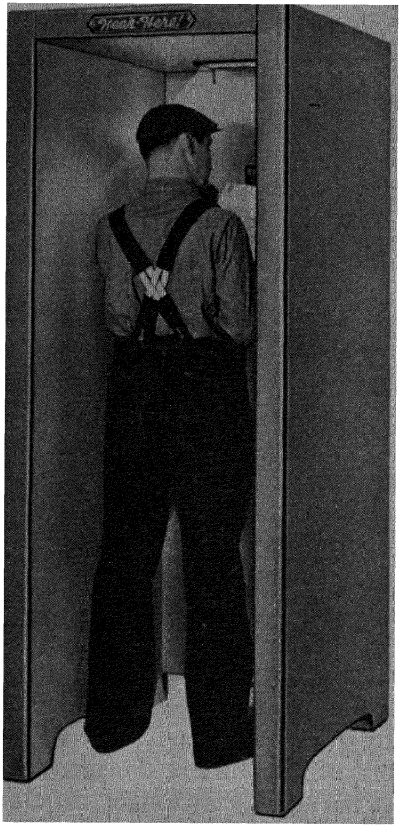
Insulation. In selecting equipment for the control of moisture, heat, or cold it is important to remember that insulation may be used to minimize the work which must be done by other equipment. Insulation cannot of itself create desirable conditions of moisture or warmth, but air in an insulated room will retain its characteristics longer, so that a smaller amount of conditioning treatment is necessary. Insulation is required around the conditioning equipment itself — heating units, refrigerating units, air ducts — to increase its efficiency by preventing the dissipation of heat or moisture where it is not effective in conditioning the air in the room.

MAINTENANCE

One of the most important factory services is maintenance (including repairs). It serves not only the production floor, but also all of the other factory services — heating, lighting, housing. Because of its importance, further consideration is given this topic in a separate chapter. (See Chapter VIII on Maintenance Management.)

NOISE CONTROL

Contrary to general opinion, excessive noise in a manufacturing plant is not something to be tolerated and deserves attention when the plant and its equipment are being selected. The most effective solution to the noise problem is to eliminate it at the source, adjusting machines so that vibration is reduced by the proper care and oiling of machinery, the use of pads between moving parts, and so on. Air-borne noise can be absorbed by sound-absorbent materials in floors, walls, and ceilings so that its distracting influence is deadened. Vibration-absorbent foundations should be used to choke noisy vibrations from machinery so that they will not be transmitted through the entire structure of the building and through the ground to neighboring buildings. Figure 41 shows a recent development in noise control in connection with the handling of internal plant communications.



Courtesy Acoustic Division, Burgess Battery Co.

FIGURE 41. ACOUSTI-BOOTH

An acoustically lined telephone booth for use in industrial plants. This booth creates a zone of relative quiet for the user and transmission is substantially improved due to decreased level of noise reaching mouthpiece.

CONDUITS

Conduits for electric cables, plumbing, and steam and gas pipes should be incorporated into the building and, therefore, selected when it is designed. These may be placed overhead or underneath inside the floor structure (Fig. 40). Tunnels in the floor are safer to maintain, and there are no overhead pipes to cut off light and interfere with material handling, but they tend to become litter traps.

When selecting conduits, oversize designs should be specified to take care of emergencies when the voltage has dropped or water pressure is low, and also for future expansion. A liberal number of outlets will also be valuable when alterations are made.

COMMUNICATION

Good management demands that provision be made for a proper and adequate communication system in the planning of a plant. It must not only be adequate, but also convenient, and the units of the system so located that they may be readily seen by operators and supervisors if of the signal type and easily heard if of the sound system. The communication system should not be allowed to interfere with easy handling of machines and material-handling equipment, but it should

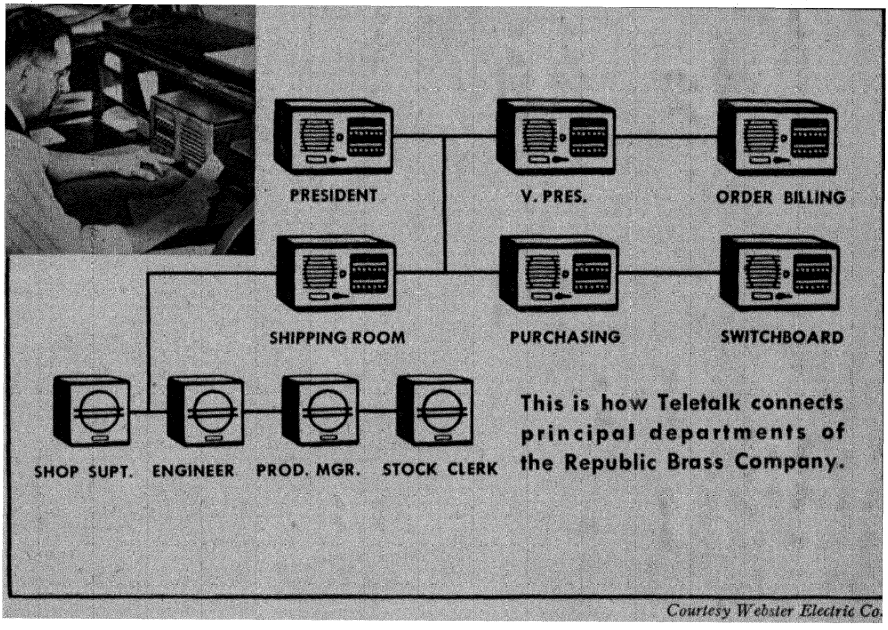


FIGURE 42. ILLUSTRATION OF INDUSTRIAL COMMUNICATION SYSTEM

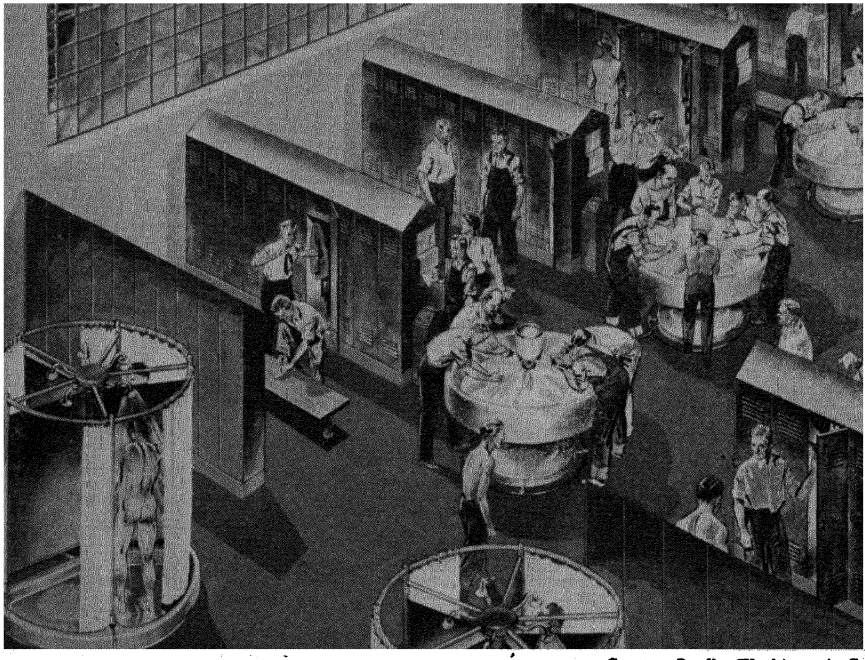
be considered in placing these. Production control is greatly simplified when the plant has a good communication system. There must be a means of proper and speedy interchange of information if unnecessary delays and lost production time are to be avoided. Workmen need to know what to do as well as when and how to do it. Similarly, delicate recording instruments and controls must be provided for adequate process control. In locating these, they must be kept free from vibration and abrupt temperature changes.

EMPLOYEE FACILITIES

In planning the physical plant, management cannot afford to skimp in providing clean, comfortable, commodious, and modern facilities

for employees. People react favorably and unfavorably to surroundings. Good morale is the result of careful attention to attractiveness and comfort in the work place. The following are matters to be given attention in the provision of employee facilities.

Comfort facilities. Particular care should be taken to see that comfort facilities are conveniently located and adequate in number to take



Courtesy Bradley Washfountain Co.

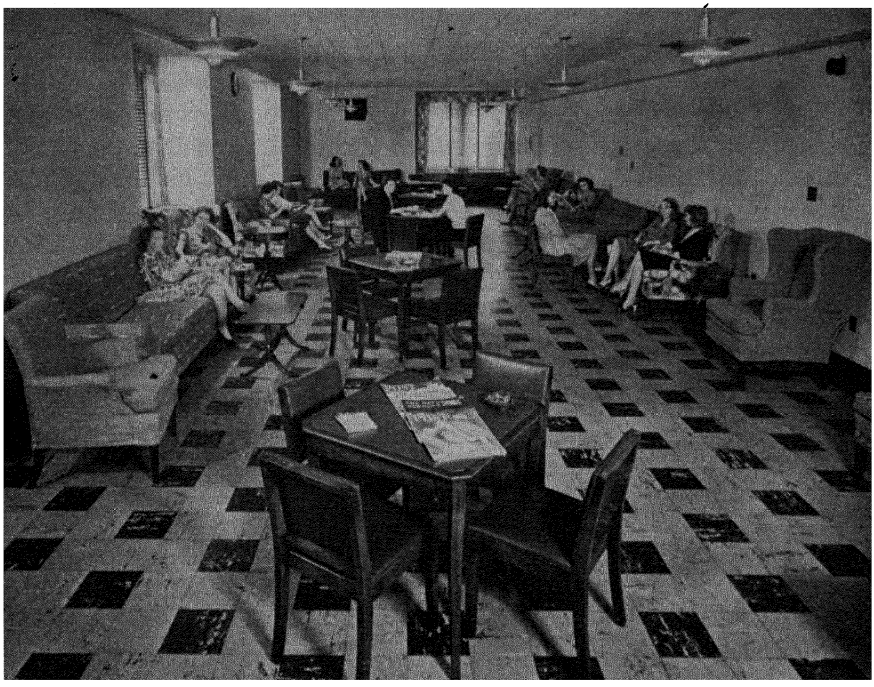
FIGURE 43. ARTIST'S CONCEPTION OF AN IDEAL INDUSTRIAL WASHROOM

Pictured above are modern circular Bradley Washfountains which serve 8 to 10 persons simultaneously, supplying each with clean, sanitary running water from a self-cleaning central sprayhead. This type of equipment saves time and space and reduces water consumption. Illustrated also are sanitary Bradley Multi-Stall Showers. Each of the curtained stalls is private with individual water mixing control and provision against scalding. The use of this type of equipment leaves ample space for locker facilities.

care of peak periods of use. This is important not only from the standpoint of worker convenience, but also from that of lost time. If each man has an excuse to take a 5-minute walk twice a day, with ample opportunity to lengthen it to 20 minutes as he passes his friends, the production of all concerned is bound to suffer. Comfort facilities are often located on mezzanine floors where they are easily reached and do not occupy valuable area on the production floor. Comfort facilities need to be kept clean. In selecting toilet equipment consideration

needs to be given to equipping toilet seats with ultraviolet-ray lamps to prevent crabs, body lice, and so forth.

Proper supervision, rather than poor light or uncomfortable temperatures, should be used to prevent comfort stations from becoming havens for loafers. Women's rest rooms should be provided with a matron in charge, and also with comfortable couches for resting during



Courtesy Lever Bros. Co.

FIGURE 44. SECTION OF WOMEN'S REST AND RECREATION ROOM IN ADMINISTRATION BUILDING OF LEVER BROTHERS COMPANY

Over 400 women are employed in this modern office building of these soap and shortening manufacturers.

the day. No less important than toilets are locker rooms, showers, washstands, and drinking fountains.

Locker rooms should provide for ventilating and drying damp work clothes between shifts. Showers should be of a type that can be kept clean easily. Hot and cold water should be premixed thermostatically. Water for washstands should be premixed thermostatically also. Drinking fountains that are conveniently located throughout the plant are timesavers. Fig. 43 shows installation of industrial washstands, lockers, and showers.

The material to be used in employee facilities should not be of cheap quality. Tile floorings and porcelain fixtures are recommended. Good lighting is essential in the interest of cleanliness and sanitation. In this connection, one expert recommends mixing fine-ground cork in paint to be used on toilet-room walls to discourage art works and earthy poetry.

Other employee service facilities. The location of the plant — whether it is in a city or suburban or rural area — will determine the number and variety of employee service facilities necessary. If suitable restaurants do not exist near the factory, a cafeteria for employees will be appropriate. If the personnel program calls for mass meetings and entertainments, a large meeting hall or auditorium must be provided. In other cases, libraries and indoor or outdoor recreation facilities will be valuable supplements to those provided by the community. Figure 44 shows a modern rest and recreation room for women employees. Well-kept grounds about the factory buildings are also a good investment from the standpoint of developing pride and loyalty among workers and their families, as well as obtaining favorable reaction from the general public. (Aesthetic considerations are treated later in this chapter.)

Courtesy Edward L. Koenig Co.

FIGURE 45. CORRECT POSTURE CHAIR

The above illustration shows a picture of a "Sit-Rite" chair as used in modern industry for reduction of human fatigue.

The present-day emphasis of employee welfare and industrial insurance makes a medical dispensary a necessity for all but the smallest plants, and this may be combined with the examination room for giving physical tests to applicants for employment.

Another vital factor in employee comfort and health is the provision of correct posture chairs at regular workplaces. These chairs are designed so that they may be adjusted to individual differences in size, and give correct support to the back. In some instances it may be necessary to encourage employees to actually rest their backs against these chairs (see Fig. 45) in order to receive the full benefit of them.

FACTORY BUILDINGS

Industrial buildings should be tailor-made to fit the production floor and factory services. A manufacturing organization which must be adapted to the limitations of poor housing facilities has the same competitive disadvantage as an athlete whose uniform restricts his movements. A building is a means of providing shelter and protection

to the machinery, materials, and men. It is not the starting point in the design of a manufacturing enterprise, but the last major part which should be considered after tentative selections and organizations have been made of the remainder of the physical property. The housing will then be a factory service in the full sense of the word, and not a master dictating restrictions to the remainder of the organization. Exceptions to this principle arise only when the expense is prohibitive or construction is physically impossible. For example, very heavy machinery must be placed on the ground floor. Here construction limitations determine the layout of the general plant, but this is only the exception that proves the rule that the most desirable arrangement of the plant should dictate the design of the building.

When buying machinery and equipment for a new industrial plant, it is often convenient to have a building for the storage of machinery and equipment before manufacturing is commenced, and the cheapest one immediately available is often selected. After all the physical property has been assembled, there is a temptation to save further transportation and purchasing expense by using the building which already contains the equipment. Such a policy is short-sighted. It sacrifices long-time advantages in location, layout, and factory services for immediate savings in initial investment. From the long-time standpoint, it does not permit capacity utilization of machinery and equipment because these must be adapted to the limitations established by the location and design of the building.

A factory building serves three primary functions: it provides protection against undesirable outside influences — inclement weather, theft, trespassing, and sabotage; it provides protection among internal departments from heat, moisture, noise; and in addition most factories provide for more intensive utilization of land by means of upper floors and overhead supports for equipment. The walls and roof supply the protection against outside influences, and also support upper floors or overhead equipment. Internal partitions separate various departments and processes.

The considerations which are of major importance in selecting a factory building are discussed below:

Single vs. multistory buildings. Considerations of cost, layouts, supervision, flexibility, and material handling all enter into the choice between single and multistory buildings.

The problems of making efficient plant layouts, discussed in Part III, are greatly simplified by the use of a single-story building (Fig. 46). The layout engineer is not hampered by posts, elevators, partitions, and allowable floor loads. While it is often convenient to place some processes directly above others, thereby eliminating long horizontal trans-

portation of equipment by means of short vertical trips, these situations may be taken care of by the use of mezzanine floors rather than complete second stories. A single-floor layout may be planned with little regard for the difficulties housing it. Provided the site contains sufficient area, the productive centers or departments may be made as long and wide as is individually desirable rather than fitting them into floors of predetermined area.

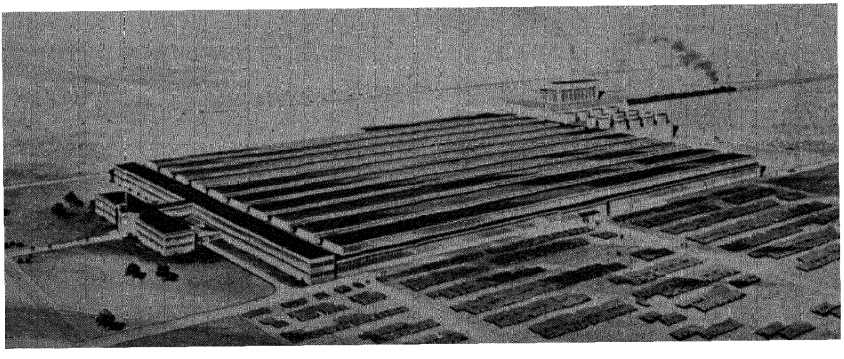


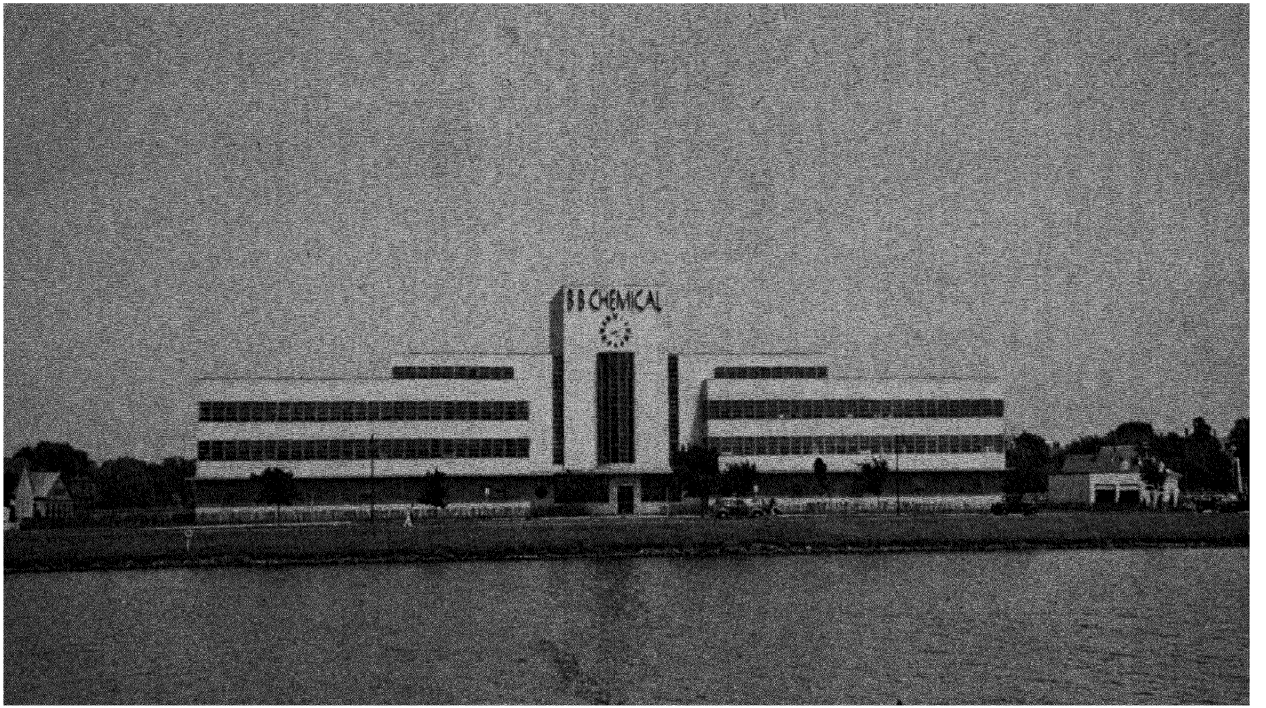
FIGURE 46. MODERN SINGLE-STORY BUILDING *Courtesy General Motors Corporation*

This photograph shows the Buick plant at Melrose Park, Illinois, where Pratt & Whitney airplane engines are manufactured.

The housing of extremely heavy machinery and equipment practically demands a single story because of the cost of supporting the weight on upper floors. For this reason a heavy machine shop or a locomotive works will be contained in one floor.

The problem of obtaining natural lighting is greatly simplified by employing a single-story building, with some type of glass roof. It is then unnecessary to limit the width of the building or to locate machinery near windows rather than according to the flow of production.

The justification for a multistory building (Fig. 47) usually arises from the cost of the land for the site, together with the desirability of locating there rather than in some section where land is cheaper. A multistory building is most readily adapted to an industry manufacturing a small, light product and using relatively light machinery and equipment. Most industrial processes must be modified to fit into the limitations of a multistory building. Machinery must be located between posts. The straight flow of materials must be altered to accommodate heavy equipment on the ground floor. Valuable area is occupied by elevator shafts and stair wells, and the flow of materials must be adapted to these vertical transportation channels. In addition,



Courtesy BB Chemical Co.

FIGURE 47. MODERN MULTISTORIED BUILDING SITUATED IN DESIRABLE AND ATTRACTIVE LOCATION ON PARKWAY NEAR CHARLES RIVER, CAMBRIDGE, MASSACHUSETTS

some departments must be divided between floors, thereby creating a problem of supervision.

Multistory buildings are preferred for some types of process, such as those using gravity to convey materials from one process to the next. Typical of these is flour milling and paint and varnish manufacture.

Foundations. It is absolutely essential that a firm foundation be provided for all types of buildings. If the foundation is unsatisfactory so that the building begins to settle, unsightly cracks develop on the walls, then parts of the building begin to sag, and finally the life and safety of the occupants and equipment is endangered.

The most desirable foundation for any building is bedrock, with the entire bottom of the building in contact with a level surface of the rock. The fact that bedrock exists near the surface of Manhattan Island is one of the reasons why that small area is a desirable site for the many skyscrapers it contains. Hardpan or gravel are also generally satisfactory. Sand and silt are reliable only when dry and confined. Even if there is no moisture in a sand foundation, there is danger of the soil shifting if an excavation is made for an adjacent building.

In order to be certain of the exact character of the soil before completing the plans for the building, soundings should be taken at frequent intervals over the entire site. The soil characteristics are ascertained both from the ease with which the drilling for the soundings is performed and from the samples of soil removed. When the character of the soil makes it difficult to predict how much the building will probably settle, full-size test piers may be constructed and loaded with cast iron or concrete. Careful measurements of settling are then made for as long a period of time as possible.

When it is impossible to rest the building itself on a solid foundation, piling must be used. A pile is a large stake or post driven into the earth to support a building. Wooden piles are satisfactory if the soil is dry or continually moist, but alternating periods of moisture and drying deteriorate the wood. Piles are also made from various combinations of steel and concrete. When it is possible to drive piles down to firm soil, they act as pillars between the firm soil and the bottom of the building. In other cases, the building is supported by the friction between the wall of the pile and the soil into which it is driven.

In designing the foundation, it is also necessary to know the total weight of the building and its equipment. In addition, provision must be made to take care of uneven distribution of this weight. The section of a factory containing heavy machinery will tend to settle more rapidly than the part containing the offices, for example. If the remainder of the manufacturing enterprise has been tentatively organized before considering the building, this information will be readily available.

Construction. Regardless of the materials used, building structures may be either the *bearing-wall construction* or the *skeleton construction.* In the bearing-wall construction the walls carry the weight of everything above. In the skeleton construction the weight of the structure and its contents is transmitted to the foundation by a rigid framework or "skeleton." The walls are attached to the frame, but the frame, not the walls, support the weight of the building. In contrast with bearing walls, the walls in skeleton construction are termed "panel" or "curtain" walls.

There is much latitude in the selection of materials and methods of factory construction. Recent developments in cements, ceramics, metals, and combinations of these materials have resulted in many new trade-name building materials each with its own particular advantages and methods of construction. In general, there are three main types of factory-building construction, and these are discussed briefly below.

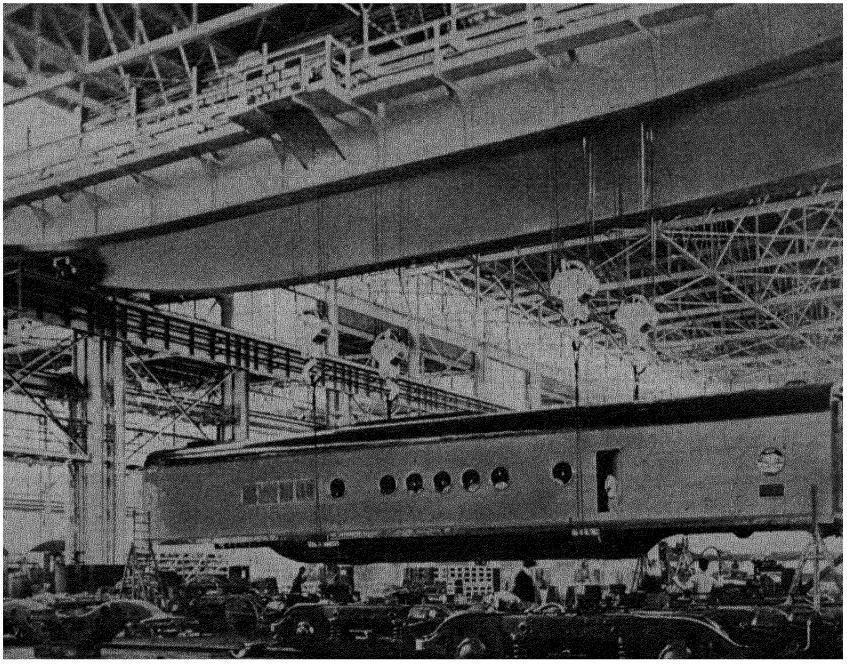
Mill construction. This type of building dates back to the early textile mills in New England. The walls are of brick or masonry and wood is employed for beams, floors, and roofs. By elimination of concealed spaces, and by the installation of fire walls, enclosed stairways and elevator shafts, and sprinkler systems, this type of construction has been refined so that it all goes by the name of *slow-burning* construction (Fig. 48).

Courtesy The Austin Co.

FIGURE 48. INTERIOR OF MULTISTORY MILL TYPE BUILDING WITH STEEL COLUMNS AND GIRDERS

Protected steel or reinforced concrete may be substituted for parts of the wooden structure without changing the general type.

Steel construction. This type consists of a steel skeleton or framework to which may be attached walls, floors, and roofs of a great variety of materials — sheet steel, masonry, glass, or wood. The frames may be either riveted or welded, and approved fireproofing material should be used to protect all steel members, as steel loses its strength at high temperatures (Fig. 49).



Courtesy The Austin Co.

FIGURE 49. PHOTOGRAPH OF INTERIOR OF MODIFIED DESIGN ALL WELDED STRUCTURAL STEEL BUILDING

Aisle width is 100 feet and is equipped with 200 ton crane.

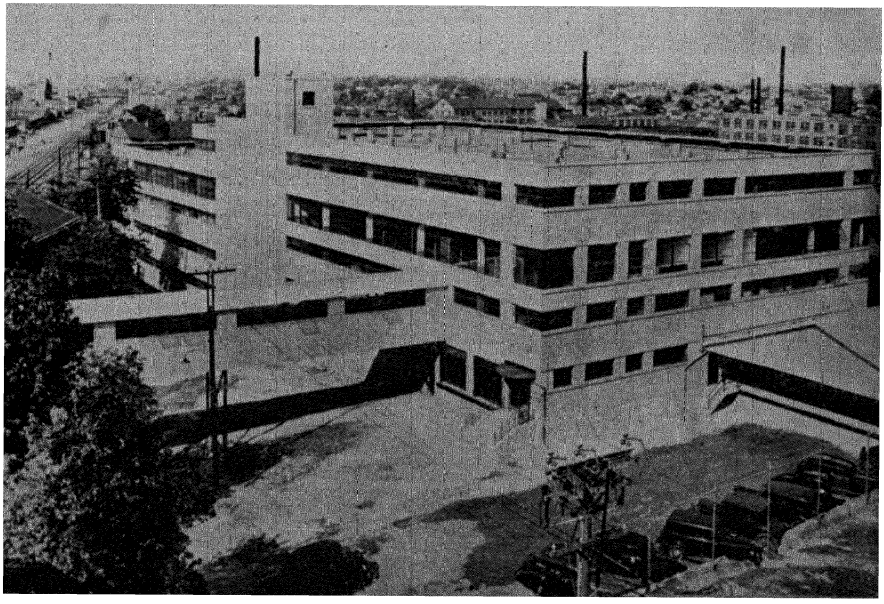
Reinforced concrete. Concrete reinforced with steel is extensively used for factory buildings. Precast slabs may be assembled on the site, or the concrete may be poured on the spot, in which case the building is monolithic. Reinforced-concrete buildings are completely fireproof and, like structural steel buildings, may be erected very rapidly. Figure 50 shows a reinforced-concrete building of modern design.

Floors. The type of construction used for floors will be determined by the construction of the whole building — mill type, reinforced con-

crete, or structural steel — but many different kinds of floor surfaces may be employed regardless of the construction used. Floor surfaces should be durable to withstand material-handling traffic, easy to replace when worn out, easy to maintain, and not slippery even when covered with water or oil.

Wood blocks on a concrete base are becoming popular because they provide heat insulation, are easy on workers' feet, and are replaceable when worn or when machinery is moved. Other materials include concrete imbedded with a filling such as iron filings or chipped granite, sheet steel, rubber, and tile.

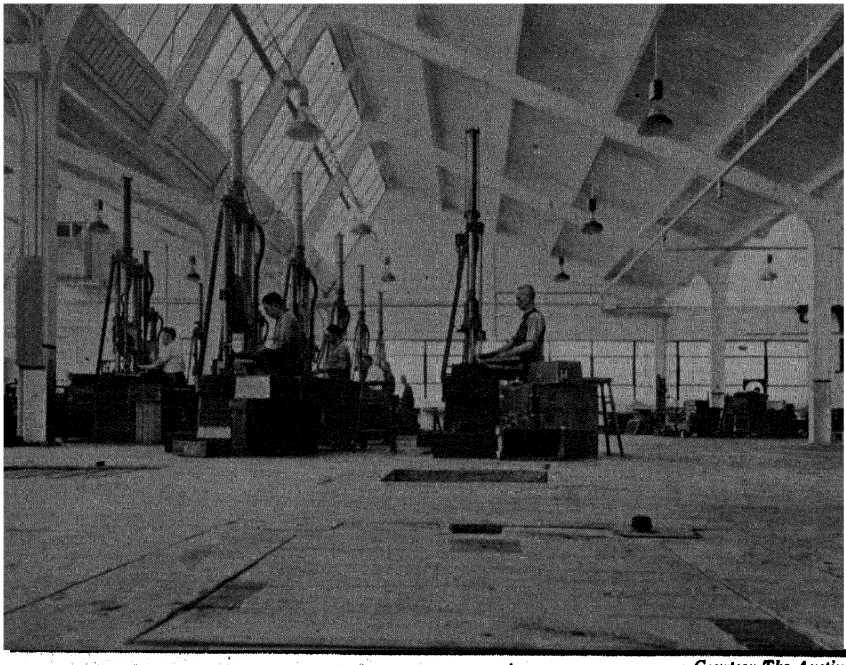
Roofs. The flat roof, the saw-tooth roof, and the monitor roof are the three types generally used on industrial buildings. The flat roof is almost universally employed on multistory buildings since artificial lighting is necessary anyway for the other floors and expensive roof trusses are avoided (Fig. 50). Single-story buildings with saw-tooth and monitor roofs (Figs. 51 and 52) require little artificial lighting, and the openings at the top of the building enable fumes and heat to escape by means of inexpensive natural ventilation.



Courtesy The Austin Co

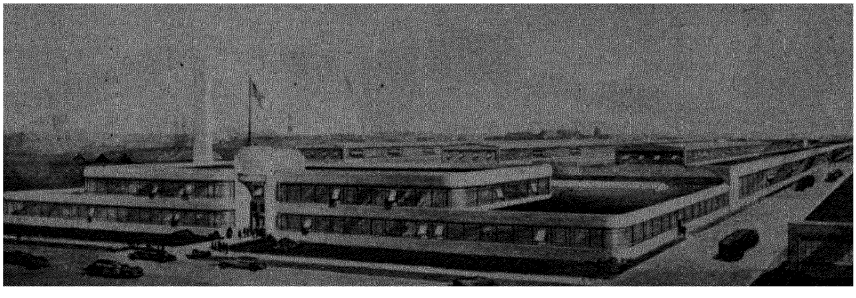
FIGURE 50. MULTISTORY REINFORCED-CONCRETE BUILDING. THIS BUILDING IS OF FLAT SLAB CONSTRUCTION

There is a great variety of satisfactory roofing materials on the market. Managers should seek advice from roofing experts when considering factory roofing problems. Subroofs are necessary to support the exposed roofing surface and may also be designed to provide valuable heat insulation and noise absorption.



Courtesy The Austin Co.

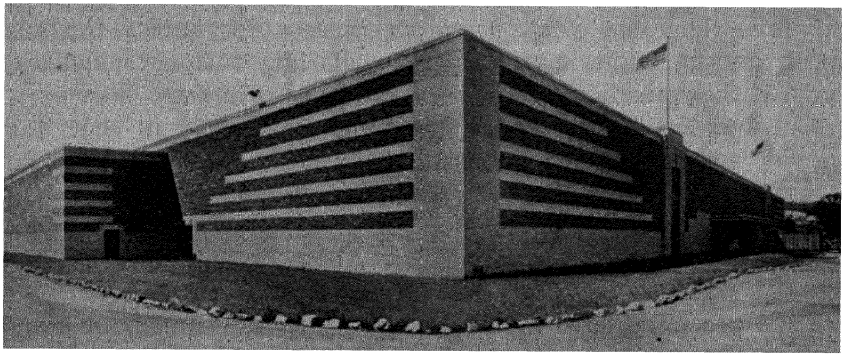
FIGURE 51. INTERIOR VIEW OF RIGID FRAME SAW-TOOTH ROOF BUILDING
Note cross members of conventional truss are omitted.



Courtesy Central Manufacturing District (Chicago, Illinois)

FIGURE 52. FACTORY BUILDING OF MODERN DESIGN SHOWING MONITOR ROOF CONSTRUCTION

Windowless plants. The outstanding recent development in industrial buildings is that of the windowless factory. The Simonds Saw and Steel Company's building in Fitchburg, Massachusetts, was a pioneer in this field, and it has been copied by others throughout the country (Fig. 53).



Courtesy Simonds Saw & Steel Co.

FIGURE 53. CONTROLLED CONDITIONS — WINDOWLESS PLANT OF THE SIMONDS SAW & STEEL COMPANY

The elimination of windows was made possible by rapid developments of industrial lighting, and is not a publicity stunt, but a plan which has many distinct advantages. It gives the plant engineer complete control over the physical atmosphere inside the plant. At best, natural lighting varies with the seasons, the time of day, the pleasantness or disagreeableness of the outside weather, the care of the windows by the maintenance department, and must be supplemented by artificial lighting even during day shifts. Besides being only doubtful providers of satisfactory illumination, windows are one of the biggest problems in designing a satisfactory air-conditioning system. Windowless plants have been found to be more satisfactory both from the standpoint of first cost, maintenance costs, and employee morale. Windows are expensive to install and keep clean, and the greater part of the lighting equipment would have to be installed even if there were windows, particularly if there are night shifts. Employee reaction has been favorable because a working place with pleasant lighting and air conditioning at all times is more satisfactory than one whose atmosphere changes with shifts in the wind.

Safety in buildings. The most obvious considerations of safety in connection with buildings is in connection with fire and building col-

lapse. Buildings must be strong enough to carry not only their own weight and weight of the personnel, machinery, and equipment that may be placed in them, but also to withstand wind, snow, and earthquakes. Buildings which contain machinery with large moving parts must be designed to absorb the vibration as well as the weight of the machinery.

The design of a building can also materially reduce the damage by any fires which may start. Fireproof construction protects the building itself, and in addition proper fire walls and enclosed passages will prevent the spreading of fires between departments and floors.

The building design also affects safety indirectly in that it must provide adequate area for other factory services — lighting, air conditioning, traffic control, and safety for maintenance workers.

Standard buildings for factory use. The development of standard production methods during the past three decades has had a very marked influence on factory-building design and construction. Standardized processes have made possible the establishment of standard widths, clear heights, units of length, floor loadings, light, and ventilation. This trend has taken place just at times when there has been a greater demand for industrial buildings which can be erected quickly and at a minimum cost. The result is the creation by industrial architects of so-called industrial buildings for factory purposes.

Types of standard buildings. Standard buildings are two types: (1) the permanent, substantial, modern building which is designed for many years of service, and (2) lighter, cheaper forms of construction which might be termed "portable buildings" and which are intended for temporary use.

Design. In designing standard buildings, industrial architects have worked out basic units which permit considerable flexibility and combination. Spans, spacings, and general arrangements are so selected as to use materials of construction up to safe limits. This makes for a minimum of waste and for economical design. One large industrial architect has some 10 standard buildings which in combination cover a large variety of industrial structures — from light manufacturing and storage buildings to heavy machine and assembly shops. Still other industrial architects have standard buildings for other uses such as forge shops, foundries, rolling mills, and power houses.

Advantages of standard buildings. Standard buildings should be considered particularly when a manufacturer is in a hurry to erect a new structure because he needs to expand his present process or take care of an emergency situation in the procurement of parts or materials needed for existing processes. The following are advantages claimed by the architects who furnish designs and seek contracts to construct them:

1. There is economy in the time saved of construction because the preliminary work of design is done and construction can be started just as soon as the contract is awarded.
2. Considerable time is saved in putting the building together. Workmen have erected these same buildings before and time is not needlessly spent for studying plans and deciding what materials to use.
3. There is no delay for procurement of material for construction. The materials of construction for standard buildings are regularly stocked by industrial architects who are in this business.
4. Economy in the cost of materials results from the purchase of large quantities of construction materials to be stocked pending the attaining of contracts. This permits buying advantageously in terms of the market price and also in terms of quantities.
5. The manufacturer attains additional savings in that he is able to undertake his production program more quickly than if he builds a specially designed structure. Standard buildings have been erected in 30 days whereas from 3 to 6 months have been required previously to build the same construction before standardization took place.

Aesthetic considerations. Aesthetic aspects of factory design are deservedly receiving increasing attention. Today factory workers spend a greater portion of their total waking hours in the factory workplace than they do in any other one place. For many of them, a home is a place to sleep, obtain (hurried) meals, and perhaps spend a few hours relaxing. Various amusements, as well as travel for business or pleasure, scatter the remainder of the worker's time over many different locations.

Since the factory is the one place of which workers are conscious for many hours day in and day out, it is only logical that conditions should be as pleasant as possible in order to foster a friendly, cheerful, and vigorous morale. Many of the factory services previously discussed — lighting, air conditioning, employee facilities, and so on — are primarily and directly designed to make the working atmosphere as pleasant as possible. In addition, proper aesthetic design and upkeep of buildings and equipment can add much to working efficiency.

During the past century there was a tendency to give absolutely no consideration to the aesthetic features of industrial design, or else tack on some pillars or motifs that were poor imitations of ancient Greek design. Such a condition indicated decadence in art. Greek temples were built of stone, and their parts were designed to be correct from an engineering standpoint as well as artistically. Modern buildings are not made of stone, but of wood, concrete, or steel. These materials can also be shaped into forms which are both structurally and artistically sound; it is not necessary to imitate a bygone age with decorations adapted to different materials in order to have industrial plants which

are beautiful. Modern knowledge and materials possess infinitely greater possibilities for the development of an art which expresses the spirit of the present age and so is in keeping with the thoughts and attitudes of the workers and the public.

Present-day industrial art, insofar as it is developed, reflects the metallic precision and streamlining which typifies this age. Even when these characteristics are not necessary from the standpoint of functional design, they are being incorporated because of their artistic attractiveness. For example, a stationary electric motor is shielded with a streamline sheet of metal, and the "gingerbread" decorations on buildings are being replaced by smooth glass or metallic fronts. Nor is there any great disparity between the practical and the artistic value of these changes. The simplicity of modern industrial art facilitates cleaning, painting, and maintenance. In the use of color, too, practical and esthetic values may be combined. Rather than painting all machinery and equipment the conventional black or grey, a light shade of yellow has been found to be more restful for the workers' eyes, and more conducive to cleanliness and a pleasant working atmosphere.

CHAPTER VII

COST CURVES OF PHYSICAL-PROPERTY MANAGEMENT

Every industrial plant is a result of a combination of physical property. Machinery and equipment, buildings and plant services are organized to make particular products or to render particular services.

When selections are made of the various items of physical property which go to make up an industrial plant, it is necessary to give careful consideration to such items as mechanical proficiency, power requirements, and the productive capacity of units that are to be installed. Efficiency in operation demands that productive capacities of various machines be in balance, that maintenance costs justify themselves in the light of the usefulness and value of the machinery and equipment to be required. These considerations in themselves, however, do not give management all the information it requires in order to render sound judgment in selecting physical property. It is important too that attention be given to such matters as the following: expected costs of power; costs which may result when some parts of a productive unit are idle and others in use; extra costs made necessary by provision of expansion; costs which may be expected when units are combined, additional units brought into the plant, extra floor area brought into productive use, and so on.

The cost-curve patterns and concepts which the manager must understand in order to get an over-all cost picture of physical-property selections requires a knowledge of the significance of fixed and variable costs of plant operation and careful study of their characteristics as applied to machinery and equipment under varying conditions and degrees of utilization. The following discussion of cost-curve patterns is aimed to provide the plant manager with essential concepts he needs to have regarding these matters.

Fixed and Variable Costs [1]

Fixed costs are expenses which arise from the ownership of physical property. Some of these remain constant regardless of the volume of manufacture, and others fluctuate with changes in production volume. Those which remain constant are expenditures for taxes, insurance,

[1] Fixed and variable costs are discussed also under Control of Variable Costs. The repetition here is in the interests of coherence of the material contained in this chapter.

depreciation, and interest on investment. These are called "nonvariable fixed charges." Those which rise and fall with the volume of production include expenditures for maintenance, repairs, and supplies (cleaning material, oil). These are termed "variable fixed charges."

Contrasted with variable and nonvariable fixed charges, there are manufacturing costs which are wholly variable. These are raw materials, labor, and manufacturing supplies which go into the product. The relation between fixed and variable costs is affected also by the length of the period of time for which they are to be used.

As this time period increases, more and more cost items become variable rather than fixed. For example, if a boiler company receives a large order which requires a year to complete, a machine purchased specially for use on this one order could be classed as a variable cost. The expense is incurred because of the order, and the machine will probably not be usable again. But if the same machine were purchased by a small machine shop receiving many small orders, it should be classified as a fixed cost, because it will be used for several years on whatever orders may be received which require its use.

Graphic Analysis of Fixed and Variable Costs

The internal financial structure — the relation between fixed costs, variable costs, sales, and profits — may be shown graphically by what are known as "profit graphs" or "crossover charts" (Fig. 54) and their various modifications.

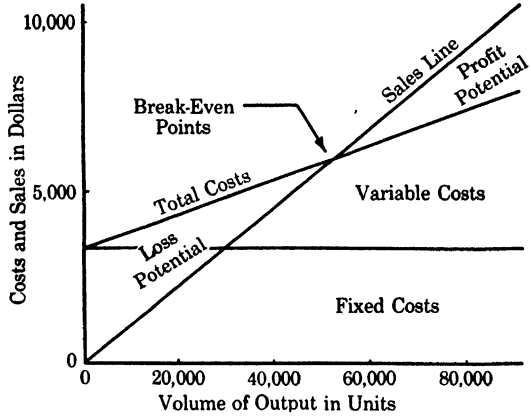


FIGURE 54. TYPICAL PROFIT-GRAPH OR CROSSOVER CHART

These charts are made by plotting volume of production on the horizontal axis and dollars on the vertical axis; dollars may refer to either sales or costs. The sales line, starting at the lower left-hand corner, or origin, of the chart, shows that the sales in dollars increase

directly with volume. The lower rectangular area represents the fixed costs; the "fixed" nature of these costs is shown graphically by the fact that the height of this area does not change, regardless of the volume. The total costs line adds up the fixed and variable costs for all of the different volumes, and shows the extent to which total costs increase with increases in volume. The relation between the total cost line and the sales line for each volume shows whether the volume will result in a profit or a loss. When the volume is low, the value of the sales will not even be enough to pay the fixed costs, as shown by the

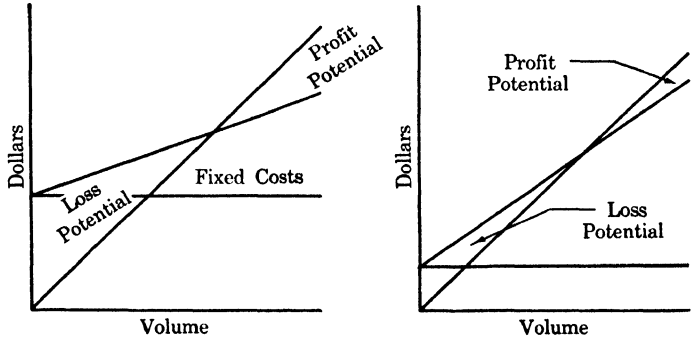


FIGURE 55. RELATION OF THE RELATIVE IMPORTANCE OF FIXED COSTS TO PROFIT AND LOSS POTENTIALS

fact that at the beginning the sales line is below both the fixed cost line as well as the total cost line. As the volume increases, a point of intersection, called the "crossover point" or "break-even point," is reached between the total cost line and the sales line. At this crossover point, sales income is just equal to total costs, and there is neither a profit nor a loss. Before this point is reached, the total costs are above the sales line, indicating a loss, and beyond this point the relationship is reversed, indicating a profit.

The relative importance of the fixed costs determines the profit-and-loss potentials of a business. When the fixed costs are large, sizable losses will be sustained if the volume is below the break-even point volume, but beyond this volume, substantial profits may be enjoyed. This is shown graphically in Fig. 55 by the large areas, labeled "profit potential" and "loss potential," between the sales line and cost line. Conversely, when the fixed costs are relatively unimportant, both the profit potential and loss potential are much smaller; losses below the break-even point are smaller and profits above the break-even point are smaller. Large profits or losses are typical of industries such as steel where there are violent fluctuations during periods of depression and prosperity and equipment entails many fixed costs.

Straight lines are used for simplicity only in the first few illustrative figures. They will seldom occur in actual practice. The sales line will curve if prices change with the quantity sold; costs of production tend to increase at intermittent intervals with increases in output. It is often convenient to modify the diagram by showing costs for only the anticipated range production volume, that is, the volume scale need not begin at zero.

Individual cost curves. In plotting costs and output, the totals for a whole firm are often compared with the sales to determine the profit potential at various quantities as illustrated in Fig. 54. In other cases, it is desirable to plot the costs and quantity of output for only one piece of physical equipment and compare this with the value of the work done by similar pieces of equipment, showing the extent to which the operation of each is profitable. The profit graph for the whole firm may be thought of as made up of many belts, each representing the cost of operating one piece of property at various volumes. This conception is particularly valuable in the selection of physical property, for a complete factory is not purchased at once, but many different types of property are selected and combined. The result of this combination determines the profitableness of the business, which can be controlled only by careful selection of the many individual investments that make up the whole.

In many cases it will be impractical to use time and effort to collect or estimate all the information necessary to draw the cost curves discussed below, but this fact does not invalidate the importance of the concepts which they present. After understanding the principles, the student may then carry their applications to a degree commensurate with each individual problem.

Characteristics of cost curves. The output of a machine may usually be increased by increasing the variable costs — labor, supplies, and so on — connected with the operation of the machine. For example, the production of a lathe may be increased by hiring an assistant for the regular operator.

However, there are mechanical limitations imposed by the construction of the lathe which render it impossible continually to increase its output by the addition of further supplies or operators. An assistant operator may help to make certain adjustments more rapidly, but the increase in the value of the product will not be doubled because the number of operators has been doubled; and if further assistants are added, they may get in each other's way and so detract from the value of the total work done on the lathe. In other words, the addition of variable cost items to a given piece of machinery will not continue to give similar increases in the output.

The amount of increased production to be obtained from an added amount of variable cost will not necessarily be the same at various volumes of output. Continuing the illustration used above, if a lathe with one operator is producing 20 pieces of work a day, the added variable cost of hiring a helper might bring the output up to 30 units, an increase of 10 units. But when there are 2 men working on the lathe producing 30 units of output a day, the additional cost of hiring another will not necessarily result in the same amount of increased production as before, namely, 10 units. In other words, a constant change or increment — the wages of one laborer in the above example — will not necessarily result in constant increments of production. The amount of additional production may vary according to the volume upon which the addition is made. This is illustrated by the fact that the addition of one helper to a lathe may increase the output 10 units per day, a second helper, 6 more units per day, and a third, 2 more units per day. In each case the increment of cost is the same, the wages of one helper, but the increment of output diminishes as successive additions raise the volume at which the next increment of cost is applied.

The relation between increments of cost and corresponding increments of output may be one of increasing, constant, or diminishing returns. Each of these is discussed below.

Diminishing returns. The example cited above was one of diminishing returns, and this characteristic is also extensively treated in economics textbooks. In diminishing returns, successive increments of output become smaller as equal increments of cost are applied (see Fig. 56). This idea was first studied in connection with the decreasing yield to be obtained from land by continuing to add more laborers or give more tools to a constant number of laborers. In economics the discussion of diminishing returns generally assumes that only one factor, such as land or labor, is changing while the others are remaining constant. This assumption is valuable for theoretical economic analysis, but in the practical field of management, additions of variable costs to physical property usually involve both labor and capital. That is, if

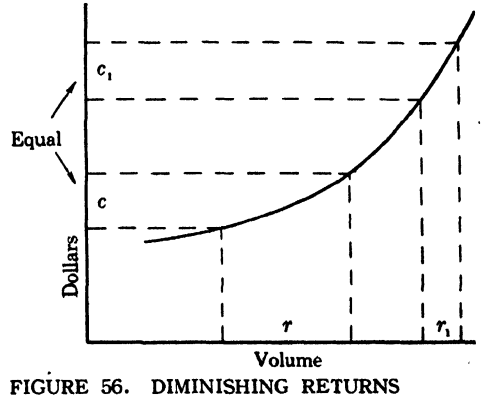


FIGURE 56. DIMINISHING RETURNS

Equal increments of cost (c and c_1) result in smaller increases in volume (r and r_1) as volume increases.

an additional worker is hired, tools are also provided for him to work with.

Constant returns. The condition of constant returns exists when successive equal increments of cost result in successive equal increments of output (see Fig. 57).

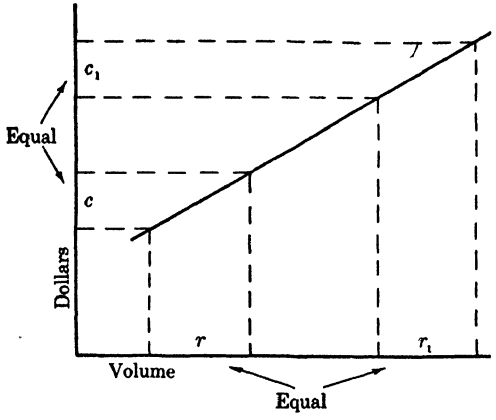


FIGURE 57. CONSTANT RETURNS

Equal increments of cost (c and c_1) will result in equal increments of volume (r and r_1) anywhere along the cost curve. (Must be a straight line in this case.)

Increasing returns. Increasing returns occur when successive equal increments of cost produce successively larger increments of output. That is, as you continue to spend money you get more and more from each additional expenditure. This is just the opposite of diminishing returns, and is shown by Fig. 58.

Increasing, constant, and decreasing returns in order. The cost curve of a piece of physical property will usually contain increasing, constant, and decreasing returns in that order (see Fig. 59). If actual data is plotted, the curve may appear to change from increasing to decreasing returns because the intermediate range of constant returns will be so small.

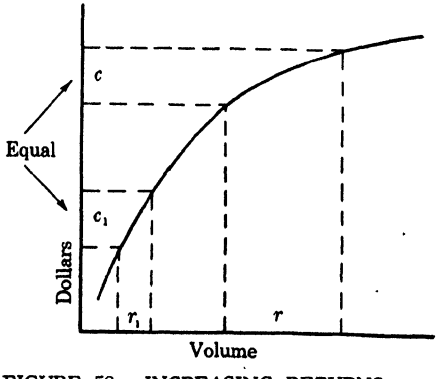


FIGURE 58. INCREASING RETURNS

Equal increments of cost (c and c_1) result in greater increases in volume (r, r_1) as volume increases.

It should be noted that all three of the characteristics now being discussed are characteristics of the cost curve and not of any one particular point. They are of no consequence if only one particular point on a curve is being examined by itself, because they deal with the relation between the points on the curve. The question of increasing or decreasing returns becomes pertinent when different points on the same curve are being compared.

The points where constant or diminishing returns begin should not be considered as points where the addition of variable costs should be

discontinued. These points are merely characteristics of cost curves — they tell us something of the nature of the curve, helping to describe it. They do not imply that volume of output should be reduced merely because it happens to be at a point on the curve that is within the area of constant or diminishing returns, or that output should be increased merely because the present operating point is within the area of increasing returns. The questions of increasing or decreasing the variable costs and consequently the output is affected by many other considerations.

With any given piece of plant, machinery, or equipment, a point will always be reached where diminishing returns will set in. Operators (variable costs) may be added beyond this point of diminishing returns, but eventually one of three other points will be reached: (1) the total cost of one lathe and its operators will be less than that of two lathes or a larger lathe with fewer operators — change-over point; (2) the capacity of the lathe cannot be increased regardless of the additional variable costs — capacity points; or (3) the total cost of the one lathe and its operators will be more than the value of the work done — profitable limits. Each of these points is discussed in more detail in the separate paragraphs which follow.

Change-over point. As the variable changes applied to a given piece of physical property are increased, points will be reached at which the total costs of producing a given quantity with a single machine will be greater than total costs of two similar machines, or, a larger machine producing the same output. That is, it will be more economical to invest in two machines or a larger machine and use proportionally less variable costs in connection with each. The output may then be increased by adding variable costs until another change-over point is reached. Figures 60 *a* and 60 *b* show the costs of one single unit and of two similar units operating together. In Fig. 60 *c* the curves are superimposed to show the change-over point from one unit to two.

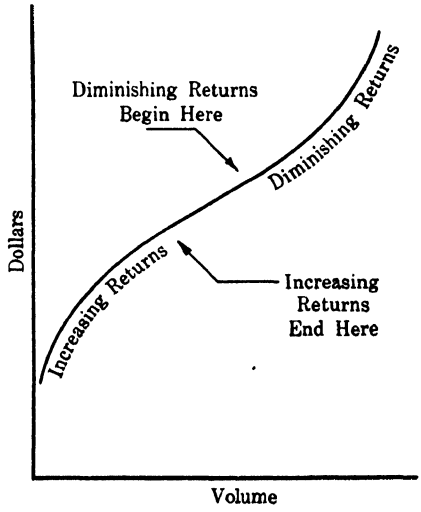


FIGURE 59. COMPOSITE CURVE.
Typical of most physical property and includes increasing, constant, and decreasing returns.

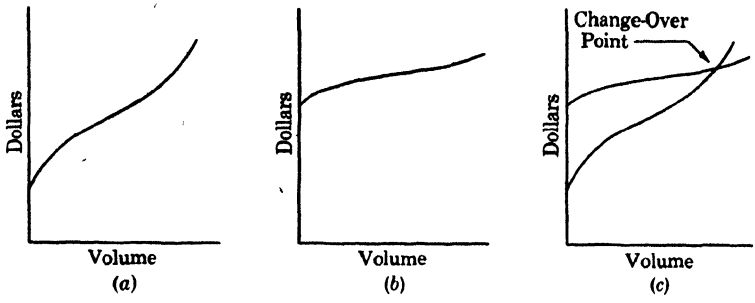


FIGURE 60. INDIVIDUAL COST CURVES (*a*) AND (*b*) SUPERIMPOSED—TO FIND CHANGE-OVER POINT

Capacity points. With some types of physical property, a point of capacity is reached beyond which output cannot be increased by the addition of variable costs. Such a curve is shown in Fig. 61. This might be true, for example, of a power-driven pump operating at maximum speed. In this case, output cannot be increased unless another unit is added.

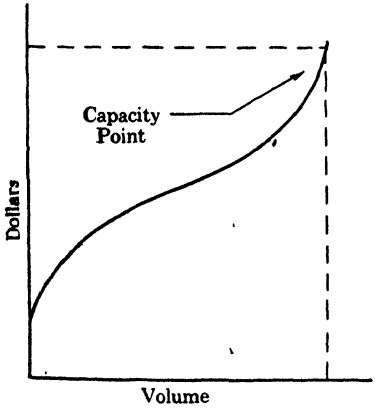


FIGURE 61. CAPACITY POINTS

Profitable limits. The addition of variable costs to a piece of physical property may bring the total costs higher than the total value of its productivity. Ordinarily, a change-over point will be reached before the profitable limit, that is, it will become economical to increase the investment before the existing property begins to operate at a loss because it is overloaded. However, factors of availability for use, first costs, rent, or even lack of purchase funds may render it uneconomical or impossible to make a change in investment.

There is also a lower profitable limit below which the value of the small volume of output is not equal to the cost of producing it. The upper and lower profitable limits define the *profitable operating range* (see Fig. 62).

While no business can operate permanently at a loss, there may be sound justification for operating individual pieces or property beyond their profitable limit. Many different pieces of physical property are necessary for the manufacture of any product, and there is no justification for stopping manufacture because one factor, such as a milling machine, is overloaded. The loss in the operation of the milling machine

may be compensated for by the gain from the operation of other parts of the business.

This principle illustrates the flexibility of vertical combination of industry. If each process were performed by a separate company, continual price and quantity adjustments would have to be made. The efforts of each firm to keep out of the red would result in continual price and quantity adjustments. However, as more processes are brought under one management, it becomes possible to continue production even though one of the processes may be temporarily out of economic adjustment. By the same token, in a large firm one or two profitable departments may cover up others that run at a loss.

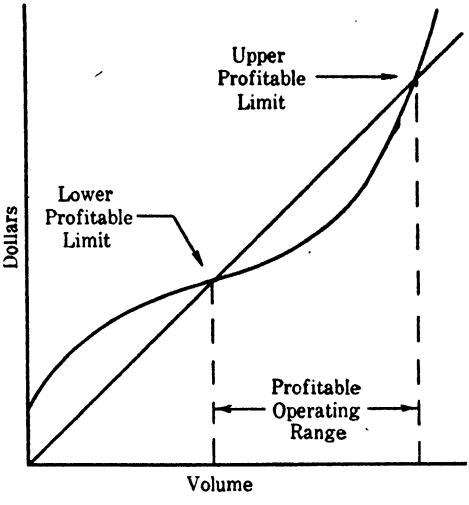


FIGURE 62. PROFITABLE LIMITS AND PROFITABLE OPERATING RANGE

Composite Selection Curve

If production were to remain constant at one particular quantity, the selection of equipment would be a matter of lowest total cost at the given quantity. When charts showing costs and quantities for various possibilities are superimposed, the equipment with the lowest total cost line at the given quantity may then be selected. The lowest total cost at various quantities is shown by a composite line made up of segments determined by the change-over points at quantities where individual cost curves become the lowest on the chart. When this composite line has been established, it may be used to select the most economical piece of property for any one volume of output, and other lines may be eliminated from the chart (see Fig. 63).

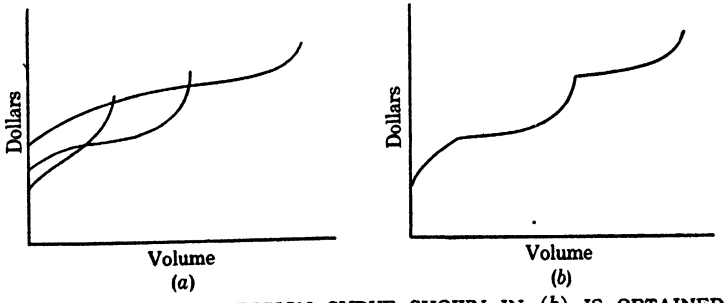


FIGURE 63. COMPOSITE SELECTION CURVE SHOWN IN (*b*) IS OBTAINED FROM THE SUPERIMPOSED COST CURVES SHOWN IN (*a*)

Selection of physical equipment is often based on estimates of future production. These are more properly stated as a *probable range* between two quantities rather than only *one specific quantity*. When change-over points occur within this probable range of future production, a composite line composed only of the lowest segments of each cost curve is not a sufficient basis for selection. When neither one of two individual cost curves is lower over the entire range of probable production, the one with the lower average for this range should be selected. In determining this average, care should be taken to consider the distorting effects of extreme values, and possibly the anticipated range should be broken down into several ranges with different possibilities. For example, equipment with cost curve A, Fig. 64, has lower average costs over the given range than equipment B, but the extreme fluctuation of A at the further end of the range renders investment in A of doubtful value. However, if a reconsideration of the probable range should reveal that this end of the range is much less probable than the remainder, then the case for equipment A is more favorable.

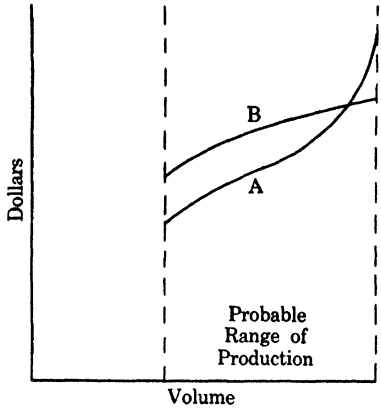


FIGURE 64. STUDY OF CURVE SEGMENTS THAT FALL WITHIN PROBABLE RANGE

On the type of chart shown in Fig. 65 it becomes necessary to show segments of individual cost curves on both sides of the change-over points. This modification is shown in Fig. 65.

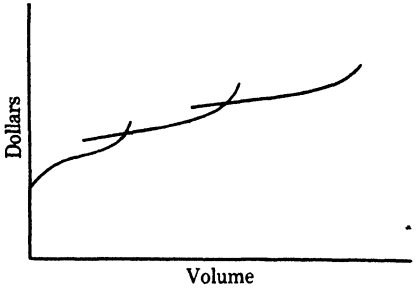


FIGURE 65. OVERLAPPING COMPOSITE SELECTION CURVE FOR USE WITH PROBABLE RANGES

Combination of Different Types of Property

Manufacturing consists of a series of operations which are performed upon raw materials in order to make them into finished goods. For any one operation there may be many possible methods, each using a particular type of machinery or equipment. For example, there might be a choice between riveting and welding in the assembly of a metal product. Assuming each method meets the specifications satisfactorily, the choice of method would depend upon the respective costs of the equipment. But it is unlikely that the answer will be in comparison of

total costs for complete, new equipment for each method, because other plant facilities which may be employed, such as sources of compressed air or electric power, will modify the costs of complete sets of equipment for each method.

The manager who is selecting physical property must determine the *combination* of methods, or types of building, machinery, and equipment which will give the lowest total costs over the probable range of production.[1] The particular combination selected should be less expensive than any other combination of direct-production methods, storeskeeping, material handling, production control, and cost accounting which might be devised to meet the same requirements in terms of quantity and quality of product and also financing arrangements. In terms of graphic analysis, the relation between the sales line and the total cost line over the probable range of production should be as favorable as possible.

In many industries, average figures for production or sales are not reliable guides for the determination of the amount of equipment needed because much of the work consists of rush orders that come at a few peak periods. In these cases the capacities of equipment should be sufficient to take care of peak loads. However, it is not always economical to invest in specialized machinery with a capacity sufficient to handle the peak load, as part of this investment will be idle most of the time and its cost will have to be charged to smaller than capacity production. A better procedure is to install specialized equipment to handle the ordinary demands and meet peak periods by increasing variable costs. For example, if five industrial trucks are necessary during rush periods and three are sufficient to meet ordinary demands, it may be more economical to purchase only three trucks and supplement these with additional labor during rush periods.

When supplementary equipment is used to take care of peak loads, the cost of both the standard and supplementary equipment should be added together to find the cost of the combination. The curve of the combination can then be compared with the curve of other combinations in order to select the most economical one. When making the curve of a combination containing standard and supplementary equipment, it is important to remember that the supplementary equipment is not

[1] According to the economist, the businessman adds land, labor, and capital until the marginal revenue product of each equals its marginal cost. The usefulness of this idea to the businessman is limited because he does not deal with distinct and separate units of land, labor, and capital. What he does do is decide the methods (or systems) that shall be used in each part of the manufacturing process. Each method contains different amounts of land, labor, and capital which cannot be dealt with independently. He uses the combination which will give the lowest total costs over the most probable range of production.

operated until the capacity of the standard equipment has been reached. Consequently, no variable costs will be applied to the supplementary equipment until the capacity volume of the standard equipment has been reached. The details of the procedure for adding the cost curves are as follows:

1. For volumes up to the capacity of the standard equipment, add the fixed costs of the supplementary equipment to the cost curve of the standard equipment.
2. Treat the capacity cost of the standard equipment as a fixed cost for all volumes of the combination beyond the capacity of the standard equipment, and to this add the costs of operating the supplementary equipment. The costs of operating the supplementary equipment are determined by the volumes which it handles, but the capacity volume of the standard equipment is added to these volumes before these points are plotted on the chart of the combination. This procedure is shown in Fig. 66.

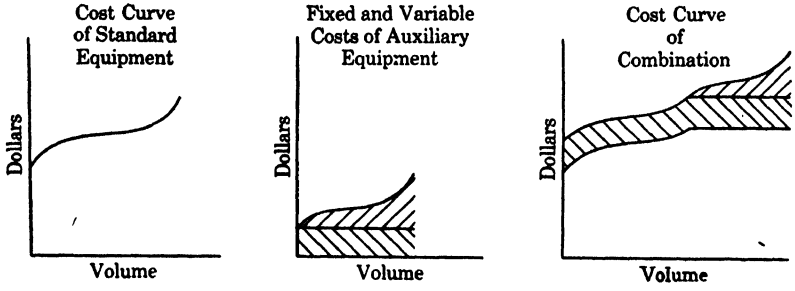


FIGURE 66. METHOD OF ADDING THE COST CURVES OF STANDARD AND AUXILIARY EQUIPMENT TO OBTAIN THE COST CURVE OF THE COMBINATION

TIME FACTORS

The period of time over which it is expected that physical property will be used is an important consideration in its selection. This life expectancy affects both the fixed charges and the quality which must be required. The longer the life expectancy of a machine, the smaller will be the depreciation charge per year. On the other hand, the greater will be the danger of the equipment becoming obsolete due to new developments or style changes; consequently, the whole investment may become unprofitable because it was based on calculations of a longer life expectancy.

As a machine becomes older, variable fixed costs such as power, repairs, and maintenance are likely to increase, particularly if the original quality of the machine was not high. On the other hand, the investment in a machine of superior quality which will only be used a short period of time is economically wasteful. At the termination

of this period the machine will still be capable of giving many hours of service which have already been paid for and yet will never be used.

These conceptions may be shown graphically by plotting cost on the vertical axis and time on the horizontal axis (life expectancy). The curve for depreciation will slope to the left, showing smaller depreciation charges as the life expectancy is increased. The curve for the variable fixed charges (power, repairs, maintenance) will show that these are increased with the life expectancy of the machine. This increase will not be in direct proportion to the life expectancy, because these costs are relatively low when the machine is new and are likely to become increasingly larger with each additional year of operation.

INTANGIBLE FACTORS

The selection of physical property is largely a matter of judgment. Records of previous expenses and present characteristics of the property can be used only as guides in estimating future costs and performance. The final selection will be influenced not only by these estimates of things which will later become tangible records, but also by intangible factors which cannot be evaluated in precise figures. These intangible factors include all the gains or losses which may come to the business because of public attitudes, general business conditions, strikes, or floods. Some of these influences will be entirely beyond the control of the individual management; others may come as a reaction to the business itself.

In the first classification come changes in demand and style which have already been mentioned in connection with the danger of obsolescence. In the second classification are reputation and good will which are generated by the ability of the business to satisfy its customers.

The reputation of a business is determined in part by the personal ability of its salesmen and others in contact with the public, but these people must always have a good product. This good will can be built up only if the business is able to produce the right goods at the right time. Breakdowns in equipment used to produce goods may precipitate losses far greater than the cost of repairing the breakdown and the goods which could have been produced while the equipment is inactive. Failure to meet delivery dates, inability to accept other orders, reduced quality due to production difficulties — all these may have far-reaching effects upon reputation and consumer good will.

Many losses due to intangible factors cannot be prevented. The potential occurrence of others may be *anticipated* and minimized in the selection of physical property. A common example of this is the use of two small motors rather than one large one so that a single breakdown will not stop production completely.

CHAPTER VIII

MAINTENANCE MANAGEMENT

It is the function of a maintenance department to keep all physical property in as good condition as possible at all times. This involves protection and care of manufacturing machinery and equipment, service equipment, and factory buildings, as well as yards, areaways, walks, and other facilities which are part of a physical plant. In addition, the maintenance department is often called upon to make installations and build special equipment and furniture. In a manufacturing industry, however, the primary purpose of a maintenance department is (1) to keep machinery and equipment in good working order by preventing the occurrence of breakdowns which will interfere with production schedules and regular work, and (2) handle emergency repairs which may arise in connection with the use of any type of physical property.

The importance of maintenance management increases with the amount of fixed investment in plant machinery and equipment. Unless this property is kept in proper working order the investment is wasted. Only with a well-organized system of inspection and repairs is it possible to maintain maximum efficiency of service from physical property. Where mechanical equipment has been substituted for a large amount of direct labor, the maintenance crew has in a sense replaced some of the production foremen; and taxes, insurance, depreciation, and other maintenance charges have replaced the wages for productive workers.

Added to this is the tendency in many industries to use greater operating speeds in production. The severe use of manufacturing machinery and equipment results in its failure. This creates financial losses and causes delays in manufacturing which in turn may require revamping of operating schedules throughout the plant.

Prevention — The Primary Function of Maintenance

In terms of the old adage, "an ounce of prevention is worth a pound of cure," the first aim of maintenance management should be to prevent breakdowns rather than to make repairs after they have occurred. The second aim should be to make repairs as quickly as possible. The function of maintenance work may be compared with that of accident insurance. In both cases payments are made because of the possibility

of untimely and unfortunate occurrences which may have serious consequences. In anticipation of these, payments are made in advance to help alleviate the damage, loss, or inconvenience which may occur from such accidents.

In many cases maintenance costs might be considerably less if a machine were allowed to run until it breaks down rather than make constant inspections and minor repairs, but a breakdown at an inopportune time might result in serious production delays and financial loss. The justification for large maintenance expenses, therefore, may often be found in the demand for continuous service, particularly during rush periods, from the equipment used directly in production.

Other Functions of the Maintenance Department

The maintenance department is one department which may have a great variety of duties and responsibilities. It is often asked to construct experimental machinery and equipment or even to make standard equipment rather than purchase it from an outside manufacturer. (This last is done in order to get returns from expensive maintenance machinery and skilled labor which would otherwise be idle except when repairs are being made. It is important in this connection to avoid using the maintenance department for making equipment which may be purchased more cheaply outside.) The maintenance department may be called upon also to supply valuable suggestions to the engineering, production, and methods departments. For example, whenever new buildings are being constructed or new methods of production are being worked out, the maintenance department is called upon to make suggestions and to furnish ideas as to the suitability of what is being planned. There follows a list of functions which some maintenance departments are expected to perform. These are not necessarily typical of any given organization.

Methods of Prevention

Some breakdowns of equipment are such as to cause interruption of production. In instances where these are likely to occur, their frequency may be reduced by (1) constant inspection to prevent the breakdowns from taking place, and (2) the adoption of a repair schedule.

Inspection. Inspection is the key to preventive maintenance and preventive maintenance is in turn the key to low operating cost and a lessening of the failure of machinery and equipment. Inadequate attention to even very minor aspects of maintenance work may have serious repercussions in production. For want of some oil, a machine may be "down." The machine that is "down" may put an operator out of work. For want of the operator's work, production is "down" and of

course when production falls, worker and factory income are "down"—all of this results for want of some oil which regular inspection would, of course, prevent.

Inspection schedules can be designed to cover all the machinery and equipment in the plant. Wherever this is done, it is important to set up not only a schedule for inspection work, but also indicate the way in which inspection is to be carried out. This can be provided in a handbook showing the types of equipment to be inspected, their location, frequency of inspections required, and special items to check regarding the condition of the equipment at the time inspection is made. If provision is made for keeping records of inspections in this same book, interest on the part of the inspectors will be aroused if they are reviewed at frequent intervals by maintenance foremen. Wherever schedules are not being complied with or where preventive maintenance is not effective, meetings can be held to discuss problems. Figure 67 shows a typical inspection and lubrication schedule.

1. Inspect every motor, daily, weekly, as indicated by schedule.
2. Oil and grease motors as per schedule.
3. Oil or grease equipment the motor is driving, such as pump bearings, gear reductions, and countershafting.
4. Clean motor housings, and drip pans.
5. Keep commutators clean.
6. Inspect belting and record its condition.
7. General inspection of humidifier, air-conditioning equipment, etc.

Bldg. No.	*Machine (Code No.)*	*Frequency of Inspection*	*Mon.*	*Tues.*	*Wed.*	*Thurs.*	*Fri.*
1	3006	"D" Daily	×	×	×	×	×
	3007	2/w Twice/wk.	×			×	
	3009	"W" Weekly	×				
2	507	2/2	×		×		
3	709	D	×	×	×	×	×
	714	2/w			×		×

FIGURE 67. SCHEDULE OF INSPECTION AND LUBRICATION

Repair schedules. No single factor is perhaps more helpful in bringing about preventive maintenance than if a plant establishes regular repair schedules. This requires the setting up of schedules to permit regular overhauling of machinery and equipment to be sure that it is in good working order and to prevent breakdowns when they are not wanted. In deciding on the schedule for machine overhauling, it is important to consider both the number of units involved and the time required to do the work. In the case of material-handling trucks, the schedule might be based on the number of miles traveled, whereas in the case of units of productive equipment it might be the number of hours

of operation. In developing the repair schedule, it is important to try to minimize peak loads on the maintenance department for overhauling work. Similarly, where production fluctuates it is desirable to try to develop a repair schedule which will help to stabilize employment, that is, assembling, cleaning of equipment, and so forth, during the periods of low production volume. The repair schedule may be worked out to include new installations and rearrangement of equipment which requires the assistance of the maintenance department. This is particularly true where the machinery and equipment is designed and built by engineers in the plant. Where these installations must be made, a schedule should be developed. Shop orders required to accomplish the work should be listed in sequence showing the way that the work is to be performed, that is, first jobs first, and jobs in order of importance so listed.

When repair and installation schedules are developed, it is important to post them in the plant so as to call attention to their importance and to make sure that the dates as scheduled are met.

Provisions to Reduce Seriousness of Breakdowns

In spite of regular inspection and repair schedules, no industry can completely avoid breakdowns. When these do occur they are usually serious and need immediate attention. Whenever emergency breakdowns occur the amount of "down" time can be minimized only when maintenance workmen are assigned immediately to the necessary repair work. In cases where the machine-hour rate (overhead cost) of machines is extremely high, it may be good judgment to place more men than ordinarily needed to do the repair work. This ought to prove helpful in starting machines more quickly, and thereby getting production moving more quickly, causing a minimum upset of production schedules.

Because unexpected breakdowns often have very serious consequences so far as needed production volume and production schedules are concerned, it is important for management to give consideration to steps to be taken that are helpful in overcoming these difficulties. These are:

1. Owning duplicate or adaptable equipment which may be substituted for that which is broken down.
2. Having replacement parts and skilled labor available for immediate repair work.
3. Carrying a large inventory of the product which will not be depleted during the time necessary for repairs.

The last will make it possible to meet customers' orders without causing disruptions in service which so often cause ill will.

Maintenance Supervision

The task of supervising maintenance work is much more difficult than that of supervising direct labor — machine operators and the like. It is relatively easy to establish standards for production work against which worker performance can be measured, but standards are much harder to establish for maintenance inspection and repair jobs. Poor work may not be apparent until years after it has been done and then it is difficult to fix blame definitely either on workmen or materials used. The good maintenance worker is not one who is "busy" all day, but the one who "works himself out of a job" by making minor repairs so that major ones are not necessary. The more efficient a maintenance worker is the less work there is for him to do.

Definite assignments of responsibility and records of inspections of repairs are necessary. One man should be responsible for the "health" of one particular type of property or the property in one department. Records need to be kept of all inspection and repair activities including the date, condition, types of repairs made, and signature of the maintenance-staff member who made them.

The success of a system of checkup by means of records depends upon its design and administration by management. Inspection of all potential danger spots must be required and proper action taken when reports so recommend.

Suggested Plan of Maintenance Control

Maintenance work is regarded by many manufacturers as an unpredictable expense item; its total amount is usually estimated and budgeted, but too often without any certainty of final results to be achieved.

Maintenance work is not really managed until it is subjected to analysis and study. When this is done, it will be found that maintenance work can lend itself readily to standards of performance — predictable times for doing the work as well as estimates of costs to be expected when the work is completed. This is true not only of repetitive and routine maintenance work, but also of that of a nonrepetitive nature.

Standards of performance. A standard of performance is an established sequence of predetermined operations to be done within a time expectancy estimated to be reasonable for the conditions under which the operations are to be performed. When these factors are known it is possible to compute a standard time and standard cost for maintenance operations.

Applied to maintenance work, a standard of performance means that the operation and time elements required to do them may be standardized for work to be done by the following maintenance-staff members:

1. Machinists
2. Carpenters
3. Electricians
4. Painters
5. Millwrights
6. Pipefitters
7. Tinsmiths
8. Welders
9. Oilers
10. Truckers (inside and outside)
11. Yard Crews
12. Warehousemen (including receiving, handling, and shipping)

By careful study of records of maintenance work done in the past as well as that now in process, work done by the above maintenance workers may be reclassified as follows:

1. Routine work
2. Repetitive work
3. Nonrepetitive work
4. Estimated work

Study of work done is needed in each of these classifications in order to arrive at standard hours which will be value received in work for whatever wages are paid.

Standard hour costs. Standard costs for maintenance work consist of cost of the labor performed plus the overhead expense of the maintenance department per hour of work and the cost of the materials and supplies used. Since some maintenance costs are a combination of fixed and variable expense items, the total cost will vary with changes in the utilization of plant capacity. (See Chapter XXXIII on Control of Variable Costs.) Maintenance costs may be budgeted by working out a schedule of maintenance activities in relation to capacity of operation over a period of years. The standard costs for maintenance work are related to normal plant activities.

Centralized Control of Maintenance Workers

In order to make the most efficient use of maintenance workers, the following steps need to be taken:

1. **Establish proper authority over maintenance.** This requires that work be done on *written authority* only and by request of the production supervisor or head of the maintenance department. If the head of the maintenance department originates the work order, it should also be countersigned by the head of the production department in which the work is to be performed. If the requisition originates in the production department, it should be countersigned by the head of the maintenance department. In some instances it may also be advisable to have the master mechanic sign the labor voucher.
2. **Introduce record system of control.** In order that the most effective use may be made of the maintenance staff, it is important to classify mainte-

nance work to be done according to priority of importance. This may be done by a card file under which jobs will be classified as follows:

a) Jobs not started
b) Jobs in process
c) Jobs completed

3. **Create dispatcher for maintenance work.** The order system applied to maintenance jobs should clear through a central dispatching office with some person or persons designated to be responsible for assigning jobs. Work should be ordered by means of job tickets similar to those which are used in standard production-control procedures. Copies of these should be sent to appropriate persons and, of course, a file copy retained in the central dispatch office. Materials for the job should be requisitioned or the maintenance worker instructed to withdraw his own materials, listing them on the back of his job ticket.

Application of incentive system. Even when standard hours for maintenance work are established there is no assurance that maintenance workers will perform within the limits set. A system of bonus payments will give some assurance of obtaining desired results. The amount of reward to be paid should be based on time saved or the differential paid on actual hours as computed. These may be computed first by classes of work — routine, repetitive, nonrepetitive, and estimated — to determine to what extent costs are being kept at a minimum. When this same information is rearranged by classification of workers — carpenters, electricians, and so on — it can then become a basis for payment of a bonus to each of these groups, or individuals within the group, depending upon how the work has been done. It is also an excellent source of information for a maintenance-performance report which top management can use for control purposes.

Maintenance-performance report. The most important cost item to control in maintenance work is that of maintenance labor. This control can be accomplished through proper use of *performance* standards. Figure 68 shows a form for recording scheduled and actual times which can be used as a basis for *performance reports* to top management.

The performance report shows actual hours spent and standard hours established for machinists, millwrights, carpenters, and others. This becomes a guide for top management in judging the efficiency of the various groups in their work. It provides a basis also to use in computing bonuses earned by various workers.

Conference method of control. In order to bring an awareness of maintenance costs to those concerned with the work, it is recommended that each of the production-department heads be given summaries of maintenance work to which their departments have given rise. Maintenance costs can be computed weekly or monthly by manufacturing

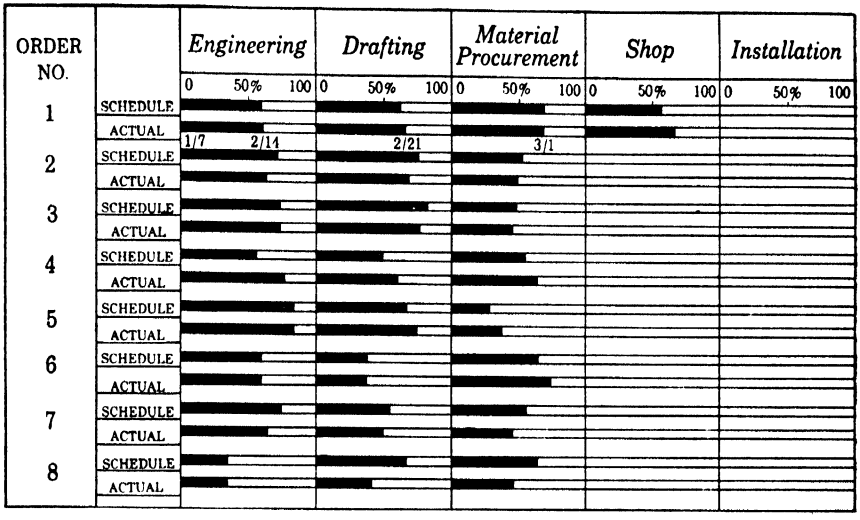


FIGURE 68. FORM FOR RECORDING SCHEDULED AND ACTUAL LABOR TIME FOR PERFORMANCE OF MAINTENANCE WORK

departments to show records of labor and material cost summarized by departments. This method is comparable to presenting a bill to a man for work he has ordered. It should serve as a reminder of variations in costs and an encouragement to the production supervisor to follow up his maintenance for verification of the moneys expended. This in itself is a useful control procedure.

Control of emergency breakdown costs. Contrary to popular conception, emergency breakdown costs are controllable as are routine and other types of maintenance work. When an emergency breakdown occurs, the calculation of cost comparisons is followed and when an incentive system is installed the bonus will be effective in getting desired results.

Maintenance analysis reports. The efficiency of the work of the maintenance department can be appraised by managers by the use of maintenance-analysis reports. These are summary reports on maintenance by classification of the work done. The gain or loss as shown by a comparison of budget standards with actual expenditures can be used as a basis for discussion and control of maintenance. For this purpose, it is suggested that department heads meet with top management to obtain both an over-all picture of plant maintenance work as well as the situation in their own particular departments. This is, in effect, a supplementary control procedure.

QUESTIONS

CHAP. III. (PRINCIPLES OF SELECTING PHYSICAL PROPERTY)

1. What is meant by physical property from the viewpoint of industrial management?
2. In what order should physical property be selected?
3. Explain "capacity utilization."
4. Give in detail the order-of-selection list for procuring physical property.
5. Why should there be a question of "how much to manage"?
6. How are the principles of capacity utilization applied to the following: plant location, production control, personnel administration?
7. What is the procedure for obtaining capacity utilization?
8. Are there benefits from enlarging the scope of management activity?
9. How can the manager avoid financial management obligations?
10. State briefly the limitation on effective use of capacity.
11. Outline the management considerations of owning vs. leasing.
12. Distinguish between the gross lease and the net lease.

CHAP. IV. (SELECTING THE SITE — PLANT LOCATION)

1. Indicate why the following are or are not industrial areas:
   a) the Chicago-Detroit section of the United States
   b) Puerto Rico
   c) Western Canada
2. What factors will determine whether or not a given area of the world may become a prosperous industrial center?
3. If you were asked as a management consultant to find a location for a particular new type of industry, what information would you ask from your client who seeks the location, and what information would you attempt to discover yourself?
4. Outline the steps of procedure for locating an industrial plant.
5. What is the advantage of locating in a manufacturing district which is privately controlled?
6. Explain "battle for the smokestacks."
7. List the factors which have influenced the growth of industry in the United States.
8. Why is the significance of location factors changing constantly?
9. A large mail-order house has decided to acquire a wallpaper plant to manufacture its requirements of this commodity. The product will be manufactured for stock and will be shipped to its warehouses located in Atlanta, Philadelphia, Chicago, Dallas, and Seattle, from which customers' orders will be filled as required. No plant suitable for its requirements is available for purchase, and you have been given the task of selecting a site for the new plant. Explain in some detail how you would proceed, giving careful consideration to the types of information you will require, where you will look for these data, and what use you will make of them in arriving at your decision.
10. An industrial firm seeking a new location has listed the following factors as primary considerations. These are listed in the order of their importance:

a) Labor supply
b) Available buildings
c) Transportation facilities
d) Nearness to markets
e) Available raw materials

In the light of this, a consultant has reported that the following towns which he has examined have potential abilities to meet these requirements as follows (1 = best; 2 = second best; 3 = third best):

	Town I	*Town II*	*Town III*
Labor supply	1	3	2
Available buildings	2	1	3
Transportation facilities	3	2	1
Nearness to markets	1	2	3
Available raw materials	2	3	1

Which town would you select? Show how you made the selection.

CHAP. V. (SELECTION OF MACHINERY AND EQUIPMENT)

1. Should the manager rely on his own judgment in making selections of machinery and equipment?
2. What are the "performance characteristics" a manager needs to understand in order to guide his decisions in the selection of machinery and equipment?
3. What is meant by the mechanical efficiency of a machine? Contrast this with financial efficiency.
4. What are helical gears?
5. Explain the purposes of keys, pins, and roller bearings.
6. Distinguish between a positive and friction clutch.
7. What is drop-feed oiling?
8. Explain the use of cams.

CHAP. VI. (SELECTION OF FACTORY SERVICES AND BUILDINGS)

1. Name the services required by most factories.
2. Explain the three types of power drive and state the advantages and disadvantages of each.
3. What are important considerations to be met in determining whether to produce or buy power requirements?
4. Name the systems of lighting.
5. What are the four major types of lighting?
6. List the considerations to be met in passing upon the effectiveness of any lighting system.
7. Why is air conditioning important as a service?
8. Explain the significance of noise control.
9. Of what importance is humidifying?
10. How is management aided by a good communication system?
11. Outline the relationship between morale and provision of good employee facilities.
12. What are correct posture chairs?
13. Why is it important to select factory services when planning arrangement of the building?
14. What are functions of a factory building?
15. What is a saw-tooth roof building?
16. State the advantages that may be claimed for the single-story building as compared to the multistory building?

17. Name the types of building as classified according to construction.
18. List the advantages of standard buildings for factory purposes.
19. Define the term "standard building."
20. Of what importance are aesthetic considerations in building design?
21. Name the types of buildings as classified by roofs.

CHAP. VII. (COST CURVES OF PHYSICAL PROPERTY MANAGEMENT)

1. Explain the significance of a crossover chart.
2. Distinguish between variable and nonvariable costs.
3. Why use individual cost curves?
4. State briefly the characteristics of cost curves.
5. What are change-over points?
6. Define "profitable operating range."
7. What is meant by "intangibles" of physical-property selection?
8. What are the time factors involved in physical-property selection?
9. Explain the use of a composite selection curve.

CHAP. VIII. (MAINTENANCE MANAGEMENT)

1. State the purpose of repair schedules.
2. How is preventive management carried out?
3. Tell why maintenance management is often called "preventive" management?
4. By what means can management take care of unexpected breakdowns?
5. Of what significance is centralized control in maintenance control?
6. Describe how an incentive system may be used effectively in maintenance control.
7. Designate the classifications of work which may be used for various kinds of maintenance work.
8. Of what importance is a maintenance-performance report?
9. What can management do to control the costs of emergency breakdown?

PROBLEMS

Problem 1. The Stevens Manufacturing Company [1]

An Analysis of the Factors to Be Considered in Locating a Plant

The Stevens Manufacturing Company plans to construct a new plant. The owner of The Stevens Company has decided to build a plant to produce 100 tons per day. In this decision he has been influenced by his ability to sell that output and his ability to raise enough money to build such a plant, but for an engineering analysis of plant location more information is necessary.

A consulting engineer has been engaged by The Stevens Company to make a scientific analysis of the plant-location factors which should influence the location of the proposed new plant.

The engineer has submitted a complete report and recommendations for a desirable location, from which the following information is taken:

The Plant-location Factors

The factors to be considered in locating the proposed plant include:

1. Trade possibilities for expansion
2. Low distribution costs and speedy delivery
3. Cost and quality of raw material
4. The first cost of the plant and the resulting overhead costs
5. The cost and quality of labor

Trade Possibilities for Expansion

A study of the manufacturing requirements of The Stevens Company brought the following questions to mind:

1. How much land is required for future development? To answer this question a general survey of the trade is necessary.
2. Might this plant eventually be called upon to supply several times the capacity at present assumed? Government reports are of great value in determining the possible magnitude of the industry and its probable growth.
3. With a knowledge of the present distribution of the product, the factor governing distribution must be decided upon. Is it population, per capita wealth, climate, or some other factor?
4. Is the geographic distribution likely to remain about as it is now? If not, what change is likely to occur?

The Cost of Distribution

A complete study of the potential market for Stevens products was made, definite quantities were used for sales forecasts, and maps and charts were prepared to visualize the situation more clearly, especially the sales distribution by states. This was followed by a complete tabulation of distribution points and probable shipments to these points.

[1] By courtesy of Emmett B. Carter, Consulting Engineer, New York City.

From the maps of sales distribution and a knowledge of freight rates, it was seen that a good distributing point lay somewhere in the Delaware-Pennsylvania area. However, since the industry, which is considered in the present analysis, receives the bulk of its raw material from Europe, full cargo steamers should be able to unload directly into its plant; and, therefore, with the state of Pennsylvania in mind as a good distribution point, New York, Philadelphia, and Baltimore appeared to be possible locations.

A further study of the raw material, however, disclosed the fact that one ingredient of which considerable tonnage is necessary should be purchased in New Hampshire; hence, the New England ports had to be considered. This widened the possibilities so that the Atlantic ports from Boston to Norfolk had to be considered.

Freight Rates

A tabulation of comparative freight costs from the locations considered was then made as is indicated in Table 1, in which are included only enough destinations to illustrate the method used (see Table 2).

One may think that if it costs 30 cents to ship a commodity 100 miles, it should cost something like $3.00 to ship it 1000 miles, but freight rates have been built up on a system of literally "charging what the traffic will bear." It has been to the interests of the railroads to help build up business for industries on their lines. When one of these industries could show that a lower freight rate was required to develop new business or to invade territory served by a competitor, the railroads have tried to cooperate by lowering rates. For example, industries located in New England on the New Haven Railroad have the same freight rates for points west of Harrisburg as those shipping from New York City.

Special import rates exist at a few ports and help to put these ports on a better basis in competition with other seaboard cities. For example, a domestic rate from Boston to Bloomsburg, Pennsylvania, is 34 cents, while the import rate is 25½ cents.

Commodity Rates

Special products have been favored with commodity rates from and to certain points where a special demand has existed. A manufacturer should always present his request for such a rate to his railroad if he can show that his competitor has a commodity rate and thus is securing an unfair advantage to reach a certain market. The possibility of securing additional commodity rates must always be considered in plant-location work.

Cost of Importing Raw Material

In the case under consideration, the largest tonnage of raw material comes from Spain in full cargo steamers drawing 25 ft. of water. This required a study of government maps of harbors. As the cost of unloading and shipping any distance by rail was very expensive, it indicated that the plant must be on deep water.

A review of port conditions for the principal ports was made and a sample of the study for Baltimore is included to indicate the points covered. Due to the distance which these steamers must travel, the question as to which one of the North Atlantic ports was selected for the plant appeared to make no difference in the cost of ocean freight.

It might be added that the question of anchoring ships and barging raw material to a plant having shallower water was considered, but the two spots under consideration, namely, Narragansett Bay and Delaware Bay, were thought to be unsuitable for such operations because of high winds and ice conditions in winter months.

TABLE 1. COMPARATIVE COST OF FREIGHT ON FINISHED PRODUCT TO CONSUMER

Destination	*Tonnage*	(Freight costs in dollars when shipped from)					
		Boston	*New London*	*New York*	*Wilmington*	*Baltimore*	*Norfolk*
Ashtabula, Ohio	5,800	51,968.00	51,968.00	49,358.00	46,632.00	45,675.00	44,834.00
Buffalo, N. Y.	1,670	12,909.10	12,909.10	11,973.90	11,973.00	11,973.90	13,660.60
Cincinnati, Ohio	113	1,241.84	1,241.84	1,241.84	1,190.94	1,164.93	557.58
Grand Rapids, Mich.	1,118	13,024.70	13,024.70	13,024.70	13,521.60	12,275.64	10,520.38
		(Other destinations and figures pertaining to them have been omitted)					
Total Costs		317,728.00	323,800.00	312,083.00	315,575.00	314,830.00	329,563.00

TABLE 2. A COMPARISON OF THE PRINCIPAL VARIABLES IN OPERATING COSTS FOR DIFFERENT LOCATIONS

	Boston	*Providence*	*New London*	*New York*	*Phila.*	*Wilmington*	*Baltimore*	*Norfolk*
Del. exp. on raw material from abroad	$ 77,630	$ 80,505	$ 80,460	$ 82,225	$ 81,125	$ 79,080	$ 76,080	$ 79,980
Frt. on domestic raw material	5,734	5,841	6,417	8,064	8,510	8,747	9,779	11,346
Overhead on plant	93,440	73,600	68,400	95,600	82,800	81,200	80,000	78,200
Fuel	73,815	73,815	69,375	64,935	61,605	61,605	58,905	55,944
Factory labor	250,000	225,000	225,000	275,000	225,000	200,000	200,000	175,000
Frt. on finished product	317,728	321,621	323,800	312,082	312,960	315,575	314,830	329,563
Land rent			4,000					
Totals	$818,347	$790,382	$777,452	$837,906	$772,000	$744,307	$739,994	$730,033

The raw material used from New Hampshire amounted to 1220 tons per year, and the freight costs to different locations were about as follows:

Boston	$5,734	Philadelphia	$ 8,510
Providence	5,841	Wilmington	8,747
New London	6,417	Baltimore	9,979
New York	8,064	Norfolk	11,346

Port Surveys

It was necessary to make a survey of the expenses and working conditions at the various ports under consideration. No great variation was found in the relative expenses of these ports, but this information was not ascertained until a port survey was made for each city such as that made for Baltimore and shown in Table 3.

TABLE 3. ACCOUNT OF EXPENSE OF A STEAMER DISCHARGING AT BALTIMORE

Entrance at Custom House	$ 5.00
Clearance at Custom House	5.00
Custom House fees	5.00
Quarantine fee (Health Officer)	10.00
Running lines (in and out)	5.00
Fumigation (about)	90.00
Coopers, if required, $8 per day	
Tally clerks, if required (estimated)	350.00
Wharfage, no wharfage account, steamer at usual railroad berths, agency fee	100.00
Use of preliminary bond	10.00
Postage and miscellaneous	10.00
Telegrams, telephone, etc. (actual cost) (estimated)	15.00
Pilotage inward, say, 23 ft. at $5.50	126.50
Pilotage outward, say, 13 ft. at $5.50	71.50
Tugs, docking, about	75.00
Undocking, about (no shifts figured)	75.00
Stevedoring, discharging 5000 tons at $1.50 per 2240 lb.	7,500.00
Tonnage tax, 3800 net register tons	228.00

NOTE: Average rate of discharge, 650 tons per weather working day of 8 hr.

Pilotage. Rates for pilotage for Chesapeake Bay: Vessels drawing more than 13 ft., $5.50 per foot deepest draft.

Quarantine. Federal quarantine station is located about 6 miles below Baltimore. Each vessel is charged $10.

Fumigation. Fumigation is performed by the U. S. Public Health Service only.

Custom House. Vessels coming directly from foreign ports, except ports situated in countries enumerated below, must pay a tax to the Federal Government of 6 cents per ton net register for each entry, but the total tax paid within any period of 12 months is not to exceed 30 cents per ton.

Vessels plying between the United States and the following countries are subject to a tonnage tax of 2 cents per ton net register for each direct call, but the tax paid within any period of 12 months is not to exceed 10 cents per ton: Canada, Bermuda, Mexico, Bahama Islands, West Indies, Central America, and that portion of South America bordering on Caribbean Sea up to the Orinoco River.

TABLE 4. ESTIMATED COSTS OF PLANTS

	(An approximate comparison if built at)							
	Boston	*Providence*	*New London*	*New York*	*Phila.*	*Wilmington*	*Baltimore*	*Norfolk*
Bldgs. and equipment	$ 840,000	$810,000	$810,000	$ 890,000	$ 840,000	$ 785,000	$790,000	$780,000
Land	100,000	80,000	lease	100,000	85,000	50,000	70,000	40,000
Dock or bulkhead	70,000	existing	existing	60,000	55,000	50,000	40,000	40,000
Dredging	25,000	none	none	none	none	25,000	30,000	35,000
Grading	20,000	none	5,000	15,000	10,000	25,000	15,000	20,000
Piling for plant	75,000	30,000	40,000	75,000	15,000	35,000	25,000	20,000
Approach railroad	20,000	existing	existing	existing	15,000	20,000	10,000	12,000
Approach road	8,000	existing	existing	15,000	existing	10,000	existing	5,000
Water supply	10,000	existing	existing	40,000	15,000	15,000	10,000	25,000
Total cost of plant	$1168,000	$920,000	$855,000	$1195,000	$1035,000	$1015,000	$990,000	$962,000

American, Norwegian, and Swedish vessels plying between ports of Norway, Sweden, and the United States are required to pay a tonnage tax of 2 cents per ton net register for each direct call, but the tax paid within any period of 12 months is not to exceed 10 cents per ton.

If vessels are plying between both 2-cent and 6-cent ports, the total tax paid within any period of 12 months is not to exceed 40 cents per ton.

Entrance and clearance charges made by government authorities amount to $2.50 to $10 for entrance and $2.50 for clearance.

Brokerage fees are $5.00 for entrance and $5.00 for clearance.

Custom House bond charge is $10.

Dockage and wharfage. Vessels discharging or loading at piers owned by railroad companies do not pay any wharfage if any portion of the cargo moves over the railroad where vessel is berthed. On material moving over side or over the dock of a railroad other than the railroad owning the pier at which steamer is docked, there will be a top wharfage charge of 12 cents per 2000 lb. This also applies on freight delivered to lighters of railroads other than the railroads at whose dock the steamer is discharging.

Towage. Towboat companies have fixed tariffs. The average cost of a shift is $80 to $100. The average cost of docking and undocking is about $60 to $70 total per steamer.

Boatmen. Charges for running ship's lines are $3.00 for mooring and $2.00 for unmooring each shift.

Watchman. The rate for watchmen is about $4.50 per day of 12 hr.

Stevedoring. Rates of stevedores depend upon the commodity to be handled.

Tally clerks. Clerking is contracted for by the ton or by the day.

Water. Fresh water can usually be obtained at the railroad piers at a cost of $1.00 per 1000 gal. Delivery by boat is 65 cents per ton.

Surveyors. For inward cargo, the hatch-survey charge is $15. For outward cargo, the New York Board of Underwriters' survey charge is usually $15.

Bunker oil and coal. Bunker oil and coal can be secured at favorable rates and upon short notice.

The Cost of the Plant

A considerable variation was found in the cost of buildings and equipment erected in the different localities. The labor-union regulations, such as prevail around New York, boost costs materially in such cities. This was especially true in concrete and pipe work.

In the study of the properties available, the existing buildings, roads, and water supply were of course taken into consideration as well as the amount of piling required for buildings and docks, and especially the length of piling that would probably be required.

Taxes also were determined, as they entered into the cost of plant overhead. Dredging became an item in plant overhead when docks would not have extended to government channels.

Real-estate Surveys

A personal inspection was required of properties available, and in one investigation all properties along the Atlantic Coast having 25-ft. depth of water and large enough for the plant from Maine to Virginia were investigated. The results are given in Table 4, page 144.

By way of illustration Table 5 shows in detail the survey of land found available at Boston. A similar survey was made for all cities under consideration. (For purposes of solving this problem it is not necessary to have similar data for the other cities under consideration. These data were contained in the original report but have been omitted to conserve space.)

TABLE 5. SURVEY OF PROPERTIES AVAILABLE AT BOSTON

Description of Property	*Approximate Cost of Land*
No. 1. On Mystic River. Requires dock and piling for plant and some dredging	$200,000
No. 2. On Commercial St., served by deep water on the Charles River. Dock required but no dredging	400,000
No. 3. On Chelsea Creek. 25 ft. of water on property. Dock required	100,000
No. 4. Medford on the Malden River. A barging proposition up the Malden. This is marsh land. Requires dock, piling for plant, no dredging	40,000
No. 5. East First Street, South Boston, near army base. Assumed value	400,000
No. 6. On Malden River, near U. S. Government property. It would be a barging proposition	20,000
No. 7. South Boston, on Boston Harbor, $\frac{1}{4}$ mile from 35-ft. channel. A channel 50-ft. from property to main channel would cost $75,000. Has railroad siding	175,000

Variation in Factory Wages

From information available, common factory labor rates appeared to run as follows:

City	*Cents per Hour*
Norfolk	35
Baltimore	40
Philadelphia	45
Wilmington	40
New York	55
New London	45
Providence	45
Boston	50

The pay roll on the basis of Boston was estimated at $250,000 per year, and as all general factory labor in the various localities varied about in proportion to the common labor, the pay rolls for the various districts were about as follows:

City	*Yearly Pay Roll*
Boston	$250,000
Providence	225,000
New London	225,000
New York	275,000
Philadelphia	225,000
Wilmington	200,000
Baltimore	200,000
Norfolk	175,000

a) What additional general and specific information would you seek from all the cities under consideration in order to compare their relative advantages?

b) How would you procure such information?

c) What other factors might influence your selection of a location?

d) On the basis of a careful study of the information included in the report, in which city would you choose to locate this plant?

e) What factors would tend to make for similar costs of discharging at seaports? Dissimilar?

f) What are the imponderables connected with the selection of any such plant location? Which apply here?

Problem 2. The Bradford Company

THE SELECTION OF A FACTORY SITE

The Bradford Company, located in northern New Jersey, manufactures medium-priced upholstered furniture; its products are distributed through both department stores and furniture stores in New York, New Jersey, Pennsylvania, and New England.

During the decade of the thirties, competition in the furniture field became intensified due to a combination of declining purchasing power and an existing productive capacity greatly in excess of demand. Southern plants employing low-priced, unskilled labor were able to penetrate the Northern market, and then take advantage of increased profits from sales to install mass-production machinery and equipment, enabling them to sell better quality products at low-quality price levels.

The managers of The Bradford Company have analyzed the geographical distribution of the company's sales and find that the company has been able to maintain its competitive position in New York, New Jersey, and Pennsylvania, but not in New England. They attribute this to: (1) distance from the market, (2) increased total cost because of transportation expense, (3) delivery delays, and (4) inability to keep in closer touch with the trends of buying in the Boston regional market.

After careful consideration of the entire problem, the management has concluded to establish a branch manufacturing plant in the vicinity of Greater Boston (Greater Boston includes an area within a radius of approximately 40 miles of the city of Boston). Its decision is influenced primarily by the fact that transportation of raw materials in bulk is relatively less expensive than transportation of the finished product.

The Bradford Company has stated its essential plant, labor, and transportation requirements to be as follows:

Building (Single or Multistory)

Company prefers to buy or build factory building, with 250,000 sq. ft. useful floor area. Safe floor load needed, 200 lb. per square foot minimum. (Railroad siding desirable.)

Working force

225 employees divided as follows:

- 50 cabinet makers (expert craftsmen)
- 40 upholsterers (all grades)
- 25 painters and decorators
- 40 apprentice workers — all fields
- 20 clerical workers
- 50 miscellaneous, including supervision

Transportation

Good rail, trucking service

Careful analysis of location trends in the industry reveals the importance of plant location factors for the furniture industry in order of importance to be:

Markets	Available factory buildings
Labor	Living conditions
Transportation	Power
Materials	Near related industries

The general area for the new plant has been selected already, thereby rendering some of these factors practically constant when compared on the basis of offerings of specific Greater Boston communities within the area. Markets and raw materials, for example, demand only minor consideration. For considering of these factors, the management has devised the following rating scale for its use in selecting a community:

Location Factors	*Maximum Points Allowable*
Labor	800
Transportation	700
Available buildings	300
The community	300
Power	200
Near related industries	100
Taxes	200
Banking	100

After study of many Greater Boston towns and cities, three cities have been selected late in the year as most deserving of consideration. (For obvious reasons, the names of the cities must be obscured.)

Statistical data has been compiled on each city as follows:

	City No. 1	*City No. 2*	*City No. 3*
Population (approximate)	16,000	15,000	77,000
Unemployment (approximate)*	2,200	2,000	3,700
Average yearly wage	$911	$956	$1,567
Foreign-born population (approximate)	2,700	2,500	17,650
Per cent of families renting homes	46	44	46
Tax rate per $1000	$ 38.80	$ 44.00	$ 32.00
Bonded debt per capita	39.79	53.30	57.88
Power costs (Rates subject to local bargaining)			
Assessment of rate (Rates subject to local bargaining)	80% of cost	75% of cost	82% of cost
Population of surrounding communities (approximate)	33,000	20,200	66,250
Unemployment in surrounding communities (approximate)*	4,100	3,650	7,800
Average yearly wage, surrounding communities	(Approximately the same as for cities above)		

The approximate labor costs in each city are estimated to be:

Cabinet workers	$24,000
Upholsterers	18,000
Painters and decorators	18,000
Apprentice workers	9,000
Clerical workers	6,000
Miscellaneous	6,000
Total	$81,000

* Supplementary information on estimated available labor supply, including surroundings, are:

	City No. 1	*City No. 2*	*City No. 3*
Cabinet makers (expert)	40	35	75
Upholsterers (all grades)	25	30	30
Painters and decorators	40	30	60
Apprentice workers (all fields)	75	70	150
Clerical workers (all fields)	100	90	200
Miscellaneous	(Adequate for needs of company)		

Local public utilities and carriers for hire have quoted transportation costs on raw material, finished goods, and supplies as follows:

	City No. 1	*City No. 2*	*City No. 3*
Raw materials	$3,241	$3,221	$2,948
Finished goods	5,947	6,024	5,567
Supplies	842	820	765

The Bradford Company is interested in locating in the best possible community because it will reflect directly upon company profits. The company wishes to investigate local governments in order to obtain some idea of possible future real-estate tax burdens. Housing facilities are to be examined since they determine different characteristics and attitudes of workers. The company wishes also to investigate the adequacy of public services since water power, trucking, and other services must be purchased. The Bradford Company's management believes these factors to be of equal importance for purposes of evaluating the three communities under consideration.

The following general information about the three communities has been compiled also by an investigator:

City No. 1 is a small manufacturing city located on the western edge of the Boston area. Originally an agricultural community, it became one of the leading shoe manufacturing cities in the country during the heyday of the shoe industry in New England. With the death of a prominent shoe manufacturer and expiration of his patents, this industry and others related to it disappeared. Several shoe establishments still remain, but nearly all related industries have been lost and the city is not considered a progressive shoe center. New but small firms of diversified interests have not restored the community to its former position as a manufacturing center.

The remaining shoe shops still dominate the labor situation with seasonal peaks in March and August, but with very small pay rolls in November. The population of the city has been relatively stable despite the loss of industries. The union situation is at present peaceful, although labor trouble in the past has given the city a bad reputation from the labor standpoint. The existence of two competing unions is a potential source of agitation.

The efficiency of the local government has disappeared with the industries, although the public services of fire, police, water supply, and sewerage are suitable for industrial and residential expansion. This is not true of housing however. Building activity has been at a minimum during the past decade, and existing structures have suffered from depreciation and lack of repairs.

Freight service only (no passenger service) is provided by the branch lines of two railroads. Trucking service is much more frequent and is generally employed by local manufacturers shipping within a 200-mile radius. The city is located on one of the main roads between Boston and New York, and shipments may also be made to any part of New England over a well-developed system of public highways. Bus lines provide regular and frequent passenger service to surrounding communities. Although a small airport exists, it is privately owned, and has the lowest possible rating.

An adequate supply of electric power is available, although the rates do not compare as favorably with those in larger cities. Anthracite coal comes by rail directly from Pennsylvania; soft coal and oil are hauled by truck from Boston, resulting in a differential of 50 cents per ton on coal. The rates will be approximately 10 per cent higher than in the largest city.

The valuation and tax rates on taxable property have been reasonable, and taxes have not been considered a burden by local manufacturers.

Five local banks all have ample resources for ordinary industrial demands.

At present there are three vacant buildings (see Table 6). Although none of these have railroad sidings, they are centrally located for labor and trucking facilities. A great deal of undeveloped land is available for building, although that near the railroads is not convenient for labor.

City No. 2 is a small industrial city and seaport located about 40 miles from Boston. At one time it had many industries, but now is badly in need of new plants to support its population. Its principal industry is shoe manufacturing, and cotton textiles have dropped to one-fifth their former volume. Diversified industries once established there have migrated elsewhere. Like City No. 1, the city was lost in the shuffle of consolidation in the shoe industry.

Public services in the community are sufficient to meet an extensive increase in demand, as they once served a much larger industrial population. Living conditions have not improved since the city lost many of its firms, and the decline in purchasing power has greatly reduced the size of its retail business. In spite of this decline, the population has been relatively stable, resulting in increased unemployment which has brought wage rates to a level below that of surrounding communities. Only one union exists in the city, and its cooperation with management has been good.

The city itself is a retail trade center for communities in its area, and is located on the main rail and trucking lines to northern New England. The harbor has two wharves which receive lumber, and storage warehouses are available. At present there is no airport, one which was contemplated having been abandoned when Federal funds were not obtained.

The city has a good government which has cooperated with the local Chamber of Commerce in attempting to attract new industries to the city. Consequently, every effort has been made to make the city an attractive place for industry to live.

Tax costs have been reduced (property values have been kept low and the tax rate lowered recently).

Several empty factory buildings are available in the city (see Table 7). These are in various stages of repair, most of them having been used as shoe factories previously. Electric power rates are 50 per cent higher than those for the largest community, banking facilities are adequate, and local bankers are eager to make loans to new industries.

City No. 3 is located on the sea coast 8 miles from Boston. Many of its residents are gainfully employed in the larger metropolis, but the city also has many industries of its own. Industrial growth and improved transportation to Boston have contributed to a marked population increase during the last two decades. This has occurred in spite of the fact that one of its major industries has declined in the same period. The mainstay of the city's industrial prosperity is one large concern whose pay roll averages 4000 men in normal times, but fluctuates violently according to the orders received. During slack periods the welfare burden on the city government becomes excessive, and is one of the reasons why citizens have censored the local government as dangerously inefficient.

The Bradford Company officials have been informed that they might expect a higher labor turnover and wage rate in this city than would be encountered in outlying communities where the people will accept lower wages and are more willing to be trained in skilled trades.

The city has had two important strikes during the last decade, and the major firms are well unionized.

The local retail market is becoming a rival of the larger Boston shopping center, hence a factory in City No. 3 would have possibilities as a retail distribution point for local products.

TABLE 6. DATA ON AVAILABLE FACTORY BUILDINGS — CITY NO. 1

Name	Bevins Building	Yardley's	Wilbur property
Price	None quoted	Rent only Long-term lease	$80,000
Age (years)	58	23	54
Previous use	Shoes	Laundry	Shoes
Condition	Poor	Good	Fair
Land	200 ft. × 400 ft.	1000 ft. × 657 ft.	500 ft. × 300 ft.
Approximate useful floor area	475,000 sq. ft.	14,000 sq. ft.	425,000 sq. ft.
Type	5-story	1-story	3-story
Construction	Wood	Masonry	Wood
Safe floor load	175 lb./sq. ft.	No limit	200 lb./sq. ft.
Natural lighting	Good	Poor	Fair
Ceilings	10 ft.	9 ft.	12 ft. 1st floor 11 ft. 6 in. 2d floor 11 ft. 4 in. 3d floor
Stair wells	4	None	2, fireproof construction
Elevators	1 freight Safety features will not satisfy present laws	None	2 freight 1 passenger Proper safety features
Material-handling equipment	None	None	None
Transportation	On main road No RR siding 600 yd. to station	On side road 2 miles from RR station	On main road ½ mile from RR station
Water	City supply	City supply	City supply Own storage tank
Fire protection	Inadequate	Fireproof construction	Sprinkler system
Power	Gas and electricity available	Small steam boiler Electricity available	Steam power plant Gas and electricity available
Heat	Steam system in disrepair	From power plant	From power plant
Remarks	For sale for taxes	Near-by unused land may be purchased	

TABLE 7. DATA ON AVAILABLE FACTORY BUILDINGS — CITY NO. 2

Name	Milton Company	Lancaster Company	Vester Factory	Sterling and Johnson	Spinnet
Price	Open to offer	Lease only	Open to offer	Price on request	Lease only
Age (years)	34	37	53	40	29
Previous use	Shoe manuf.	Textile machinery	Shoe manuf.	Textile manuf.	Textile manuf.
Condition	Fair	Excellent	Good	Good	Good
Land	500 ft. × 11,000 ft.	400 ft. × 800 ft.	300 ft. × 900 ft.	400 ft. × 700 ft.	100 ft. × 350 ft.
Approximate useful floor area	2,650,000 sq. ft.	945,000 sq. ft.	250,000 sq. ft.	820,000 sq. ft.	15,000 sq. ft.
Type	5-story	3-story	1-story	3-story	4-story
Construction	Wood, brick facing	Reinforced steel	Wood, brick facing	Wood, brick facing	Masonry
Safe floor load	200 lb./sq. ft.	350 lb./sq. ft.	300 lb./sq. ft.	175 lb./sq. ft.	225 lb./sq. ft.
Natural lighting	Poor	Excellent	Good	Fair	Good
Ceilings	10 ft. 8 in. 9 ft. on top story	12 ft. 6 in.	11 ft.	10 ft. 10 in.	9 ft. 11 in.
Stair wells	6	4, fireproof construction	——	3	4
Elevators	2	4 freight 1 passenger	——	1	3
Material-handling equipment	None	Industrial railroad on 1st floor	None	None	None

DATA ON AVAILABLE FACTORY BUILDINGS (*continued*)

Transportation	RR spur track	On waterfront Own dock also RR spur	On main road 1 mile from RR	On waterfront Own dock	RR spur
Water	City supply Own tank	City supply	City supply	City supply Own tank	City supply
Fire protection	Sprinkler	Excellent	Sprinkler	Poor	Sprinkler
Power	Electricity	Own power plant	Own power plant	Electricity and gas	Electricity Own power plant
Heat	Steam	From power plant	From power plant	Steam	From power plant
Remarks	½ of building only now vacant	Mortgage may be taken over by purchaser		Part of the building may be rented	

City No. 3 is served by a branch-line railroad which has many sidings. Its proximity to Boston harbor and the current improvements of the local harbor facilitate shipping by water. Trucking services compete with the rail and water transportation to provide favorable transportation costs. Power resources are well developed and service is less expensive than in smaller communities.

At present there are no vacant buildings suitable for The Bradford Company. The current harbor improvement has enhanced the desirability of many possible sites.

Determine the city in which The Bradford Company should locate its proposed plant.

Problem 3. The Vulcan Company

SELECTION OF TYPE OF BUILDING — BUYING, BUILDING, OR LEASING

PART I

An examination of statistical data held in the office of the Vulcan Company, an eastern manufacturing concern, shows that industries using the Vulcan products are tending to become localized in the Middle West. Up to the present time Vulcan has been able to produce in its home plant in the East and sell its output in the Middle West at a fair profit, since the Vulcan quality has made its products preferred over those of competitors. However, the fact that the Vulcan Company has to pay for transportation to the Middle West has given the Middle Western competitors an opportunity to improve their quality and sell at a lower price. Several of Vulcan's Middle West customers have advised relocation of the Vulcan plant in the Middle West as a means of meeting competition.

The Vulcan Company general manager has sent Mr. Brown, its vice-president in charge of production, to investigate the possibilities of obtaining in the Middle West a suitable plant or location site. Mr. Brown was advised that the new Vulcan plant would require a minimum of 30,000 sq. ft. of useful floor area. He was instructed to examine and consider all possibilities for an advantageous location; and the company's letter of instruction to him mentioned particularly the desirability of reporting on the relative advantages of suburban location opportunities as opposed to urban properties available.

In addition, his employers requested a report on the advisability of (1) buying an existing plant; (2) building a new plant; or (3), leasing a plant built particularly for the Vulcan Company; and if the last plan were followed, the type of lease that should be obtained, that is, gross or net lease.

As a result of his search for information on existing urban or suburban properties, Mr. Brown has narrowed his consideration to two equally desirable properties; (1) a four-story urban loft building, and (2) a single-story suburban building. The following information relative to costs is taken from Mr. Brown's report; all other cost data are comparable and of no consequence in selecting one site as opposed to the other.

	Loft	*Single Story*
Building	Urban, 4-story	Suburban
Valuation (assessed)	$170,000	$130.000
Floor space (sq. ft. per floor)	10,000	32,000
* Unavailable area (per cent)	10	3
Taxes (per $1000 valuation)	$50	$25
† Insurance (per $100 coverage)	$2	$0.50
Light (kw-hrs per year)	500,000	40,000
Power (kw-hrs per year)	300,000	300,000
Electricity (per kw-hr)	$.05	$.09
Elevator service (kw-hrs per year)	40,000	None

* Unavailable area: partitions, columns, stairways, etc.

† Insurance: assume a coverage of $100,000 for both urban and suburban location.

a) On the basis of per square foot of useful area, determine which location is more desirable.

b) What are the relative advantages of each type of building?

PART II

Having decided to locate in the Middle West, the company wished to determine whether it would be to its benefit to undertake the construction of a new building, to buy a building outright, or to take advantage of one of various types of lease.

Plan A. Buying an existing building. The loft building mentioned in the preceding problem is entirely adequate for the Vulcan Company, having been built 5 years ago. The building may be purchased for $200,000. The company can afford to pay $100,000 of its own money and can secure a first mortgage of $100,000 at 6 per cent per year. Taxes are $50 per $1000 of valuation, insurance $2.00 per year per $100 coverage, depreciation 3 per cent per year, heating and operation $18,000 per year, electricity cost at $0.05 per kw-hr, and maintenance and repair $1000 per year.

Plan B. Building a new plant. Use 40,000 sq. ft. floor area (as above). Specifications: 10,000 sq. ft. per floor, four-story building, 80 ft. wide, 125 ft. long, and a 12-foot ceiling height. The contractor has given an estimated price of $0.52 per cubic foot as the price of the building. The design of the building is well suited to the process employed by the Vulcan Company. The Vulcan Company will invest $100,000 and borrow what is needed at 6 per cent interest to cover the cost of construction. Assume the insurance, heating, electricity, and maintenance costs to remain the same as in Plan A. Also assume the tax rate to remain the same and valuation per taxes to be 75 per cent of cost. The depreciation is based on the new cost at 3 per cent per year.

Plan C. Leasing a plant built to order. An investment company in this field finding the Vulcan Company to be a manufacturer of satisfactory rating, has expressed a willingness to build the plant according to specifications submitted (as in Plan B). The investment company will lease to the Vulcan Company this new plant for a term of 10 years at $32,000 per year. The Vulcan Company has the option of buying the plant outright for $255,000 upon termination of the lease. In this case the Vulcan Company must bear the costs of heating and operating, electricity, maintenance, and repair work. Other costs will be carried by the investment company.

Plan D. Leasing by net and gross lease (using building in Plan A). A net lease can be obtained under which the tenant will pay all local taxes, carry proper insurance, heat and operate the building, pay the power charges, and maintain it in good condition. The rental charge is $23,000 per year.

The Vulcan Company is offered complete services for $95,000 on the basis of a gross lease.

c) Should the Vulcan Company build a new plant, lease a built-to-order factory, or buy the existing factory loft building? Examine both original cost and building expense.

d) Discuss briefly the merits of net and gross leasing.

Problem 4. The New Process Manufacturing Company

The New Process Manufacturing Company has obtained the following information in relation to its power needs and the means of satisfying them for a manufacturing period of 28 days. On the basis of careful analysis of the following data, what action do you recommend?

Cost of operation of own power plant for entire period in terms of capacity provided:

Capacity, kw-hr	*Total Cost*
15,000	$ 8,400
20,000	10,000
25,000	11,000
30,000	12,500
35,000	13,000

Public-utility wholesale rates based on use:

First	40,000 kw-hr:	$0.032 per kw-hr
Additional	80,000 kw-hr:	0.025 per kw-hr
Above	80,000 kw-hr:	0.015 per kw-hr

It is estimated that the peak power requirements of the New Process Manufacturing Company at any one time will not exceed 21,000 kw-hr. The consumption estimated for the entire manufacturing period under consideration is estimated to be 524,000 kw-hr.

a) Should the New Process Manufacturing Company produce its own power, or buy from the public-utility company?

b) What factor might influence the company to produce its own power even though cheaper to buy from the local utility?

Problem 5. The Ajax Corporation

PURCHASE OF MATERIAL-HANDLING EQUIPMENT

The Ajax Corporation must determine the amount of money which it can expend in order to purchase the material-handling equipment it requires to move its product from one department to another while in process. Careful investigation of all the factors involved in the analysis of this problem reveals the following data:

Work being done at present by two men, who are being paid $4.00 a day each, can be done by one man using an electric truck. It is estimated that when the plant operates 200 out of 300 days per year, the increased efficiency will make possible additional savings amounting to $320 per year. The percentages allowed for various cost purposes are as follows:

	Per cent
Investment	6
Insurance, taxes, etc.	5
Upkeep	15
Allowance for depreciation and obsolescence	20
Annual cost of power and supplies amounts to	$300
Expected saving in overhead expense is	$315

PART III

ORGANIZATION OF THE PHYSICAL PLANT

In order to have a plant that is an efficient production machine, those responsible for its physical organization must have a clear understanding of basic principles, techniques, and special problems involved in its arrangement and layout preparatory to beginning manufacturing operations.

No two industrial plants are exactly alike, and therefore, physical arrangements will differ widely, but all require application of common principles which are the requisite background for those who manage the business. These are outlined briefly under major headings as follows:

1. **Plant layout and management.** The objectives sought by management through efficient plant layout must be clearly defined whenever physical organization is undertaken. The management objectives are: economies in handling; lower costs of useful areas; minimizing of production delays; avoidance of bottlenecks; better production control and supervision; avoidance of unnecessary and costly changes once a layout is made; improvements in production processes and methods; provision of a layout that permits meeting of competitive costs; and incorporation of safety into the physical plant as part of the layout and organization.
2. **Techniques of plant layout.** The solution of layout problems is greatly simplified by use of special techniques. An understanding of these is essential for those who actually make the plant layout as well as those who must pass upon final results — top management. An understanding of techniques must be predicated upon an understanding of manufacturing processes. Definite steps should be followed also in making layouts. These save time and energy and make for greater appreciation of the problems involved. Finally, there are visual aids as well as experimental procedures, which deserve careful study as useful tools of layout procedure.
3. **Motion study and plant layout.** Problems of layout are greatly simplified through application of the basic principles of motion study. When these are understood and applied while solving layout problems, costly changes and revampings, which often have

to be made after plants are in operation, may be avoided. Process charts, for example, are a valuable tool of motion economy which help to eliminate nonessential operations in manufacturing processes; and the motion-economy principles of plant layout make for a smoother functioning of manufacturing operations. Finally, *the basic steps of motion-study procedure* have application in plant-layout work and the solution of a great variety of problems.

4. **Material handling.** Every manufacturing process involves handling materials from the receiving room through various manufacturing operations and then to the shipping room. Material handling and plant layout go hand in hand. Physical organization of the plant, therefore, must be considered in the light of possible savings through careful application of basic principles of handling and costs which result from selection and installation of various kinds of equipment. In this connection, it is helpful to understand how to calculate the amounts of equipment required to move various quantities and kinds of material.
5. **Organization and layout for storeskeeping.** No aspect of plant layout may be considered without attention to space for storeskeeping. Careful thought must be given to methods of piling and arranging storage areas in relation to the production processes. Once the general location of storage areas has been decided upon, attention may be focused on layout of individual storerooms. There are also many special problems of storeskeeping which require solution when the plant layout is under way.
6. **Plant layout and safety.** When a plant is being designed and arranged it is possible to "build in" safety. A safe working place is usually an efficient one. Plant layout and safety include these topics: introduction of safety into layout of work areas; elimination of material-handling hazards; prevention of dangers of faulty stowage practices; anticipating hazards of maintenance work; provision of proper air and light; safeguarding of machinery and power-transmitting equipment; and, finally, incorporating safety and protection in the building and plant property.

CHAPTER IX

PLANT LAYOUT AND MANAGEMENT

Plant layout as viewed by management is a technique for achieving an economical working arrangement of manufacturing processes in conjunction with plant services. Its objective is to make efficient use of various combinations of physical property — machinery, buildings, and plant services — so as to achieve the greatest possible output of high quality at the lowest possible total cost of manufacturing. It involves (1) planning and arranging manufacturing machinery, equipment, and services for the first time in completely new plants, and (2) the improvement of layouts already in use in order to introduce new methods and improvements in manufacturing procedures. Some industries even go so far as to abandon present plants and build new ones.

The efforts spent in selecting a desirable plant site, efficient machinery, and the right type of buildings may be entirely wasted unless the industrial manager also devotes careful attention to internal organization of his plant for production.

The search for lower costs through making improvements in the internal layout and arrangement of industrial plants is a never-ending consideration of progressive management. The particular advantages sought through application of principles of scientific management to plant layout are these:

1. **Economies in handling.** Manufacturing processes consist of a series of machines and/or hand operations through which materials pass to undergo some treatment or change. This is usually accomplished in a definite process sequence and requires that the materials be moved from one step of the process to the next.

   The cheapest way to handle materials is not to handle them. Careful study of manufacturing processes often results in arranging equipment so as to either "cut down" the amount of space that must be traveled, or eliminate specific handling operations entirely. The economies to be made from handling are perhaps the most significant of any to be obtained through scientific management of plant layout.
2. **Lower cost of useful areas.** The useful areas of a plant consist of the floor space that can be used for manufacturing purposes. The manufacturer may wish to study and revise his plant layout for these purposes:

(1) To make into useful manufacturing space, areas not now classified as useful; (2) to free present manufacturing areas for other purposes; (3) to conserve space and reduce total plant space requirements. Achievement of each of these objectives nearly always results in a lower cost per square foot of useful area and makes for greater efficiency in the use of plant space.

3. **Minimizing of production delays.** The deadline dates for delivery of production orders are a bugaboo to management. Manufacturers everywhere know that an established reputation for keeping promises on deliveries means repeat orders and new customers, while only cancelations of orders and possible business failure awaits those unreliable in this respect.

The layout of the plant is no small factor in getting out work according to schedule. Delays are often the result of space limitations (crowded machines, cramped storage space, and congested aisles) which prevent rapid handling of materials, or, conversely, machines may be so far apart that needless travel time and expense is required to complete the process. The results of such conditions can only be delayed schedules, lost time, and spoiled work due to hurried workmanship.

Where working conditions are in good order and the plant is laid out according to carefully prepared plans of executing the work promptly and intelligently, these maladjustments disappear.

4. **Avoidance of bottlenecks.** A fundamental objective of management's attention to plant layout is a smooth flow of goods in process at a constant rate of speed. Despite every effort toward this end, poor judgment with respect to either process arrangement, or the capacity required to manufacture at a profit, may create a so-called bottleneck. This term designates any place in a production process where materials tend to pile up or proceed at rates of speed less rapid than the previous or subsequent operations. It may be due to inadequate machine capacity, poor placement, handling, or inadequate space for storage, or even speed of the operator. Not only does the bottleneck cause production delays and lower output, but also it bears directly on the efficient utilization of shop capacity.

The production capacity of a group of machines or manufacturing plant is governed by the least efficient unit or step in the process. This is illustrated in the following table:

Process	*Machines*	*No. of Machines*	*Rates of Output per Hour*	*Hours per Day*
Step 1	202	2	150	8
Step 2	301	2	125	8
Step 3	304	2	175	8

When a product passes through these three steps to completion, the speed of the entire process cycle is governed by step 2, or Machine 301, which has a capacity of 2000 units per day for an 8-hour day. It will be noted

that step 3 of this process has a capacity of 2800 units per 8-hour working day. Not only is there considerable wasted machine capacity due to the bottleneck operation, but the capacity of the shop is pegged by its rate of output.

5. **Better production control.** When the arrangement of shop processes is wisely planned, simple and effective procedures of control can be easily installed. These help to avoid unnecessary production delays and assure a more likely maximum use of available machine time and man-hours. In addition, orderliness and system prevail and those charged with control of plant operations can better understand their respective jobs and responsibilities. Good plant layout is a requisite of good production control and provides the plant control officers with a systematic basis upon which to build organization and procedures.
6. **Better supervision.** Good plant layout is also a first step in good supervision. Orderly manufacturing procedures make possible clear standard instructions and, therefore, assist foremen in carrying out their schedules. Layout has a very definite bearing on the number of men that the supervisor can handle. If a given operation is divided between two floors of the same building or in different buildings, two supervisors instead of one may be needed, and the cost is doubled.

   Finally, layout arrangements should recognize the need of conserving time of shop supervisors. By situating their office so the whole shop may be viewed at once, inspection and discipline can be achieved with a minimum of effort. (Workers who know they are easily scrutinized seldom need watching.)
7. **Avoidance of unnecessary and costly changes.** If the plant-layout problem is one of arranging operations in a new plant, it is possible to give consideration to possible expansion needs at the time of construction and so arrange shop processes that costly modifications and alterations in the building structure itself may be avoided later. This is equally true if proper care is devoted to plant layout when a manufacturer occupies a vacant factory building; that is, care in layout must be exercised before occupying the building and not afterwards. To make alterations in a structure in order to facilitate machine placements and handling once the equipment is installed, is not only costly from the construction standpoint, but also causes considerable additional expense from lost time of both men and machines, as well as the possible loss of customers who cannot wait for deliveries.

   Some firms have been very successful in keeping at a minimum the costs of rearranging the layout of a going concern. This has required much advance planning and scheduling so as to interfere with production as little as possible.
8. **Improvements in production processes and methods.** The discovery of opportunities for improvements in processes and methods are a result of careful study of layout problems. Familiarity with the details of process requirements nearly always points the way for new manufacturing procedures and methods. It is often possible to eliminate some steps

altogether and still others may be combined, that is, two or more operator or machine elements may be made part of one operation. These achievements lead to new methods and new machines, and, in the end, to a better product. A study of the process may also lead to product design changes which result in less steps in the manufacturing procedure, and consequently changes in time and cost for handling space.

9. **Output obtained needed to meet competitive costs.** Where the product manufactured must be sold in competition with those of other manufacturers, it is often necessary to recognize in advance of actual production that market price predetermines the cost to be met. If manufacturers are to sell their products in competition and still obtain a profit, their cost of production cannot exceed those of competitors. Material and labor costs are subject to market controls and, therefore, are usually much the same for all manufacturers in a given field. But unit burden or overhead expenses vary greatly from plant to plant causing wide discrepancies in relative profit margins.

If the market sales price of a product is $3.00 per unit, and the combined material and labor expense amounts to $2.50, the overhead costs per unit cannot, therefore, exceed $0.50 or an operating loss will result. Since the total amount of overhead expense is of necessity more or less fixed and since unit costs are dependent upon volume of output, it is important that a plant layout be achieved which will allow an output sufficient to keep burden costs within the range of those of competitors. Assuming a burden cost must not exceed $0.50 per unit, the following table shows the production capacity needed:

Possible Capacities (Depending on Layout)	*Total Overhead Expense*	*Burden Cost Per Unit*
2,500 units	$1,000	$0.40
2,000 units	1,000	0.50
1,800 units	1,000	0.555

Production must be 2000 units or over to break even on overhead expenses.

An important consideration of profit making from a plant-layout standpoint, therefore, is provision of adequate capacity and a plan of production to assure its attainment. Even though the capacity of machines may provide an output above that needed to meet competitors' overhead costs and still make a profit, its actual accomplishment may be defeated by poor material-handling facilities, space limitations, or inadequate storage facilities.

10. **"Built-in" safety.** When a shop or departmental arrangement is being planned, the principles of safety engineering can be incorporated. This may be thought of as "building safety into the plant."

Employees do their best work under working conditions which are not only clean, neat, and orderly, but also safe and healthy. Like begets like. Safe and healthy working conditions encourage high standards of employee performance which are reflected in lower costs of production. The reasons are:

a) *Lost Time Is Reduced.* Accidents cause injuries to workers and damage to machinery and equipment. These result in lost man-hours and machine-hours. Working conditions that are safe and healthy reduce absenteeism due to accidents and illness; similarly, safe working conditions prevent needless damage to machinery and equipment. Temporary shutdowns to make repairs cause changes in production schedules and often result in delays in deliveries which may cause the loss of future business.

b) *Capital Investment Losses Are Lowered.* Machinery and equipment injured beyond repair must be junked and charged off as operating losses, thereby causing extra and unnecessary cost of manufacturing. In addition, the procurement of new machinery and equipment to replace that destroyed often causes delay and inconvenience in production to say nothing of added burdens to maintenance men, supervisors, and general management.

c) *Material Losses Are Lessened.* If accidents occur when operators are processing materials on a machine or at a bench, damage to materials often results. Except as these can be reclaimed there is total loss and if they are reclaimed the work involved is just so much additional cost.

Many types of goods in storage are also subject to deterioration and not infrequently raw materials and finished goods are damaged through improper protection. Adequate safety precautions in connection with storage areas eliminate these sources of loss.

d) *Employee Morale Is Enhanced.* Elimination of every possible accident hazard is the only defensible ethical course for top management to follow. Employee morale which is so important in getting employees to do their best on their jobs is in part a reflection of what the employees sense to be the interest of their employers in their welfare. This is revealed in a large degree in the safety precautions incorporated in the plant. A safe place to work is a good place to work.

CHAPTER X

TECHNIQUES OF PLANT LAYOUT

Organization of the Production Floor

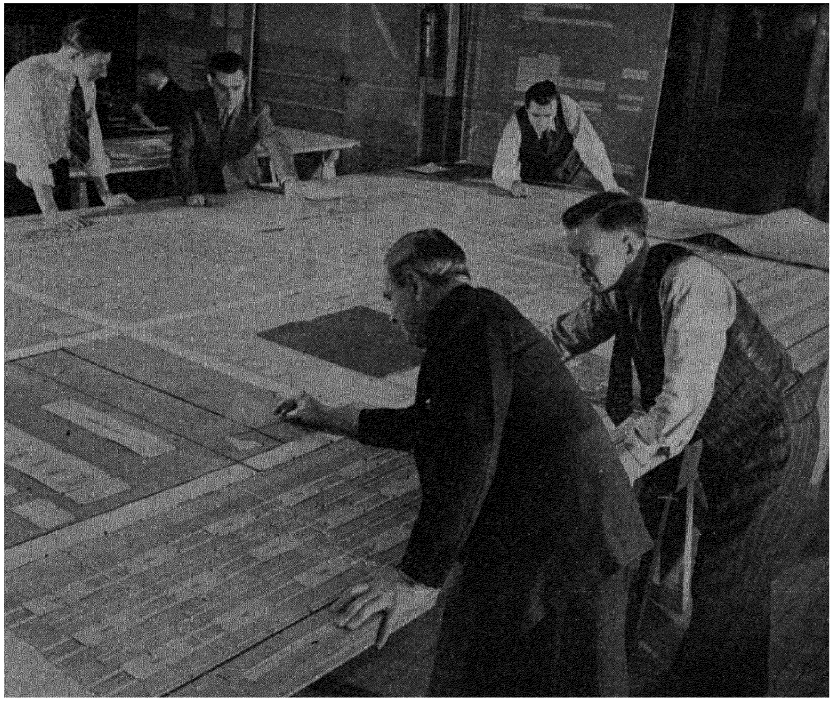
Preliminary to undertaking the layout of an industrial plant, management must analyze its product to determine the nature of the operations required in its fabrication. Whether the management seeks to revise an existing layout or to plan and arrange a plant for the first time it must not only make its own analyses but also discover ideas and information which other manufacturers in the same field of production have found to be effective.

The complete analysis of any plant layout will reveal many special problems that center particularly around the organization of the production floor. These have to do primarily with the recognition of the type of process to which the product to be manufactured lends itself and in turn the kind of organization that will permit the adoption of the process decided upon. A brief discussion of manufacturing processes follows.

Manufacturing Processes

The purpose of all plant layout is to make a product or fulfill a special service. Each presents an internal organization or layout situation peculiar to itself. For example, contrast the layout of a sugar refinery, a steel mill, and a cleaning-and-dyeing house or laundry. The first merely processes a raw material — sugar cane; the second passes its raw material through many stages until it becomes a hard metal; and the third renders a special service for the home. Each demands application of different skills, the use of special machines, or the new application of old ones. Each has an individuality of its own, reflecting the organization of men, materials, and machines which different managers believe most suitable to their particular situations.

Despite the individuality of industrial plants, they may be broadly classified according to their processes of manufacture. Since these designations are more or less synonymous with the advantages and disadvantages claimed for each, they assist management in choosing a type of plant layout most adaptable to the product to be manufactured.



Courtesy Chrysler Corporation

FIGURE 69. CHRYSLER CORPORATION PLANT ENGINEERS DEVELOP THE LAYOUT OF THE PLANT IN WHICH THEY MAKE 25-TON TANKS FOR THE U. S. ARMY

This plant is 500 feet wide and 1380 feet long. On the final assembly line 66 tanks are in the process of assembly at one time. Materials are brought in on the opposite side of the plant from the assembly line and finished tanks are shipped by freight car from the other end.

These may be grouped: (1) according to their purpose; (2) by process arrangement, and (3) according to their direction of movement.

1. **Process classification according to purpose.** Processes are either *analytical* or *synthetic*, or a combination of both. The *analytical* process starts with a material and breaks it down into component parts. This is exemplified by the meat-packing industry, which makes a variety of products from a single steer. A *synthetic* process is one which combines several different products to produce a final one. Paint, for example, is a combination of white lead, oils, and color pigments. The type of process which illustrates the combination of the two, or the breaking down and then building up of materials, is found in the manufacture of rayon. Cellulose is made from wood pulp and then processed and combined with special chemicals to make rayon thread.
2. **Process classification according to arrangement.** A process is a series of manufacturing operations which result in a completed product. All proc-

esses may be described, therefore, as *continuous* or *intermittent.* The continuous process is one which flows from raw materials to finished goods without interruption and where a series of steps in a distinct cycle complete the product. This is exemplified by the manufacture of paper. The intermittent process moves along by stages, that is, it consists of separate and distinct processes needed to make the final product; each is dependent upon the others and contributes to a completed finished product. An industry manufacturing motors for assembly must have its parts fabricated prior to their combination with others for the final assembly of the motor.

Either the continuous or intermittent methods of manufacture may be further classified as *repetitive* and *nonrepetitive.* If the process is performed exactly the same each time it is undertaken, it is repetitive. Of course, this may allow for some minor variations in color, size, and so on. When variations in design and shape or special considerations must be performed to meet individual customer's needs, even though the steps or stages remain the same, the process becomes nonrepetitive; in most nonrepetitive processes the process elements are changed.

3. **Processes classified according to direction of movement.** All processes have a further designation as either vertical or horizontal to indicate the direction of their movement. The horizontal movement of materials demands either mechanical or hand material handling; automobile assembly lines, steel rolling mills and radio-tube plants lend themselves to the horizontal arrangement. In vertical movement it is possible to take advantage of gravity but it frequently is necessary to install equipment to move material between floors. Flour milling lends itself to movement by gravity while shoe manufacturing in multistoried buildings requires handling equipment.

An Illustration. By way of illustrating the foregoing terminology, it is possible to designate a given manufacturing cycle as "a continuous, synthetic, nonrepetitive, and vertical movement of materials." This means that a complete process is used to combine materials in a multistory building arrangement and that the product is manufactured according to customer specifications.

THE STEPS IN MAKING A PLANT LAYOUT

The steps followed in making a layout will depend upon the details of each individual manufacturing plant. The following list includes steps which may be omitted from relatively simple problems, that is, plant layouts which are revisions of existing ones:

1. Make a process chart of the manufacturing operations to be performed. (This assures familiarity with every operation to be considered.) The symbols to be used in making a process chart are presented on page 171.
2. List in the order of their importance the *considerations* which affect the layout of the particular plant. These may include:

a) Arrangement of machines according to natural flow of process.
b) Grouping of machines by types.
c) Grouping machines in terms of limitations imposed by power drives.
d) Grouping machines in terms of building limitations (boiler in basement).
e) Grouping machines in terms of plant services (storeroom facilities, gas, water).
f) Grouping machines to facilitate supervision.
g) Recognition of esthetic considerations of layout, that is, arrangement of offices and employee services.
h) Recognition of the needs of employee facilities as affecting the entire layout.

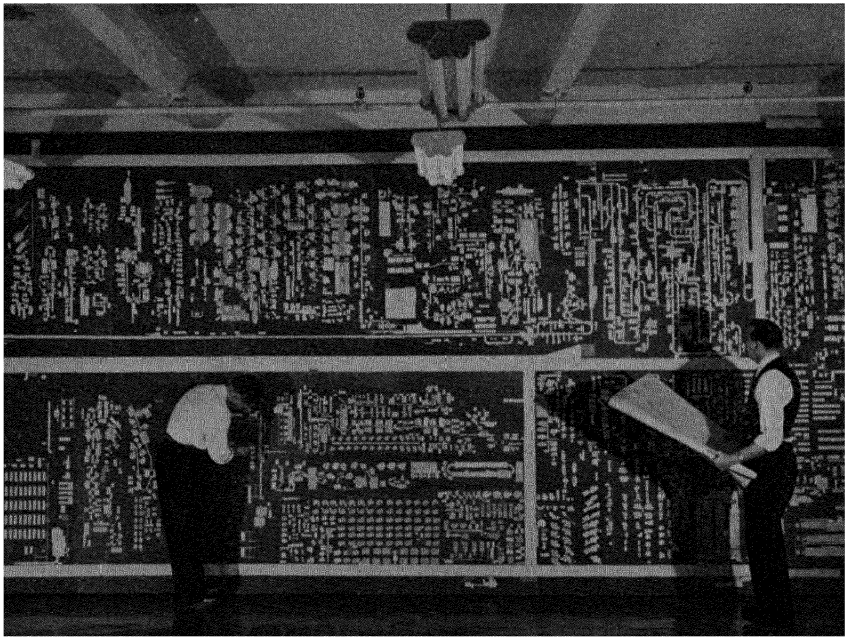
3. Classify the manufacturing processes or services according to their importance under each of the considerations listed in Step 2.
4. Select two, or possibly three of these considerations as being most important as starting points for preliminary layouts.
5. Use visual aids to experiment with possible arrangements.
6. Having arrived at a satisfactory arrangement in terms of the most important considerations, make provision for other needed areas and special items with a minimum of rearrangement.
7. *a*) Make a detailed drawing of the entire plant layout. This applies to both revised layouts and original layouts.
   b) If a new plant is being constructed, draw floor plans for the proposed building. These will be used by architects in designing the building.
8. Have the entire layout and building checked at this point by experts in specialized fields — that is, obtain suggestions from architects, plumbers, electricians, lighting experts, and the like.
9. Make necessary revisions in terms of Step 8.
10. Make a new process chart, flow chart (diagram showing flow of operations), as well as model to facilitate a final check on the plant layout.

VISUAL AIDS

The quality of the layout of any plant can be judged accurately only after it has been in actual operation under all possible conditions. It is very costly to make and revise actual layouts and, therefore, it is highly desirable that experimenting be confined to the drawing board and the laboratory; that is, any arrangement finally installed should be as perfect as possible.

To facilitate judging the effectiveness of proposed layouts without actually seeing them in operation, there are many devices which enable the manager to visualize the plans in terms of actual operation. These follow:

Templets. The areas required by machines (or by departments or storerooms) may be cut to scale from a sheet of heavy paper, fiber, or



Courtesy General Motors Corporation

FIGURE 70. FACTORY DEPARTMENTAL LAYOUT OF PONTIAC MOTOR DIVISION, PONTIAC, MICHIGAN, WITH EMPLOYES PLACING MACHINERY TEMPLETS

Templets are paper scale models, usually of different colors, denoting equipment, stairways, aisles, loading platforms, and other permanent features.

wood. The resulting templets may then be placed in experimental positions to represent possible layouts (see Fig. 70).

Templets and cross-section paper. The use of templets in making layouts is greatly simplified when they are used in conjunction with cross-section paper. This involves cutting the templets to the right size to represent machines, conveyors, racks, etc. These templets are then attached to cross-section paper with Scotch tape. The use of the cross-section paper eliminates much measuring as the squares on the paper can represent various scales. Various colored papers representing machines, conveyors, and so on, may be used and samples of these placed in the templet layout margin. If desired, the templet layout which results may be put through a white printing machine to obtain a plan of layout on cross-section paper as shown in Fig. 71. This method has the advantage of limiting the need for making permanent tracings. It permits making a number of copies for distribution to proper parties

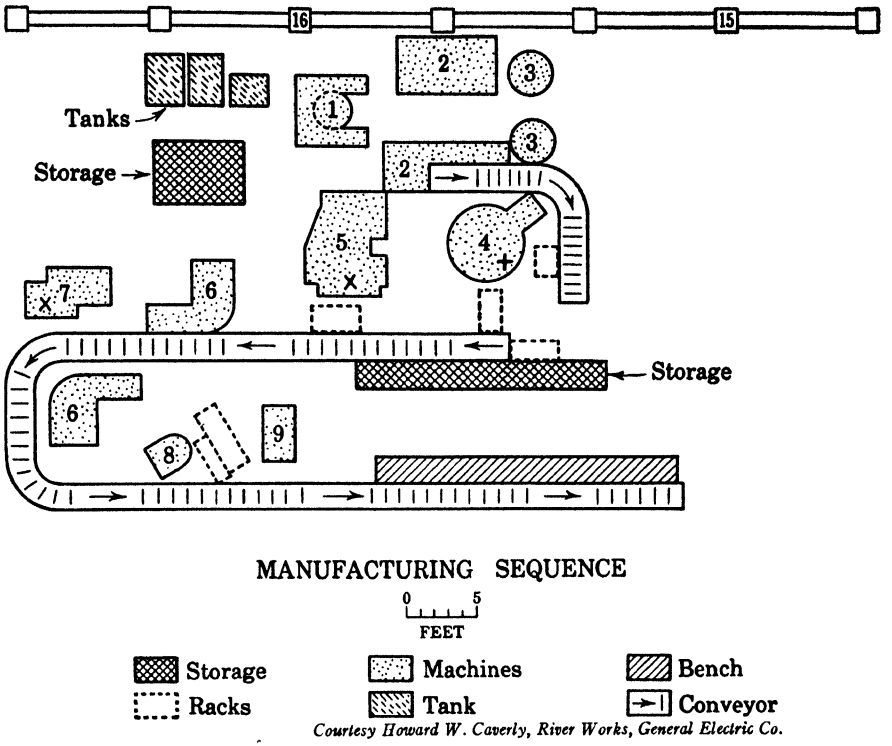


FIGURE 71. PHOTOSTAT OF TEMPORARY TEMPLET LAYOUT

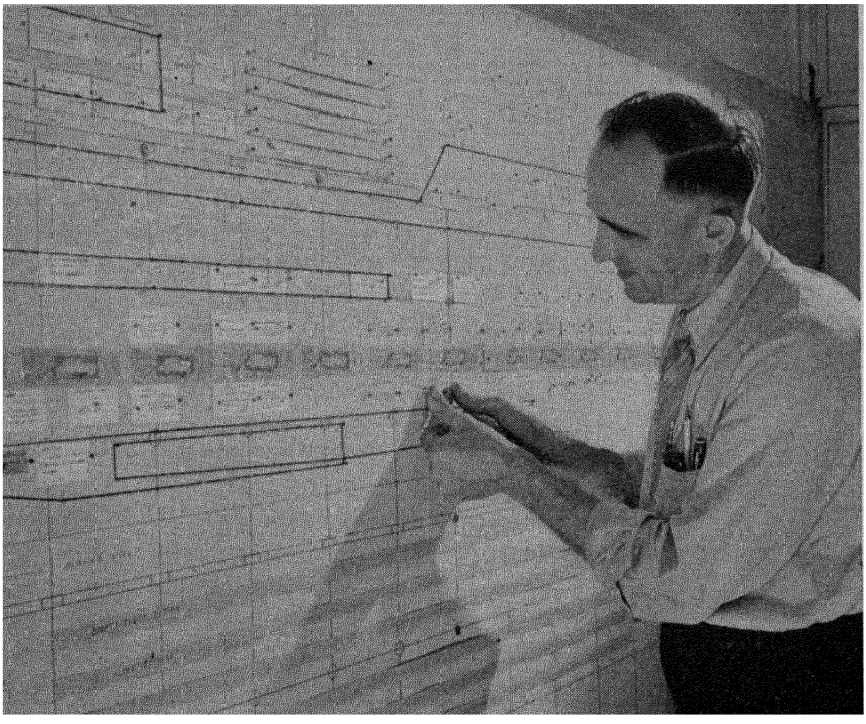
Photostatic copies such as the one above may be made of many possible layouts for purposes of comparison or to obtain several copies for use of different persons. Templets may be made of colored papers which indicate machines, racks, benches, etc. These become a type of standard terminology which indicates to shop supervisors, maintenance men, and others what the different templets represent — machines, racks, etc.

including job foremen, millwrights, and others interested when layout changes are being made.

String. Strings of various colors may be used to represent the flow of different materials from process to process. The shorter the length of string required, the shorter will be the distances over which materials must be transported (see Fig. 72).

Pins. Coded pinheads may be used to designate operations or problems which might be eliminated by improved layout, such as piling, loading, unloading, cross traffic, and bottlenecks (Fig. 72).

Machine models. Three-dimensional models, rather than two-dimensional templets, help the manager to visualize the space requirements for the operation and maintenance of machines, and also most desirable routes and types of equipment for material handling.



Courtesy General Motors Corporation

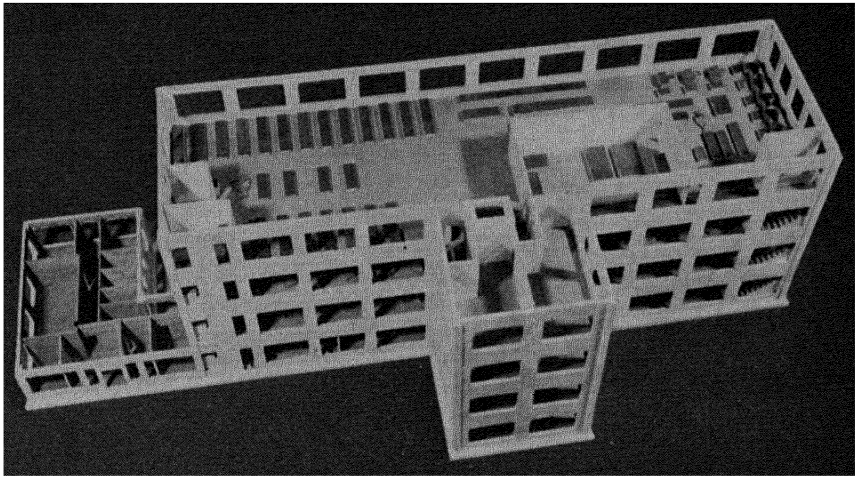
FIGURE 72. AL GERBER PLACES AN ASSEMBLY CREW IN THE CADILLAC MOTOR CAR DIVISION'S UNIQUE PLAN FOR WORKING OUT PRODUCTION PROBLEMS ON A TEMPLET LAYOUT

Upon completion, management can tell by a glance at the board exactly how and where assembly manpower is distributed.

Floor plans. For purposes of plant layout, floor plans need show only the location of walls, posts, stairways, and the like, rather than their structural details. Templets or models may be "shuffled" over the floor plan until the most desirable location is determined. The templets may then be (temporarily) pinned to the plan, attached with glue, or the outlines of the machines drawn directly on the plan (Fig. 70).

It is possible also to make a black on white print or a blueprint of the floor-plan layout. Templets can be attached with Scotch tape to the floor plan so as to be easily removed. This permits making in quick succession accurate reproductions of several different arrangements which can be used for purposes of comparison. Figure 72 shows a plan made by this process.

Floor models. When working with multistory buildings, it is much easier to visualize the relationship between floors by using a model than



Courtesy Industrial Engineering Dept., Northeastern University, Boston

FIGURE 73. SCALE MODEL OF FOUR-STORY SHOE FACTORY

Roof is removed to show wooden templets representing machinery and equipment layout of top floor and layout of offices.

by trying to visualize this relationship from successive floor plans. Chutes, elevators, conveyors, and stairs must be provided for at the same location on different floors (Fig. 73).

Process chart. The process chart uses standard symbols to list in order the steps in the manufacture of a product. This isolates the sequence and types of processes from the details of the physical layout and technical aspects. In addition, it focuses attention on nonproductive operations, such as transportation, inspection, and temporary storage, that may be eliminated by improved layout. Figure 74 shows the symbols most commonly used.

Process charts may also be useful in planning the whole manufacturing process as well as plant layouts. The process chart as a tool of plant layout is treated more completely in the chapter on Motion Study and Plant Layout.

Flow chart. The flow chart shows the physical movement of materials through the entire manufacturing process. It is drawn to scale, and

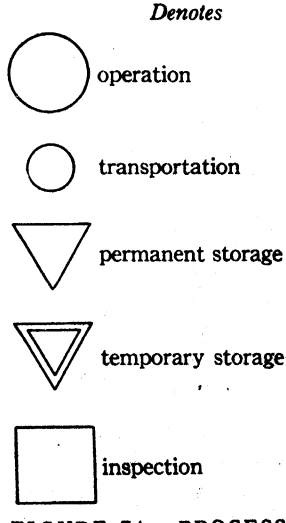


FIGURE 74. PROCESS CHART SYMBOLS

the path of each material is represented by a single line. No other details, such as machines or floor plans, are shown on the chart (see Fig. 75). When multistory buildings are involved, isometric or oblique drawings may be used to advantage (see Fig. 76). The floor chart focuses attention upon the distance and paths over which materials must be moved. Crossed lines should be eliminated if possible, and an effort made to reduce the length of the flow-chart lines.

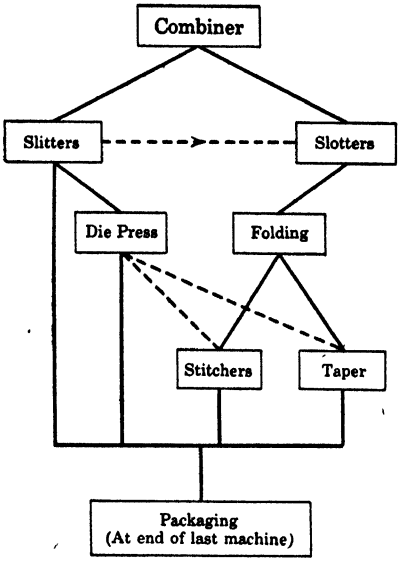


FIGURE 75. FLOW CHART
Lines indicate possible flows of work. Dash lines show channels that are less frequently used.

EXPERIMENTAL PROCEDURE IN ARRANGING LAYOUT

The most satisfactory layout of machines or departments is usually discovered only after trial-and-error experimenting with the visual aids discussed in the previous section. Merely listing the layout requirements does not reveal the full possibilities of floor arrangements. Lists have only one dimension — each item either precedes or follows the others. But every layout has two and sometimes three dimensions. Using these extra dimensions, it is often possible to satisfy several different requirements. Each of these may be stated by a listing or grouping of the machines in the order which best satisfies the particular requirement. In the ideal situation, one list may be satisfied by the arrangement of the machines in that order down the length of the building; another, by the order across the width of the building; and a third by the vertical order of machines. In making a layout, the order of machines according to the most important requirement may be used as a start, laying them out in sequence along a straight line. This line may then be modified to satisfy as many different requirements as possible.

For example, assume a problem in which the sequence of production is through departments A, B, C, D, E, F, and G. Assume also that similar machines are used in A, C, and F, and another group of similar machines in C and G. The nature of the work is such that if all the machines of one type are located as near together as possible, it will facilitate supervision, flexibility, and maintenance work. Therefore,

we have two requirements to satisfy in the layout: (1) that the line of flow be continuous between departments in the alphabetical order named above, and (2) that departments A, C, and F be adjacent to each other, and also departments C and G.

If the order of production sequence is most important, we can start out by placing each machine in order along a straight line. But with a straight-line arrangement, each department can be next to only two other departments, the one before and the one after, and it is impossible to satisfy the requirements of the two different factors with a simple, straight-line arrangement. Hence, we will modify the straight line by using two dimensions. Each department can now be adjacent to at least four others, those before, after, and on each side. This number may be increased if the border is shared by two or more other departments. If adjacency requirements are satisfied by placing machines above or below as well as on either side, the addition of top and bottom permit each machine to be adjacent to at least six others. Coming back to the requirements of our assumed problem, we can place departments A, B, and C adjacent in that order, and A adjacent to C, by putting A and C end to end, and B above, below, or on either side of both A and C (Fig. 77).

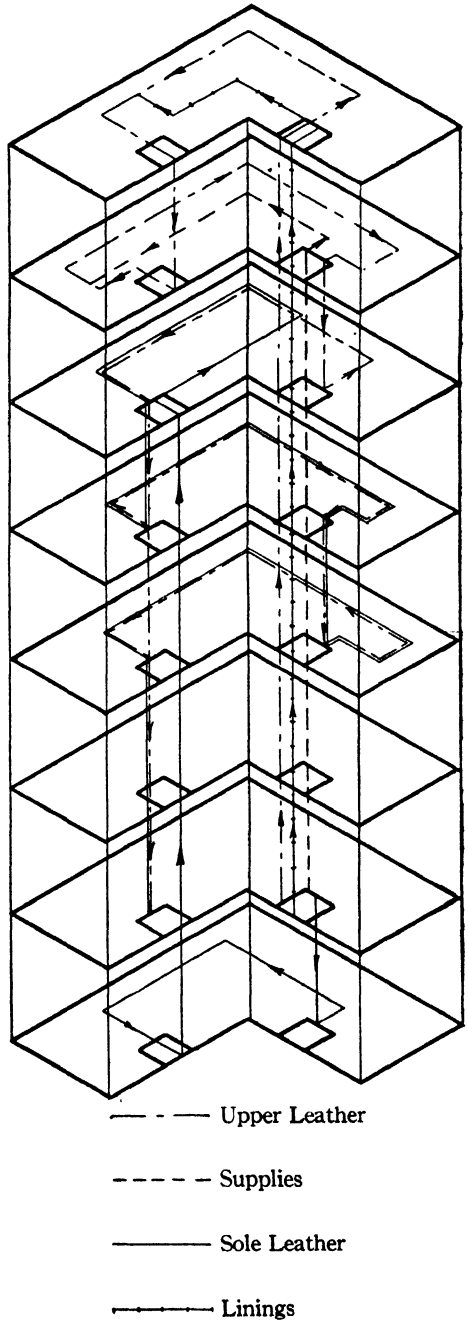


FIGURE 76. ISOMETRIC FLOW CHART OF EIGHT-STORY SHOE FACTORY

The next step in our problem is to place F next to A. This might be done as in Fig. 78.

It is also possible to place G next to C if there is no objection to G being totally surrounded. If there is this objection, one alternative is to place D, connecting C and E, either above or below G rather than beside it (Figs. 79 and 80).

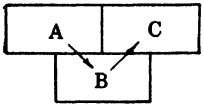


FIGURE 77

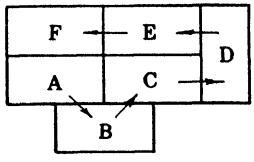


FIGURE 78

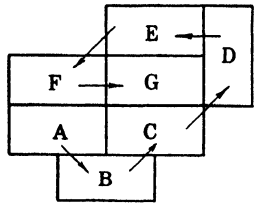


FIGURE 79

In order to increase the adjacency possibilities about any one department, this particular department should be thought of as a central hub around which the other departments radiate as spokes. The separate parts of each "spoke" may then be arranged in sequence, and the order, or angle, of spokes arranged according to some other classification. If a third dimension is permissible, this arrangement may become a sphere, or successive layers of "wheels" arranged according to a third basis of classification. The reader who is familiar with mathematical axes will recognize the relationship as similar to that between rectangular and polar coordinates (Fig. 81).

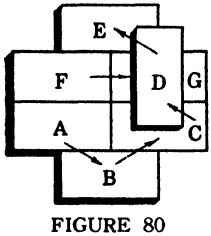


FIGURE 80

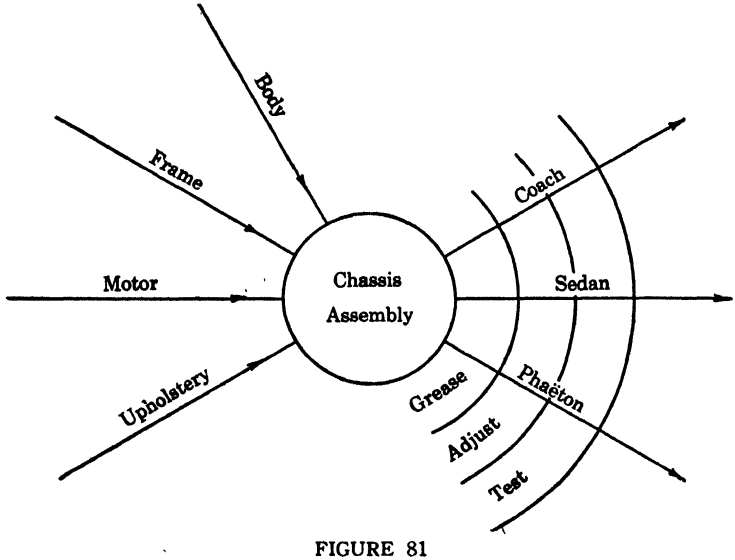


FIGURE 81

CHAPTER XI

MOTION STUDY AND PLANT LAYOUT

Prefatory Note

Nearly every topic of industrial management has a close relationship with all the others which are of concern to the industrial manager. Motion study is one of these and for purposes of presentation may be viewed to best advantage from two angles: (1) its function in relation to the layout of the industrial plant and (2) its significance in relation to the worker. Those aspects of motion study which have to do with plant layout will be presented in this chapter. The application of motion-study principles to improving efficiency in worker performance is treated in the chapter entitled Motion Study and the Worker.

* * *

Motion study as used in manufacturing industries may be defined briefly as an analysis of one or any combination of movements connected with manufacturing. These may be either movement of physical objects during the manufacturing process — materials, supplies, internal communications, and so on; or bodily movements of human beings in the performance of work.

Some of the most profitable applications of the techniques of motion study are in the analysis and improvement of the arrangement of the production floor — coordination of power, material-handling service, and storage facilities with the production machinery. The analysis and improvement of the motions or steps in a manufacturing process in relation to layout results in "finding the one best way." This means the "best way" for every individual plant; seldom does one "best way" fit every case. In almost any industrial plant or shop, however, motion study may be applied to achieve any one or all of the following:

1. More economical material handling.
2. Greater efficiency of work stations in relation to the manufacturing process.
3. Safer working conditions.

Just how motion study can be used to obtain each of these desired results is worth reviewing briefly.

1. More economical material handling. No single factor can make for more efficient and lower cost production than production floors

which are correctly planned for material handling. By means of the so-called process chart techniques (pp. 177–182), each step in a manufacturing process can be set down in symbol chart form. A careful study and analysis of each symbol often reveals much handling that can be avoided by rearrangement of plant machinery and equipment. This not only involves handling on the floor, but handling between floors, and, in some cases, handling in the yard. The analysis of material-handling problems, therefore, frequently results in an improved and more efficient plant layout — the initial step in achieving low manufacturing costs. *The cheapest way to handle materials is not to handle them.*

2. Greater efficiency of work stations in relation to the manufacturing process. In some industries a complete product is made at a single workplace — bench or machine; in others, the product passes from one workplace to the next; in still others, the manufacturing process is a combination of these. The application of motion-study principles, therefore, to the individual workplace saves manufacturing time, not only so far as the individual workplace is concerned, but also in connection with the entire process. The proper planning of the workplace — correct placing of tools and materials — results in a speed-up of work done at each separate work station and in turn an increased productivity for the whole plant. Since the workplace is part of the entire layout and the whole plant must be made into an efficient unit, it is just as important to apply motion study to what the worker does at his machine or workbench as to material handling on the production floor.

The motion-study analyst proceeds on the basis that output achieved in any workplace varies directly with the efficiency of its arrangement. Motion-study principles are applied to the workplace to lessen the number and kind of hand, arm, and body movements in the fulfillment of an operation.[1] Provision is made to have tools and materials in convenient places and for operators to either sit or stand in order to work with the least fatigue. In short, the improvement in the efficiency of a production center or even workbench enables an operator to increase output with less fatigue, and, at the same time, achieve greater safety for himself and his fellow workers. The arrangement of workbenches and special work areas must be considered along with the layout of the entire production floor.

3. Safer working conditions. Most plant managers admit that motion-minded employees are likely to be very safety conscious; this is because they appreciate that work to be done with the least sacrifice of time and energy must be done under safe working conditions. The fear of injury slows down an operator's pace and, therefore, material handling that is well planned, as well as application of the correct motion

[1] Discussed in detail in the chapter on Motion Study and the Worker.

for accomplishing any task, presumes the introduction of the best safety practices.

Process Charts vs. Motion-cycle Charts

Motion study in practice is carried out by the use of a common language. This consists of symbols that are employed in professional practice. An individual who has a keen mind may be able to observe a process and be able to suggest desirable changes immediately. This does not mean, however, that standard nomenclature is not necessary, but rather that its purpose is one of an accepted common denominator for group cooperation in dealing with motion-study problems, the solution of which is not readily apparent.

The symbols which comprise the common language used in connection with the analysis of plant-layout problems are called "process-chart symbols." These are shown below. The so-called therbligs (see page 366) comprise an industrial shorthand used to make *motion-cycle charts* for analysis of human body movements in the performance of work.

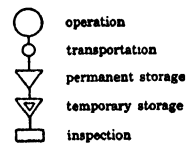
The type of chart to be used must depend primarily upon the degree to which it is desired to break down movements of men, materials, and machines. The process chart deals with operations as a whole and studies the relationships between one operation and another. The motion-cycle chart is used for making minute detailed studies of the movements of the body, arm, and fingers.[1] For example, in supplying fuel to a boiler the following steps are involved: (1) Unloading the fuel from the railroad car to the coal pile, (2) moving the coal from the pile to the storage bin, (3) stoking the boiler with fuel, (4) removal of the ash.

The process chart deals with each of these steps as a whole, whereas the motion-cycle chart would show in detail the actual body, arm, and finger movements in one step such as stoking the boiler or removing the ash.

The process chart is used primarily in studying plant layouts and material handling and the motion-study cycle chart is used to analyze movements of men in relation to these.

PROCESS CHARTS

There are many process-chart symbols, but those most ordinarily used are:



These symbols are an industrial shorthand which motion-study analysts use to record the elements or steps in manufacturing processes and operations which they observe.

[1] *Ibid.*

Process charts are generally of three types:

1. *A flow chart* which shows movements of men or materials, or paper work (such as production-control procedures), and the sequence of operations performed (see Fig. 82).

FLOW PROCESS CHART

Subject: Operations on Hotshot 1/2 HP Electric Motor — Department: 16

Date: January 3, 1943 — By: B. J. H.

MOTOR BASE					MOTOR BODY					STATOR				
Dis Feet	Standard Minutes	Sym. Freq	Sym-bol	Description	Dis. Feet	Standard Minutes	Sym Freq	Sym-bol	Description	Dis. Feet	Standard Minutes	Sym Freq	Sym-bol	Description
		1	▽	First floor bin			1	▽	3rd floor bin			1	▽	3rd floor bin
55		1	○	To sandblast	55		1	○	To bench #1	55		1	○	To bench #1
		2	▽	On truck at sandblast			2	▽	On truck at bench #1					
	3.2	1	○	Sandblast all over		1.8	1	○	Assemble stator to body					ROTOR
		1	□	By foreman			1	□	By foreman			1	▽	3rd floor bin
		3	▽	On truck at sandblast			3	▽	On truck at bench #1	55		1	○	To bench #2
20		2	○	To elevator										
		4	▽	Wait for elevator	8		2	○	To bench #2					
6		3	○	Into elevator			4	▽	On truck at bench #2					
		5	▽	Wait for full load		1.5	2	○	Assemble rotor to body					PROTECTIVE SHIELD
14		4	○	To 2nd floor								1	▽	3rd floor bin
6		5	○	Off elevator			2	□	By foreman	55		1	○	To bench #3
		6	▽	Wait for porter			5	▽	On truck at bench #2					
20		6	○	To milling machine	8		3	○	To bench #3					
		7	▽	On truck at miller			6	▽	On truck at bench #3					
	1.1	2	○	Mill bottom		0.4	3	○	Assemble protective shld. to body					SCREWS
		2	□	By foreman								1	▽	3rd floor bin
		8	▽	On truck at miller			3	□	By foreman	55		1	○	To bench #4
5		7	○	To vertical miller			7	▽	On truck at bench #3					
	2.0	3	○	Profile bottom	8		4	○	To bench #4					
		3	□	By foreman			8	▽	On truck at bench #4					
		9	▽	On truck at profiler		1.3	4	○	Assemble body to base, 6 screws					
5		8	○	To drill										
	0.9	4	○	Drill and tap 6 holes			9	▽	On truck at bench #4	20		10	▽	To packing room
		4	□	By foreman								14	▽	On truck in packing room
		10	▽	On truck at drill	8		5	○	To inspector		2.4	5	○	Pack in boxes
							10	▽	On truck at inspector					
20		9	○	To elevator			4	□	By inspector			15	▽	On skid
		11	▽	Wait for elevator			11	▽	On truck at inspector		0.3	6	○	Stencil and label
6		10	○	On to elevator	20		6	○	To elevator					
14		11	○	To 3rd floor			12	▽	Wait for elevator			16	▽	On truck in packing room
6		12	○	Off elevator										
		12	▽	Wait for porter	6		7	○	On to elevator	55		11	○	To warehouse
					14		8	○	To 2nd floor				▽	In warehouse
20		13	○	To bench #4	6		9	○	Off elevator					
							13	▽	Wait for porter					

FIGURE 82. FLOW PROCESS CHART

2. *Operator charts* which show the motions made by the right and left hand and the other parts of the body in performing work (see Fig. 83).
3. *Operator and machine charts* which show the coordinated activities of men and machines (see Fig. 84).

The *operator chart* and the *operator and machine charts* (Figs. 83 and 84) are most commonly used in the analysis of benchwork and of handling materials into and out of machines. The objects of the operator charts

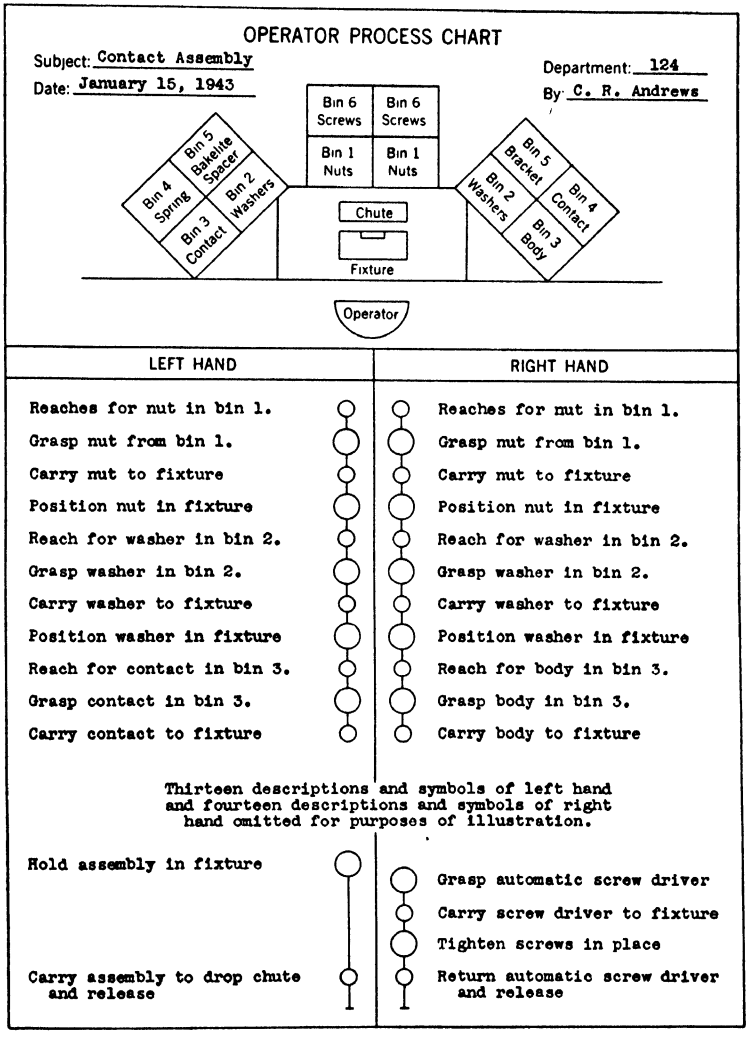


FIGURE 83. OPERATOR PROCESS CHART

and operator and machine-chart analyses are to improve bench layouts, arrangements of materials and tools, either on the bench or beside the bench, and to improve material handling to and from work stations. In this connection the principles of the circular workbench are applied (see Fig. 87).

The *flow chart* is commonly used to study the following: (1) movements of men in relation to material handling; (2) material handling as related to plant layout; (3) improvement in the steps of the manufacturing process itself, such as combining machines. The advantage

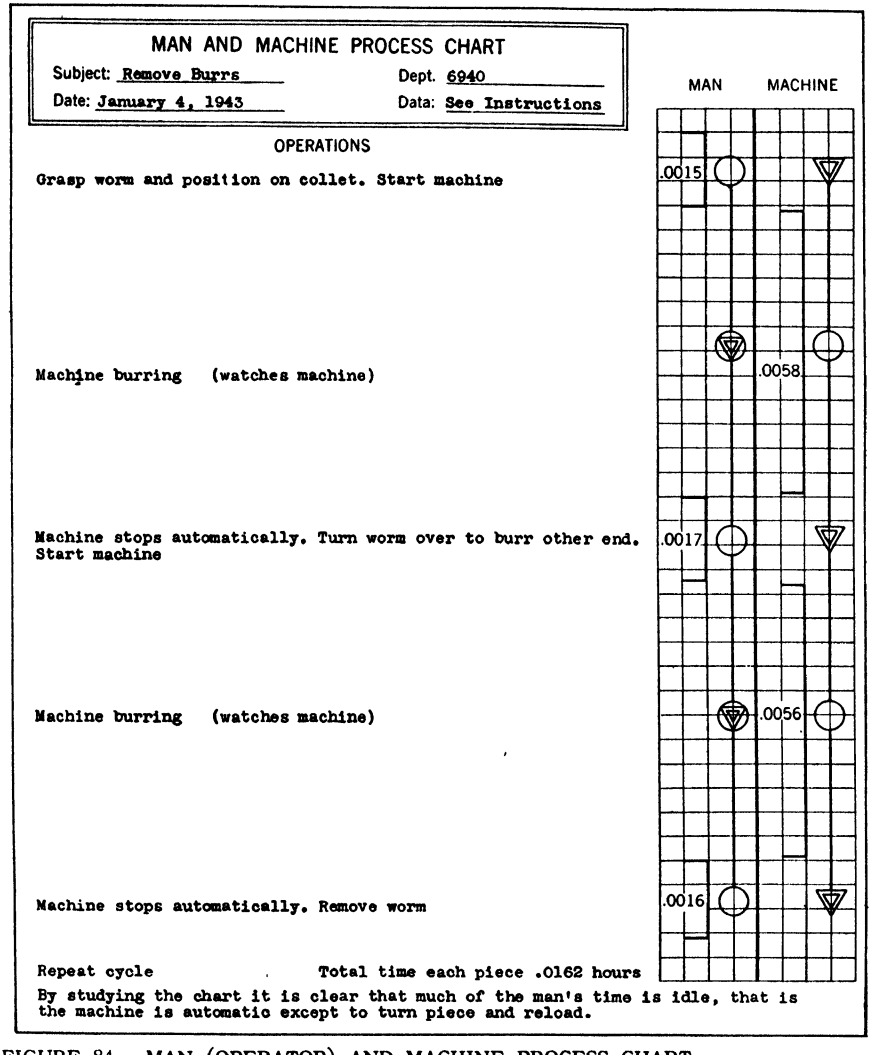


FIGURE 84. MAN (OPERATOR) AND MACHINE PROCESS CHART

sought by use of flow charts is increased productivity at a lower cost per unit. The efficient use of manufacturing space will bring about a reduction of distances required for handling materials during a manufacturing process, a lowering of time requirements for production cycles, and an increased output at less cost.

Making process-chart analyses. The motion-study analyst observes carefully the operation or task which he wishes to improve. Having in mind the process-chart symbols, it is customary to use a process-chart

N SI-108

SHEET 2 OF 6

PROCESS CHART

PART NAME Fittings (Parker & Weatherhead) ANALYSIS NO 2

BY R. W. Young PART NO -

DATE 1-29-42

NO.	OPERATION	MOVE	STORE	INSP.	DESCRIPTION	DISTANCE	P & L	CONVEYOR
10	○	●	△	□	To bench	3'	3 ea.	Hand
11	○	○	▲	□	On bench			
7	●	○	△	□	Remove all fittings from boxes			
11	○	●	△	□	To bench or scale	2'	36 ea.	Hand
12	○	○	▲	□	On bench or scale			
8	●	○	△	□	Check weigh or count			
12	○	●	△	□	Replace in box	1'	36 ea.	Hand
13	○	○	▲	□	On bench			
13	○	●	△	□	To storage bins	95'	3 ea.	Truck
14	○	○	▲	□	On truck			
14	○	●	△	□	To bins	3'	3 ea.	Hand
9	●	○	△	□	Dump in bins			
15	○	○	▲	□	In bins (Army stores)			
10	●	○	△	□	Remove from bins sort for cad & brass (Approx. 50% ea.)			
16	○	○	▲	□	In boxes			
15	○	●	△	□	Cad plated back to bins	3'	1 ea.	Hand
11	●	○	△	□	Dump in bins			
17	○	○	▲	□	In bins			
16	○	●	△	□	Box from floor to outgoing bench	95'	1 ea.	Hand
18	○	○	▲	□	At bench			
17	○	●	△	□	To truck	5'	1 ea.	Hand
19	○	○	▲	□	On truck			
18	○	●	△	□	To cad plate (elevator one way)	700'	-	Truck
20	○	○	▲	□	On truck			
19	○	●	△	□	To bench			
21	○	○	▲	□	On bench			
TOTAL								

Courtesy Allen Mogensen

FIGURE 85. PROCESS CHART ANALYSIS SHEET

analysis sheet to compile essential data pertaining to the operation or process under consideration. Figure 85 shows a *process-chart analysis sheet.* This has six columns which, for convenience, may be called from left to right: 1, 2, 3, 4, 5, and 6. Number 1 is used to record the frequency occurrence of process-chart symbols in the analysis of any oper-

ations or processes. Number 2 provides a convenient means of recording the symbols to be used. Three describes briefly what the symbol signifies; 4, the distance traveled; 5, the number of "pick-up and lay-down" operations involved; 6 provides space for noting the type of conveyor involved in performing the operation or process.

When the foregoing information about a manufacturing process, task, or operation has been recorded on the process-chart analysis sheet, the motion-study analyst attempts to eliminate or combine as many of the recorded symbols as possible. In particular, he focuses attention upon those which designate travel and temporary storage. Both of the latter often signify unnecessary delays or lost time in production. For example, if a process-chart analysis has to do with the *material handling in relation to plant layout*, the travel distances and time elements of the whole layout are studied with a view to making improvements. A new layout is planned in the light of revisions suggested from this study.

The improvement of any manufacturing operation subjected to process-chart analysis often entails one or more of the following:

1. The rearrangement of workbench or production center.
2. The rearrangement of machinery and equipment to facilitate material handling to, from, and at the workplace as well as to correct bodily movement on the part of the operator.
3. The construction of special jigs and fixtures to make possible the application of the best principles of motion economy (see page 96).
4. The development of special tools and handling equipment.
5. The redesigning of the product being manufactured in order to eliminate unnecessary or costly manufacturing operations.

Training incidental to analysis work. When an operation has been improved or the methods of performing it changed, it is often necessary to retrain the operator doing the work or to train new operators. This involves teaching the operator to give up old habits of work and to adopt new ones in keeping with the best principles of motion economy. A more complete discussion of this is made under the heading "Introduction of Motion Economy into the Plant" in the chapter which deals with Motion Study and the Worker.

PRINCIPLES OF MOTION STUDY WHICH APPLY TO PLANT LAYOUT

Application of the process-chart technique to the analysis of plant-layout problems is greatly facilitated by an understanding of the principles of motion economy which apply directly to the physical organization of the industrial plant. The successful application of these principles results in efficient coordination of all the manufacturing processes involved. Widespread successful use of motion-study principles in con-

nection with problems of plant layout results in greater output at lower costs. The motion-economy principles of plant layout follow:

1. **Determine the easiest thing to move.** When every motion-study problem is carefully studied, it is often found that there is a choice of things to be moved. For example, either the product itself may be moved, as on a conveyor belt, or the product may remain stationary and tools brought to it. An example of the former is the conveyor-belt assembly of a motor, and the latter the building of a large turbine. Factors which will influence the decision in this connection are the weight of the objects involved and the distance the objects are to be moved.
2. **Movement on the production floor should be facilitated wherever possible.** This may be accomplished in the following ways:
   a) By designing the object to be moved so that it is easily moved and grasped and so that it will remain in position, that is, the means of grasping should be upright and readily accessible. The movement will be facilitated also if the product is designed so that it may be easily released and so that it will stand impacts.
   b) The equipment used to move the object may also be *designed* to facilitate movement. Specially designed handling equipment such as tractors, prongs, hooks, and pliers are examples of the application of this principle.
   c) Movements should be facilitated by *application of the principles of balance.* For example, when a person is walking and carrying a 20-pound object in one hand and a lighter object in the other, movement is made difficult. The same principle applies to balancing materials and objects to be moved in the industrial plant. A balanced load is easier to move than an unbalanced one.
   d) *Movement is Facilitated by Prepositioning.* This demands that objects be placed so that they are in positions to be used when they are needed. Tools, for example, should be arranged so as to be most easily accessible and available in connection with the flow of operations on the production floor. For example, machine operators should have both materials and tools easily accessible to their workplace to avoid walking to get them (see Fig. 86).
3. **Determine the best location for stationary objects.** The use of motion study in plant layout is to eliminate unnecessary movement. This is true whether the objects under consideration are machines, material-handling units, or permanent storage units. Process-chart analysis shows where stationary objects may be best located to eliminate unnecessary steps, handling, and travel distances.
4. **The principle of gravity should be used wherever possible.** Every factory should avoid paying to move materials wherever it is possible to move them by providing a downward slope, the use of a roller conveyor, and so on. This principle should be incorporated in planning feeds of materials at work stations as well as handling materials between work stations.

5. **Application of force.** In studying the movement of materials, it is necessary to decide whether an intermittent or steady force is better for achieving desired results. A steady movement force provides maximum control and minimum shock and vibration. To move some objects, however, an intermittent or sudden impact will be all that is required to accomplish movement.

Courtesy Factory Magazine and Northeastern University

FIGURE 86. CORRECT USE OF BOTH HANDS IN ASSEMBLY WORK

Operator uses both hands to assemble contact maker. Screw driver is *prepositioned* and provision is made for drop delivery. This setup achieves a saving of eleven seconds per unit assembly.

6. **Application of the principle of rhythm.** Activities which involve the use of rhythm are more easily accomplished where rhythm is present. All bodily movements are rhythmical in nature. The arrangement of an industrial plant should be designed to introduce rhythm into the pattern of work. When closely harmonized with natural rhythmic tendencies, movement is greatly simplified. This principle may be applied to many mechanical operations.
7. **Use direct routes wherever possible.** A straight line is the shortest distance between two points. Consequently, every plant layout should

strive to achieve the shortest possible route for handling materials in the process.

8. **Movements should incorporate the principles of continuity.** Work should be so arranged that in its actual performance the steps naturally follow one another. When a worker jumps from one type of work to another, inefficiency nearly always results. A continuous sequence of operations facilitates application of the principles of motion study. Most mass-production operations recognize this principle and provide for a continuous flow of work. This requires that the machines which are used to complete a given product should be so grouped as to minimize travel distances and provide a short, rapid flow of work.

The ordinary telephone illustrates many of the foregoing principles. It is located in a central room in the house, preferably near the sections that are most frequently occupied at the time when calls are likely to be made — near the living room rather than a bedroom (location of stationary objects). It is placed on a stand or hook in such a position that it may be easily grasped (prepositioning). A person moves his body to a comfortable seat near the telephone, then moves the receiver up to his ear — rather than bringing the telephone to another part of the house, or bending over so that the telephone may be used without moving it (best things to move). The instrument itself is shaped so that it is easily grasped (designed to facilitate movement). When the instrument is removed from the stand or hook, the line is also connected. The receiver and mouthpiece are placed on the same instrument (kill two birds with one stone).

Workplace Layout

In the application of motion-study principles of plant layout to the workplace, motion-study analysts have made particular use of the *circular workbench.* Its principles are useful in laying out work areas for machine and bench operations so that they serve the worker to the best advantage. A circular workbench incorporates these principles:

1. An area called the "normal work area" which is comfortable for reach of the hands and arms in either sitting or standing positions.
2. An outside work area beyond which the worker should not attempt to reach. To do so causes strain and fatigue. This is the place for location of tools and materials.
3. Drop delivery, that is, a hole and a chute to receive products when the worker is through with them. This permits the operator to combine the motions of putting away or laying aside the finished product and grasping or picking up new materials and parts to start production of another unit.
4. Hopper feed for parts to be assembled or materials to go into the product.
5. Adequate tray facilities for parts.

6. Flexibility of arrangement of both hoppers and trays. Figure 87 shows a motion-study laboratory model of a circular workbench. This workbench is used in the solution of actual problems.

BASIC STEPS OF MOTION-STUDY PROCEDURE

The objectives of motion study as applied to plant layout are to make the whole process of manufacturing as simple and straightforward as possible. This means finding a way to do the work with a minimum amount of labor, least fatigue to those working, and with minimum utilization of plant capacity — machinery and buildings — by application of the motion-economy principles of plant layout; the objective sought is lower costs of production.

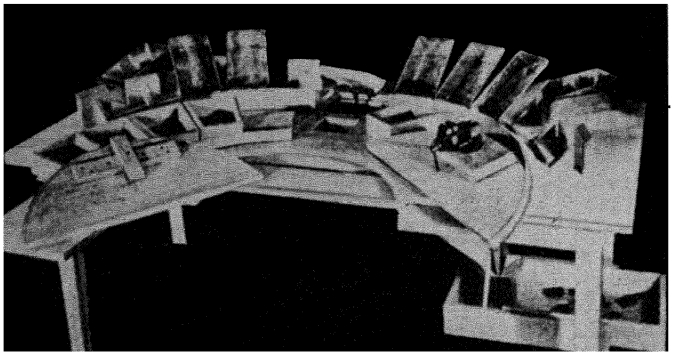
In approaching the solution of a plant-layout problem the *basic steps of motion-study procedure* [1] should be followed. These are:

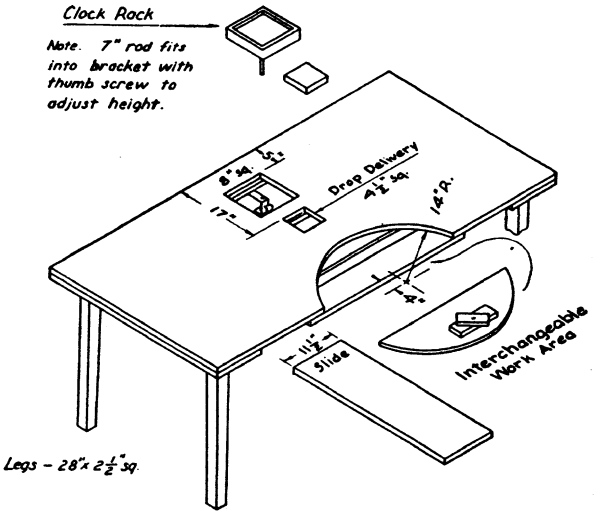
1. Define the problem. The problem to be analyzed should be defined in terms of the ultimate results to be accomplished, rather than the present means of doing the work, that is, the function to be performed, rather than the technique being used. For example, the problem might be that of supplying bench workers with the various parts for the assembly of a machine. The problem is to assemble the machine. To define it as the need of supplying the workers with the proper parts as needed may eliminate the type of solution which places the machine on a conveyor belt that passes through the sections of a plant where the parts are made, and where they may be added to the machine as it passes by on the belt. The function here is to assemble the machine. There are many possible techniques which might be used to perform this function. If the problem is stated in terms of one of the techniques, the solution is limited to improving that particular technique, rather than discovering other more adaptable methods.

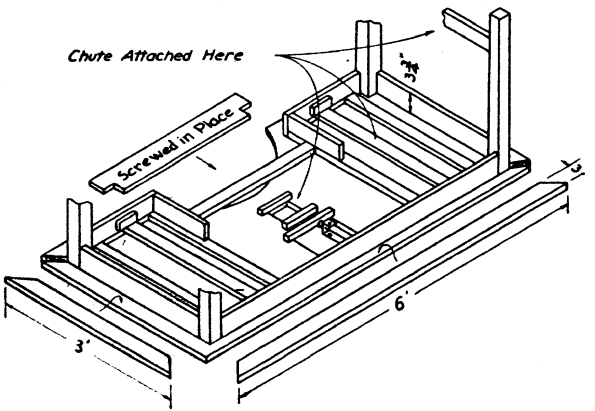
2. Study present methods. In order to become familiar with the details of the problem, the present method used in the plant and/or methods used in other plants may be studied. Careful analysis in the case of plant-layout problems will be facilitated by the use of the process-chart symbols.

3. Improve present method. Ways to improve the present method should be sought. This step of problem analysis may be approached from two different standpoints: (1) *Further application of principles now used.* Naming and classifying the principles which are now being applied may indicate opportunities for applying them further. (2) *Application of new principles to present techniques.* Consider each part of the present

[1] These same steps have application in the solution of any problems which require analysis.







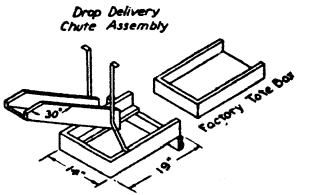


FIGURE 87. LABORATORY MODEL. *Circular Work Bench* for experimental and training purposes.

technique in combination with other principles which might be applied to improve it. In other words, see if the principles which are being applied in one part of the process may also be applied to other parts of the process.

4. Look for entirely new methods. Disregard the previous methods and their modifications. Go back to the definition of the problem and the principles of motion economy to find entirely new methods. This step might be placed immediately after the definition of the problem, as it is sometimes easier to think of new methods before old ones are firmly established in mind.

5. Progressively select the best method. The most promising methods may be selected for more detailed study and comparison in order to find the one which is the best answer in the particular circumstances.

6. Record the method selected. Make a complete description of the method selected so that it may be properly installed and taught to those who must use it as well as retained for future reference.

7. Install the new system. This includes installing the actual physical equipment, "selling" the method to the workmen, and training them in its proper use.

8. Check results. Check the actual results with those anticipated and watch for opportunities to make further improvements.

CHAPTER XII

MATERIAL HANDLING

Modern factory organization and production is dependent upon the efficient and speedy handling of materials. From the time raw materials arrive in the receiving room until they are fully fabricated and placed in finished-goods storage, material handling is the backbone of the manufacturing process.

Material handling must be given attention by the industrial manager at the time he is laying out his plant for production because it has direct bearing on both the operating cost and productive capacity of the factory. The lowest possible cost of manufacturing can be best achieved only when waste is at a minimum in the use of men, machines, equipment, and areas devoted solely to getting materials through the manufacturing process. Similarly, the maximum use of plant facilities is possible only when they are arranged to allow optimum efficiency in their arrangement. Both of these objectives are expressed differently and succinctly in this slogan: *The cheapest way to handle materials is not to handle them.*

MATERIAL-HANDLING PRINCIPLES

The first step in the sound management of material handling is the designation of some person or department to be responsible for the following:

1. To keep the material-handling methods and equipment in stride with the manufacturing process, developments, schedules; that is, provide the best possible service.
2. To recommend improvements in material-handling procedures.
3. To keep the cost of material handling at a minimum.

The task of the material-handling manager, therefore, is to achieve certain objectives by constant study of all handling operations. These will be attained in conjunction with and should be regarded as joint products of every analysis, not as individual aims to be arrived at separately. These are:

1. Savings in travel distance. The distance between manufacturing operations must be reduced to a minimum. Careful analysis of the linear feet of floor area to be traveled in moving materials often leads

to the relocation of machines and equipment, combinations of steps in the manufacturing process, and so on.

2. Increased speed. Unless the speed and efficiency of material handling is equal to that of the productive equipment, the effective capacity of the plant will be greatly hampered.

3. Elimination of handling operations. Not infrequently, effort is wasted in rehandling, piling, and storage of materials due to: (1) poor arrangement of the manufacturing and storage areas; (2) use of an improper type of handling equipment. Simultaneous study of layout, storage, and handling procedures assists in the elimination of needless handling operations. A possible by-product of this study is the uncovering of potential bottlenecks and the minimizing of production delays through the introduction of regular schedules of material movement within the plant.

4. Mechanical handling wherever economical. Where operations are continuously performed, mechanical-handling equipment usually results in savings in time and cost, as well as hastening the time required for the manufacturing process. When handling operations occur infrequently, however, the investment in special equipment is seldom justified.

5. Avoiding unnecessary duplication of investment in handling equipment. Every department likes to have material-handling equipment for its exclusive use, even when needed only occasionally. Unless this practice is regulated carefully, the unnecessary duplications increase manufacturing costs unduly.

In many industries the cost of material transportation is an item of major concern. Money invested in permanent equipment affects fixed charges, such as taxes, interest, maintenance, and so on, and consequently ties up funds that might otherwise be used for the purchase of raw materials or hiring labor. It is the responsibility of top management to invest funds where they will yield the greatest return to the company; those who are responsible for only one small part of the business are not in a position to make these decisions.

6. Coordination of interdepartmental handling. Greatest flexibility and minimum investment are achieved when the type and quantity of equipment purchased are based on the needs of the whole plant rather than individual departments. In the same way that standard railroad equipment is a tremendous advantage in the nation's transportation system, internal systems should permit continuous and flexible service throughout the entire plant. Equipment temporarily needed in one department should be adaptable to possible future uses in other departments. Standard tracks, roadways, and container sizes permit shifting equipment to remedy bottlenecks occurring at unforeseen times and

locations. In addition, the centralized control and scheduling of the operation of handling equipment assure timely and adequate service for every manufacturing operation. In the solution of material-handling problems, the plant manager does not need to be concerned with the technical details of apparatus. His primary concern is to receive and act upon the recommendations of the material-handling expert.

There follows a schedule of steps, expressed in management terminology, which will be of assistance to the plant manager in evaluating engineering reports on material handling:

I. The Problem and Present Procedure
  A. Product
    1. Sources of supply of materials
    2. Units — bags, tons, and so forth
    3. Characteristics of product or material
    4. Value of materials to be handled
  B. Quantity to handle
    1. Amount
    2. Quantity in terms of units
    3. Requirements in terms of production
  C. Handling procedure
    1. Receiving
    2. Storage
    3. Requirements of manufacturing process
    4. Space requirements and allowances
      a) Special considerations
      b) Layout of plant
    5. Steps involved in handling from storage to stock
      a) Process chart
    6. Shipping and traffic management
  D. Handling costs
    1. Fixed charges
      a) Equipment
      b) Handling department expense
      c) Handling costs
        (allocation of these in terms of (E) below)
    2. Labor costs
  E. The time elements
    1. Present handling time
      (Ratio of handling time to total production time)
    2. The period of time material is to be handled in the future
    3. Correlation of time and cost factors

II. Revised Procedure
  A. Product
    1. Changes in sources of supply of materials
    2. Changes in units — bags, tons, and so forth

3. Changes in characteristics of product or material
4. Value of materials to be handled

B. Quantity to handle
1. Changes in amount
2. Changes in quantity in terms of units
3. Changes in requirements in terms of production

C. Handling procedure
1. Changes in method of receiving
2. Changes in method of storage
3. Changes in requirements of manufacturing process
4. Changes in space requirements and allowances
a) Special considerations
5. Steps involved in handling from storage to stock
a) Revised process chart
b) Changes in layout to correspond with process chart
6. Shipping and traffic management

D. Revised handling costs
1. Revised fixed charges
a) Equipment
b) Handling department expense
c) Handling costs (allocation of these in terms of (E) below)
2. Revised labor costs

E. Revised time elements
1. Ratio of handling time to total production time
2. Revised period
3. Correlation of time and cost factors

F. Cost of new plan:
Equipment _____
Other costs _____
Total _____

G. Savings over old plan:
Direct labor _____
Indirect labor _____
Material _____
Other savings _____
Total _____

H. Time required to pay for new equipment

I. Significance of improvements in relation to profits

PRINCIPLES OF MATERIAL TRANSPORTATION

In order to arrive at an intelligent solution regarding any material-handling problem, the specialist in this field needs to have knowledge of the engineering aspects of transportation.

There are many companies which specialize in the design and sale

of various types of material-handling equipment, as well as the solution of material-handling problems. Their services can be used to best advantage only by customers who are thoroughly familiar with the fundamental principles which underlie the transportation of all materials. Not only will this prove helpful when particular equipment is needed to solve an individual problem, but also when it is necessary to make a suitable combination of the devices of several concerns, or to concoct new ones which are not listed in standard catalogs.

The study of the principles of material transportation should be predicated upon these basic concepts:

1. The problems of material handling and plant layout are so intimately associated that they should be considered together. Efforts to reduce handling expense point to improved layout, and vice versa.
2. The cheapest way to handle materials is not to handle them, or handle them as little as possible. Internal transportation of goods adds to their market value only as it facilitates the manufacturing process. Reductions in handling consistent with the needs of the manufacturing operations make for savings which do not sacrifice quality, reputation, or markets.
3. Whenever hard and continuous manual handling is being performed, some sort of machine can be designed to reduce both physical labor and the expense.

WHAT TO MOVE

The first step in solving a problem in material handling is to determine *what to move.* When there are several processes and machines used in the manufacture of a product, the management must decide between: (1) moving the product from process to process; (2) moving machines, operators, and supplies to a product which remains stationary.

The choice between these two alternatives depends upon the relative mobility of each factor. In the automobile industry the cars are moved from one step to another in the process; in the shipbuilding industry, workers and machines must be moved around the ship. In brief, either the product or the worker and his tools may be stationary while the other factors are moved. It is possible also to keep the worker and the product stationary and move the tools only.

Having selected what is to be moved (materials, machines, or men), it is desirable to make a further analysis of the problem in the light of the following check list:

Materials to be moved. Unit article in containers or bulk (solid, liquid, gas); physical characteristics of containers or bulk materials.

Care and conditions required. Temperature, humidity, shock. Oftentimes drying, shaping, hardening, or a cooling process may be performed during transportation.

Transportation required.

1. Horizontal movement
2. Vertical movement
3. Piling, loading, and unloading

Quantity and time requirements.

1. Number of units to be moved per period of time, such as pounds per hour.
2. Continuous or intermittent: (1) supply and (2) demand.
3. Length of time (months or years, and so on) the service will be needed.

Power available. Electricity, gas, steam — relative costs.

Available routes. Along the floor, overhead, tracks.

Equipment installation and operating costs. Purchase cost, fuel, manpower, taxes.

Equipment maintenance. Need for repairs, inspection, and relative costs.

Labor available. Trained personnel needed to operate equipment. Licenses required.

Lost time and productivity due to change-over of handling methods. Man- and machine-hours lost which cannot be recovered.

TRANSPORTATION TECHNIQUES

The principles considered in the following paragraphs are stated in general terms in the hope that their study may lead to new applications and adaptations. When a specific example is given to illustrate a principle, it is not intended that the case cited should be considered as the only possible application. Such illustrations are used solely to clarify the general terms used to state the principle, and not to restrict the meaning of these terms.

The principles underlying the selection of transportation techniques will be treated under the following headings:

1. Routes for material conveyances
2. Methods of moving material
3. Methods of applying power
4. Continuous vs. reciprocating movement of conveyances
5. Piling, loading, and unloading

1. Routes for Material Conveyances

Floor roadways. Any type of material to be moved can be placed in some sort of container and moved over open roadways and ramps. Aisles of sufficient width can provide for two-way traffic of many different types of trucks and foot passage as well. Open aisles, then,

provide a very flexible arrangement for routing materials. However, they must be kept smooth and hard under the abuse of rapid or heavy traffic.

Floor tracks. Tracks facilitate the control of a long train of conveyances and also centralize the floor wear on a definite area that is more economical to maintain than a wide roadway. The small contact area and hard surfaces of rails reduce rolling friction to a minimum. On the other hand, tracks inject an element of inflexibility in that materials can only be moved to locations provided with tracks, and insufficient switching facilities cause traffic tie-ups. Moreover, tracks render the passage of other vehicles more difficult. The use of floor area for both the processing of materials and their transportation between processes places a premium upon floor space and low-studded buildings. The above discussion also applies to conveyors, pipe lines, and canals at the floor level.

Overhead routes. If materials can be transported on overhead routes, an economy of floor area is effected. It is usually easier to relegate transportation to overhead routes than to carry on processing in these spaces. However, overhead transportation involves a more careful and expensive installation and maintenance because of the added potential danger as well as the difficulties of accessibility. Accidents occur most frequently as a result of careless attachment of loads to overhead handling devices rather than because of defects in the equipment.

Piling, loading, unloading, scooping, and dipping are often greatly facilitated when an overhead system is used.

2. Methods of Moving Material

Slide the material. Less motive power is required to move materials when the friction between the moving object and fixed surface is at a minimum. But it then becomes more difficult to control or stop the movement. In theory, sliding friction is eliminated only in a vacuum, although for most purposes the air resistance of moving materials may be neglected. Materials are often moved by sliding them over solid surfaces, that is, an elevator is guided by sliding contact with vertical shafts, and material slides down certain types of gravity conveyors. Sometimes floating materials are moved by placing them in a fluid to slide them along.

Use wheels. Rolling friction is usually less than sliding friction. Hence, power requirements will be reduced by placing wheels between an object and the fixed surface over which it is to travel. The best place to attach these wheels varies with the problem under consideration. The several possibilities are:

a) *Attach the Wheels to the Conveyance Itself.* For example, in transporting oil by rail, wheels are attached to the tank, making a tank-car, rather than placing the tank on a flat car (Fig. 88).

b) *Place the Material on a Conveyance With Wheels Attached.* Boxes may be piled on a truck rather than attaching wheels to each box (Fig. 89).

c) *Place Free Rollers Between the Object and the Surface.* This method is often used when a large object must be moved a short distance (Fig. 90).

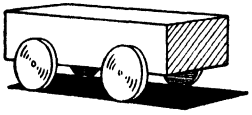


FIGURE 88

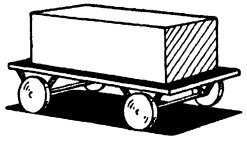


FIGURE 89

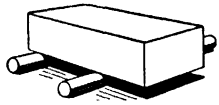


FIGURE 90

d) *Attach Rollers to the Surface Over Which the Materials Are to Move.* This device is commonly called a "roller conveyor" (Fig. 91).

e) *Place the Materials on a Secondary Surface Which Is Moved by Rollers.* In an elevator, the materials are placed on a platform which is moved by winding the cable around a drum. A conveyor belt provides a surface which is moved by rollers at either end (Fig. 92).

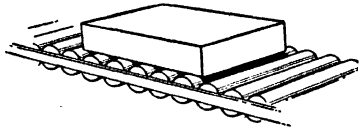


FIGURE 91

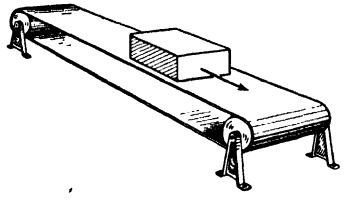


FIGURE 92

3. Methods of Applying a Motive Force to Material to Be Moved

Generation of the mechanical power on the conveyance itself. Energy in some form must be supplied to the conveyance in order that mechanical power may be produced. In the case of gas and steam engines, this is done by periodically supplying the conveyance with fuel (oil or coal) which becomes the source of mechanical energy. When electric motors are used, the energy may also be supplied periodically by changing batteries, or continuously by a direct connection with an outside source of electrical energy.

There are several methods of applying the power in order to produce motion:

a) *Rotate the Bearing Wheels.* This is the method commonly used on automobiles and locomotives. There must be sufficient friction between

the surfaces and the wheel to prevent the wheel from rotating without moving the object. On the other hand, too much friction wastes power (Fig. 93).

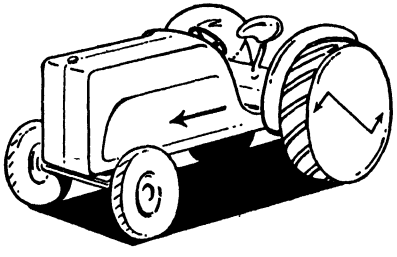


FIGURE 93

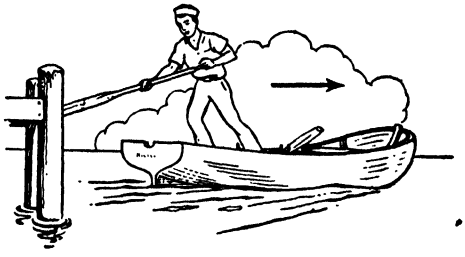


FIGURE 94

b) Apply Pressure to Something Outside the Conveyance. This is shown in Fig. 94. For example, a snow sled may be driven by an air propeller. Mechanical power is produced on the sled and applied to the air surrounding the sled. Again, a monorail conveyer may be supported from bearing wheels and driven by another wheel that presses upward against the supporting rail (Fig. 95).

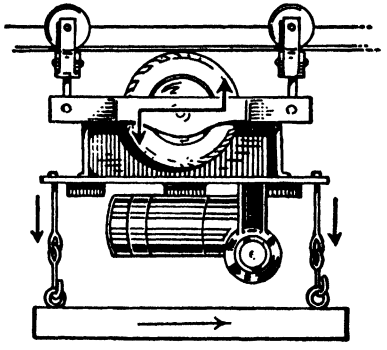


FIGURE 95

c) Pull the Conveyance Toward an Outside Object. If one end of a cable from a conveyance is attached to a fixed outside object, tension of the cable will move the conveyance toward the fixed point. When a rope from a ship is attached to the dock, and then wound onto a winch on shipboard, the ship is drawn towards the dock (Fig. 96).

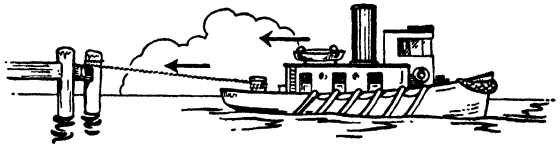


FIGURE 96

Generate the mechanical power outside the object moved. When this is done, the material moves because a force from an outside source has been applied to it rather than because the unit is self-propelling.

a) Rotate Fixed Rollers Upon Which the Conveyance Rests. If an object is resting on rollers whose axes are fixed, that is, the rollers are

free to turn but not to travel, rotation of the rollers will move the object. This principle is utilized in some roller conveyors (Fig. 97), and in the movement of a rack by a gear.

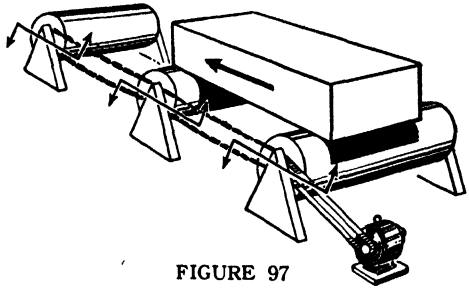


FIGURE 97

b) Create Differences in Pressure. When the pressure on one part of an object is greater than that on another, the object will tend to move away from the point of greatest pressure (Figs. 98 and 99). This pressure may be applied through a solid, liquid, or gas. Rods or hammers may be extended from stationary points to move objects, or the push

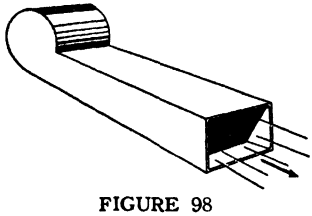


FIGURE 98

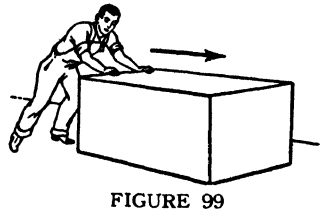


FIGURE 99

may be supplied by another conveyance moving under its own power. Pumps are used to create differences in the pressure on fluids inside pipes or channels, thereby moving the fluids. Sometimes solids may be moved by floating, suspending, or dissolving them in these fluids.

c) Pull the Conveyance. This may be done by a moving object (tractor, truck) with a connection of fixed length (Fig. 100), or by pulling a rope toward a second, fixed point (Fig. 101). In the second

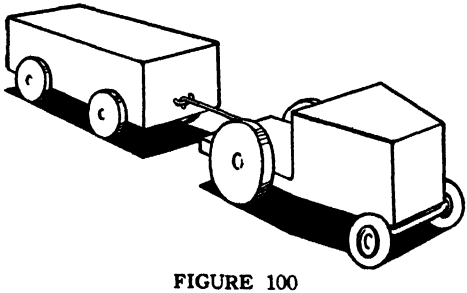


FIGURE 100

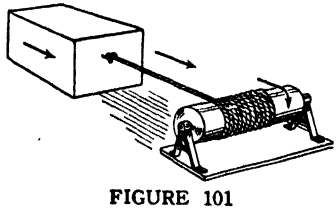


FIGURE 101

case, the source of power is fixed and the connecting link becomes shorter as the movement continues, whereas, in the first case the source of power moves as fast as the conveyance. Sometimes electromagnetism is used instead of physical couplings or cables.

d) Utilize the Downward Pull of Gravity. It is generally easy to utilize gravity when moving objects downward, but there is often danger that the movement will be difficult to control (Fig. 102).

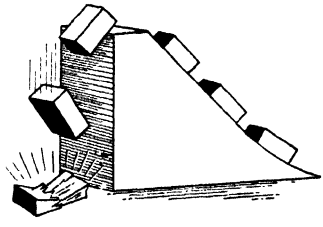


FIGURE 102

Continuous vs. vibrating application of motive force. The motive force used to move material may be applied as a steady, constant push, pull, or twist; or intermittently as a series of shocks. More energy is imparted to the material if the propelling force has motion before its application to the material, that is, the energy transfer to the material is greater under the condition of impact due to the addition of momentum, or kinetic energy as part of the motive force. The practical application of this principle is limited to materials which will not be damaged by the shock of the impact.

Methods of controlling physical movement.

a) Direction

(1) Apply motive force so that object moves in the desired direction.

(2) Provide paths over which the material must travel if it moves at all. Oftentimes the directional character of the force will not be sufficient to guide the object over the desired route. Tracks keep the cars of a train in line and prevent an elevator from swaying.

b) Speed

(1) To control speed, reverse or reduce the motive power which initiated the movement.

(2) Increase the rolling or sliding friction.

(3) Provide barriers in the path of the movement.

4. Continuous vs. Reciprocating Movement of Conveyance

Reciprocating movement. When an ordinary elevator reaches the top of the shaft, it must come to a full stop and change the direction of movement before it can provide further vertical transportation. Throughout its entire operation, the elevator shuttles between the top and the bottom of the same shaft. Because of this, only one elevator can be operated on the shaft, and only one load can be in the process of transportation at any one time. The same would be true of a hand truck operating in narrow passages that did not allow passing or turning, or a one-track railroad.

Continuous movement. Contrast the ordinary elevator with a bucket-conveyor elevator. The buckets reverse their direction by turning rather than coming to a full stop and starting again in the other direction, and travel downward without interfering with others that are coming up.

Comparative advantages. Using the hoist elevator and the bucket conveyor as illustrations — the same principles apply to other devices as well — the *advantages* to each type can be noted. The continuous device permits many loads to be in process of transportation at one time. The reciprocating one must be brought to a full stop and started again even though it is not necessary to facilitate unloading. On the other hand, if a long stop must be made for loading and unloading, there is little to be gained by suspending many items in transit while this is taking place. The continuous device is most advantageous for materials which can be loaded and unloaded while the conveyor is moving. This includes bulk items, such as sand, coal, and grain, and packages which are not damaged by automatic handling. For items requiring careful handling, a series of reciprocating elevators may be more desirable.

When floor trucks or overhead railroads are limited to a one-way passage or a single track, the disadvantages of the reciprocating elevator will arise.

5. Piling, Loading, and Unloading

Much of the time, energy, and expense consumed in handling materials is devoted to piling, loading, and unloading, rather than to transportation from one point to another. Ordinary piling of objects from the floor up involves: (1) a vertical movement equal or slightly greater than the height of the pile, (2) a horizontal movement over the top of the pile, so that the object is properly centered, and (3) the release of the object into the desired position. Some of these movements may be eliminated if the route of the conveyance is on a higher level than the top of the pile, rather than on the same level as the base.

In loading and unloading any conveyance, there are two general possibilities:

(1) The conveyance may be stopped and the material entered from the top, ends, sides, or conceivably the bottom. The loading process may often be facilitated by stopping the conveyance in a position that minimizes the handling necessary for piling or pouring. For example, freight cars may be loaded from a platform which is at a level with the floor of the car, and a freight elevator may be continually lowered to keep the top of the pile at a level with the floor, eliminating the necessity of lifting the materials to place them on the top of the pile.

(2) Material may be placed in a position so as to be picked up by the conveyance as it moves along. (Materials which are delicate or fragile are not adaptable to this type of loading.)

Much laborious piling may be reduced by the use of tote boxes or movable racks. For example, materials may be piled beside a processing machine as they are moved by the operator, then repiled on an industrial truck for transportation to the temporary storeroom for drying, piled again from the truck to the storeroom racks, and later piled onto a truck for transportation to the next process. But if they are piled on a movable rack as they are taken from the first process, this rack may be taken to the storeroom, left there, and then moved to the next process, where it is unloaded by the operator as he feeds his machine.

STANDARD MATERIAL-HANDLING EQUIPMENT

Various types of material-handling equipment listed may be purchased from concerns who specialize in this field. The following list is not intended to be exhaustive, because there are innumerable combinations and adaptations.

Tote boxes, skids, and pallets. Great economy of effort is achieved in moving small objects when they are placed in larger containers. Tote boxes and baskets are temporary containers which may be easily moved, and sometimes have interlocking features so that they form stable piles; that is, ridges and grooves, or pegs and holes, on adjoining surfaces of the boxes prevent them from sliding horizontally when they are piled (see Fig. 103).

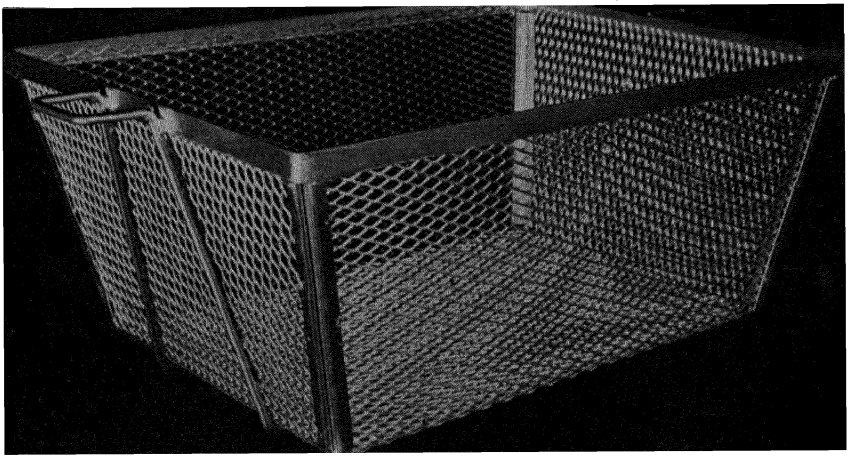
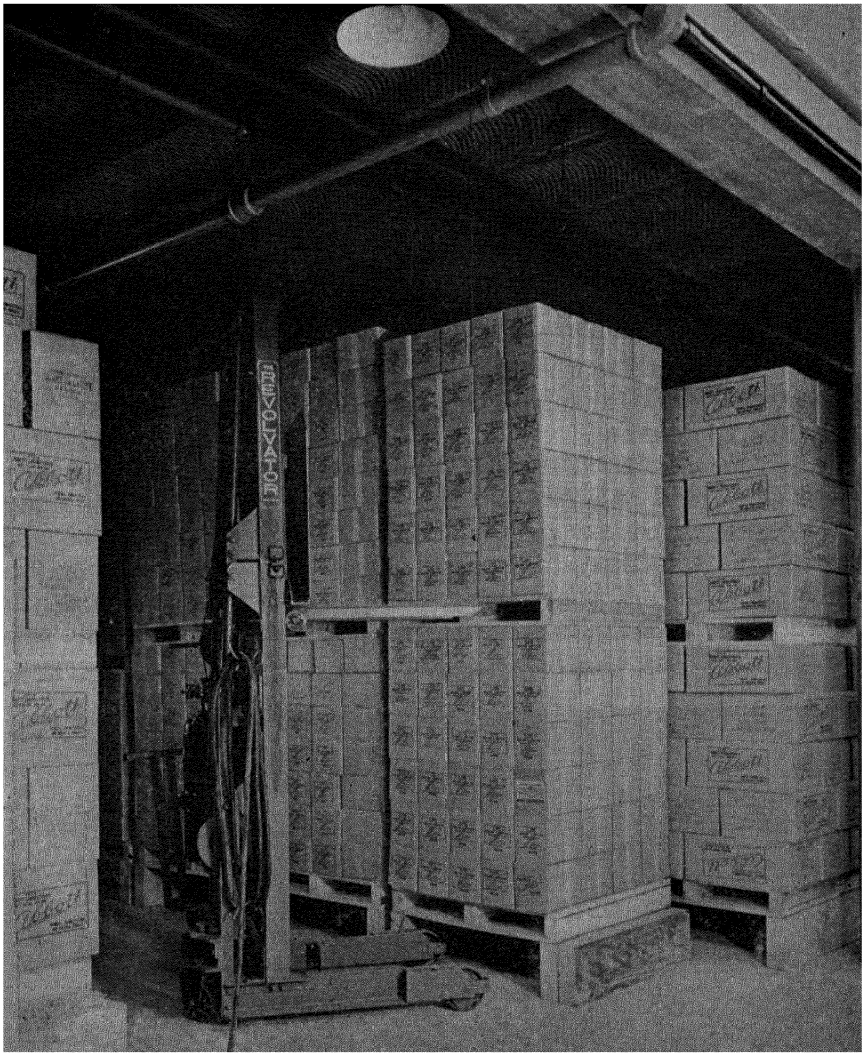


FIGURE 103. ANGLE FRAME TOTE BASKET *Courtesy Consolidated Expanded Metal Cos.*

A skid is a material container with short legs that elevate it from the floor so that a better purchase may be had for piling, loading, and unloading. Many skids are nothing more than small, low platforms; others may be special types of boxes or racks (see Fig. 104).

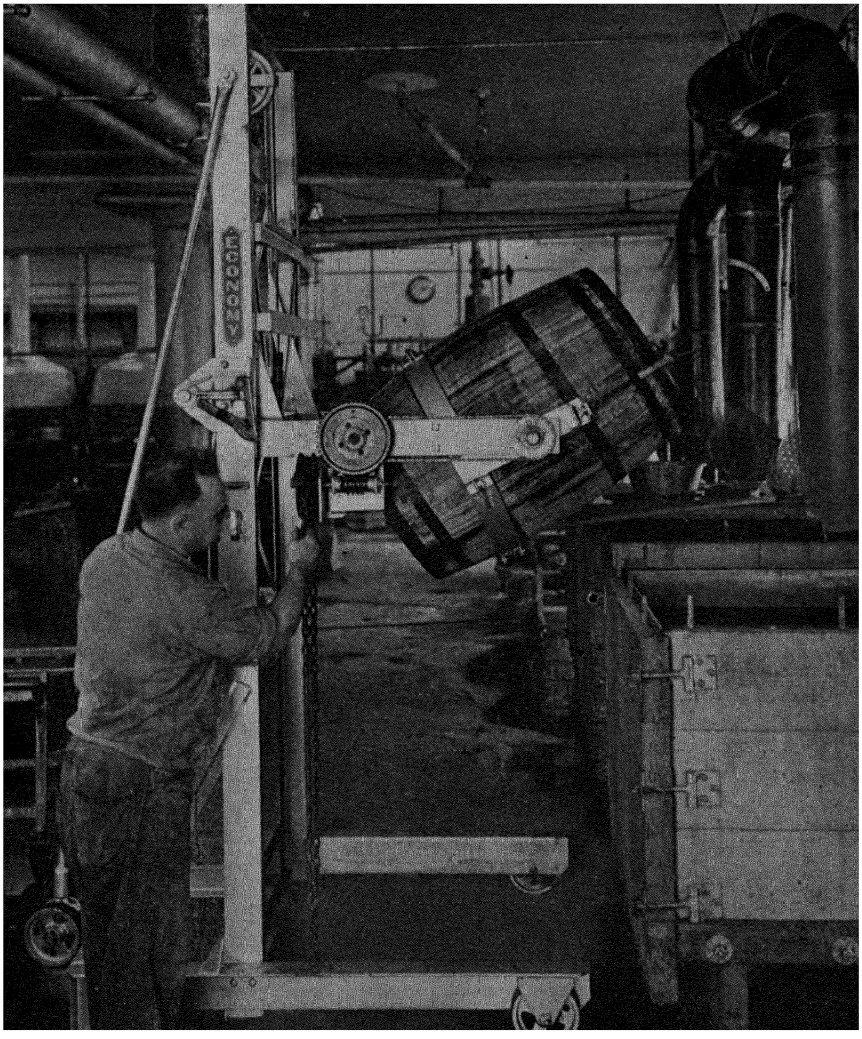


Courtesy Revolvator Co., and John E. Williams & Son, Boston

FIGURE 104. PHOTOGRAPH OF STORAGE AREA SHOWING LIFT FORK TRUCK, DETAIL OF SKID PLATFORMS AND PALLETS

Skid platform is next to platform and wheels of truck. A fork which may be elevated is about to be inserted into a pallet. Pallets facilitate piling.

The pallet is a refinement of the skid. It usually consists of two flat surfaces a short distance apart, so that it is a very shallow box with open ends. Materials placed on pallets are readily piled and moved by lift forks, and loads moved on pallets may be formed into more stable piles because the pallet provides a flat bearing surface for the upper load and spreads the weight over the top of the lower load (see Fig. 104).



Courtesy Economy Lifters

FIGURE 105. PICTURE SHOWING SPECIAL TRUCK CALLED A LIFTER WITH CRADLE AND TILTING WINCH

Hand-operated vehicles. There are a great variety of ways in which wheels and boxes or racks may be combined. These include the wheelbarrow, the cart, the baggage truck, the barrel truck, the rack truck, the platform truck, and numerous other combinations which are designated by trade names. These vehicles may be pushed or pulled by hand, or used in connection with power vehicles.

It is important to note that hand-operated equipment is not completely eliminated by more complicated mechanical devices. The simpler equipment will always possess greater flexibility because special tracks do not limit the extent of its operation; less skill is necessary on the part of the operator, and maintenance requirements are negligible. For this reason, hand equipment is a useful reserve for taking care of peak loads and periods when other equipment is under repair.

If an ordinary flat hand truck is provided with a surface which may be raised or lowered slightly, it becomes a *lift truck.* With the platform in the low position, the truck may be driven under a skid, and the skid loaded onto the truck by raising the platform, thereby eliminating the labor of lifting the load, carrying it over the surface of the truck, and placing it in position (Fig. 104).

Power vehicles. Gasoline and electric trucks have a wide application in internal transportation systems. As is the case with hand trucks, they may be fitted with a variety of containers, boxes, and racks for carrying different kinds of material. Hoisting and loading devices may also be connected with the same sources of power, greatly facilitating the loading and unloading, which is often more laborious than the actual transportation (see Fig. 105).

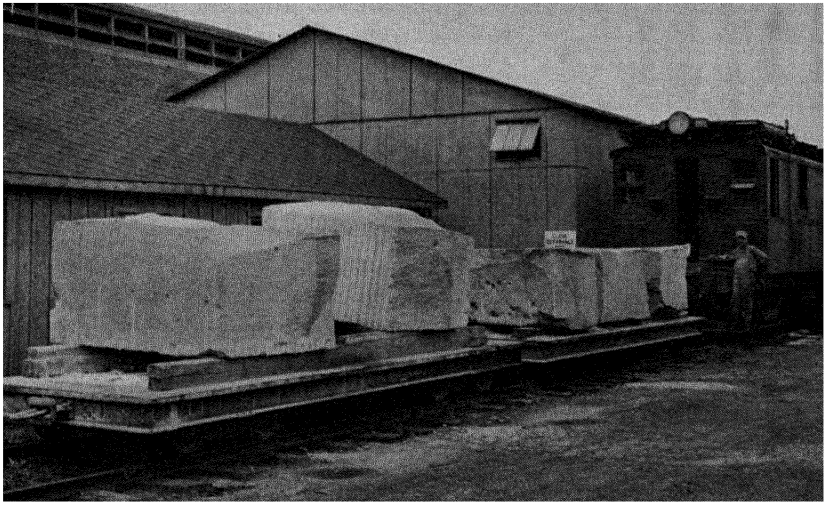
Trains of tractor-drawn trailers (Fig. 106) are particularly well adapted where bulky and heavy materials must be moved considerable distances. The path of movement should avoid back tracking, and the material movement should be subject to a handling schedule.

One of the recent and useful developments in this field is the lift-fork truck (Fig. 104). This truck is equipped with a lift fork which may be raised from the ground level to a height of several feet. The lift fork is inserted in a pallet or underneath a skid, and the load carried on the fork or placed on a trailer (Fig. 104). At the end of the trip, the loaded pallet is placed on the floor or on top of a pile by adjusting the height of the fork and moving the truck. The lift fork is in effect a small elevator that can be slid underneath the load to be lifted.

Industrial railroads. The use of rails, rather than an open roadway, permits the use of longer trains and heavier loads on each car. Gasoline or electric engines are often used with a standard-gauge track so that material may be shifted from the internal to the external system without reloading (see Fig. 107).

Courtesy Baker Industrial Truck Division of the Baker-Raulang Co.

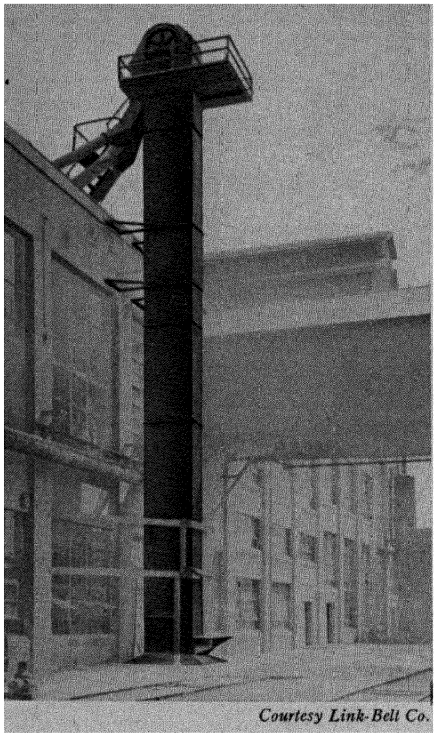
FIGURE 106. ELECTRIC TRUCK PULLING LOADED TRAILERS



Courtesy Easton Car & Construction Co.

FIGURE 107. INDUSTRIAL RAILROAD SHOWING A FREIGHT CAR CARRYING GRANITE BLOCKS

Elevators. Ordinary elevators provide straight vertical transportation over a path that is determined by the construction of the building. The cost, inflexibility, and potential danger of elevators has led to the introduction of many other devices to provide vertical transportation. However, it is doubtful if elevators will ever be entirely eliminated; they are a major item in the design of any multistory plant (see Fig. 108).



Courtesy Link-Belt Co.

FIGURE 108. ENCASED BUCKET ELEVATOR

Used to lift lime received on railroad cars to overhead storage.

Ramps and chutes. By means of ramps, material-handling trucks may move from floor to floor, avoiding the necessity of unloading onto an elevator and loading onto a truck again. Furthermore, there is no mechanical equipment requiring constant inspection and maintenance. Ramps require more floor area than elevators, and ordinary floor trucks may not have the power to ascend ramps when they are loaded.

Chutes (Fig. 109) utilize and control the pull of gravity to move objects from one level to a lower one. The steepness of the chute will be limited by the danger of breakage to the material being delivered. Side walls control the direction of descent, and a reverse grade at the bottom will bring objects to a stop at the desired location.

A combination of chutes and elevators is frequently used, elevators moving raw material to the top floor, where it is processed and dropped into chutes (see Fig. 108).

Roller conveyors. When rollers are attached to a drop chute, articles may be moved over a long horizontal distance at a slight pitch. Continuous movement in one direction is obtained with the expenditure of very little mechanical energy (see Fig. 110).

Spiral chutes. When material is to be moved vertically downward, it is often inadvisable to let it fall freely; some means of control must be used. Elevators are expensive, and straight conveyors occupy considerable floor space. Spiral chutes overcome these two difficulties.

Courtesy Department of Public Relations, General Motors Corporation

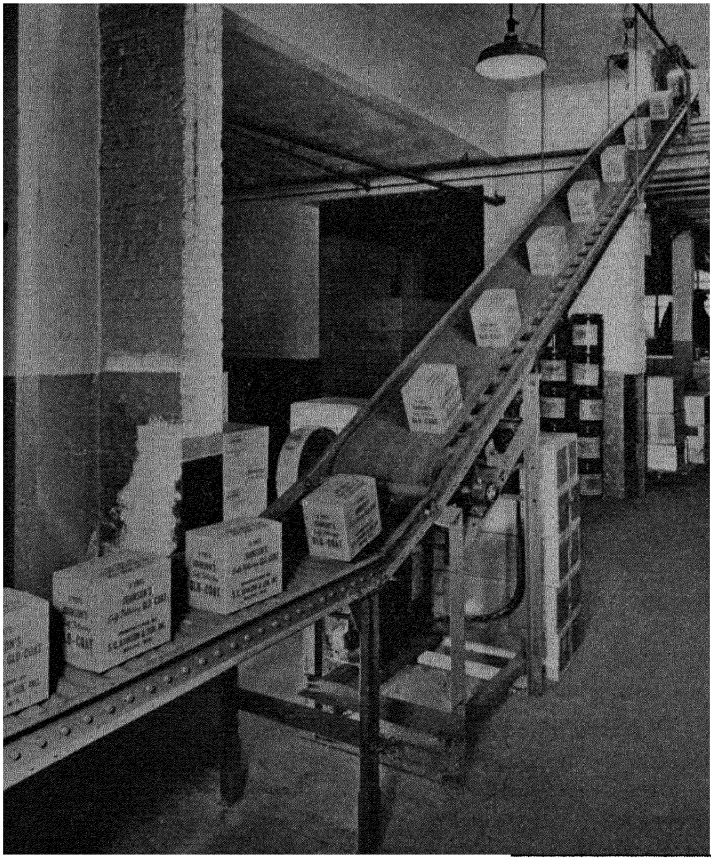
FIGURE 109. SCRAP MATERIAL STARTS ITS TRIP TO MORE USEFULNESS AT THE PONTIAC MOTOR DIVISION, PONTIAC, MICHIGAN

Steel scrap being loaded on a conveyor belt. It will be baled and sent to the foundry for use.

Moving conveyors. There are many types of conveyors which may be used for horizontal or vertical transportation. Ordinarily, the material must be placed so that it is picked up by the conveyor, although special types of loading conveyors may be moved so that they "eat" into a pile of bulk material. All moving conveyors consist of some sort of belt or chain moving continuously over two or more pulleys. Belt conveyors may be either flat or troughed. Slats, hooks, buckets, or scrapers may be attached to chains (Fig. 111). What is known as a "flight conveyor" (Fig. 112) consists of a series of scrapers or flights attached to a chain which travels through an enclosed channel, carrying the material along with it. These flight conveyors may be used for both horizontal or vertical transportation, can turn corners, and eliminate dust and fumes.

Screw conveyor. A rotating spiral surface inside a tube will move materials through the tube (Fig. 113). Mixing blades may be attached to mix materials in transit.

Pipelines and canals. Pipelines are closely related to flight conveyors. The direction of flow is controlled by the sides of the pipe or canal, and the material is moved by differences in pressure. Not only fluids, but solids suspended or dissolved in fluids may be moved also through pipes or canals.

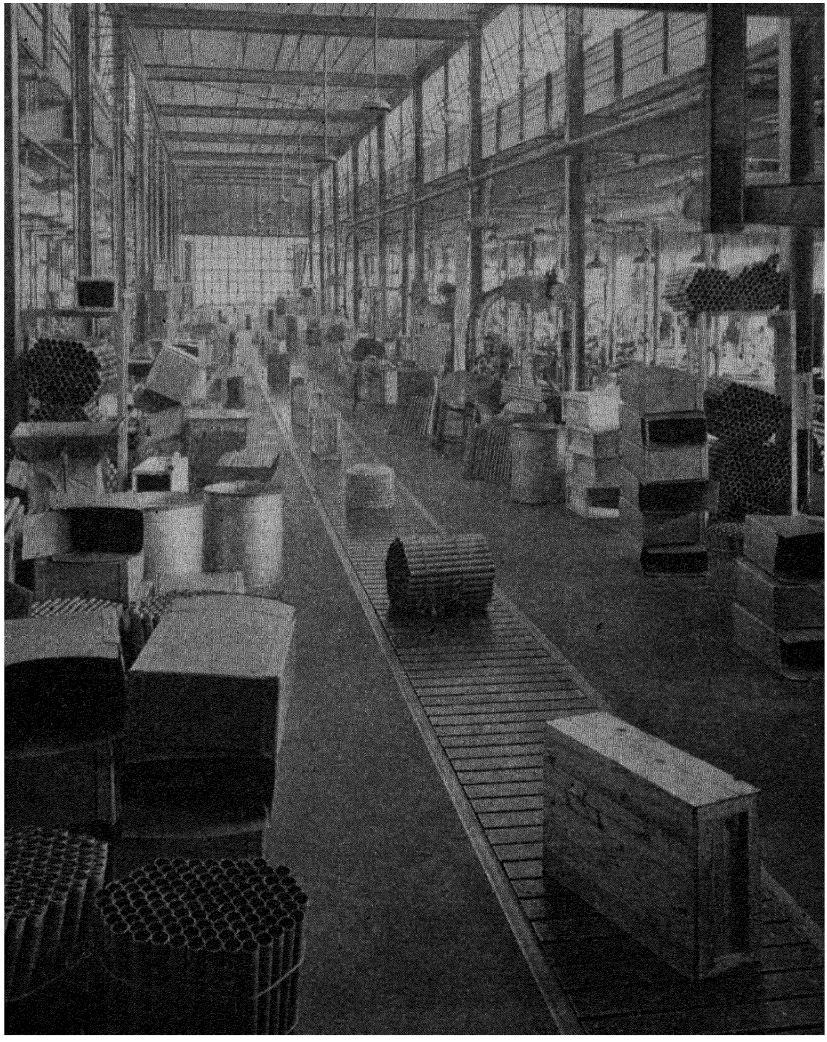


Courtesy Lamson Corporation

FIGURE 110. COMBINATION BELT AND ROLLER CONVEYOR

Overhead handling equipment. Overhead handling equipment may often be used to advantage because floor area is freed from productive operations. Piling and dipping operations are simplified.

Jib cranes. The most flexible apparatus for lifting material is the moving jib crane. Mounted on a tractor tread or railroad wheels, it can move material within the radius of the jib and the length of the roadway (see Fig. 114).



Courtesy Lamson Corporation

FIGURE 111. SLAT CONVEYOR INSTALLED IN SEALRIGHT COMPANY, FULTON, NEW YORK

Monorail. Perhaps the simplest form of overhead handling installations is the hand-operated monorail system in which a trolley hoist is suspended from an overhead track (Fig. 115). With this device, material may be picked up and moved in either direction beneath the track.

With a power drive attached to the trolley, many tons may be carried at one time.

Overhead moving conveyor. A continuous chain may be suspended from an overhead rail and driven by a stationary motor. Material to be moved is attached to the moving chain (see Fig. 116).

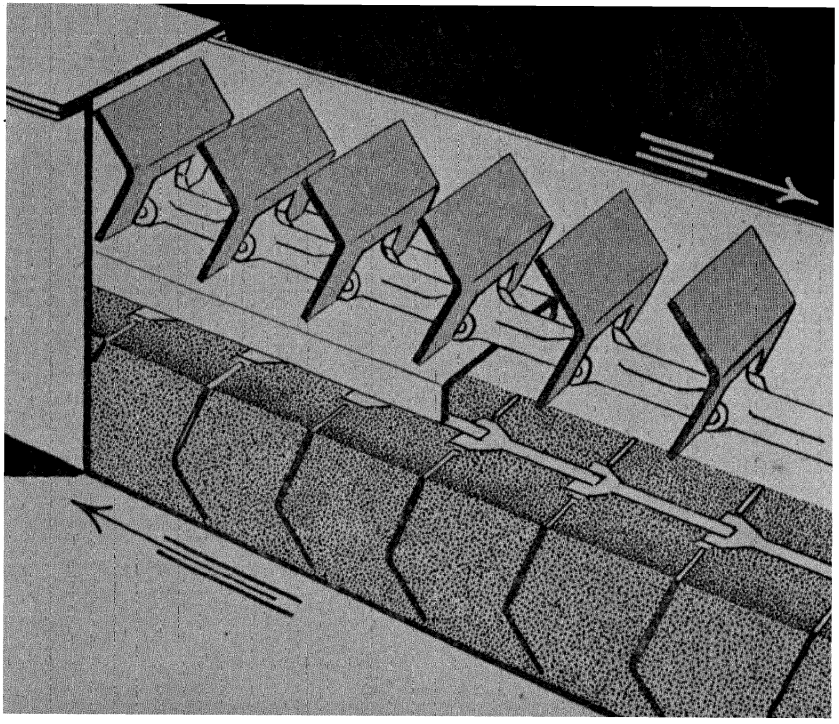
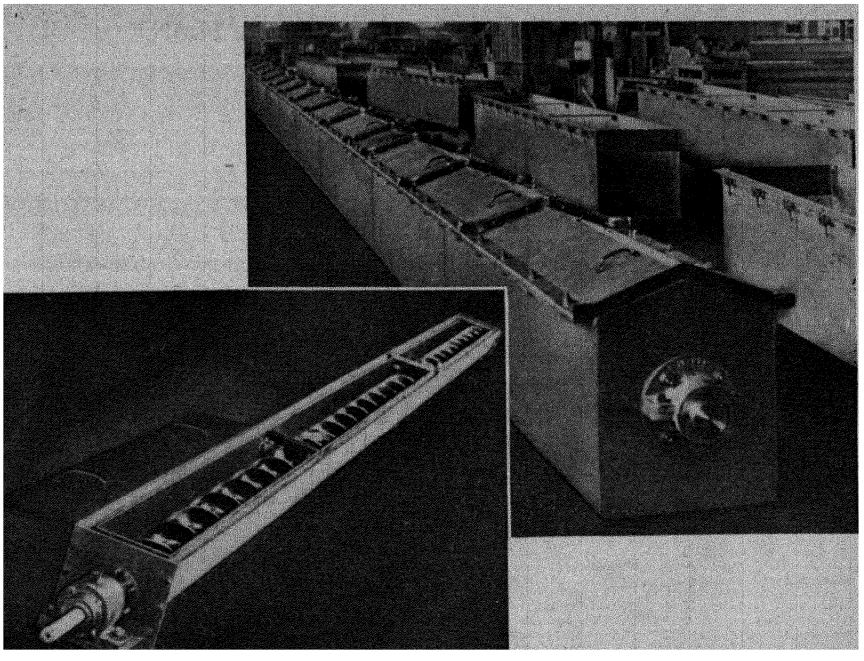


FIGURE 112. FLIGHT CONVEYOR *Courtesy Link-Belt Co.*

Overhead traveling crane. A moving "bridge" is suspended between two parallel overhead rails, and a trolley hoist runs along the span of the bridge. Materials may be moved anywhere within the area defined by the length of the rails and the width of the bridge (see Fig. 117).

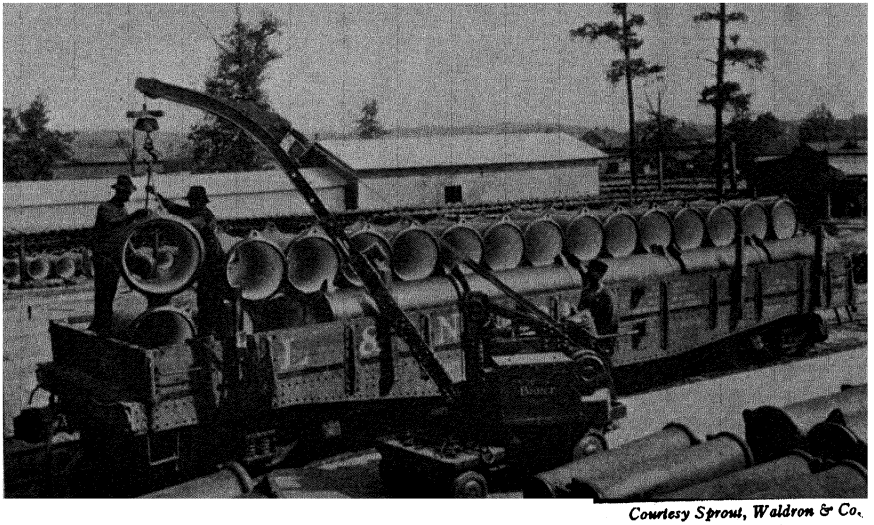
CALCULATIONS OF QUANTITIES OF EQUIPMENT NEEDED

In planning the layout of an industrial plant, those charged with the solution of material-handling problems must decide not only the type of handling equipment best suited to bring efficiency to particular manufacturing processes, but also in what combinations and quantities equipment must be procured to do the job. The relative advantages of



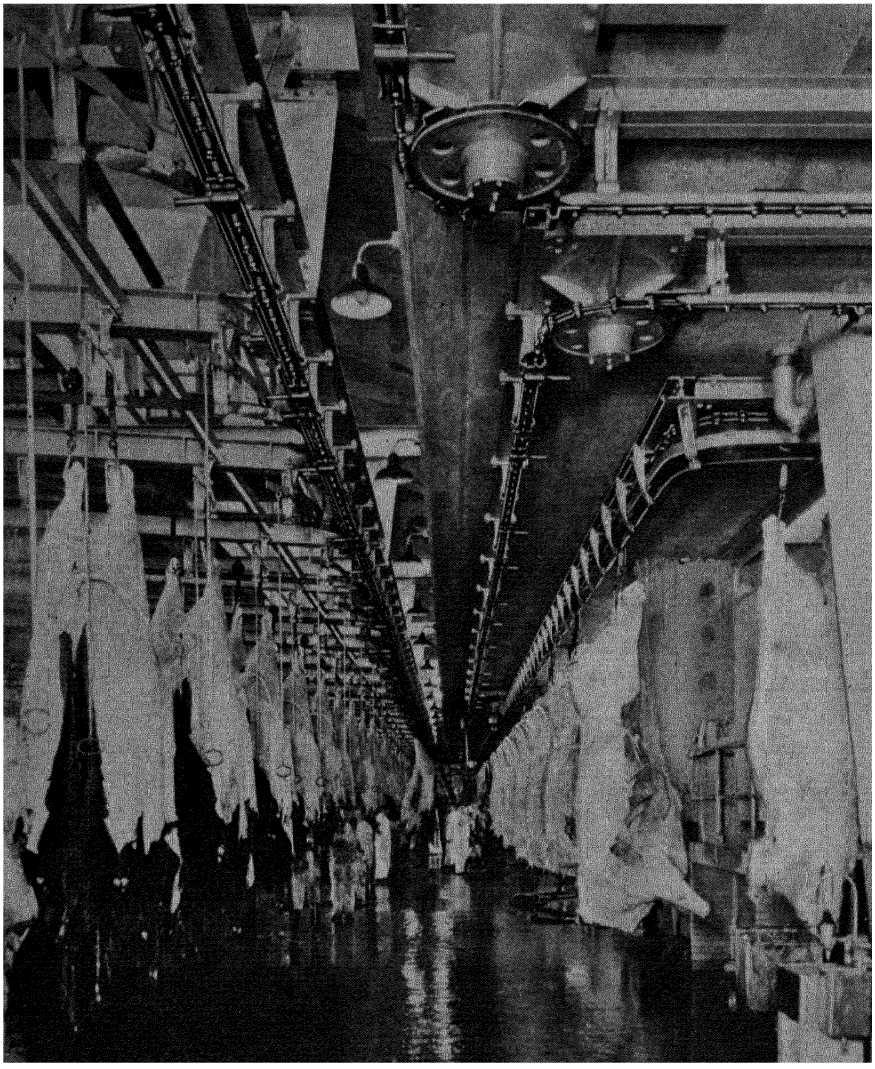
Courtesy Sprout, Waldron & Co.

FIGURE 113. SCREW CONVEYOR



Courtesy Sprout, Waldron & Co.

FIGURE 114. JIB CRANE BEING USED TO LOAD RAILROAD FLAT CAR



Courtesy Link-Belt Co.

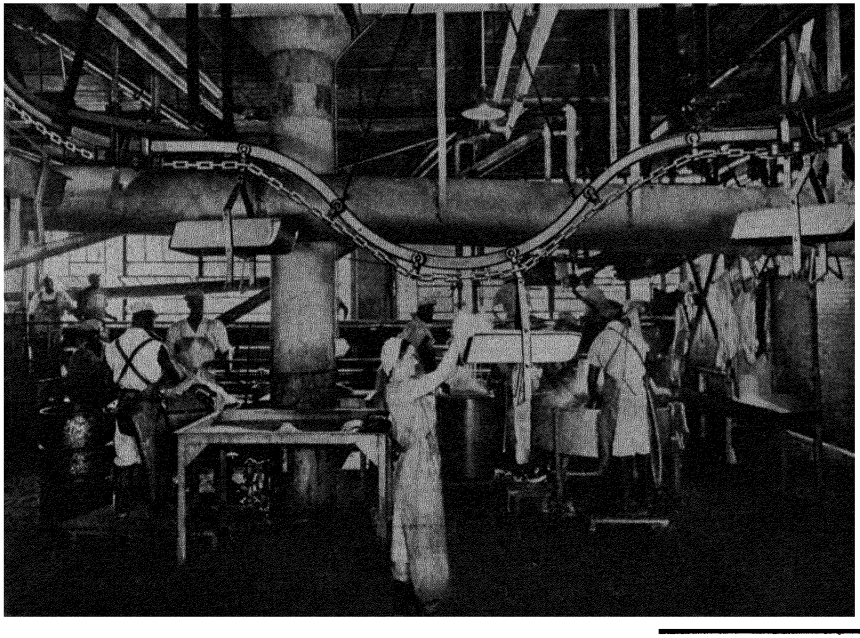
FIGURE 115. MONORAIL SYSTEM STEEL CHAIN PUSHER TYPE OVERHEAD CONVEYOR WHICH IS AN ADAPTATION OF MONORAIL SYSTEM

hand versus mechanical equipment, as well as competing types of mechanical equipment, must be weighed carefully.

Managers can secure needed advice on these problems by calling upon the technicians who work for sales organizations and manufacturers of the many types of handling equipment. Professional consultants with widespread experience are helpful in this connection

also. Any recommendations on material-handling problems, however, should include specific information on the following:

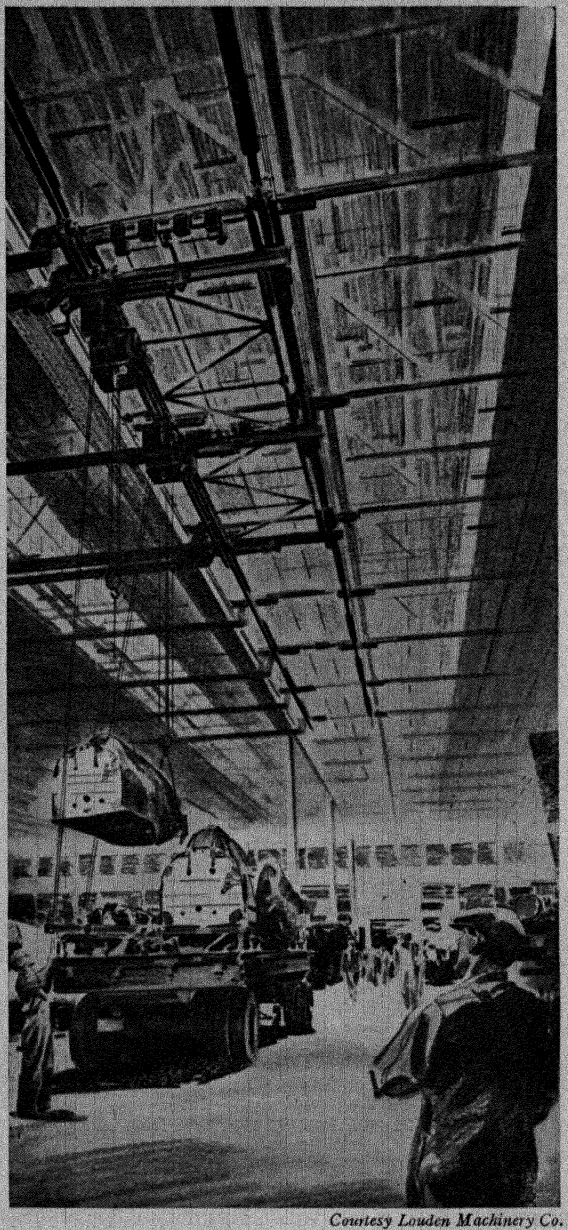
1. **What** — the nature of the handling problem and the approach used to reach a solution.
2. **Why** — the suitability of the equipment available as proved by use; and advantages of alternative equipment.
3. **How much** — the initial financial outlay required, fixed charges to arise from ownership as well as operating costs including power service, operators, and maintenance.



Courtesy Link-Belt Co.

FIGURE 116. CHAIN CONVEYOR — OVERHEAD TROLLEY CONVEYOR

In many problems, a particular type of equipment will suggest itself immediately as a desirable solution — overhead cranes, combination hoists and cranes, monorail systems, trucks, or conveyor belts. Since material-handling equipment is expensive, however, management cannot afford to make installations which must be modified or completely replaced because their selection was primarily experimental or guesswork. Therefore, it is of value to all managers to know the various types of equipment available for use, and to the mechanics in calculating how many units of each type will be required. Calculations will involve these data: (1) the amount of material to be moved between departments or work stations; (2) the times when movement is to take



Courtesy Louden Machinery Co.

FIGURE 117. OVERHEAD CRANE

place; (3) the total length of the time in which materials must be moved during the working day; (4) the capacities of equipment selected to do the handling; (5) the size of the units involved in the handling; (6) limitations imposed on motor power of handling equipment if it is to be vehicular, that is, grades and distances to be traveled; (7) extra units needed in case of breakdown; (8) auxiliary equipment for loading, such as trailers, skid platforms, pallets; (9) number of trips or moves equipment can make: $\frac{\text{distance}}{\text{speed}}$; (10) number of attendants required; and (11) operating costs.

Those who use these data to solve material-handling problems and those who pass on the recommendations will be greatly aided in their judgment by having knowledge of how to combine them in arriving at solutions.[1] Common among the types of equipment where calculations based on the above information are necessary are trucks or tractors and trailers, and various types of conveyor belts. A brief discussion of each is presented below:

Trucks or Tractors and Trailers

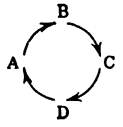
This type of equipment is used where materials to be moved are heavy and where it is not always convenient to load and unload according to some predetermined material-handling schedule. Heavy castings and sheet metals are examples. Tractors and trailers are used to best advantage also in plants where distances to be traveled are considerable and where floor surfaces and aisle widths allow use of vehicular transportation. Trailers may be drawn by either electric trucks or trucks with gasoline motors. In the latter instance, they should be used only where fumes will not be annoying and perhaps fatal to those working in the plant. Wherever trucks and trailers are used, there should be a well-designed material-handling schedule. Extra trailers should be provided to be loaded in different departments and these picked up and dropped at particular times so that departments may know when movements are to take place. Moreover, there should not be any backtracking, which means that movements should be straight forward. The first step, therefore, in a solution of a problem of this kind is to work out a material-handling schedule for a working day. Figure 118 sets forth the materials to be moved among four manufacturing departments, A, B, C, and D, and then translates these data into a material-handling schedule form which is typical of those used by traffic departments in industry. This schedule reveals the maximum quantities to be moved

[1] Many of the technical problems which may arise (power requirements, friction losses, metals used in equipment) will have been settled prior to this stage of calculation. This is best left to recommendations of technical experts.

Average tonnage of materials to be moved among four departments, A, B, C, and D during working day as follows:

Time	*Originating Dept.*	*Receiving Dept.*	*Quantity*
8-hr. day	A	B	35
8-hr. day	A	C	40
8-hr. day	B	C	25
8-hr. day	B	D	30
8-hr. day	C	A	25
8-hr. day	C	D	40
8-hr. day	D	B	35
8-hr. day	D	A	40

When trucks or tractors and trailers are to be the material-handling device, the schedule works smoothest when there is no backtracking, that is, materials going to departments precede those which are sending them on the route schedule, must go straight through successive departments of the entire circuit of travel until designation is reached.



Where there is no backtracking, the above data may be scheduled as follows:

Originating Departments	*Receiving Departments*			
	A	*B*	*C*	*D*
A	×	35	40	
B		×	25	30
C	25		×	40
D	40	35		×

Examination of this schedule reveals that the maximum load to be handled during a working day between all departments is as follows:

From A–B	*From B–C*	*From C–D*	*From D–A*
A–B = 35	B–C = 25	C–D = 40	
A–C = 40	A–C = 40		
D–B = 35			
110	B–D = 30	B–D = 30	
	95	C–A = 25	C–A = 25
		95	D–A = 40
			D–B = 35
			100

105 = the maximum load. Amount of equipment sufficient to handle it will take care of all other handling requirements between any two departments in this plant.

FIGURE 118

between any two given points of the entire route during a working day, including all shifts. If a sufficient amount of equipment is provided to move the maximum load between two points, the same equipment will be adequate to handle any quantity under the maximum so long as the schedule is not altered or upset by special requirements (moving part of the materials at a time contrary to schedule).

In addition to working out the schedule and finding the total maximum tonnage to be moved between two points, the following information is necessary to arrive at a correct answer on the number of units (trucks, tractors, and trailers) necessary to meet given material-handling requirements:

1. The length of the working day.
2. The pulling capacity of the carrying device. (This involves calculation of tractive effort [1] in relation to the steepest grade over which the train must be moved.)
3. The weight of the carrying device, or trailer in this instance.
4. The load-bearing capacity of the trailer.
5. The limit on the number of trailers that can be handled in one train and still make curves and bends in the plant.
6. The speed at which the whole train can travel fully loaded. (Only fully loaded units should be used in making calculations.)
7. The distance to be traveled.
8. Time required for hooking and unhooking loaded trailers in departments.

An example of application of the foregoing information follows:

Maximum of total tonnages to be moved between any two departments = 500 tons

Tractor to be used = sufficient tractive effort or pulling capacity to carry 20 tons over ramps with the steepest grades in the plant

Length of working day = 8 hours

Weight of trailers = 4 tons

Capacity of trailers = 6 tons

Number of trailers allowed per train = 2

Speed of the train = 100 feet per minute

Distance to be traveled = 1500 feet

Time required for hooking and unhooking trailers in manufacturing departments = 15 minutes per trip

The calculations are:

$$\frac{\text{20 tons (T.E.)}}{\text{10 tons (fully loaded trailer)}} = \text{2 fully loaded trailers per train per trip}$$

Load for two trailers per trip = $2 \times 6 = 12$ tons

Working day = 8 hours or 480 minutes

[1] Formulae may be found in standard handbooks to calculate weights that can be moved over a given grade of incline by a given tractive effort.

$$\text{Time for each trip} = \frac{1500 \text{ feet}}{100 \text{ feet}} = 15 \text{ minutes} + 15 \text{ minutes (load and unload)} = 30 \text{ minutes total}$$

$$\text{Number of trips} = \frac{480}{30} = 16$$

$$\text{Capacity per day} = 16 \text{ trips} \times 12 \text{ tons per trip} = 192$$

$$\text{Number of trains} = \frac{500 \text{ tons to be moved}}{192 \text{ tons per day per unit}} = 2^{+} = 3$$

This means *three* units of the particular type of equipment are required because a fractional handling unit cannot be used.

Conveyor Belts

Conveyor belts are very useful where materials need to be transported horizontally or up an incline or both together if required. They are useful in handling coal for boiler houses, crushed ores, grated materials, lump rocks and gravel, coke, wood chips, and packages. Conveyor belts generally divide themselves into two types: (1) those that carry bulk — *troughed and flat belts*, and (2) those used to carry packages — designated as *package conveyors*.

The great variety of materials that can be handled successfully by conveyor belts and the varied conditions under which the belts may be operated makes each conveyor-belt installation a special problem. Estimates should be prepared according to the judgment of experienced technicians in this field.

It will be helpful to the students of management, in passing judgment upon recommendations of technicians, to have a familiarity with the type of information needed to solve conveyor-belt problems and the calculations required to determine the number of units needed. Wherever actual installations are to be made, however, it is recommended that conveyor-belt specialists be consulted before final decisions are reached.

Troughed belts. Figure 119 presents an oversimplified picture of the prospective amounts both a troughed and flat-bulk conveyor will carry. Troughed belts can hold quantities *A* and *B* and flat-surface belts quantity *A* only. When capacities are given for troughed belt the amount of the load represented by arc *A* is called "surcharge."

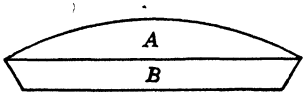


FIGURE 119

The capacity of a troughed belt depends on the quality of the belt used and how material can be piled on the belt to be moved safely. When these are known,[1] the amount a given belt may be expected to carry may be determined. This information is used in turn to calculate

[1] See F. V. Hetzel and R. K. Albright, *Belt Conveyors and Belt Elevators*, 3d ed., John Wiley & Sons, Inc., New York, 1942, Table 8-B, p. 197.

the number of belts, either of standard or different sizes, needed to move any amount of materials between two points. The data follow:

1. Total tonnage to be moved.
2. Width of the belt — this determines size of belt and depends upon type of material to be handled (see Table 8).
3. Carrying capacity — the total load of the cross section per square foot is calculated by consideration of the width and angle of surcharge (see Table 8).[1]
4. Speed of the belt per minute. See Table 9 for speed to operate the belt and Table 8 for quantities and tons moved at 100 feet per minute for materials of varying weights.
5. Length of working day.

An example follows showing the use of the above information to determine the number of conveyor belts needed to handle a given amount of material between two points.

Total tonnage to be moved = 15,000 tons of powdered feldspar weighing 100 pounds per cubic foot
Width of the belt = 30-inch belt recommended
Angle of surcharge = 20 degrees
Speed per minute = 500 feet (see Table 9)
Working day = 8 hours (1 shift)
Table 8 shows that a 30-inch belt having surcharge angle of 20 degrees and traveling 500 feet per minute will carry 815 tons per hour (5×163)
To move 15,000 tons in 8-hour day requires $\frac{15000}{815 \times 8} = 3$ belts of size recommended

Package Conveyor

The conveyor belt is usually the best and cheapest means of transporting light-weight packages, papers, wrapped goods, pottery, and the like. The quality of the belting used on the package belt conveyor varies with what is to be moved. Belts that are used to carry light goods are usually solid woven of a thickness corresponding to four-ply rubber belts. Where boxes and heavy parcels are to be conveyed, the belt surface needs to be toughened in order to withstand blows and scratches. Some such material as stitched canvas, soaked in linseed oil and painted with a paint made of a drying oil and a mineral pigment, is satisfactory.

The capacities of package conveyors are much less than belts designed to handle bulk materials. The service is frequently intermittent rather than continuous. Speed seldom exceeds 105 feet per minute. The belt width is frequently determined by package size rather than quantity to be handled. The carrying capacity is sometimes determined by the

[1] *Ibid.*

TABLE 8. CARRYING CAPACITY OF TROUGHED BELTS WITH A UNIFORM FEED[1]

Width of Belt, inches	*Angle of Surcharge, degrees*	*Total Load Cross Section square, foot*	*Tons of Material per Hour (2000 lb.) at 100 f.p.m. for Material Weighing in Pounds per Cubic Foot*					
			35	*50*	*75*	*100*	*125*	*150*
14	10	0.074	7.84	11.2	16.8	22.4	28.0	33.6
	20	0.096	10.0	14.3	21.5	28.7	35.8	43.0
	30	0.117	12.2	17.5	26.3	35.1	43.8	52.6
16	10	0.101	10.5	15.1	22.7	30.3	37.8	45.4
	20	0.131	13.7	19.6	29.4	39.3	49.0	58.8
	30	0.162	17.0	24.3	36.4	48.6	60.7	72.8
18	10	0.134	14.7	20.1	30.1	40.2	50.2	60.3
	20	0.173	18.1	25.9	38.9	51.9	64.8	77.8
	30	0.214	22.4	32.1	48.1	64.2	80.2	96.2
20	10	0.170	17.8	25.5	38.2	51.0	63.7	76.4
	20	0.220	23.1	33.0	49.5	66.0	82.5	99.0
	30	0.272	28.5	40.8	61.2	81.6	102	122
24	10	0.257	26.9	38.5	57.8	77.1	96.3	116
	20	0.332	34.8	49.8	74.7	99.6	125	149
	30	0.410	43.0	61.5	92.2	123	153	185
30	10	0.421	44.1	63.0	94.5	126	157	189
	20	0.542	57.0	81.5	122	163	203	244
	30	0.669	70.0	100	150	200	250	300
36	10	0.622	65.1	93.0	139	186	229	278
	20	0.803	84.0	120	180	241	300	360
	30	0.991	103	148	222	297	370	444
42	10	0.869	91	130	195	260	325	390
	20	1.12	117	168	252	336	420	504
	30	1.37	143	205	308	411	513	616
48	10	1.16	121	174	261	348	435	522
	20	1.48	155	222	333	444	555	666
	30	1.83	191	274	411	549	635	822
54	10	1.45	151	217	326	435	543	652
	20	1.90	199	285	427	570	712	854
	30	2.33	244	349	524	699	873	1048
60	10	1.83	191	274	412	549	686	824
	20	2.36	247	354	531	708	885	1062
	30	2.91	305	436	654	873	1090	1308

[1] F. V. Hetzel and R. K. Albright, *Belt Conveyors and Belt Elevators*, 3d ed., John Wiley & Sons, Inc., New York, 1942, Table 8–B, p. 197.

speed of discharge — how fast packages can be taken away at the discharge point. This is usually over the end pulley or at some intermittent point. Sometimes discharges are made onto other belts which change the direction of movement of the article conveyed.

Below is a sample calculation to determine the number of belts or belts of the same size as package width needed to move 5000 packages during two 6-hour shifts.

Belt width = adequate for package size
Speed determined by removal at discharge point = 5 packages per minute
Packages handled per 12-hour day on belt = 3600
Number of belts necessary = 2 (to convey 5000 packages)

TABLE 9. RECOMMENDED MAXIMUM BELT SPEEDS — F.P.M.[1]

Material to Be Conveyed	*Belt Width*										
	14	*16*	*18*	*20*	*24*	*30*	*36*	*42*	*48*	*54*	*60*
Crushed material — nonabrasive Coal — earth	300	300	400	400	500	500	600	600	600	600	600
Lump material — nonabrasive Coal — earth	300	300	400	400	400	450	450	450	450	500	500
Crushed material — abrasive Coke — gravel — ore — rock — sand — stone — slag . .	300	300	400	400	500	500	500	500	500	500	500
Lump material — abrasive Gravel — ore — rock — stone — slag	300	300	400	400	400	400	400	400	400	400	400

Select belt speed within normal operating range to permit use of minimum belt width for lump size and tonnage required.

[1] This table appears on p. 1024 of General Catalog 800 of the Link-Belt Company and is reproduced by special permission of Mr. Webster of the Boston office.

CHAPTER XIII

ORGANIZATION AND LAYOUT FOR STORESKEEPING[1]

Many plant managers think of storeskeeping as an adjunct of production control. Consequently, treatises on industrial management deal with the whole subject of storeskeeping as an integral part of controlling manufacturing operations. In the actual operation of the plant, however, a major consideration of storeskeeping is layout of the main storerooms in relation to the production process. Moreover, temporary and permanent storeroom requirements must be recognized constantly in laying out an industrial plant. It is also true that a major function of the storeskeeper is the handling of materials into and out of the storeroom to facilitate the manufacturing process.

The layout and storeroom organization aspects of storeskeeping are treated in this text along with plant layout and material handling. The chapters which deal with the control of manufacturing operations present those aspects of storeskeeping which relate particularly to production planning and cost control.

Storeskeeping is a service of production. Its functions include: (1) accepting for safekeeping and protection all materials and supplies (raw materials, work in process, plant and office supplies); (2) furnishing materials and supplies under authorized requisitions to fabricating and other departments; (3) receiving, storing, and issuing tools used in connection with plant manufacturing processes or plant-maintenance work.

Incident to these functions, the storage areas provide these services:

1. Aging of material in process or raw materials when needed.
2. Holding until needed large stores of raw materials bought at a favorable price for future consumption.
3. Controlling materials manufactured for stock to be used in further production.

Storeroom operation has a direct bearing upon inventory record keeping and the work of the cost department in accounting for materials.

[1] The content of this chapter is based on material prepared for the Ronald Press Company by A. S. Knowles to appear in the revised edition of the *Cost and Production Handbook* to be published sometime during 1943–1944. Permission has been granted by the Ronald Press Company to use this material.

Except as the storeroom does its job efficiently and keeps closely in touch with departments in charge of accounting and inventory records, this work may become wasted effort. (The record keeping and work incident to inventory and cost control are treated in Part V, Production Control.)

The topics of major concern to managers who wish to establish, check, or revise a storeskeeping system as part of the layout of an industrial plant follow:

- Management-cost implications
- Planning for storage
  - Information to be compiled
  - Calculations preliminary to layout of storage areas
  - Location of stores areas
  - Storeroom layout
- Special problems of storeskeeping
  - Maintenance stores
  - Storage of tools and fixtures
  - Material handling

MANAGEMENT-COST IMPLICATIONS

Storeskeeping in an industrial plant has a direct relationship with some problems of industrial administration which bear directly upon profit making and therefore deserve the careful attention of all plant managers:

Maximum Efficiency in the Use of Plant Productive Capacity

The unwise use or location of space provided for storage may deprive a manufacturer of plant area needed for additional productive capacity and manufacturing efficiency. Not only must storage area be laid out effectively in the beginning, but also utilized to best advantage in meeting production requirements. The accumulation of excessive quantities of infrequently used material is an unnecessary tax upon floor area which should be made available for productive use.

Economy in Cost of Materials and Supplies

Materials and supplies cost not only what is paid to get them to the factory, but also the expenses incurred in caring for them until they are used, that is, protecting, handling, and accounting for them. Similarly, the storage of finished goods adds to the total cost of manufacturing. The costs of storage are the overhead expenses (heat, light, taxes) incident to the areas set aside for storage, the wages of storage personnel, the cost of providing both storage and material-handling

equipment for the storeroom, and the interest costs on the value of materials and supplies held in storage.

Maximum Productivity from Capital Investment

Sound storeroom management prevents the accumulation in excessive quantities of any materials and supplies that are readily obtainable. Capital tied up unwisely in ordinary inventories cannot be used productively elsewhere. Moreover, capital invested in inventories may be completely lost to productive use when materials are not properly protected. Typical of capital losses which can be prevented through storage are those arising from damage, deterioration, obsolescence, and theft. (When any portion of capital investment is lost, it merely lessens the rate of return on the entire investment.)

PLANNING FOR STORAGE

The following principles apply not only to the planning of storerooms, but to the layout of store yards or the arrangement of stores adjacent to production operations.

Planning for stores cannot be done by any one formula. The requirements of production, accounting, and so on must be carefully considered and combined to give the solution which is most desirable for the whole plant. To do this, it is first necessary to (1) examine all the factors which may influence the final plan, (2) consider each requirement and its limitations, and (3) determine the combination which will provide maximum service balanced with minimum expense.

INFORMATION TO BE COMPILED

Information on the following topics should be compiled and studied before making definite plans:

1. Services to be rendered
2. Available facilities
3. Stowage procedure with particular reference to stowage control
4. Storeroom equipment

Services to Be Rendered

All the items to be stored should be listed with detail as to:

1. Size and weight of the unit in which the items will be handled. (The unit may be a container rather than a single article.)
2. The maximum number of units which will be stored at one time. This generally is determined by the quantity in each new lot, and the quantity of the old lot on hand when the new lot arrives.

3. Space or special care required in handling and transporting.
4. The place where the material is received and the point(s) at which it is to be delivered.
5. The quantity usually requisitioned and the frequency of requisitions.
6. Special requirements of light, heat, temperature, humidity, ventilation, and protection.

Available Facilities

Plant areas and equipment which will be used in performing these services must be carefully coordinated with the material-handling and storing operations; that is, the methods of transporting material within the plant, as well as the areas available for actual storage, must be taken into consideration.

1. **Area.** Available areas should be listed with detail as to any particular advantages or disadvantages, such as floor strength and nearness to elevators.
2. **Transportation equipment.** Knowledge should be obtained of plant elevators, conveyors, industrial trucks, and other conveying equipment as follows:
   a) *Capacity.* The number of units that can be handled per hour over the proposed distances by the equipment to be used in handling material between the storeroom and production should be determined, as well as
   b) Space required by mobile equipment for straight-line travel, corners, passing, loading, and unloading.
3. Information must be compiled also concerning the legal regulations which regulate the construction, operation, or alteration of plant and equipment, that is, building laws, fire laws, elevator regulations, and so on.

Stowage Procedure

Before proceeding to the actual layout of a stores area, it is necessary to give attention to the *methods of piling* that will be used in actual storeroom operation. These benefits will result: (1) efficient utilization of space; (2) assure complete turnover of inventories; (3) facilitate physical counting; (4) provide flexibility; (5) reduce to a minimum the handling equipment needed; (6) facilitate inspection of materials in storage. (This helps to keep inventory up to date and makes theft readily apparent.)

Definitions

Preliminary to any consideration of methods of piling are the following definitions:

Item: Any one kind of stores; for example, 2-inch round-head wood screws. If a change is made in any one of the above characteristics,

a new item is created, as for instance, when a nickel finish is added to the original screw.

Article: Any single piece, as one 2-inch round-head wood screw.

Pile: A group of units. When the piling is not done systematically, an irregular heap results. Systematic piling may be done with one or more of the forms defined below.

Column: A vertical, regular pile; one unit wide, one deep, and two or more high (Fig. 120).

Stack: A regular pile, two or more units wide, one deep, and two or more high. A cubical stack consists of two or more adjacent columns piled along a straight line (Fig. 121). Stacks may be also pyramidal in form (Fig. 122).

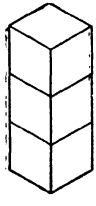


FIGURE 120.
COLUMN

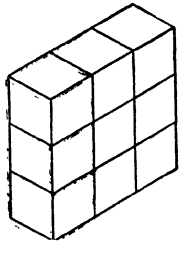


FIGURE 121.
STACK

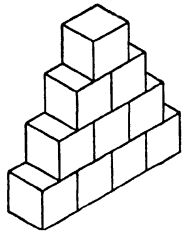


FIGURE 122.
PYRAMIDAL STACK

Tier: A separate unit of a column, or horizontal row — layer — of a stack. Tiers are numbered in the order of piling, from the bottom up (Fig. 123).

Block: A regular pile, two or more units high, wide, and deep. Two or more adjacent stacks (Fig. 124).

Course: The horizontal layer of a block. Two or more adjacent tiers (Fig. 125).

Section: The vertical layer of a block.

Lot: The quantity of units usually ordered at one time and received in one shipment.

Selection of Proper Unit Sizes

It is highly economical to have materials pass from the receiving room to the point of utilization with as little handling as possible. Under an ideal arrangement, goods would arrive at the plant in containers to be stored, issued, and transported to the production department without further packaging or unpacking. This standard size container, rather than the small, individual article, becomes the unit in which the item is handled. Of course, when items are large, such as bags of cement or castings, the unit is also the article itself, but with

small items, small parts, or fastenings, units containing a multiple of articles save labor for the procurement, stores, and accounting departments.

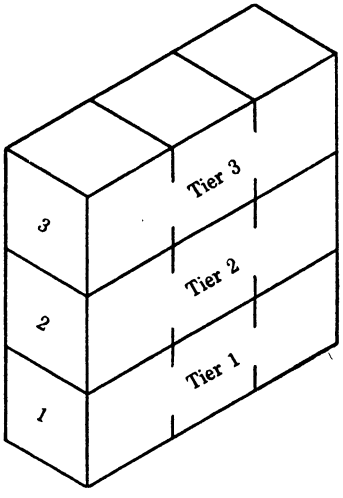


FIGURE 123. TIERS

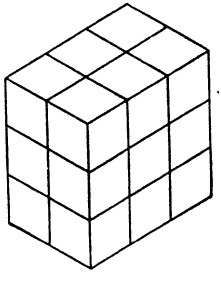


FIGURE 124. BLOCK

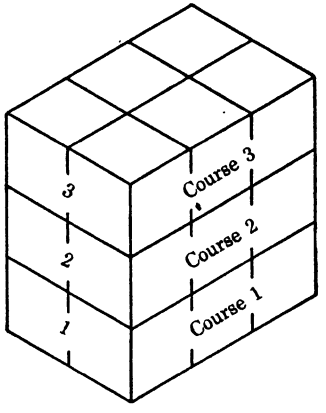


FIGURE 125. COURSES

Methods of Piling

1. Cubical piling. Packages or bags are piled directly on top of each other to form columns and then rectangular blocks. Cubical piling is economical in the use of space; it is easy to keep the piles regular and uniform; the units are easier to count; and there is a minimum of exposure to the weather. Cubical piles should not be permitted to reach a height that will prevent the effective operation of the sprinkler system, and with some types of material, there is danger that a high column will crush the lower units. While the height of cubical piles is often limited by their stability, walls, partitions, and bins may be used to advantage in this respect. In some cases, *mezzanine floors* will greatly increase the capacity of a storage area.

Uniform, cubical piling is much easier to count than irregular, circular, or pyramidal piling. Definite dividing spaces between items, and units placed so that labels are visible, will simplify taking the physical inventory and prevent overstocking. Whenever possible, goods should be piled so that they practically make their own count. This may be accomplished by a number scale painted along the floor or wall, reading in the number of units from the starting point to the edge of the pile. When a moving-division system is used, the total inventory is the difference between the readings at either end of the moving division, subtracted from the total (Fig. 126).

The order of piling and removing must be uniform if the stowage systems are to operate smoothly and neatly. Here again, there is no one best system, but a good one should be adopted and followed. One standard procedure is to begin a column in the back, left-hand corner of an area and come forward with adjacent columns until the predetermined depth of the block has been reached. The next column is then started in the back, to the right of the rear column and the section just completed. The same procedure is reversed in removing. The extreme right front column is first removed, and then the rest of that section, one column at a time. Of course, this procedure must be modified when individual columns are not stable (Fig. 127).

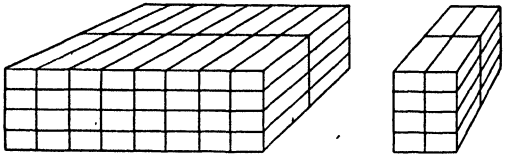


FIGURE 126. PILING TO FACILITATE COUNT

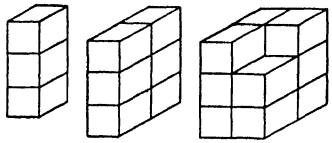


FIGURE 127. ORDER OF PILING AND REMOVING

2. Pyramidal piling. A pyramid form of pile enables round or spherical objects to be placed in a pile which is self-supporting after the bottom layer has been braced. The peaked shape of the pile also renders it easier to protect from the weather. The following formulas give the number of units in pyramidal piles:

For a pyramidal stack:

$$\text{Number of units} = \frac{\text{Number on bottom tier (Number of tiers} + 1)}{2}$$

For a full pyramid:

$$\text{No. of units} = \frac{\text{No. on bottom tier (No. of tiers} + 1)\ (2 \times \text{No. of courses} + 1)}{2}$$

First-in first-out systems. When a new lot of material arrives, it is often piled in front of the old stock, so that the new units are used first. As a result, the packages in the bottom of the stockpile are not removed unless the inventory becomes dangerously low, and then they may be found to be deteriorated or out of date. One solution is to remove all the old stock from the storage area, pile the new stock in the back, then put the old stock back in the front. But this requires tedious extra handling and adds nothing to the value of the material. Several other more practical suggestions are listed below:

a) *Coupon System.* Two coupons are made out for each container. One is attached to it; the storeroom address of the container is noted on the second coupon, and it is placed in the coupon file. When material is requisitioned, the oldest coupon is taken from the file, and its corresponding container is located according to the address on the coupon.

This system is not convenient when containers must be piled in large blocks and all containers are not readily visible or accessible without removing the more recent lots which may have been piled in front.

b) *Double-area System.* While this system is often referred to as the "double-bin" system, this connotation tends to limit the application of the principle to bins only, whereas it applies to any area or equipment used for storage.

The area allocated to an item is twice that required for one lot. As each new lot is received, it is stored in the empty area, but not used until the old lot in the other area has been depleted. But often the additional area or storage equipment required for this system will not be available.

c) *Moving-division System.* This system may be used with goods stored in cubical piles in an oblong area. Goods are removed from

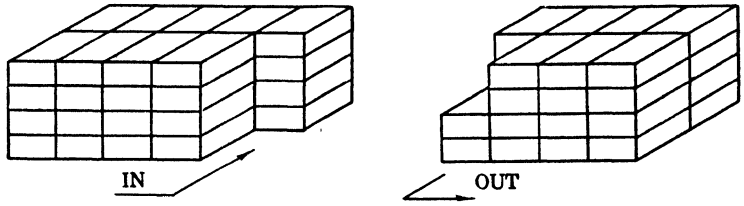


FIGURE 128. MOVING DIVISION SYSTEM OF PILING

one end of the pile, let us say the left, so that as the pile is depleted, the point of removal moves to the right. When a new lot arrives, the pile is started at the extreme left of the area and extends as far to the right as necessary. Sufficient area is allotted to the item so that there is always a dividing space between the piles. Goods are removed from the right of this moving division and added to the left, so that it repeatedly moves across the area from left to right (Fig. 128).

d) *Gravity-feed Systems.* Certain types of materials dispensed in bulk may be stored in gravity-feed storage bins; common examples are grain and coal dispensers. This principle may be applied also to circular package goods by constructing a sloping rack, the pitch of which must be determined by the nature of the units to be stored. Additions are made at the upper end of the rack and removals from the lower end. If desired, a counter may be attached to the rack (Fig. 129). Gravity feed racks are easily constructed and installed.

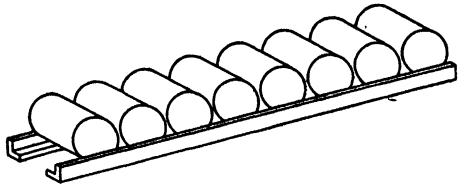
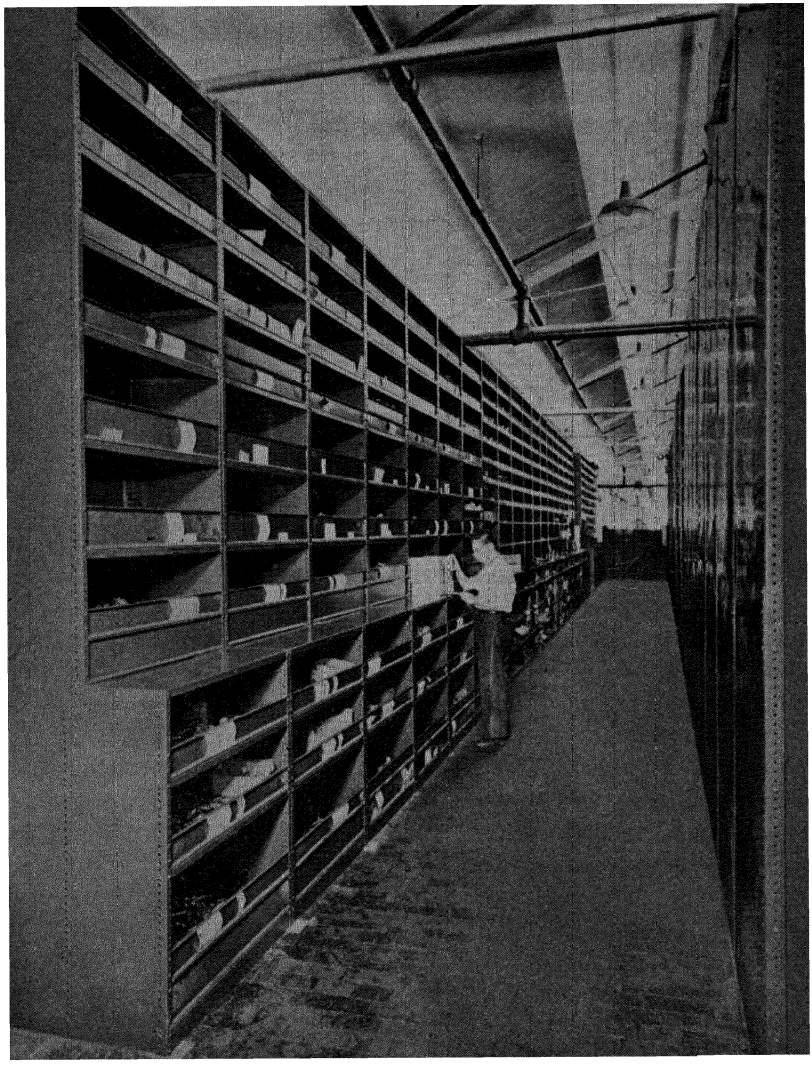


FIGURE 129. GRAVITY FEED STORAGE RACK

Storeroom Equipment

The over-all efficiency and flexibility of the storeskeeping process can be greatly increased by the use of the proper storeskeeping equipment. The maintenance departments of some concerns construct most of the shelving, bins, and so on, designing them to fit the particular



Courtesy Berger Manufacturing Division, Republic Steel Corporation

FIGURE 130. VIEW SHOWING A MODERN STORAGE AREA WITH CONVERTIBLE STEEL SHELVING

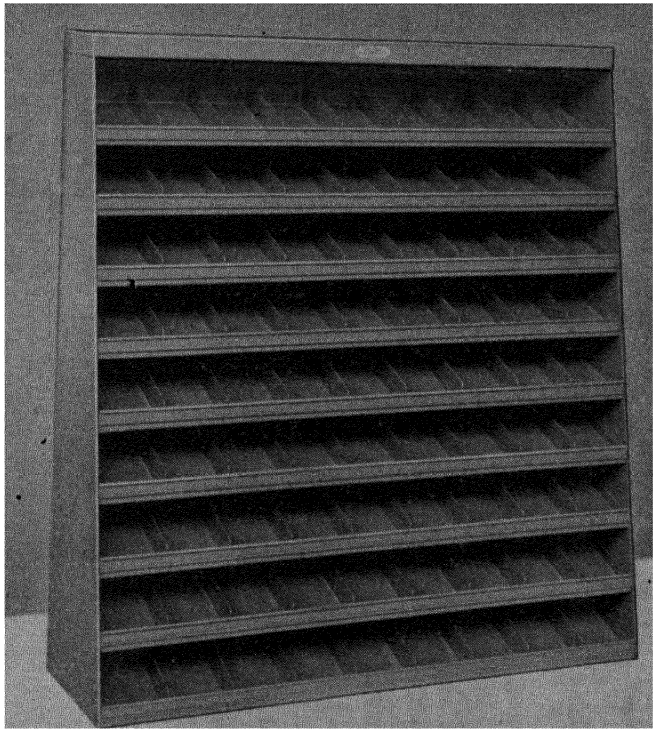
requirements and constructing them with lumber and plywood. When standard equipment is required, it may be purchased from manufacturers specializing in the field. Manufactured sheet-metal equipment has the advantages of strength, durability, and flexibility.

The principal types of equipment are listed below. Most of them may be constructed by maintenance departments or purchased from manufacturers.

When there is an early limit to the height to which units may be piled, or when there is a great variety of items, *open-type shelving* will greatly increase the capacity of the floor area. *Sway braces* may be added if the loading is heavy.

Closed ends and backs added to open shelves give greater stability to piles and may also serve to separate items (see Fig. 130).

When *bin fronts* are added to the above equipment, small, irregular objects may be accommodated. The shelving has now become a series of storage boxes.



Courtesy De Luxe Metal Furniture Co.

FIGURE 131. SLOPING SHELVES AND SHELF SUBDIVISIONS

Courtesy Berger Manufacturing Division, Republic Steel Corporation

FIGURE 132. VIEW SHOWING STEEL SHELVING RACK

The rack includes divided shelves, drawer inserts, lock cabinet, and milling cutter panel (center of picture). Note that milling cutters are supported by milling cutter inserts.

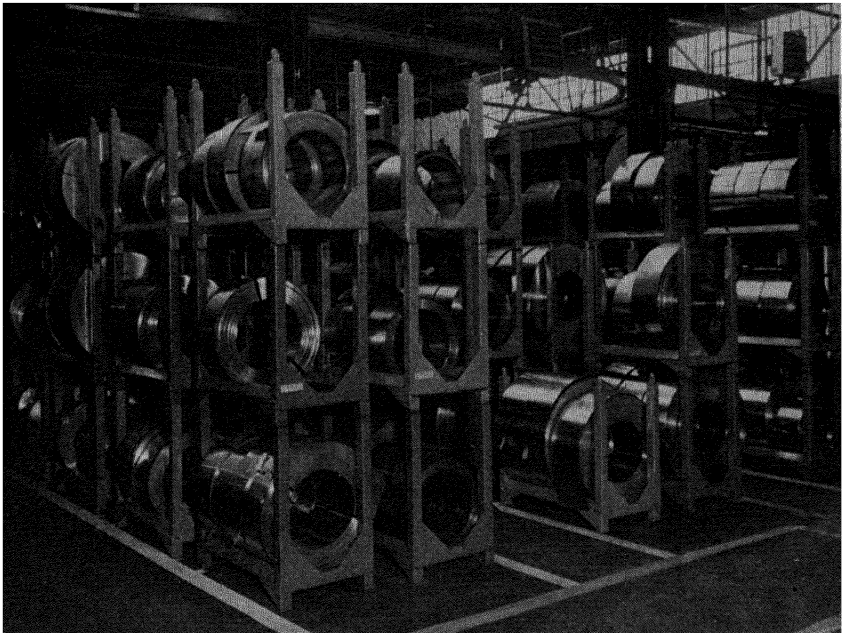
When a small number of many items must be accommodated, *bin dividers* may be inserted to separate the items. These do not give any structural support to the whole assembly.

Combined sloping shelf inserts and *shelf subdividers* are often convenient when each article is different and must be readily visible to facilitate quick selection (Fig. 131).

Counter-height ledges added to any of the above shelving provide convenient temporary storage space when goods are being added, removed, or sorted.

Roller shelves enable heavy articles to be piled and removed with less difficulty.

Doors provide protection against theft and dust. In many cases, sliding doors are preferable to doors on hinges. *Drawer inserts*, in addition, provide greater capacity for small articles than does bin-type shelving, and the drawers may also be removed to function as tote boxes (Fig. 132).



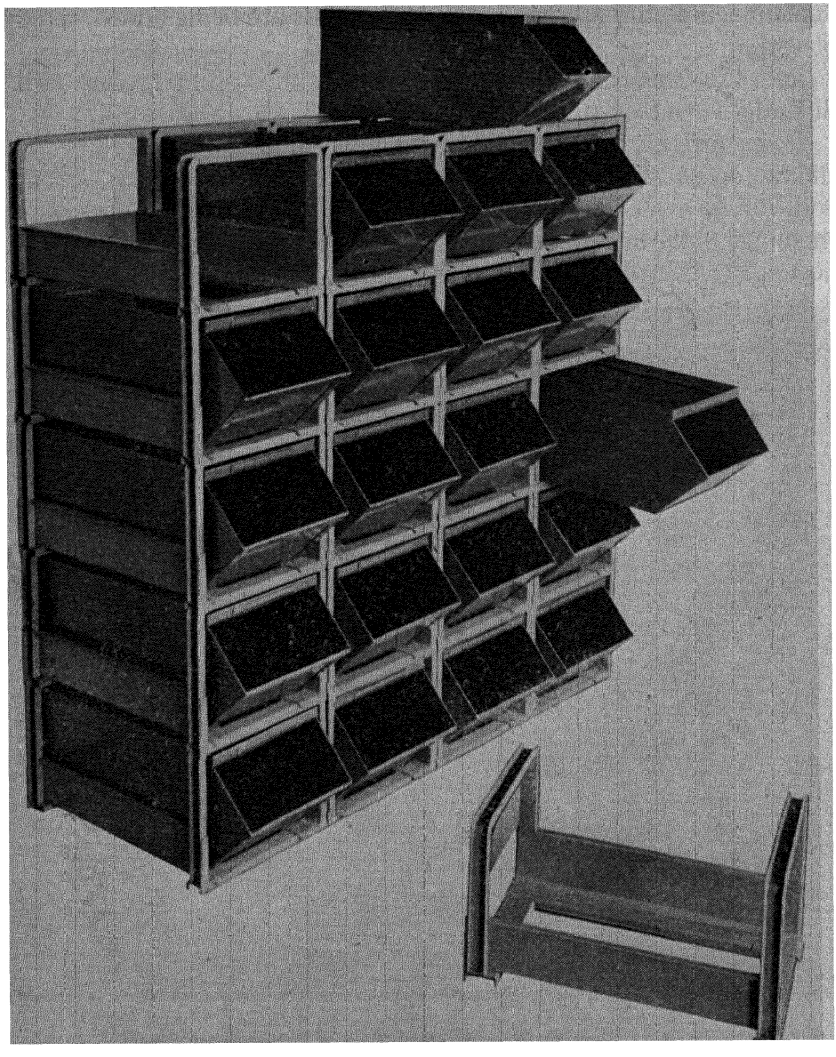
Courtesy Mechanical Handling System, Inc.

FIGURE 133. M. H. S. TIERING STORAGE RACKS FOR COILED STRIP STOCK

Top racks may be moved by means of high lift truck and moved to processing operation. Racks constructed of square welded steel tubing with nested plug welded to top of each vertical member. Stock is kept in order by use of racks and with minimum use of floor space.

Maximum flexibility of shelving arrangements is attained with *stackracks*. Individual units are so constructed that they may be locked firmly together without tools, enabling temporary or permanent shelving to be assembled quickly with a minimum of cost.

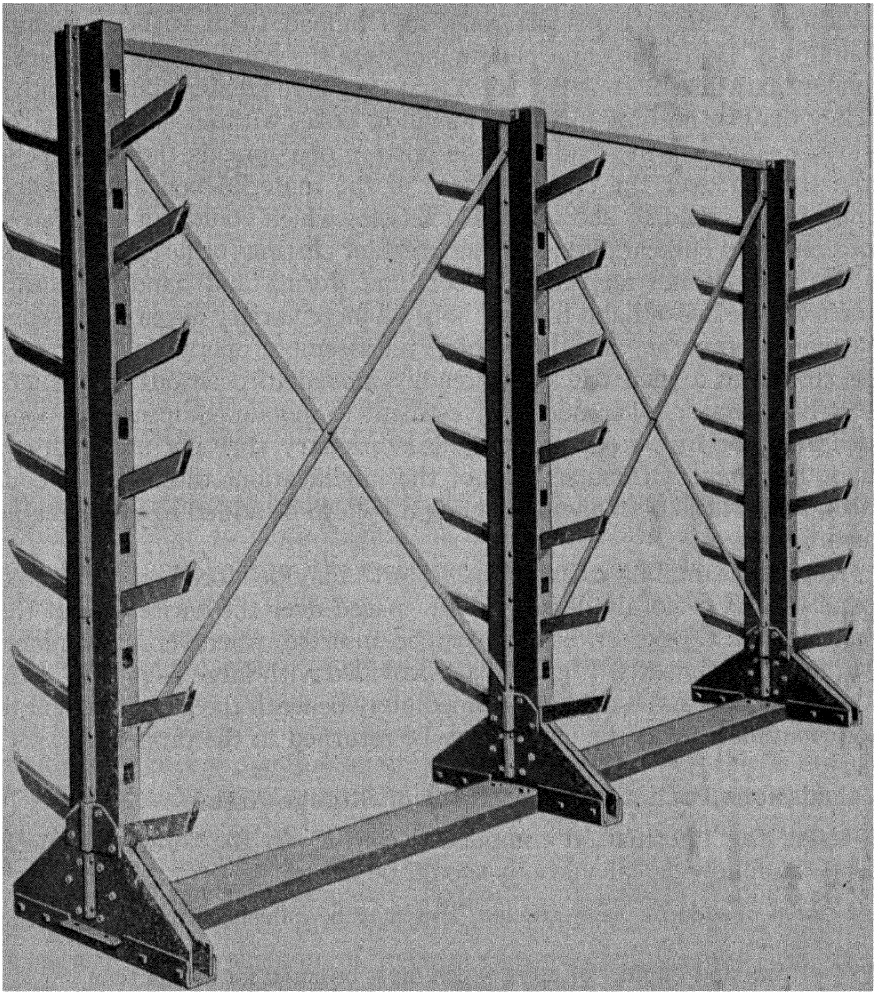
Cylindrical and spherical objects such as coil stock may be supported in racks as shown in Fig. 133. These may be designed to permit tiering.



Courtesy Stackbin Corporation

FIGURE 134. STACKING BOXES WITH DRAW INSERTS AND SLOPING BIN FRONTS
These permit easy storage on assembly floor.

Stacking boxes are essentially tote boxes with an interlocking feature which enables them to be stacked to form a stable, self-supporting pile. They are particularly useful in storing and transporting small articles and fastenings because they may be easily carried and quickly placed in a self-supporting pile for temporary storage. When they contain several different articles, they may be piled on an assembly bench within convenient reach of the operator. Sloping bin fronts permit



Courtesy Berger Manufacturing Co., Republic Steel Corporation

FIGURE 135. RACK FOR PIPES AND LONG METAL BAR STOCK

ready access to the contents of all boxes in any column without unstacking (Fig. 134).

Racks. Racks for lumber, long bar stock, and pipes are essentially posts with horizontal bearing surfaces attached (Fig. 135).

Moving ladders may be self-supporting or guided by a track or cable.

The use of *skids* and *pallets* will improve the efficiency of handling and storing many materials. Bags, cartons, and sheet stock are loaded on skids when unpacked, or even shipped already packed on skids or pallets. High lift-fork trucks are then employed to pick up the loaded skids and pallets, transport, pile, and unload them without manual handling. Both skids and pallets facilitate the handling by lift trucks; pallets may also be constructed so that they give greater piling stability. They may be nothing more than shallow boxes without sides. The top surface supports the load and the bottom one spreads the pressure of the column over the entire surface of the material beneath. Pallets may be designed to accommodate articles which could not be stacked ordinarily in cubical piles, such as irregular castings or large pipe stock.

It is sometimes advisable to combine storing and handling equipment by the use of hand trucks. When a large variety of parts is needed in many temporary locations about an assembly operation, they may be stored on a shelf truck and readily moved to positions convenient for the operator. The added investment in mobile equipment is compensated for by a reduction in the stationary shelving and reduced handling time. Of course, any of the modifications discussed in connection with the permanent shelving may also be added to the portable arrangements.

Keys, tags, milling cutters, and so forth may be stored on perforated panels. The perforations are closely spaced over the entire face of the panel so that pegs or hooks may be inserted wherever convenient. Milling cutter inserts (Fig. 132) are provided with large pegs (Fig. 132) for each cutter and a tag hook immediately beneath the peg to designate the location so that the cutter may be returned to the proper peg.

Calculations Preliminary to Layout of Storage Areas

Using the information compiled according to the foregoing check lists, the following calculations should be made:

1. **Area needed for each article.** This may be influenced by the following factors:
   a) Size and number of units which must be cared for at one time
   b) Methods of piling
   c) System of stowage control
   d) Storeroom equipment used
   e) Special requirements

2. **Size of aisles in stores areas.** The aisles in the storeroom must be sufficiently wide to accommodate the handling of material, not only in straight-line travel, but also around corners, and when loading and unloading.

LOCATION OF STORES AREAS

Centralization vs. Decentralization of Storerooms

The organization and location of storeskeeping areas must depend upon the individual needs of each plant. Even among manufacturers engaged in the same pursuits, the location of stores areas vary greatly. These result from differences in production requirements, plant size, process arrangements, special department needs, and singular building facilities (one- and two-story buildings, scattered plants, and so on). The types, quantities, size, and nature of the materials to be stored also create special problems of storeskeeping organization. Despite these limitations, these basic principles are important:

1. Storeroom areas and arrangements should be developed to provide maximum storeskeeping service at a minimum cost; that is, storeroom placement must serve the convenience of manufacturing processes in keeping with both space and clerical cost limitations.

2. Every storeskeeping organization should provide for a maximum of flexibility in order to meet changing conditions. Plant rearrangements or changes in manufacturing procedures may alter storeskeeping service demands.

When materials are bulky or require special handling equipment, it is often desirable to store them near the receiving department or to move them directly from the receiving platform to production centers where they are used. Bulkiness or weight may require that manufacturing departments be located near points of material ingress.

Materials purchased to order or manufactured to order which are to be used in further production should go directly from the receiving department to the production floor. Care must be taken, however, to provide adequate protection against loss or damage when this is done. There is also some advantage in having decentralized storage or departmental storerooms for items used only by single departments, avoiding unnecessary handling and record keeping.

The centralized storeroom has these advantages: (1) responsibility may be definitely fixed; (2) supervision is simplified; (3) clerical costs are lessened; (4) duplication of inventories is avoided, thereby simplifying record keeping and eliminating unwise tie-up of capital.

Against these advantages must be balanced added cost and time of transportation and possible loss of production efficiency due to inability to cater to special departmental storage needs.

Temporary decentralization. It is not always necessary to build storage areas to achieve decentralization. Increasingly, portable and special equipment, designed to these ends, is coming into use. It is now possible to move materials to the production floor and to place them under lock at night by using movable equipment, having drawers, shelves, or clothes racks. The shelf truck is an example. A number of firms have built temporary storage areas by using stacking boxes or bins which can be transported and arranged for special purposes at any point along the production line.

Factors Affecting Location of Stores

From the standpoint of material handling, it is desirable that the flow of materials from the raw-materials receiving platform to the finished-goods shipping platform be as near a straight-line flow as possible. This can be accomplished only by considering the layout of the plant as a whole and placing the storage areas in a direct line between succeeding processes. In practice there are many requirements and limitations that will necessitate a modification of a straight-line flow. The extent of these modifications and the areas allocated to individual articles within a storeroom will be governed by the following:

1. **Difficulty in transportation.** Articles which require special equipment, labor, or care in transportation should be transported as little as possible.
2. **Special dispensing equipment required.** Liquids which must be specially measured and articles that must be weighed have first claim on the stores area adjacent to the measuring equipment.
3. **Frequency of requisitions.** When numerous trips are required to obtain small quantities of the same article, the traveling distance should be shorter than for articles obtained in large quantities with few trips. This principle also applies to the height at which items are stored, as well as their location on the floor. The storeroom attendant should be able to obtain frequently requisitioned articles with a minimum of effort.
4. **Convenience in storing and handling items together.** It is sometimes convenient to store together all articles of similar size or shape even though they may be required by widely separated production departments. Thus, all small parts and fastenings are contained in one store area, and bar and pipe stock in another. This permits specialization of the storeroom equipment and accounting system in each section of the storeroom and avoids duplicate storage areas and inventories in different parts of the plant.
5. **Convenience in locating stores areas adjacent to production departments.** In direct opposition to the consideration discussed above is the desirability of decentralizing the stores areas so that all the supplies for each production area are located next to it. This arrangement should eliminate production delays because of want of materials, as the stockpiles come under the observation of the production foreman, and materials are always immediately at hand when needed.

STOREROOM LAYOUT

A typical storeroom layout is shown in Fig. 136. It combines the following principles:

1. **Objectives.**
   a) Materials held in the storeroom must be readily obtainable when needed.

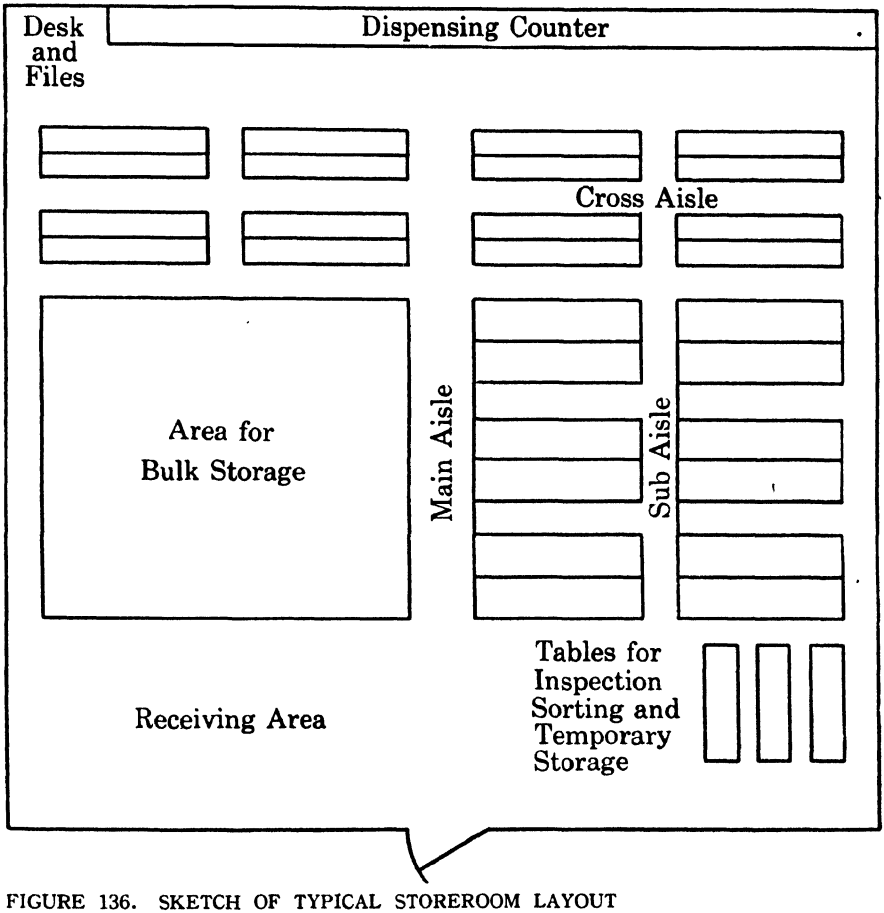


FIGURE 136. SKETCH OF TYPICAL STOREROOM LAYOUT

   b) The layout should facilitate stowage control.
   c) The layout should be as flexible as possible; that is, it should be set up to permit changes and expansion with a minimum additional investment.
   d) The proportion of aisle area to stowage area should be as low as the above considerations will allow.
2. **Dimensions of storage areas and bins.** The size and proportion of the individual areas in a storeroom will affect (1) the proportion of aisle area to storage area and (2) the flexibility of the arrangements.

These dimensions should be multiples of as many unit dimensions as possible. For example, if unit dimensions are 3 feet by 5 feet, and another unit which might be stored in the same area has dimensions of 4 feet by 7 feet, a storage-area depth of 11 feet would always have some unused space, but a depth of 12 feet would provide efficient accommodation for both items. The wider the storage area, the fewer subaisles will be necessary (Fig. 137).

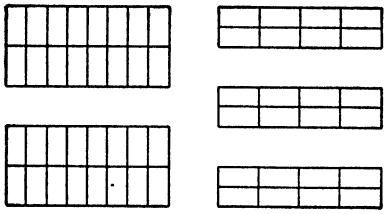


FIGURE 137. ECONOMY OF FLOOR SPACE THROUGH USE OF WIDER STORAGE AREA

3. **Aisles.** The main aisle will run the length of the storeroom, from the receiving point at one end to the distributing point at another, unless the location of these points dictates some other arrangement. Adequate width, usually 5 to 10 feet, should be provided to avoid traffic congestion. Large storerooms often require subaisles parallel to the main aisle at distances of about 20 feet.

Subaisles perpendicular to the main aisle provide access to bins or racks or separate self-supporting piles of large units. The width of the storage areas will determine the number of subaisles. They need be wide enough to accommodate one-way traffic only, and allow sufficient space for loading and unloading.

4. **Storeskeeper's desk and files.** These can usually be located next to the distributing counter, rather than in an office in a distant part of the room.
5. **Table space.** Tables located near the distributing counter will be convenient for a multitude of purposes: inspection, temporary storage, minor operations, and so on. Tables for inspection and unpacking should also be provided at the receiving point.
6. **Location of items within the storeroom.** The same principles considered on page 238 will govern the allocation of items to different racks and bins.
7. **Area for unpacking, inspection, and temporary storage.** During rush hours, materials may be received faster than they can be unpacked and placed in the proper bins. Sufficient area should be provided in the storeroom to avoid congestion because of this.
8. **Storeroom address system.** The numbering system should start at a permanent corner and increase in the direction toward which there may be expansion. Letters and numbers may be used alternately, letters being more convenient when there are many items to designate. Thus, a theater usually uses letters for the rows and numbers for the seats. Corresponding stacks or bins should be given corresponding designations. A standard system should also be followed for labeling subdivisions of bins or stacks. For example, if one bin in a row should be omitted for some reason, its number should be omitted in order to preserve the regularity of notation (Fig. 138). The relationship of the storeroom address system to production control is discussed in Chapter XXIV, *Nomenclature*.

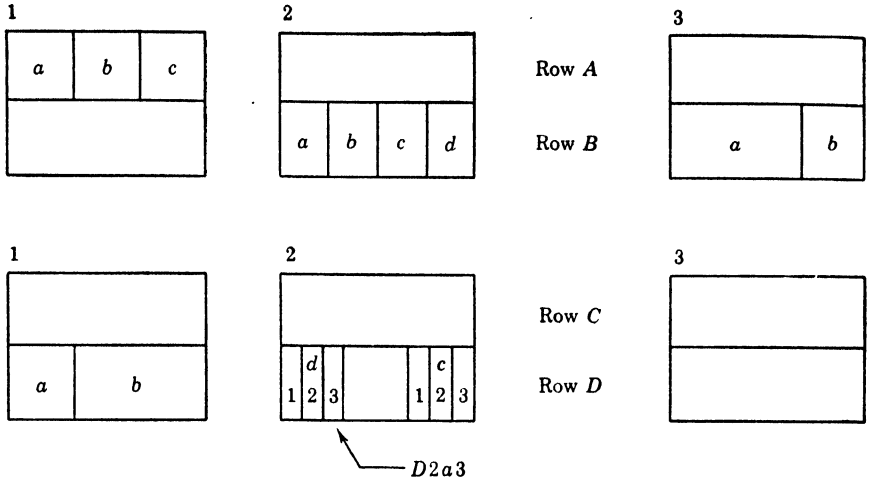


FIGURE 138. STOREROOM ADDRESS SYSTEM

SPECIAL PROBLEMS OF STORESKEEPING

The principles of storeskeeping already discussed have universal application and are based on accepted practices. These must be adapted to meet the needs of individual plants. There are, however, a few specialized problems of storeskeeping which are common to many industries and which deserve brief consideration when laying out the stores areas.

MAINTENANCE STORES

The supplies and raw materials used by the maintenance department should come under regular storage protection and control. Those for routine work will be taken care of by established storeroom procedures. It must be borne in mind, however, that much of the work of the maintenance department is of a "hurry-up" nature. It is always desirable to arrange storage maintenance materials and tools so that those most likely to be needed in emergencies will be readily available. In emergencies, however, storeskeeping red tape with respect to requisitions and withdrawals may prove costly or disastrous, and storeskeepers should exercise common sense in relinquishing routine.

STORAGE OF TOOLS AND FIXTURES

While in some plants it is desirable to give every man a complete set of tools, such policies are costly. Great economies can be effected by making the storerooms responsible for tool investment. Wherever possible, tool storage should be in a central area. The chief advantages

of centralizing tool storage are convenience in reconditioning, speed in handling, no investment in unnecessary amounts of tools, and elimination of theft.

Centralized Tool Storage

Tools should be stored on special racks and shelves and each tool given a specific location. These racks and shelves can be purchased easily, or built by the maintenance staff of most plants. All tools should be labeled or marked with appropriate symbols and their repositories plainly labeled according to standard indexing systems. When complete, each tool must be given a file card which will be cross-indexed for easy identification. The mechanic requesting a tool signs a tool check which is placed on file. A duplicate ticket or similar tag containing the same information as the tool check is filed also under the name of the mechanic in order to provide a quick means of checking the number of tools in the possession of one individual. When tools are returned, the tool check is removed from its hook and the mechanic's tag filed under his name is destroyed.

Decentralized Tool Storage

The use of portable tool racks, stacking bins, and other equipment makes possible the erection of temporary tool storage areas in close proximity to manufacturing operations. These temporary racks should be removed and all tools taken to the central tool room when the purpose for which they were issued no longer exists. Tools issued for temporary storage in decentralized areas must be requisitioned as in the case of individual withdrawals.

MATERIAL HANDLING

The stowing and movement of materials within the storeroom constitute a major problem of joint concern to the storeskeeper and the material-handling manager. From the storeskeeper's viewpoint, overhead cranes, monorail conveyor systems, and overhead movable chain conveyors (which are used to handle materials within the storeroom) require the making of modifications in storeroom layout and arrangements. In turn, the material-handling manager must provide the storeroom with proper handling equipment.

The general principles of material handling have direct application in moving materials from the production floor to the storeroom, stowing materials inside the storeroom, and moving materials for shipment. These principles are presented in detail in the chapter on Material Handling.

CHAPTER XIV

PLANT LAYOUT AND SAFETY

Prefatory Note

Safety engineering as a topic of industrial management is similar to motion study in that the effectiveness of its presentation is enhanced by treatment in two separate parts. The aspects which have to do with plant organization and layout are treated here. Those aspects of safety which have to do with morale and employee organization are presented in Chapter XVI.

* * *

Plant layout and safety go hand in hand. There is no better time to introduce safety in the plant organization than when a new plant is being designed and arranged or when an existing plant is being reorganized from the layout standpoint. Recognition of safety principles at these times results in "built-in safety."

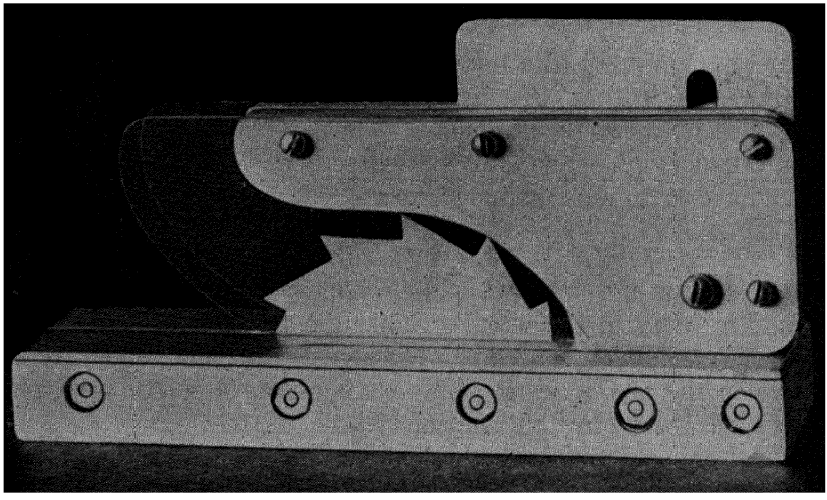
Those who are concerned with plant layout must become familiar with conditions out of which accidents arise and adhere faithfully to some basic principles to correct them. The manager needs to have a knowledge of these principles if he is to obtain the advantages of safety and pass effective judgment on layout arrangements submitted for his approval. Safety is closely related to the plant layout in these ways:

1. Introduction of safety principles into layout of work areas.
2. Elimination of material-handling hazards due to layout.
3. Recognition of safety principles in making layout of storage areas.
4. The introduction of safety into planning for maintenance work on machinery and equipment which is to be installed.
5. Provision of air and light for safety.
6. Provision of safeguards for power-transmitting equipment.
7. Elimination of safety hazards of the building.
8. Incorporation of fire protection in layout.

Introduction of Safety Principles in Layout of Work Areas

The provision of a safe working area has to do primarily with the application of safety principles to the space occupied by the worker in doing his job. Space must be adequate to provide for physical movement. Congestion makes for accidents; equipment, tools, and material

should not be crowded into areas so that they become a hazard to the worker in performing his work. Not only must adequate working space be provided about machinery and equipment, but between work stations so that work areas do not overlap. (These can be given attention when layout of the production floor is on the drawing board.) It is important too to provide for storage, traffic, and other services in relation to the work area itself.

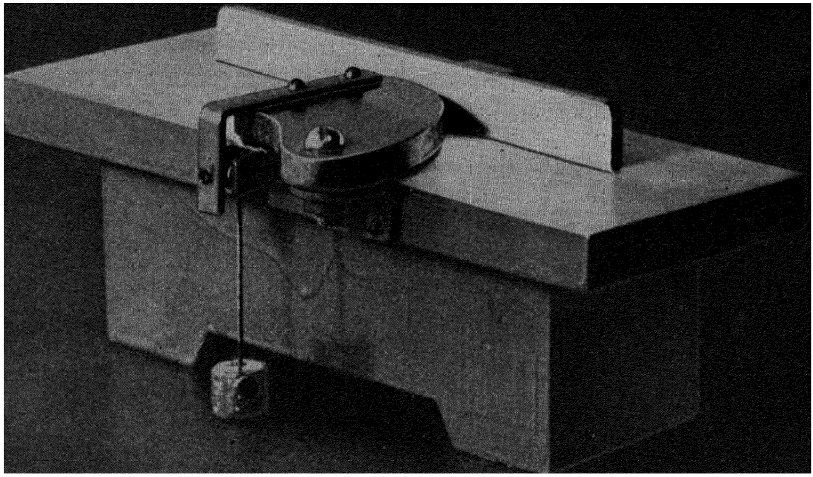


Courtesy Liberty Mutual Insurance Co.

FIGURE 139. MODEL OF HOOD AND SPLITTER GUARD FOR CIRCULAR SAW. SIDE PANELS ARE MADE OF FIBESTOS

The worker must be protected in his workplace against moving parts of machinery and equipment by proper safeguards about the machinery he uses (Figs. 139 and 140). Over one-third of industrial accidents are caused by moving mechanical equipment such as gearing, shafting, and so on. In general, it may be said that mechanical accidents are more severe than nonmechanical accidents due to the force exerted by power-driven machines. To be caught in the gearing or other moving parts of the machine usually means laceration and frequently results in the loss of hands or other limbs involving serious or total disability.

One of the best times to safeguard machinery is at the time it is designed in relation to the workplace or when installation is being planned. Table 10 shows a list of some common types of machinery and the guards which each requires. This list mentions the safety protection needed for some common types of machines only.



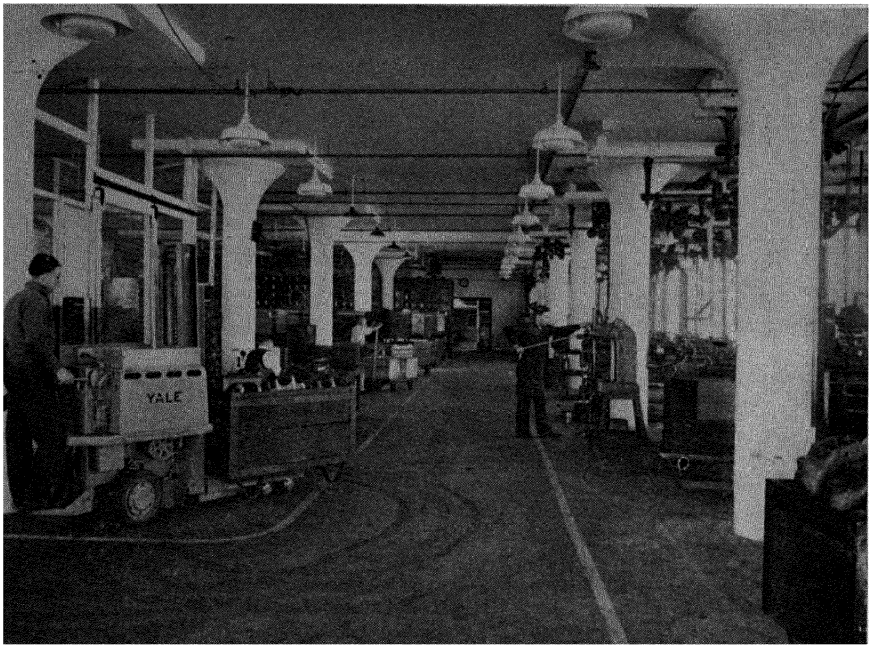
Courtesy Liberty Mutual Insurance Co.

FIGURE 140. MODEL OF GUARD AND PUSHER BLOCK FOR JOINTERS

TABLE 10. METHODS OF SAFEGUARDING MACHINERY

Machines	*Safety Protection*
Band saws:	Enclose entire blade, except working area. Use feed mechanism to prevent injury to fingers.
Abrasive wheels:	Enclose wheels by a protective hood to retain pieces if wheel breaks. Exposure should not exceed 90 degrees.
Hammers:	Equip with sweep-motion device to brush aside hands of operator before blow is delivered.
Tumblers:	Equip horizontal side-opening tumblers with an interlocking device to prevent application of mechanical power while the barrel door is open.
Power press:	(1) If hand feed, use fixed guard to prevent workers' fingers from slipping under plunger. (2) Equip with semi-automatic or mechanical feed so work is fed without assistance from operator. (3) Equip with fully automatic feed. (4) Equip with sweep guard to sweep hands away. (5) Equip with vacuum pick-up or other hand tools to place work under plunger.
Punches:	Equip with device to prevent fingers from coming between punch and die.
Planers:	Equip planer bed with covers to prevent injuries by shear between carriage and planer bed. When carriage is at end of travel should be at least 3 feet clearance.
Wire-drawing machines:	Equip blocks with either a stopping device so arranged as to shut down the block automatically in case operator is caught; or install a bar along the side of the machine to act as a switch.
Extractors:	Equip metal covers with interlocking device to prevent cover from being opened while basket is in motion.
General:	Wherever possible require both hands of operator to be on controls outside of the danger point in running machine.

The work stations should be laid out to give protection against shock from exposed wires and against burns from unprotected pipes carrying hot fluids. These are matters which must be given attention at the time a plant is arranged and require particular attention on the part of the maintenance department.



Courtesy The Austin Co.

FIGURE 141. VIEW OF PRODUCTION FLOOR SHOWING WHITE LINES MARKING AISLE SPACE FOR MATERIAL HANDLING

Every work space should be arranged also to prevent falls. These result from the following: unprotected floor openings, improper housekeeping; sudden motions and quick changes in movement; trash in and about the workplace; and slippery material on the floors such as oil, water, and grease.[1]

Safe storage at the workplace is accomplished by providing space for piling materials so they will not fall on the workman or cause him to fall. In addition, materials and tools should be so stored and piled that strain from improper lifting is prevented.

[1] Falls account for thousands of accidents in industry each year. Safety organizations can provide sets of rules and suggestions to eliminate causes of falls.

Elimination of Material-handling Hazards Due to Layout

Another primary source of danger to both workers and physical property are the hazards which result from traffic in and about the industrial plant. To avoid traffic accidents it is essential to provide adequate space at machines so that traffic may move to and from them

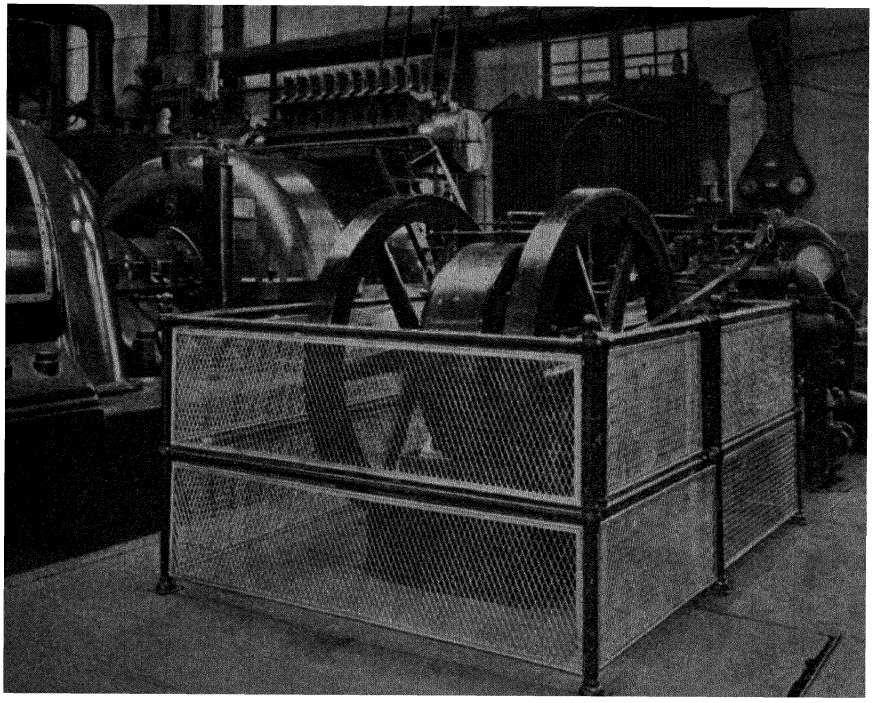
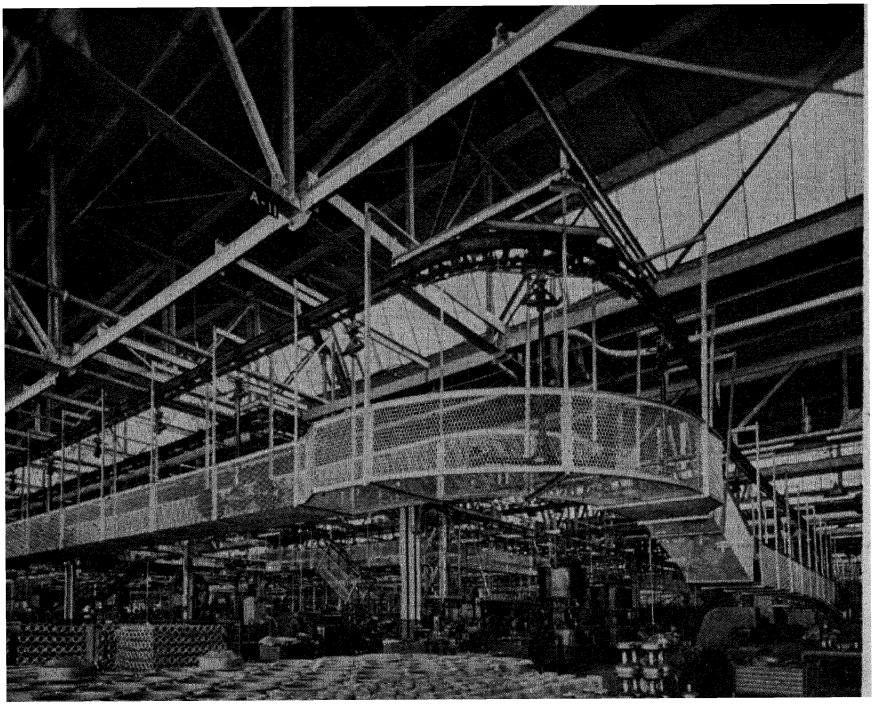


FIGURE 142. PIPE RAIL FILLER GUARDS *Courtesy Consolidated Expanded Metal Companies*

freely. When power trucks are used to transport materials, aisle space must be adequate (Fig. 141). The width should be 3 feet wider than twice the width of trucks. Aisle widths should be planned also to accommodate rush-hour traffic that occurs when employees are going to and from work between shifts and at lunchtime. Because the primary considerations of aisle space are to avoid danger to the employee (pedestrian) when traffic is moving on the floor, warning signals, lines indicating paths of the routes of material-handling vehicles, and areas for loading and unloading should be clearly marked, warning employees to keep away. In some places where foot travel parallels carrier routes such as trucks and plant railways, it is necessary to have guardrails to protect employees (Fig. 142).

Space adequate for safe overhead handling is also important. It is necessary to provide adequate clearance so that employees may not be in danger, and particular attention should be given to the strength of fastenings for the material-handling devices that are to be supported from the ceilings and overhead structure when materials are to be swung over workplaces (Fig. 143).



Courtesy The Consolidated Expanded Metal Companies

FIGURE 143. CONVEYOR GUARD CONSTRUCTED WITH ANGLE FRAME AND STEEL-CRETE 1½" NO. 9 — SAFE-T-MESH

Note the angles, curves, slopes, and rises, the visibility and lightness of supporting structures and the simplicity of construction.

Elevators. Elevators are essential for the effective use of multistory factory buildings. They facilitate the handling between floors of both freight and people. If maximum efficiency is to be made of a given factory building, the problems presented by the installation and use of elevators must be anticipated and coped with at the time the area of the industrial plant is planned.

Elevators may be owned outright or they may be leased. More commonly they are procured under a lease arrangement with one of the

established elevator-manufacturing companies. For an established rental charge, maintenance service and regular inspection are provided, and engineers of these companies are eager to cooperate with layout engineers in making provisions for elevators and making them most serviceable to manufacturing processes and factory buildings.

So far as safety and plant layout are concerned, the considerations with respect to elevators have to do with: (1) locating the elevator for maximum efficiency of material handling and foot traffic between floors in the factory building; (2) provision of adequate space for the elevator shaft, counterweights, gates, and landings; and (3) provision of adequate space in front of the elevator doors or gates to permit free movement of materials and workers.

For most industrial purposes combination passenger and freight elevators are desirable. At the same time space is provided for the elevator shaft and counterweight enclosures, it is desirable also to provide space for the convenience of repairmen in keeping the elevators in good working order after they are installed. In this connection, adequate provision must be made for an elevator pit at the bottom of the shaft and a penthouse at the top; both of these are essential in installing the elevator mechanism and in cleaning the elevator shaft.

Landings or thresholds of elevators at each floor must be both ample in area and well lighted. Space must be provided in laying out the plant for material handling and foot traffic onto and off elevator platforms. It is desirable also to make provision for a signal system (bell, buzzer, or light) to be installed at each landing so that signals may be given if the elevator is desired at that landing. This precludes any chance of injury to persons who open doors to look into shafts to locate the cars. Other factors of importance in connection with elevators are these: Freight elevators should be equipped with vertically sliding, fire-resisting doors or gates, having locks or latches so constructed that they cannot be opened from the outside of the hoistway. Doors of passenger elevators should be fireproof and have dual controls installed at each floor. (Dual control means that both the door of the elevator and that of the landing must be opened at once in order to open either at a given landing.) Doors may be either self-opening or manually operated. It is desirable to have both freight and passenger elevators microleveling, which means that the elevator platform automatically levels itself with the floor before doors and gates may be opened. This permits handling materials onto and off the elevator platform without upsetting. Moreover, hazards which may arise in connection with persons tripping in getting onto and off elevators are removed.

Since elevators are often necessary as an exit from multistory buildings when there is a fire, it is important that crowding of equipment at

the access to elevators be avoided and that elevators be so placed in buildings as to avoid congestion of foot traffic in emergency periods. (Elevator shafts should be lined with brick, concrete, terra-cotta tile or some other fire-resisting material. It is desirable also that separate power controls be available to guarantee elevator service in case of fire even though the main power lines of the factory are shut down.)

There are many additional considerations to be met in connection with elevators. Typical of these are the relative merits of push-button elevators as compared to those which require an attendant or operator. In this chapter it is important to point out only those safety aspects of elevator installation and operation which have direct bearing on plant layout.

Recognition of Safety Principles in Making Layout of Storage Areas

The principles of safety which have to be given consideration at the time the storage areas are laid out are the following: protection of materials and tools stored against fire hazards; avoidance of blocking aisles so that fire apparatus cannot be moved quickly; and covering up apparatus. Materials must not be placed so close to overhead sprinklers that water is prevented from spreading. If materials are bulky they must be piled so as not to impair movement of people and equipment in the plant. Where heavy materials are to be stored, care must be taken to see to it that the strength of the floors is adequate to support the weight. Finally, storage areas should be made as accessible as possible so that there will be a minimum of danger from traffic in and out of the storage place and so that workmen will not be jeopardizing life and limb to get at materials in storage.

The Introduction of Safety into Planning for Maintenance Work on Machinery and Equipment Which Is to Be Installed

In the layout of every industrial plant it is important to make provision for future maintenance of machinery and equipment to be installed. Some machines are hard to get at from the point of view of repair work and others require the use of special equipment to make repairs. Adequate space must be provided and safety of the maintenance workers anticipated. Some of the maintenance problems which are encountered and which must be recognized are problems of oiling and cleaning, changing parts, adjusting and repairing belts, clutches, and gears, and overhauling machinery and equipment.

Guards should be exceptionally strong and stand up under extreme conditions. They should be located so that they offer the least possible interference for the repairman, and should be so constructed that they

can be quickly removed during repairs. Where a machine has a number of danger points, sectional guards are usually preferred. A workman should be able to remove a sectional guard to repair a part and still be protected from other dangers.

In providing for the maintenance of overhead equipment adequate space must be allowed for the workmen to reach it and to work on it. This often entails the use of ladders and suspended platforms. These in turn must provide maximum safety for those who are to work on them. Adequate provision should be made also for window cleaning and window repairing without impairing the safety of those who must do this work. Moreover, machinery that is located in pits, tunnels, basements, or penthouses should be made readily accessible so that necessary maintenance work may be done without hazards to workmen.

Provision of Air and Light for Safety

Many accidents result from fatigue. Where air is properly circulated, and cooled or heated, and where lighting is of proper intensity, the number of accidents from unnecessary fatigue is lessened. Fresh air and good light are connected closely also with occupational diseases, preventive action is necessary to avoid unnecessary illness resulting from the work situation. The principles underlying the provision of adequate air and light, as well as the advantages to be gained, are treated elsewhere. It is important only to state here that the provision of adequate and proper light and air should be considered when laying out the industrial plant. The most economical and efficient times to provide suitable ventilation systems and good artificial and natural light is when the plant is being laid out, either for the first time or as a rearrangement. The provision of adequate light for safety is not confined to the workplace or assembly line; it includes also passageways, stair wells, entrances, and exits. Good lighting prevents falls.

Provision of Safeguards for Power-transmitting Equipment

Moving shafts and belting are essential to the proper arrangement of most production floors. Some of the more important safety considerations follow:

All shafting through which power is transmitted should be firmly mounted. Shafting 6 feet or less from the floor line should be fully guarded by a stationary casing. Exposed shaft ends should present smooth surfaces. Provision should be made also for covering keyways which are not in use and for sinking or countersinking projecting parts or revolving objects, in order to prevent clothing from catching. Pul-

leys should be guarded if any part of them is 6 feet or less from the floor or work platform. All horizontal belts which are 6 feet or less from the floor should be guarded for at least 15 feet above the belt unless the total height should be 42 inches or less from the floor level, in which case a full enclosure is required. Overhead horizontal belts which are 7 feet or less from the floor should be guarded for their full length on the bottom and sides. All vertical belts should be guarded for an extent of at least 6 feet. Gears should be guarded by complete enclosures. There are numerous additional considerations which may be obtained from safety literature, but the foregoing serve to illustrate the importance of considering these matters in connection with plant layout. Many necessary guards may require special space considerations that cannot be met unless they are provided for when the layout is being arranged.

Elimination of Safety Hazards of the Building

The plant as a whole involves some safety hazards which need to be recognized. These have to do with the building itself. The possibility of a building's collapse is always a potential danger. Collapse may be traced to a number of causes, but the following are the principal ones: (1) floors which are overloaded dangerously at any particular point; (2) equipment which causes considerable vibration and is installed on a floor above the ground or basement; (3) water tanks located above the roof which are installed without proper supports to eliminate the danger of overloading the roof structure.

Other hazards in connection with the building arise from the installation of conduits. These include high-pressure steam lines, wires which carry high voltage of electricity, gas lines, and pipes that carry hot liquids. Except as these are placed to avoid contact with workers, there is danger of injury and even death through burns or electric shock.

Plant Protection

The protection of physical property of the industrial plant is not a matter solely of concern to management during war periods. There are always those who wish to gain access to buildings in order to pilfer and steal, and the incendiary who wishes to start a fire is a constant menace to society. The protection of physical property of the industrial plant involves (1) the incorporation of fire protection in plant layout, and (2) the provision of safeguards against sabotage. Many aspects of plant protection are primarily a matter of organizations of persons to see to it that the protection needed is provided. For example, the exclusion of aliens, guarding of fences around the plant yard, and inspection of credentials of persons who try to enter the premises are typical. These

subjects are all treated more specifically under the heading of "Safety and the Worker." At this point, the concern of the student so far as plant protection is concerned has to do with plant layout.

Incorporation of fire protection in layout. The physical provisions for fire protection should be planned at the time the plant is being organized for production. This demands attention to the following: (1) placing of areas to be used to store inflammable materials separate from the rest of the plant, and (2) providing, insofar as possible, for protection of physical barriers to prevent spread of fire — fire-resisting walls and fire doors.

Space provision should be made, too, for installation of automatic sprinkler systems with ample head room for spread of water so that it will be effective in quenching fires. Wherever possible, allowances should be made for adequate water-supply outlets and hoses at all times. Most states have specific laws regarding fire exits and escapes as well as their locations. These regulations must be complied with when laying out the plant.

The provision of safeguards against sabotage. Sabotage activities may take place either in time of peace or war, but deserve particular attention when new plants are being constructed and arranged for production of war materials.

Work areas where work of a confidential nature is carried on should be enclosed by wire-mesh cages or by other means. In any event, they should be so controlled that access from the exterior is prevented to avoid removal and theft of valuable papers. Areas should be provided for reception rooms in plants where the public is to be admitted by special permission only and inspected if need be. Proper fencing and other physical controls should be installed to prevent access to storage areas so that materials vital to production may not be removed or damaged. Floodlight systems should be placed to illumine persons who try to enter either the yard or inside areas not open to anyone outside the employ of the organization.

Plant protection against sabotage requires also the installation of adequate communication systems to warn guards, policemen, and others. Light and telephone control lines must also be protected. In this connection, one organization has provided that these main controls shall be reached only by a catwalk, access to which is through a hole in the ceiling near the main aisle outside the supervisor's office. Wherever similar special arrangements are needed, as in the case of plants wholly or partly engaged in war work in times of national emergency, plant-protection requirements must be considered from the standpoint of their effect on organization processes, material handling, and over-all plant efficiency.

QUESTIONS

CHAPTER IX. (PLANT LAYOUT AND MANAGEMENT)

1. What is the meaning of "efficiency in plant layout"?
2. Define plant layout.
3. List and explain briefly the advantages sought by management in solving the problems of plant layout.
4. Why must a plant arrangement permit the manufacture of a certain unit volume in some instances?
5. What factor determines the speed of a series of operations in a process of several steps with varying speeds of output?
6. Explain "built-in" safety.

CHAPTER X. (TECHNIQUES OF PLANT LAYOUT)

1. Explain briefly the following:
   a) A continuous synthetic process
   b) An intermittent analytical process
   c) A nonrepetitive continuous analytical process
2. How are processes classified according to arrangement?
3. What is meant by process classification according to purpose?
4. Describe briefly the "experimental procedure" of plant layout.
5. How are process charts used in making plant layouts?
6. List the steps in order for making a plant layout.
7. Describe three visual aids used in making plant layouts.

CHAPTER XI. (MOTION STUDY AND PLANT LAYOUT)

1. Outline the basic steps of motion-study procedure.
2. State briefly the motion economy principles of plant layout.
3. Describe the circular workbench. What are its advantages?
4. What advantages are to be gained by application of motion-study principles in making plant layouts?
5. What is the distinction between a process chart and a motion-cycle chart?
6. Reproduce on paper the process-chart symbols.
7. Name the three types of process chart and tell how each is used.
8. What may result from process-chart analyses of manufacturing processes?

CHAPTER XII. (MATERIAL HANDLING)

1. State the responsibilities of the person in charge of industrial material handling. How will he achieve them?
2. What slogan expresses the objectives of material-handling management?
3. What information does the plant manager need to evaluate reports on material handling?
4. State briefly the general principles underlying transportation techniques.
5. Outline the principles of material transportation.

6. What is meant by "standard material-handling equipment"?
7. Name the methods of moving materials.
8. How important is piling, loading, and unloading in material handling?
9. Explain the methods of applying motive power to material to be moved.
10. Give the purpose of the following: (1) ramp, (2) spiral chute, (3) screw conveyor, (4) roller conveyor.
11. Name and explain the use of five types of industrial material-handling equipment.
12. How important is material handling in the efficient operation of an industrial plant?

CHAPTER XIII. (ORGANIZATION AND LAYOUT FOR STORESKEEPING)

1. What is meant by storage procedures?
2. Name the functions fulfilled by storeskeeping in serving production.
3. Explain: stack, tier, pile, column, article, section, block, lot, course.
4. What are the management-cost implications of storeskeeping layout?
5. Describe methods of piling.
6. Explain "moving-division system."
7. What are the major types of storeroom equipment?
8. What is a double-area system? Coupon system?
9. Distinguish a skid from a pallet.
10. What calculations are necessary preliminary to laying out a storage area?
11. Describe use of stacking boxes.
12. Outline the principles to be considered in locating storage areas.
13. What factors affect locations of stores?
14. Give the principles of storeroom layout used in making the typical storeroom layout shown in the text.
15. What are the special problems connected with storage of tools and fixtures?
16. What are the special problems of storeskeeping?
17. How can use of tools stored in storerooms be controlled?

CHAPTER XIV. (PLANT LAYOUT AND SAFETY)

1. In what ways is safety related to plant layout?
2. How can safety be introduced into the workplace?
3. Why are elevators dangerous to workers?
4. How important is safety in planning for maintenance on installed machinery and equipment?
5. Explain how safety is a consideration of layout of storage areas.
6. What items require attention in safeguarding power-transmitting equipment?
7. Name the safety hazards of the building.
8. Why is fire prevention a topic of safety and layout?
9. List all the ways in which safety can be incorporated in the plant layout.

PROBLEMS

Problem 1

Plant Capacity

In a plant having a continuous process, the following departments (each a step in the process) have these capacities: (1) 270 per hour, (2) 310 per hour, (3) 260 per hour, (4) 240 per hour. How long would it take to manufacture 3600 units of its product when the plant works on a 6-hr. day basis?

Problem 2

Process Chart Analysis of a Manufacturing Process

Make a process chart, incorporating the five commonly used symbols, from the following data for the assembly of a motor. Origin of *all* assembly parts should be indicated.

Operations on motor *base*, now stored in bins in first floor of three-story elevator-equipped factory:

1st floor: sandblast all over

2nd floor: mill bottom of casting
profile bottom of casting (vertical milling)
drill and tap 6 holes

Operations on motor body:

3rd floor: Assemble stator to body (shell of motor)
Assemble rotor to body (shell of motor)
Assemble protective shield
Assemble motor body to base with 6 screws

2nd floor: Pack motors in boxes
Stencil and label boxes
Permanent storage

Distance between all machines	5 ft.
Distance between all floors	14 ft.
Distance between workplaces	8 ft.
Distance from elevator to workplaces and machines	20 ft.

Problem 3. The Tasty-Flake Pie Company

The Layout of an Industrial Plant

Machine-made Pies — The bakeries have almost put the home breadmaker out of business; the sales of store cake are estimated at $175,000,000 a year; and now the darling of the housewife, the pie, is succumbing to the merits of manufacture by wholesale.

Gone or going is the soggy undercrust. The whole unit has an appeal to the eye. Transparent wrappers protect it from contamination. It is inexpensive.

What chance has a woman against this? She cannot even talk any more about the dried eggs and the pulverized milk and the poor shortening and the desiccated fruits, and other old defects of non-home-made pies. With the aid of chemists, the boss bakers have managed to get fresh, excellent materials. It is the bread story all over again, and that is a tale of triumph. Even in the remote country districts of northern New England, the farmers' households have discovered that the loaves from the village are better than those from the old oven — and what a comfort that is in hot summer weather!

We think of the machine-age usually in connection with nonedible things, but the industrial revolution which began a century and a half ago is affecting our stomachs as strongly as our backs and our comings and goings. If you think that this is an undesirable change from the traditional usage, consult the little woman.

— Editorial, *Boston Herald*, 1935

This editorial, taken from the *Boston Herald*, tells the story of the transition from home-made to factory-made pies.

The Tasty-Flake Pie Company is a pioneer in the business of manufacturing pies on a mass-production basis and finds that the business is a successful one. The company started from scratch and erected a model plant designed and laid out to achieve maximum efficiency in the process of pie manufacture and general plant operation.

The capacity of the Tasty-Flake plant is approximately 14,000 pies a day, and it employs 150 men and women. A description of the plant itself, the processes, and the equipment are contained in this problem. Fig. 144 is a diagram which shows the arrangement of some of the essential and special features of the main floor of the building, and should be consulted in connection with the following paragraphs.

A cross-section view of the entire bakery would divide the structure into three elevations. The lower elevation, which is below the level of the ground, is the basement; the next elevation, which is a few feet above the ground line, is the main floor of the bakery; and the higher floor plane, which comprises only a small part of the entire area, is a mezzanine floor.

The basement of the building is given over to the storage of raw materials and supplies, with the exception of space for the boiler room, fuel storage, refrigeration machinery, and a receiving-department office.

The main floor of the building contains the offices of the plant, the production floor, the garage, the maintenance department, the cold-storage rooms, an accessory space given over to storage of supplies, the employees' entrance, and the general entrance with a reception lobby and information desk.

The mezzanine floor, which is located over the main-floor storage rooms, is taken up by the filler department and the central weighing department. The location of these departments on the mezzanine floor makes the handling of materials more confined and adaptable to the process.

The garage, which houses the trucks, the loading platform in front of which the trucks are stationed so that they may be loaded with their daily supply of pies, and the maintenance department are located on the right side and rear of the building. There is no basement under this part of the bakery as the additional basement space is not needed and would only create an additional expense. The loaded trucks leave the garage by the door at the front right of the building as they start on their daily delivery in the morning. When they return in the afternoon, they enter by the door at the rear of the building near the maintenance department. Before entering the garage, they stop by a gas pump and compressed-air hose, located in the rear of the building at the garage entrance, where the truck is checked to see that it is in need of no repairs before its trip the following day,

and any repairs needed are reported on a form provided for that purpose. The drivers take the trucks into the garage and station them at the loading platform, where unsold pies are returned and counted by the checker, and the trucks made in readiness to receive the next day's load of pies.

In the left rear corner of the building (see diagram) is located the maintenance department. This department is equipped and laid out to take care of all repairs to the trucks,

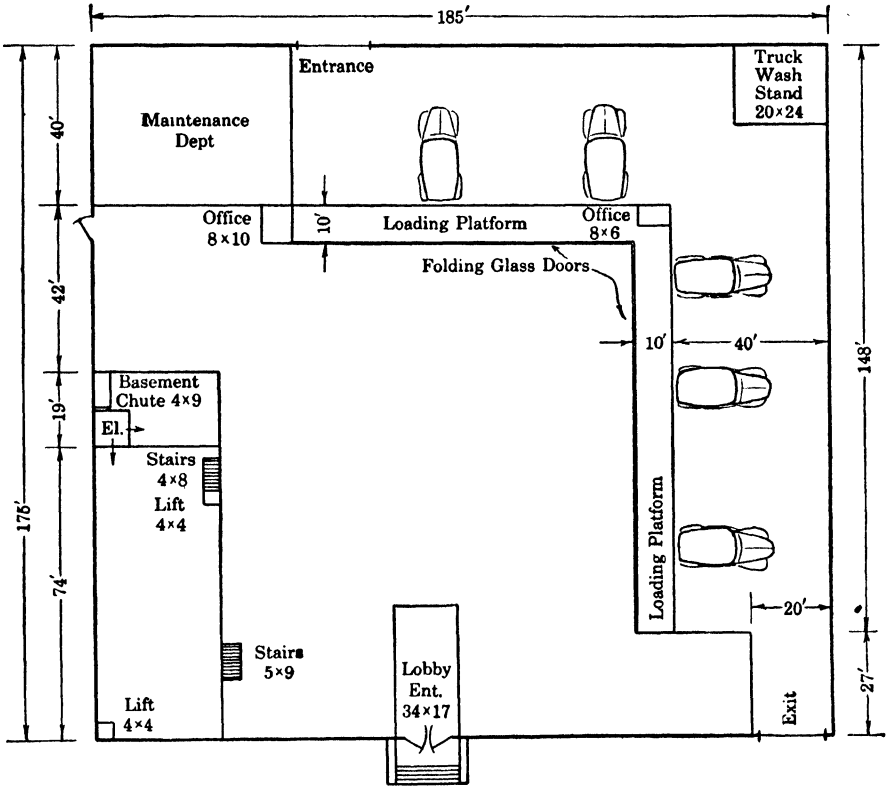


FIGURE 144. DIAGRAM OF MAIN FLOOR OF TASTY-FLAKE PIE COMPANY

all repairs to machinery in the building, all repairs to the building, and any minor alterations in or about the plant. The washstand on which the delivery trucks are washed, and which is also a part of the maintenance department, is located in the right rear of the building in a corner of the garage. Keeping the delivery trucks in first-class condition and appearance, in order that the prestige of the company may be kept at a high level, is a job of the maintenance department.

The section of the main floor of the building just described, which houses the garage and maintenance department, is separated from the interior of the bakery and production floor by a partition, and is made easily accessible by conveniently located doors which are raised overhead out of the way when not in use. The separation of this part of the bakery from the production floor closes off that part which it is not possible to keep spotlessly clean, as is the production department of the bakery.

The offices of the plant are reached through an attractive entrance from a neatly

decorated lobby. A visitor entering the lobby is received by an employee at a telephone switchboard and information desk. A corner of the lobby is furnished as a waiting room. The offices beyond consist of a production office, the general office, the sales office, the president's office, the office of the president's secretary, and the demonstration room. This demonstration room is equipped to give motion-picture demonstrations of pie making. Visiting groups, prior to being shown through the bakery, are given a talk on the product and entertained by motion pictures showing activities of the company. This room is also used by salesmen whose meetings are a very important part of the company's sales program.

The office of the shipping clerk is shown on the diagram. It is his function to make a complete check on all pies and an accurate loading of each truck in accordance with the loading slip. The office of the shipping clerk is located in the center of all the activities for which he is responsible.

All the employees, excepting the executives and the office force, are provided with lockers. The locker rooms are attractively but plainly furnished so that they may be used as rest and reading rooms for the employees during their lunch hours or rest periods. These rooms are also used as medical inspection rooms by the company doctor, who maintains a regular schedule of medical inspection of all employees. The lavatories adjoin the locker rooms.

As materials come into the basement of the building by a gravity chute, they are checked for quality and quantity in the receiving department and then loaded on to wooden skids. These skids are the permanent storage receptacle for the materials while they are being stored, and they are also the means for transferring the materials to and from storage. To move the materials stored in this way, a lift truck is used which quickly and easily transfers the goods to the desired place. The more bulky materials, and those for which the demand is more frequent, are stored near the elevator and lift, so they may be taken to the central weighing department and the filler room with a minimum of handling.

A miscellaneous storage room is located in the front corner of the main floor of the bakery. Such stores as spare pie tins, papier-mâché plates, employees' uniforms, and other accessories used on the production floor are stored in the front section of this storage space. In the second section, located next to the receiving-department elevator, is the cold-storage room (see footnote 1, page 266). Here the milk, cream, and other perishable ingredients are stored. Pie fillers are cooled here also by a quick cooling process.

Directly above the main-floor storage space is located the mezzanine floor where production operations are carried on.

Description of the Process of Manufacture

Central Weighing Department and Filler Room (Mezzanine Floor)

The central weighing department is responsible for weighing raw materials for piecrust and fillers. All materials weighed in this department for the fillers and the piecrust are weighed in "batch lots" in special tubs, which may be wheeled right up to the flour sifter, the mixing kettle, or the steam kettles, and tilted to allow the materials to flow out. This saves much handling of material and a great deal of effort on the part of the employees. Other advantages of this central weighing department are that it simplifies the control of materials, and ensures a more uniform product than could be obtained by any other known method.

As the materials are processed completely in either the mixing kettles or steam kettles they are piped to the main floor by means of gravity. The fillers, which have been cooked in the steam kettles, are piped into one of the two water-jacketed cooling tables which stand below the cooking kettles on the main floor. The tables are 8 ft. by 4 ft. and approximately 12 in. deep. Water is circulated through the pipes surrounding the tables, each of which will hold the contents of two cooking kettles. The quick cooling obtained by the use of these cooling tables is a big factor in retaining the flavor of the filler. When the cooling process is complete, the filler is drawn from the tables into stainless steel filler tubs and stored in the cooling room under the mezzanine floor until required at the proper units.

The fillers, which come directly from the mixing kettles and are not precooked, are drawn from the mixers directly into the stainless steel tubs and stored in the cooling room.

In addition to the preparation of cooked and noncooked fillers of various types, the preparation of fruits for pies is an important part of the work of the filler department. This work is carried on by means of an apple-paring machine, a cherry-pitting machine, and a berry-inspection conveyor.

The apple-paring machine is a small production unit in itself. The apples are placed on the coring and paring spindles, of which there are three. One operator is able to take care of loading the machine which then automatically pares and cores apples. The apples are next automatically ejected onto a conveyor belt that takes them past three girls who inspect them, rejecting the bad ones and removing bad spots from others. After the apples have passed inspection, the conveyor dumps them into the hopper of the slicing machine and delivers the slices into a tub placed at the end of the line.

In the operation of the cherry-pitting machine, the fruit is fed into the hopper of the machine by an operator. The machine then automatically removes the pits and discharges the pitted fruit into a washing machine. The washing machine thoroughly cleanses the fruit and delivers the washed fruit at the mouth of the machine, where it drops into a waiting tub.

Fresh fruits, such as strawberries and huckleberries, must be entirely processed by hand. These berries are dumped onto a conveyor belt which slowly takes the berries past a row of girls who carefully inspect them, removing the bad ones and plucking the stems. After the berries have been inspected and the stems removed, the conveyor dumps them into a washer which thoroughly cleanses them preparatory to the baking process. Apricots, however, must be cooked in the steam cooking tables before being used as filler for a pie.

The Piecrust Department

The piecrust department is comprised mainly of two units, each consisting of a flour sifter and piecrust mixer. These two units should be so arranged that the hoppers leading to the flour sifter and dough mixer will be easily accessible and extend to the mezzanine floor. These hoppers receive the ingredients for the piecrust in batch lots, directly from the central weighing department. When a batch of piecrust has been completed, it is removed from the mixing machines and placed in dough trucks. The filled dough trucks are stored in the cooling room until they are needed by the production units which assemble and process the pies.

Production Units 1 and 2

Production units 1 and 2, which are alike in every respect, assemble and bake all the two-crust pies. Approximately two-thirds of the entire production of the plant is made up of two-crust pies, making each unit handle approximately 6700 pies per day.

The crust for the pie is introduced at the origin of the conveyor by means of an automatic piecrust divider. The crust is forced by hand into the hopper at the rear of this machine and is delivered from it in oblong lumps which drop at regular intervals upon the belt of the conveyor.

At the first operator station on this assembly conveyor, an operator picks up every other lump of piecrust and puts it into the hopper of the dough-rolling machine at his side. Simultaneously, as he removes the lump of dough from the conveyor belt he puts an empty pie tin in its place.

A second operator, standing on the opposite side of the dough-rolling machine, receives the lump of dough from the first set of rollers and puts it through a second set. This second set of rollers rolls the dough at right angles to the direction of the first rolling, and so forms what was originally an oblong lump of dough into a round piecrust. The completely rolled piece of piecrust from the second set of rollers is placed in the pie tin put on the conveyer belt by the first operator and which has now reached the second operator.

The third operator on the assembly line is stationed on the opposite side of the belt. This operator brushes the rim of the piecrust with a wash which is necessary to stick the two crusts together in the final assembly.

At the fourth station, the filler of the pie is put in by two operators who stand on opposite sides of a tub containing the filler of whatever variety of pie is being made. By means of two scoops, which hold just the right quantity, each crust is filled without being removed from the conveyor.

At the fifth station is located a piecrust roller similar to the one located at the second station. Here an operator picks up the second piece of dough, which has been on the conveyor during the entire preceding activity, and places it in the roller. The dough is rolled in exactly the same way as that described above. The crust, when removed from the roller, is placed on the pie to form the top piecrust and completes the materials which go into the pie.

At the sixth station, which is located at the end of this assembly conveyor belt, are stationed two well-trained women operatives. These women receive each pie from the conveyor belt and trim and crimp the crust, ready for baking. The trimming and crimping operation is done by hand to give the pie a home-made look.

They then place the pie on an inspection table at their side and between them and the oven. Here an operator inspects the pie and, if it is up to standard, places it on the belt of the conveyor oven. The conveyor belt moves through an oven maintained at a temperature of 520° F., where the pies are baked approximately 25 minutes.

At the discharge end of the conveyor oven an operator removes the pies from the belt, slips them from the pie tins onto papier-mâché plates, and places them on a pie truck. This pie truck, when filled, is moved to the cooling space at the rear of the production unit, where the pies are cooled for 30 minutes before being taken to the packaging room to be packed.

Production Unit 3

This unit, like units 1 and 2, introduces the piecrust onto the conveyor belt by means of an automatic piecrust divider. Unlike the two preceding units, however, the first operator picks up each lump of dough from the conveyor and places it through the first set of rolls on the dough-rolling machine. At the same time the dough is removed from the conveyor, the operator places a pie tin upon the conveyor belt.

The second operator, on the opposite side of the dough-rolling machine, receives the piecrust from the first set of rolls and puts it through the second set of rolls to complete the bottom, and only crust of the pie.

The third and fourth operatives on this assembly line receive the tin containing the piecrust from the end of the conveyor belt and, by means of a very simply constructed machine, trim the crust and force it to take the shape of the tin.

From the trimming operation, the pie "shells," as they are now called, are loaded onto pie trucks and taken to the door of the oven to be baked. The oven used for baking pie shells and for baking pumpkin and custard pies is what is known as a "tray oven." The trays are hung with their center of gravity low, somewhat similar to the cars of a Ferris wheel, and are carried by a continuous chain conveyor from the oven door, vertically up the front of the oven, across the top of the oven, down the back, across the bottom, and up the front again to the oven door.

An oven of this type is used since the baking operations must be watched with more care than in the two previous units, and also because in the case of pumpkin and custard pies the liquid filler is introduced after the shells are placed in the oven.

When the oven is baking shells only, as in the production of meringue pies, two operators remove the shells from the trucks and place them in the oven.

When the oven is baking either pumpkin or custard pies, the process is somewhat different. In this case, one operator places the shells in the oven while the second operator handles the filling machine. This filling machine consists of a small pump to which is connected a long handle with a hand-operated valve. The operator filling the pies holds the nozzle over the pie shell and opens the valve until the pie is filled, closes the valve, moves to the next pie, and repeats the process. When the pumpkin and custard pies are removed from the oven, they are placed, as in the two previous units, on a pie truck, allowed to cool for 30 minutes, and then taken to the packaging room to be packed.

In the case of meringue pies, the baked shell is taken to the meringue assembly bench. Here one operator places the filling in the pie shell and a second operator spreads the meringue topping to complete the pie. When desired, the meringue is browned in the tray oven. These complete pies are taken to the packaging room, packed, and turned over to the loading crew to be loaded upon the delivery trucks.

Packaging Department

As the pies come from a 30-minute cooling period on the production floor, they are taken from the pie trucks, on which they are wheeled into the packaging room, and placed upon a conveyor. On each side of this conveyor is a line of girls who remove the pies from the conveyor, package them, and replace them on the conveyor. At the end of the conveyor, the packaged pies are removed and replaced in the pie trucks. These trucks are then wheeled onto the loading platform, where they are then taken by the loaders, who load the pies from the pie trucks into the delivery wagons that deliver the pies to the consumer.

The Washing Room

Baking pies on a large scale requires constant washing of pie tins to keep down the inventory cost in this equipment. The washing is done by a machine operated by two employees, and is capable of washing 1800 pie tins in 20 minutes. These tins have to be scraped before washing in a few instances,[1] and this tends to slow up the washing slightly.

The Experimental Room

In the experimental room a scientifically trained chef carries on tests of raw materials and new recipes. He attempts to iron out troubles which arise in the production depart-

[1] No grease is put in the pie tin before inserting the lower crust. There is an old-fashioned saying, "It is a pretty poor piecrust that won't grease its own plate."

ment of the plant, and works on new methods or products as originated by himself or suggested by the company or any of the employees. Here also are filed records of all tests and recipes.

The floor areas required for the proper layout of equipment, together with the space requirements of the equipment itself, follow:

Building: (outside measurements) 185 ft. × 175 ft. 32,375 sq. ft.

Departments	*Space Requirements, Ft.*	*Total Area Sq. Ft.*
Administration:		
Entrance * — Front lobby		578
Demonstration room		162
President's office		273
President's secretary		147
Production office		429
General offices		690
Sales office		429
Salesmen's room		258
Experimental department:		315
Table	2 × 5	
Stove	3 × 6	
Ice box	2 × 4	
Shelves (space allowance)	1½ × 7	
Bins (space allowance)	2 × 9	
Plant services:		
Men's lavatory (office)		90
Men's lavatory (factory)		150
Women's lavatory (clerical assistance)		112
Women's lavatory (factory)		195
Men's locker room		210
Women's locker room		270
General storage and supply storage	32 × 74	2,368
Space contained in this area for lift from basement	4 × 4	
Lift from main floor to mezzanine floor	4 × 4	
Stair well to mezzanine floor	8 × 4	
Maintenance department *		2,080
1 hacksaw	2 × 3	
1 shaper	3½ × 4	
1 power drill	4 × 4	
1 milling machine	4 × 6	
1 lathe	4 × 6	
1 anvil	1 × 3	
1 forge	4 × 8	
1 welding machine	2 × 6	
2 workbenches	4 × 20 and 4 × 12	
2 truck-repair pits	17½ × 4 each	
1 compressed-air tank	2 × 8	
Maintenance-department office *	10 × 8	80
Shipping office *	8 × 6	48
Truck washstand	24 × 20	480

* Shown on diagram.

Departments	*Space Requirements, Ft.*	*Total Area, Sq. Ft.*
Production Unit 1:		474
1 assembly conveyor table	33 × 3	
1 dough divider	4 × 4	
2 dough-rolling machines *	3 × 3 (each)	
1 oven loading table †	4 × 4	
1 inspection table	3 × 4	
1 conveyor oven	5 × 40	
Space allowances for 4–6 pie trucks 2 ft. × 4 ft. each at end of conveyor oven (not included in 474 sq. ft.)		
Production Unit 2:		474
Same as No. 1		
Production Unit 3:		294
1 assembly conveyor table	3 × 18	
1 dough divider	4 × 4	
1 dough roller	3 × 3	
1 table at end of belt	4 × 4	
Space for 2 pie trucks	2 × 4 (each)	
Auxiliary equipment for production, Unit 3:		
2 tray ovens requiring 10 ft. 6 in. each × 10 ft. 2 in. each		250
This space must be provided for in addition to Unit 3 space allowances		
1 milk pie-filling machine	3 × 4	12
Meringue assembly division:		1,152
1 scale	2 × 2	
1 double-faucet sink	3 × 8	
2 tables	$1\frac{1}{2}$ × 8 (each)	
1 meringue assembly table	$26\frac{3}{4}$ × 4	
2 meringue beaters	2 × 8 (each)	
Space provided for four pie trucks loaded with pie shells on one side of table (trucks 2 ft. × 4 ft. each)		
Space provided for four empty pie trucks on opposite side of table (trucks 2 ft. × 4 ft. each)		
Piecrust department:		300
2 flour sifters	2 × 2 (each)	
2 dough mixers	3 × 2 (each)	
10 dough trucks	2 × 2 (each)	
Cooling room adjoining general storage:	32 × 19	608
Part of this area is given over to elevator and gravity chute to basement	9 × 9 9 × 4	
Space allowance for cooling tables located below cooking kettles outside the general storage room (Main Floor)		192
2 cooling trays	4 × 8 (each)	192
6 tubs (space allowance)	4 × 8 (total)	

* The dough-rolling machines must be so placed that space will be available for two operators and two tubs at each roller requiring a space of 8 sq. ft.

† Located in front of oven.

Departments	*Space Requirements, Ft.*	*Total Area, Sq. Ft.*
Cooling room adjoining general storage: (*Continued*)		
Storage for pie cooling		1,200
54 pie trucks	2 × 4, 9 per row	
Packaging department		600
Washing department:		800
1 tin-washing machine	20 × 4	
1 table	9½ × 3	
Rack for empty tins	24 × 4 (total)	
Mezzanine-floor departments:*		
Central weighing department	20 × 24	480
4 bins	9 × 3 (each)	
1 tier shelves	12½ × 2	
2 scales	3 × 3 (each)	
Filler department:		
1. Berry-inspection division:	6 × 29½	177
Berry-inspection bench	2 × 20	
Berry-washing machine	2 × 6	
Scales for weighing	2 × 2	
3 tubs for berries	4 × 6 (total)	
2. Tub-washing division:	6 × 10	60
Tub storage space	12 × 10	120
3. Apple-preparing division:	6 × 21½	129
1 apple-preparing machine	2 × 4	
1 apple-inspection belt	1 × 12	
1 apple-slicing machine	2 × 2	
1 scale	2 × 2	
3 barrels (space allowance)	2 × 6 (total)	
2 tubs (space allowance)	2 × 4 (total)	
4. Cherry-pitting division:	12 × 20	240
1 cherry-pitting machine	4 × 4	
1 washing machine	3 × 3	
1 scale	2 × 3	
3 tubs	2 × 6 (total)	
5. Mixing and cooking division:	20 × 20	400
2 power mixers	2 × 2 (each)	
1 table	2 × 4	
4 steam cooking tables	14½ × 11¼ (total)	
Space allowances for two lifts,† elevator, and stair well from general storeroom to the mezzanine floor.		
6. Mezzanine floor supply storage area	19 × 8	152

* The mezzanine floor is located over the general storage room on the main floor (32 ft. × 74 ft.), and the cooling room (32 ft. × 19 ft.), or 32 ft. × 93 ft. for the total area.

† The lift located in the corner and farthest from the elevator (see diagram) serves the basement, main-floor storeroom, and mezzanine floor; the other lift, located next to the stair well leading from the main floor to the mezzanine floor, serves the main floor and mezzanine floor only.

Departments	*Space Requirements, Ft.*	*Total Area, Sq. Ft.*
Basement:	135 × 125	16,875
Elevator *	9 × 9	
Stair well to basement from main floor *	5 × 9	
Boiler room	40 × 40	
Shaft for lift to mezzanine floor *	4 × 4	
Storage space (all available area not used)		
Receiving department	8 × 6	

* Shown on diagram.

Required: Make a scale layout and flow sheet of the entire plant.

NOTE: Use heavy paper 22 in. × 30 in.; copy diagram on the following page, scaling drawing to fit 22 in. × 17 in. paper. Place mezzanine floor in margin of drawing paper beside general-storage and cooling-room areas.

Problem 4. The Easy-Tread Shoe Company

THE LAYOUT OF AN INDUSTRIAL PLANT

The Easy-Tread Shoe Company, manufacturers of men's Goodyear Welt shoes, has built a new plant; it has a main structure of four stories, a length of 152 ft., and a width of 45 ft. (Fig. 145). Its tower projects 30 ft. from the building and has a length of 33 ft. (Fig. 145). The administration building of one story has the same width as the main building and a length of 41 ft. in the front and 29 ft. in the rear (Fig. 145). An alley separates about two-thirds of its length from the main structure, and a corridor connects with the factory to save time communicating between the buildings.

The tower contains an elevator, requiring 36 sq. ft. beside a stairway requiring 36 sq. ft. Two other stairways at either end of the building on the front side furnish necessary communication between floors. These stair wells require a total of 250 sq. ft. on each floor. Windows occupy a maximum of wall space so that every operation has natural light. It is proposed to provide locker and washroom space requiring 435 sq. ft. on each floor.

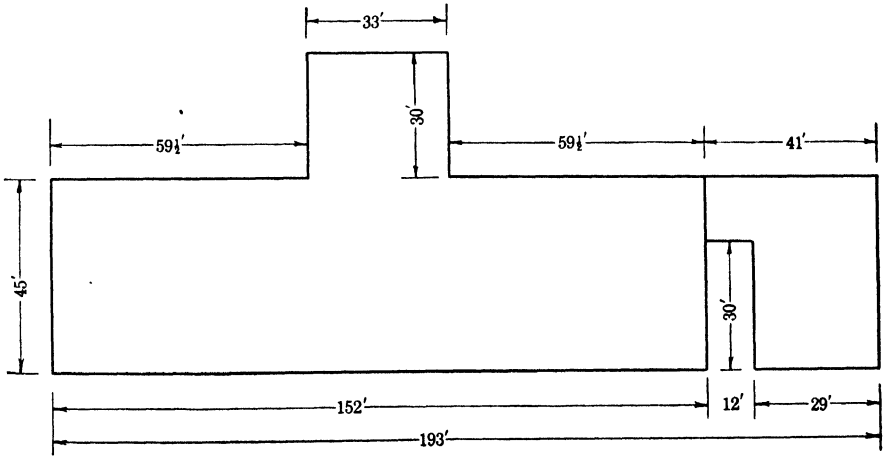


FIGURE 145. DIAGRAM OF INSIDE DIMENSIONS OF THE EASY-TREAD SHOE COMPANY BUILDING

A power plant is located approximately 100 ft. to the rear of the main factory building. Organization of the power plant has no bearing on the layout of the factory and can be disregarded.

The manufacture of shoes is a highly organized process. Copies of sales orders are received by the planning department where production orders and material requisitions are prepared. The latter are sent to the leather storage rooms, directing that the required stock be sent to the cutting room. A copy of the production order is also sent to the cutting room and from that point accompanies the lot throughout the manufacturing process until the packing room is reached. Each sales order, under normal conditions, constitutes a separate production order, which is carried through the plant independent of other orders.

Upper leather, such as kid, calf, and suède, is issued from the leather storage to the cutting department along with cheap leather or duck cloth for linings. The pieces for the upper of the shoe are cut with dies, by hand, or by a clicking machine which dies out six or seven pieces at a time. In cutting out the pieces for the uppers, the pieces which undergo the hardest wear, such as the toe and the heel, are cut from the leather along the animal's spine. Any trimmings that go on the shoe are also cut in the cutting room.

Linings are stored and cut in the lining cutting and storage department where they are prepared to be sewn to the uppers in the sewing department.

Following this, the upper pieces are pinked, perforated, or foxed, depending on the style of shoe that is being made. The linings and upper parts then go to the sewing rooms containing sewing machines placed in batteries, having a unit or group drive. Each operator has a specific operation to perform, and the uppers are passed from one operator to another until the whole upper has been sewed together.

The uppers then go to the fancy stitching department, if such work is required, and from there to the eyelet-punching machines where the holes for lacings are punched and finished. From there the uppers go to the lacing machine where the upper is laced with stout twine. The uppers are then transported to the lasting department. In the lasting department the fitted uppers and the bottom stock, which consist of insoles that have been channeled and grooved, the outsoles and the counters are assembled. This assembly consists of:

1. Tacking the insoles to the wooden lasts.
2. Placing these lasts on movable roller racks with four to six compartments, measuring 1 ft. by 5 ft.
3. The counters are then inserted between the linings and the outer leather of the fitted upper.
4. The fitted uppers and the lasts are then held together by a tack, which passes through the counter into the wooden last.

The lasted uppers are sent to the pull-over machines. Before placing the shoe in this machine, the shoe may be steamed for a few seconds. The shoe is then placed in this machine which performs a very important operation. The uppers must now be carefully fitted to the last to make a well-built shoe. The machine has pincers which grasp the leather at different points on both sides of the toe, and draw the leather securely about the wood of the last. At the same time seven tacks are driven into the leather and last to hold the upper securely in position.

The shoe now goes to the lasting machines for what is probably the most important process in shoemaking. The upper is pulled at all points so as to fit the last snugly. Both hand method and machine method are used with good results. The upper is tacked on all sides except the toe, which is fitted in the next operation, called "stapling." This operation consists of drawing the toe tightly and binding it with wire called a "staple,"

which is made fast to tacks about 1 in. back of the tip of the shoe on each side. The surplus leather is then trimmed off and some of the tacks removed from the last, preparing the shoe for the welt.

The welt, which is a narrow strip of leather, is sewed along the edge of the shoe, beginning at the front of the heel and ending at the same place on the other side of the shoe. The welt is sewed on a lip which has been previously cut in upon the insole. The needle passes through the lip, the upper, and the welt, uniting all securely and allowing the welt to extend out around the edge of the sole. This operation is performed on a welt-sewing machine. Strong linen thread is used, and the stitches are drawn tightly, the machine feeding both the welt and the thread as it proceeds. The tacks around the edges are then pulled, the toe wire is removed, and the welt is trimmed evenly and beaten down smoothly.

The tacks in the insole are now pulled and the shanks are tacked. The shoe then goes to the bottom filling machine where the sole is filled evenly with a layer of ground cork and rubber cement, making the shoe ready for the placing of the outersole.

Soles are cut from sides of sole leather by means of a "dieing-out" machine consisting of a press which forces dies of the approximate size of the finished sole through the leather. These rough-cut soles are soaked for 24 hours, then removed, put on racks in a heated room, and dried. The dried soles are then passed through a series of rollers under great pressure to compress the fibers and improve the wearing qualities of the leather. Finally, the sole is run through a slitting machine which reduces the stock to an even thickness. This operation completes the rough soles, which are held in this department until required by the sole-laying department.

The outersole is placed on a sole-laying machine after which cement is applied to it and the last is placed upon it. Pressure is applied, and the sole is securely glued to the insole. Next a Goodyear rough-rounding machine cuts away the surplus portion of the sole.

In the next operation, a Universal rounding and channeling machine cuts a channel on the outer edge of the sole so it can be sewed to the welt. The sewing is done by a Goodyear Lockstitch machine, which is like a welt sewing machine. A waxed thread is used and the stitching is drawn together very tightly so that the welt and the sole are held securely together. After the stitching, glue is applied to the channel lip on the sole and the shoe is put into a Goodyear channel laying machine which lays a channel lip back over the stitches, hiding the stitching. The next operation is that of leveling the sole. This operation is performed on a Goodyear automatic leveling machine. The lasts are held securely in the machines and rollers, worked by cams, press the soles level and shape them. This practically completes the shoe, but it must next be thoroughly dried. Therefore, the shoe is kept for a number of hours in the drying room. Afterwards, the shoe is sent to the heel-nailing machines. Here the heel is put in place, and nailed by the automatic nailing machine, then put into the slugging machines where the nails are driven in out of sight. The heels are then trimmed and shaped.

The shoe is next sent to the scourer, where the soles and heels are scoured with rapidly revolving sanding machines. After the soles have received their sand dressing, they are painted and put through the burnishing machine to give them a polish. At this point the lasts are removed from the shoe and the shoe is sent to the treeing department. In the treeing department, the upper leather is ironed with small hand irons to remove the wrinkles. Next, in the polishing department, all necessary repairs are made, dressing applied, and the shoe receives its final polishing. The shoes then receive their final inspection, are trade-marked, placed in boxes in pairs, packed in cartons in the packing departments, and remain in finished-goods storage until shipment is to be made. All shoes are shipped to customers from finished-goods storage.

In making a study of these processes to determine the space requirements for the various departments in the new Easy-Tread plant, the following data have been compiled:

Departments	*Space Requirements, Ft.*	*Total Area, Sq. Ft.*
1. Employee service:		
Locker and rest rooms		
Men (each floor)		160
Women (each floor)		275
Medical dispensary (total)		350
2. Manufacturing service departments:		
Leather storage		1600
Shipping room		1000
Receiving room		350
Finished-goods storage		2000
Mill supply and repair shop		1000
Supply and finding storage		500
3. Factory space:		
Outsole cutting and treatment dept.		1000
Lining, cutting, and storage area		250
Cutting department		
10 cutting benches	4 × 6 (each)	240
4 pinking, perforating, binding, and marking benches	4 × 10 (each)	160
Stock benches and racks (5 ft. wide)		200
Pattern-making area		200
Pattern-storage area		150
Sewing department:		
3 sewing batteries	6 × 40 (each)	720
Eyelet and lacing machines	10 × 25	250
Order-matching benches (5 ft. wide)		250
Lasting department:		
Last storage area		1200
5 pullover machines	5 × 10	250
5 lasting machines	7 × 7	245
4 upper-trimming machines	5 × 5	100
Rack storage area *		750
Welting department:		
3 welting machines	10 × 8	240
Welt-laying machines	10 × 5	50
Sole-filling machine	10 × 5	50
Rack storage area *		500
Sole-laying department:		
2 laying machines	5 × 10	100
4 rough-rounding machines	8 × 8	256
4 sole-sewing machines	10 × 10	400
Channel laying	15 × 5	75
Channel-laying machine	10 × 10	100
Sole-leveling machines	10 × 20	200
Drying department		1200
Heeling department:		
3 trimming machines	10 × 12	360
5 tackers	10 × 10	500

* Size of racks, 4′ × 2′ each

Departments	*Space Requirements, Ft.*	*Total Area, Sq. Ft.*
Sole-finishing department:		
Scouring area		250
Sand dressing area		250
Painting area		100
Burnishing area		200
Rack storage area		500
Treeing department:		
Ironing machines	10 × 10	100
Last storage		100
Shoe-cleaning benches (5 ft. wide)		100
Polishing department		500
Inspection area		250
Trade-marking area		250
Boxing and boxmaking area		500
Packing area		1000
Areas in office building		
Men's wash room		60
Women's wash room		60
Lobby		200
General office		300
Planning department		120
Superintendent department		140
Purchasing department		90
Personnel department		80
Record vault storage		70
Office supplies storage		30

Required:

Prepare sketches showing how you would lay out this plant. It should be borne in mind that a satisfactory layout includes ample space between machines, the minimum movement of goods in process, and also the best use of natural and of artificial lighting facilities. Where machine dimensions are given, they include the area necessary for the machine plus the operators and material handling at the machine. They do not include necessary area for material handling to and from the machine or area.

Problem 4*a*. The Nelson Corrugated Box Company

PLANT LAYOUT PROBLEM

The Nelson Corrugated Box Company, located in eastern Massachusetts, manufactures a large variety of corrugated paper boxes. The present plant layout does not seem satisfactory to the management and a new plant layout is desired in order that costs may be reduced and also to permit as much flexibility as possible in the manufacturing process.

Production work is carried on in a single-story building which is 294 ft. long and 200 ft. wide (see Fig. 146). A railroad spur runs along the entire length of one end of the building. The basic raw material, paper, is received in large rolls by rail and loaded onto trucks, which take it to a warehouse located at a distance of approximately 500 ft. from the main factory building. When the material is needed for production, it is brought by truck to the loading platform of the plant, and from this point it is handled by industrial trucks.

The manufacturing process for boxes is as follows: First, three of the rolls of paper are placed at one end of a machine called the "combiner." This machine glues the three sheets together to make one sheet of corrugated paper. After the material leaves the combiner, it must be temporarily stored for several days to dry out and to allow the glue to set. For this reason, adequate storage space should be allowed at the end of this operation. This aging process gives the paper strength and also facilitates the bending operation which soon follows. The corrugated sheets are stored and moved on platform skids, 6 ft. by 3 ft. in size. Movement is aided by lift trucks which are always available.

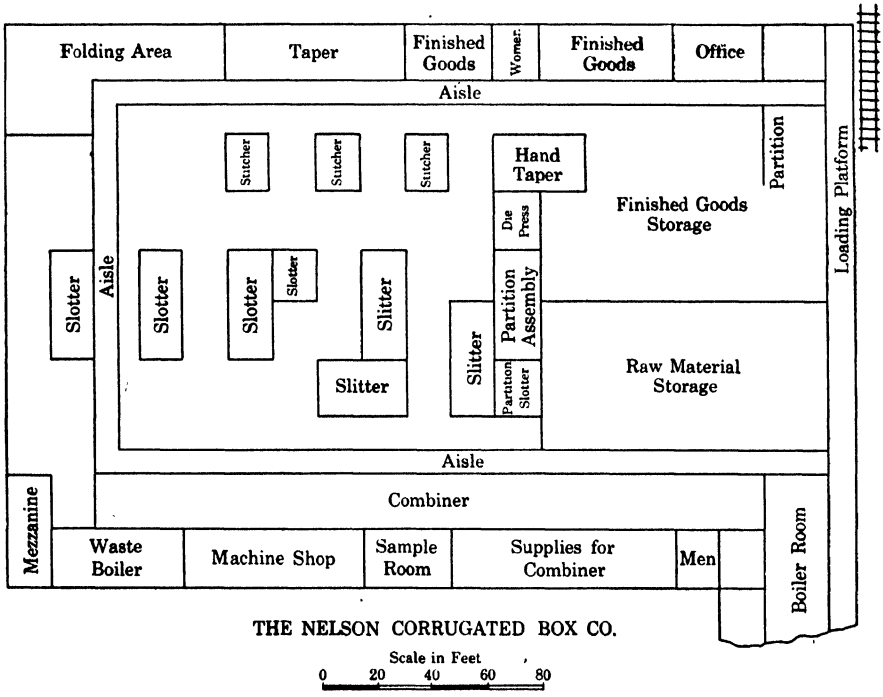


FIGURE 146. PLAN OF LAYOUT OF THE NELSON CORRUGATED BOX COMPANY

The large sheets of corrugated paper which come from the combining machine go, after storage, to either the slitting machines or to the slotting machines. The slitters cut the sheets into pieces which are used for the smaller boxes and for partitions, and the slotters cut the sheets so that they may be folded by hand into box form. It is estimated that about 80 per cent of the work goes from the combiner to the slotters and then to the folders. The remaining 20 per cent goes either to the slitters or to both the slitters and the slotters. The material which passes through the slitters may be packed immediately after leaving the machine or sent to the die (printing) press for further processing. Orders which pass through the slotters usually require folding and then go to either the taper or the stitcher. The taper is a machine which applies a gummed cloth tape to the corners of the box to hold it together. Some boxes are held together by metal pins or staples which are applied by the stitching machine. If the box needs partitions, they may be obtained from the partition slotter but they must be assembled by hand.

When the sheets are discharged from the last machine in the process, as specified by the particular job order, they are packed and taken to the finished-goods storage. The

finished-goods storage must be so arranged that there will be easy access to all skids at all times. This is due to the variety of boxes that must be stored in this area at one time. Since it is a job-order industry, every order may be for a different size, shape, or color.

In addition to the large finished-goods storage area, there must be temporary storage areas available at the end of each process. The bulky nature of the product together with the movement of some 150 employees can create a great problem in the flow of materials if proper allowances are not made. In a plant of this nature it will be impossible to designate any specific areas for any one product. The layout should, however, provide as much flexibility as possible in this respect. In general, goods in process will be stored in front of the machines that are to process them next.

The floor of the building is divided by posts into bays that support the saw-tooth roof. There are 17 bays, each 16 ft. long, running the length of the building; an additional bay located next to the railroad loading platform is 22 ft. long, making a combined total of 294 ft. There are also 10 20-ft. bays across the building. Most of the machines are placed in the rectangular areas defined by one or more bays. Listed below are the area requirements for the machines rounded off into dimensions which will take up a whole number of bays. In the actual production work, the total area required by each machine, its operators, and the material at hand, naturally falls into these easily defined areas. The standard width of all aisles is 8 ft.

Machines	*Dimensions, Including Operator Space*
1 combiner	240 ft. × 20 ft.
3 slotters	640 sq. ft. each, 2 adjacent bays
1 slotter	16 ft. × 20 ft.
1 partition slotter	16 ft. × 20 ft.
3 slitters	640 sq. ft. each, 2 adjacent bays
1 taper	64 ft. × 20 ft.
1 hand taper (for small jobs)	640 sq. ft., 2 adjacent bays
3 stitchers	16 ft. × 20 ft. each
1 die press	16 ft. × 20 ft.
1 partition assembly	16 ft. × 40 ft.
1 waste baler	960 sq. ft., 3 adjacent bays

Other required areas are as follows:

Area	*Dimensions*
Raw-material storage	approximately 5000 sq. ft.
Finished-goods storage	approximately 8000 sq. ft.
Factory superintendent's office	640 sq. ft.
Traffic manager's office — on mezzanine floor above storage area for baled waste	640 sq. ft.
Folding area	approximately 2250 sq. ft.
Machine shop	1280 sq. ft.
Sample room	640 sq. ft.
Supplies for combiner	1600 sq. ft.
Lavatories for men and women	320 sq. ft. each
The boiler room occupies 880 sq. ft. of the floor area — the remainder of the boiler room is contained in an ell of the building.	

a) Make a process-chart analysis of the entire layout.

b) Make a revised (new) layout of the entire factory.

Problem 5. The Mosler Manufacturing Corporation

THE USE OF MECHANICAL CONVEYORS IN HANDLING MATERIALS IN PROCESS

The plant of the Mosler Manufacturing Corporation, which manufactures gears and small machine tools, has six departments:

1. The receiving department and general storeroom
2. The general machine shop
3. Processing
4. Processing and storage
5. Processing
6. Finished-goods storage and shipping

The receiving-department and general-storeroom areas are located in a building connected with the main plant by a cement roadway. The remaining departments are located in the main building.

The plant operations are of such a nature that considerable movement and handling of heavy materials is required. Nearly all processing operations start in department 2, proceed through the various departments in numerical sequence, and end in department 6 for shipment.

In recent years the materials to be handled in the Mosler plant have grown in quantity to such an extent that the management believes it necessary to introduce some sort of mechanical handling equipment to replace some that is already in use and to reduce the cost of other handling that is now being done by hand trucks.

On the basis of a careful investigation by the plant engineer of the material-handling requirements and the mechanical equipment available to meet these, the management has decided to introduce tractor-drawn trailers. For this purpose, tractors having a tractive effort sufficient to pull 18 tons over the steepest grade in the Mosler plant have been recommended for purchase. Trailers weighing 1½ tons and having a carrying capacity of 4 tons each have been recommended for use also. The plant engineer has concluded that it would not be feasible to attempt to have any train contain more than five trailers, and that only fully loaded trailers should be hauled by the tractors, since considerable time would be wasted in checking the weights of partly loaded trailers in order to make sure that the whole load of a train does not exceed what a tractor can pull over the steepest grades of the plant. In determining the number of trailers to compose each train, each of the trailers must be considered as loaded to capacity. Actually, each may carry less than capacity when in operation.

It has been decided to move the materials according to a prearranged schedule by which all materials will be prepared for movement and picked up for transportation at a designated time by the tractors and trailers. It is planned also that the tractors and trailers will move on a schedule that will eliminate delays in the movement of materials, which have been occurring at an increasing rate during recent months. The trains will proceed through the departments according to their numerical sequence and will never "backstep" in movement. It is difficult to turn around a train of trailers; moreover, there are added costs for extra distances traveled when backhauling occurs.

The plant operates on two 6-hr. shifts and during the course of an ordinary working day the tonnages to be moved among the various departments are as follows: (For convenience the numbers corresponding to the names of departments will be used in designating material movements.)

Department	*Tons*	*Department*	*Tons*
1–2	140	3–6	25
1–3	45	4–2	15
1–5	15	4–6	20
2–1	10	4–6	40
2–3	40	5–4	20
2–4	60	5–4	30
2–5	10	5–6	65
3–4	30	6–4	40
3–5	40	6–5	20

The movement of these materials has been arranged in the following material-handling schedule:

MATERIAL-HANDLING SCHEDULE

Originating Department	*Receiving Department*					
	1	2	3	4	5	6
1	×	140	45		15	
2	10	×	40	60	10	
3			×	30	40	25
4		15		×		60
5				50	×	65
6				40	20	×

A study of the various departments indicates that the need for trailers to be used for loadings preparatory to movement in accordance with the material-handling schedule will be as follows:

Department
1–15
2–22
3–29
4–36
5–40
6–28

It is expected that this number of trailers will be idle and available for loading materials throughout most of the day. Those to be used for actual transportation will have to be purchased in addition. The distances between the departments are indicated in the following table:

Departments	*Distance in Feet*	*Total*
1–2	300	400
2–3	100	
	200	200
3–4	300	300
4–5	400	400
	200	
5–6	100	500
	200	
6–1	200	200

It is estimated that the tractors will travel at the rate of 200 ft. per minute. In addition, it is expected that each tractor will make 10 pickup stops and 5 drop stops per trip. The time allowances for these have been estimated to be 2½ minutes for each pickup stop and 1 minute for each drop stop.

In order to operate this proposed material-handling setup, it is planned that each tractor will have a driver and a helper. A driver can be procured at $6.00 a day and a helper at $4.50 a day. The plant operates on a year of 300 working days. The prices for the proposed tractors have been quoted at $2500 each, and if bought in a quantity of 10 or more, trailers can be purchased at a standard price of $180 each. In order to allow for possible breakdowns, one extra tractor must be purchased. The operating costs of all the tractors, including fuel, repairs and maintenance, depreciation, and interest, has been estimated to be 42 cents per productive hour, and is based on a predetermined number of productive hours the plant is expected to operate. It is expected that the trailers will be useful for 20 years and will have no scrap value at the end of this time. The capital to purchase the trailers has been borrowed at an interest cost of 6 per cent.

An added expense in connection with this proposed plan of material handling is that of a supervisor whose salary would be $2500 a year. He would have charge of all material-handling movements and the equipment being used for this process.

a) Determine the total tonnages to be moved from one department to another in the Mosler plant during the entire working day, that is, the total tonnage all the tractors will move in all trips from one department to another.
b) Determine the number of tractors and trailers that will be required.
c) What will be the frequency of service?
d) What will be the moving cost per ton of material?
e) What advantages will accrue to the management from having a centralized material-handling department?

Problem 5*a*. The Adams Manufacturing Company

NUMBER OF TRACTORS NEEDED TO PULL TRAILERS

The Adams Manufacturing Company has the following material to be moved in its plant each 8-hr. day.

From Department A to Department C — 40 tons
From Department B to Department D — 30 tons
From Department C to Department A — 60 tons
From Department D to Department C — 40 tons
From Department B to Department C — 50 tons
From Department C to Department B — 60 tons

The material must be moved directly from one department to another on a circular route and the total distance to be traveled is 1920 ft. Loading and unloading will require 12 minutes each trip according to advance estimates. How many of a type of tractor having a T.E. of 14 tons and a speed of 40 ft. per minute must be purchased to handle the material in this plant when trailers weighing 1½ tons each and having a carrying capacity of 2 tons each are used?

Problem 6. The Greenough Corporation

COMPARISON OF COSTS OF MATERIAL-HANDLING EQUIPMENT

The Greenough Corporation manufactures chains of all types, and in so doing has to move 2110 tons of material in process a day. It has been decided by the traffic manager of the plant to use tractors drawing trailers to accomplish this movement.

The Greenough plant is well supplied with load-bearing trailers which it can use to move the material in process. Each of these trailers weighs 2500 lb. and can bear a load of 2½ tons. The immediate problem is to determine the number of tractors that will be needed in order to meet the present needs of the plant.

A local dealer has quoted a price of $1146.75 for tractors with a tractive effort sufficient to pull 15.6 tons over the steepest grade in the Greenough plant. A dealer in a near-by city has quoted a price of $860 each for a tractor which can draw 13.4 tons over the steepest grade in the plant. The two tractors have approximately the same costs of operation.

The distance to be traveled in the plant is 3750 ft. each trip. The tractors can progress at an average of 150 ft. a minute. Fifteen minutes is allowed each trip for loading and unloading the trailers. The plant runs on a 12-hr. day (two 6-hr. shifts).

How many tractors will be needed? Which tractor should be purchased? Why?

Problem 7. The Johnson Corporation

UNIT COST OF MOVING MATERIALS

The Johnson Corporation operates a small refinery and in the process of each day's work must move 28,000 gal. of oil from the final stage of the refining process to the nearest storage warehouse, where large storage tanks are located. It has been decided by the traffic manager of the plant to use special load-bearing tank trucks to accomplish the movement. Each of these trucks has a carrying capacity of 600 gal. The immediate problem is to determine the number of trucks that will be needed in order to meet the present need of the plant.

The total distance included in each complete circuit from the plant to the warehouse is 4200 ft. for each trip. Each truck can progress at an average speed of 150 ft. per minute. Twelve minutes is allowed for loading at the plant and unloading at the warehouse. The plant runs on a 12-hr. day (two 6-hr. shifts) five days per week. A local dealer has quoted a price of $1200.00 for tank trucks with a tractive effort sufficient to carry a full load over the steepest grade between the plant and the warehouse. It is estimated that the operating cost will be 32 cents per hour for each truck in use and that an operator for each truck may be obtained at a cost of $30.00 per week. What will be the cost per gallon of moving the oil?

Problem 8. The Kane Corporation

SELECTION OF SIZE OF CONVEYOR BELT

The Kane Corporation wishes to move crushed limestone from its storage place to its mill proper. The lime is estimated to weigh 96 lb. per cubic foot and in bulk has a maximum lump size of 8 in. Crushed lime can be readily loaded on a 24-in. troughed belt so that the amount of surcharge will be 20 degrees. How many 24-in. belts are needed to move 4500 tons in an 8-hr. day if the belt is operated at recommended maximum speed as shown on Table 2? What size of belt will carry the total load in one day?

Problem 9. The Silky Soap Company

DETERMINATION OF SPEED OF PACKAGE CONVEYOR

The Silky Soap Company manufactures soap powder. In connection with a rearrangement of its plant, it has been decided to use conveyor belts to move filled packages of soap powder to the shipping room where they are packed in large cartons. The output of the package filling machine is 300 packages per hour. A standard package-conveyor

belt for installation may be purchased with a maximum speed of 80 ft. per minute to deliver 10 standard-size Silky Soap packages a minute over its end pulley discharging into the shipping room. What must be the speed of the conveyor belt to take care of the 300 packages each hour from the filling machine?

Problem 10. The Keith Corporation

CALCULATION OF SIZE OF CONVEYOR BELT

The Keith Corporation wishes to move approximately 1000 tons of powdered gypsum between two stations of the manufacturing process. This material is to be moved during an 8-hr. day. The average weight of the powdered gypsum to be moved is 75 lb. per cubic foot. What size conveyor belt is necessary to move this material when the belt travels at a speed of 100 ft. per minute and the angle of surcharge is 30 degrees?

PART IV

MANAGEMENT OF MANPOWER

Ever since the factory system of production came into existence, industrial managers have devoted a great deal of time and effort to the physical organization of the manufacturing plant. During recent years, however, it has become increasingly clear to top managers that a totally efficient manufacturing enterprise demands also a great deal of attention to the management of manpower.

The principles and practices which have proved their effectiveness in the development of sound employee relations as well as the profitable use of labor are discussed in separate chapters as follows:

1. **Organization and morale.** Intelligent management demands not only careful definition of lines of authority and responsibility, but also the recognition and intelligent handling of problems of morale. Grievances and individual differences must be ironed out; management must understand certain misconceptions which are apt to exist concerning its employee relations; in addition, a special effort must be made to promote morale through expressed attitudes, communication of ideas, public relations, minimizing of absenteeism, and plant broadcasting.
2. **Safety and health.** A safe working place is an efficient working place. Managers have specific responsibilities to organize safety programs and to educate workers to work safely. The problems of safety in relation to the plant have been discussed in the chapter dealing with Plant Layout and Safety.[1] There are many aspects of safety which relate to the worker, however. These include protection of eyes, guarding against falls, correct methods of working, and intelligent use of protections provided against bodily injuries. Safety involves, too, the elimination of possible sabotage and provision of protection for the plant itself.

   Not to be overlooked is the organization and administration of an employee health program. The plant clinic and health service can do much to keep workers in good health and to reduce occupational diseases. When these are accomplished, they are reflected in attendance reports and general worker competence.

[1] See Chap. XIV.

3. **Selection and training.** No less important than the selection of machinery and equipment and plant services are the procurement and maintenance of an adequate working force. Job candidates must be recruited, tested for abilities, selected, and trained. The last involves induction of the employee with proper attitudes toward the work situation.

   Special problems of training which deserve attention are the training of apprentices and the training of women, as well as use of motion study in connection with training.

4. **Motion study and the worker.** The principles of motion study which apply to organization and layout of the industrial plant are discussed in the chapter on Motion Study and Plant Layout.[1] Additional principles of motion study which have found widespread acceptance in industry have to do with the worker and his bodily movements. These are closely allied to training and safety. Improvement in methods by means of motion study is one means of making efficient use of manpower.

5. **Time study.** This topic logically follows a discussion of motion study. Both are closely related in actual practice. Rate-setting in industry has been a controversial subject for many years. Intelligent rate-setting requires an understanding of a number of specific problems of worker psychology and the application of specific techniques. The mechanics of making and computing time standards are explained in detail to give the student of management an understanding of the time-study engineer's job.

6. **Job evaluation.** The organization, selection, and training of workers, and the setting of proper job standards regarding work procedures and time requirements leads logically into a discussion of what jobs are worth. Job evaluation is a technique for determining what should be paid workers who meet minimum job requirements — base rates of pay. The steps for organizing and administering a job-evaluation program and the practices to be followed in evaluating jobs are discussed in the chapter on Job Evaluation.

7. **Merit rating — measuring manpower performance.** No two workers are exactly alike. There are differences in ability and attitudes. Merit rating is a technique for measuring manpower performance; it is used in deciding matters of transfer, promotion, upgrading, and training. The chapter on Merit Rating deals with the organization, development, and administration of employee and supervisory rating systems. It includes also the pitfalls which management must guard against.

[1] See Chap. XI.

8. **Employee compensation.** The systems or methods by which workers are to be paid deserve careful study. Perhaps more misconceptions exist concerning systems of wage payment than any other topic of management. The study of bases of pay and wage systems as instruments for giving workers proper reward for work performed according to established standards of performance should be a major concern of every manager. The chapter on Employee Compensation presents basic principles.

CHAPTER XV

ORGANIZATION AND MORALE

ORGANIZATION

To organize manpower means to build a structure, not of wood and steel, but of human beings. The people are the material of construction, their loyalty the foundation, and their cooperative spirit the mortar that holds the structure together and gives it vitality.

The word "organization" signifies both a process and a result. The process of organization produces an organization and the person who performs the process is termed an "organizer." Organization has to do with work to be done and the persons who are to do it. Combining human beings with segments of work to be done into a harmonious whole is the chief job of the organizer. His task involves either (1) assigning duties to individuals or groups already selected to work so that they will work efficiently together, or (2) arranging an organization and then fitting persons into it. At the inception of an organization, its purpose must be clearly defined, because organization is a means to an end. *It is never an end in itself.* Policies, therefore, must be clearly established before organization starts.

Organization is often thought of as the framework or skeleton of an industry or business and not a living, functioning unit. Since it is an association of human beings to attain some purpose, the efficient working of the whole depends upon the coordination of even the smallest of its parts and functions. A sound, healthy, human body depends upon the smooth working of all its parts. No less is this true of groups of people and their activities, whether they be small social groups or highly complex industrial organisms. Their objectives are attained most directly and efficiently when each component part is coordinated with all the others in a joint activity for common ends.

Just as the mind directs the body to fulfill its desires, so management is a vitalizing factor which energizes, directs, and controls organization. Management and organization, therefore, are closely related. While it is the duty of management to organize, management can achieve very little without an organization structure through which to give shape to its plans and procedures. It is difficult, too, to separate management and organization, because management at its best is *the intelligent control of manpower* and organization as a technique is the means of

coordinating manpower and management to produce a harmonious relationship in the fulfillment of duties. It is important to realize, however, that persons who are capable organizers are not necessarily capable managers, but it would be very surprising if a poor organizer proved himself to be a capable manager. Every efficient organization owes its existence to some capable organizer and as long as the organization endures, the impression of his work will remain.

Invention, business genius, or some individual with special skills may make a business produce results for a time, but no business can avoid ultimate stagnation and perhaps even disintegration if its leaders do not understand how organization is developed and by what standards its effectiveness may be measured.

Steps in Organization Development

Organizations usually grow from very small beginnings and each structure follows a similar pattern of development. Briefly it is as follows:

1. **Group association.** Persons who have common interests associate themselves to achieve common objectives. They are held together in their association by a common denominator of interest, common understandings, and joint participation in activities. Both social groups and business organizations have their start in this type of voluntary association. The business group association is founded on economic activity.
2. **Division of work.** All groups discover that they can move rather quickly towards their goals when the work is divided among the various members. This prevents overlapping and misdirection of effort. In a business organization this takes the form of *departmentalization* and assignment of different duties and responsibilities to different people.
3. **Delegation of authority.** Splitting up the activities of the associated group demands that there be authority for action. In time the group comes to vest authority in particular persons so that it may be exercised for the best of all concerned. At this stage, the group distinguishes between those who direct group activities and those who must follow. Lines of authority and responsibility are fixed to implement the performance of what each segment or department must do to fulfill group objectives. The military or departmental type of organization is typical.
4. **Recognition of leaders.** The needs of any group vary with growth and with changing times. Those who anticipate the needs of the group at work and demonstrate capacities for meeting them become leaders. They derive their authority from the group itself and enjoy privileges as long as they can enjoy the confidence of the group. Different types of activities produce different types of leaders. For every group activity, therefore, there must be some leader and it is largely to him that the problems of organization are delegated. In the industrial enterprise, it is the leader

who introduces formal organization. It is he who arranges, controls, and supervises. In so doing, he serves his particular group if he creates an organization which advances the group toward its desired ends.

5. **Creation of specialists.** As groups continue in size and complexity, it becomes obvious that some activities cannot be left to the group as a whole or to its leaders if they are to be done well, but require special attention and investigation. The result is the designation of some persons to be advisers or experts so that the best possible information will be available and useful to all concerned. The *line and staff* organization which creates advisers on special management responsibilities was an early recognition of this principle in business organization.
6. **Division of authority by specialization.** The designation of some members of the group as a staff to advise on particular problems promotes the development of specialists. The group leaders come to rely increasingly on them for advice. As organization develops and special problems increase in magnitude, the leaders are forced to relegate the handling of special problems to various specialists. In organized business, group association has taken the form of *functional divisions*, to the heads of which is delegated executive authority over all problems within their special areas regardless of where they arise in the organization.
7. **Coordination.** When one person is in charge of a group there are no conflicts of opinion or authority. When authority is divided, however, all of its parts must be made to work smoothly toward the goals of the organization. Otherwise, the group leaders may lose sight of the purposes for which they are organized and focus attention upon the organization itself. Coordination is necessary if this is to be avoided. It is a primary function of top leaders. They must see to it that all objectives and aims are kept uppermost and that those in authority combine their energies harmoniously in behalf of a cooperative effort toward achievement of desired results. A well-coordinated organization is one which approaches the ultimate in management efficiency.

Principles of Organization

When an organization comes into being, its primary test is how well it serves the ends to be achieved. The accomplishment of these ends is largely a result of recognizing and following a few basic principles. These are the principles of efficient organization:

1. **Definiteness.** Every necessary activity should contribute to the main objective of the business with a minimum of effort and a maximum of effectiveness on the part of the workers.
2. **Balance.** Every branch of the business should be equally effective and conform to the plan of the whole. This is called "organization balance."
3. **Coordination.** The organization should permit complete coordination of every branch of its work. The performance of the work of every unit should be economically related to all allied units and the whole should comply with main policies.

4. **Flexibility.** The organization should permit growth and expansion without dislocation, regardless of changes in personnel and methods.
5. **Efficiency.** All available manpower should be used to the fullest capacity compatible with the highest possible operating efficiency.

Organization Types

There are almost as many varieties of organization as there are industrial firms, but all reduce themselves to one or a combination of three main types. These are:

1. Departmental form.
2. Line and staff organization.
3. Functional organization.

1. Departmental organization. This type of organization is often called the "military" or "traditional" form. It is the earliest form and

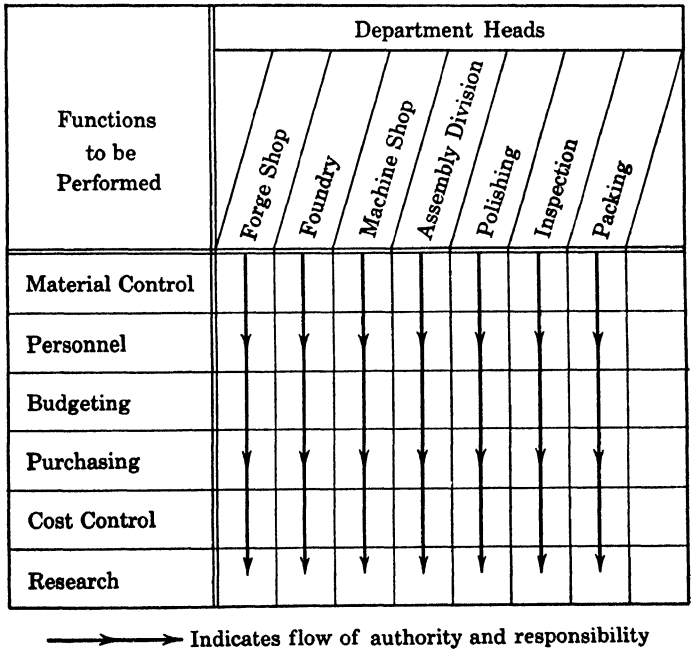


FIGURE 147. DEPARTMENT FORM OF ORGANIZATION

the simplest. The essence of it is that each department or unit of the business is self-sufficient. All activities are divided into major groups — finance, production, sales. Each of these in turn is subdivided into self-contained units or departments. For example, the production department would be divided into operating departments, such as forge

shop or assembly division. The head of each department is responsible for everything affecting its work. He selects labor, purchases his own materials and tools, and provides his own maintenance and other required services. Under this system, there is no question where credit and blame belong. The simplicity of the system, however, is its own undoing. The activities of industry, such as purchasing, maintenance, and cost control, are too complex and technical today for any one person to be expert in all. For example, the modern personnel department performs functions such as collective bargaining and job evaluation which are too specialized for complete understanding on the part of individuals who must supervise production.

This form of organization is based on an autocratic system of management. Under it, a business is subject to arbitrary decisions of one man at the top and one man in each department is responsible to the person at the top.

The departmental organization is nearly always the form assumed by the small business and has definite merits during developmental stages. Things get done and control is simple and the business profits from the initiative and driving force of the one-man management.

Business research and the development of specialized knowledge, however, have made this form of organization obsolete for the modern medium- and large-sized industrial firm. Figure 147 shows flow of authority and responsibility of the departmental form of organization.

2. Line and staff organization. As industrial firms grew in size, the managers who worked under the departmental form of organization found that they did not have time to give careful attention to every phase of management. Consequently, the "staff idea" came into being. The staff is an advisory group adjunct to the line. It does not operate the business, but advises line department heads on how to achieve results. Some define the staff personnel as *thinkers* and the line personnel as *doers*. This form of organization has called attention to the need for specialized research in the development of ideas, thereby paving the way for functional concept and more specialization of organization. Figure 148 illustrates how the line and staff organization operates.

3. Functional organization. Functionalization is a development of line and staff. Its basic concept is that parts of the organization should be based on functions or techniques. It is the opposite of the departmental idea because the functional organization disregards production processes or areas. It splits up personnel more particularly according to managerial functions such as accounting, cost control, budgeting, purchasing, research, manufacturing, production control, maintenance, and transportation. Under the line and staff organization, the work of the staff is not regarded as a specific managerial function. Under

functionalization, however, specialists become more than just advisers; they become also executives in charge of single techniques which are common under several units of the work.

Functional organization meets the needs of modern industry and overcomes the objection that production supervisors cannot be at the same

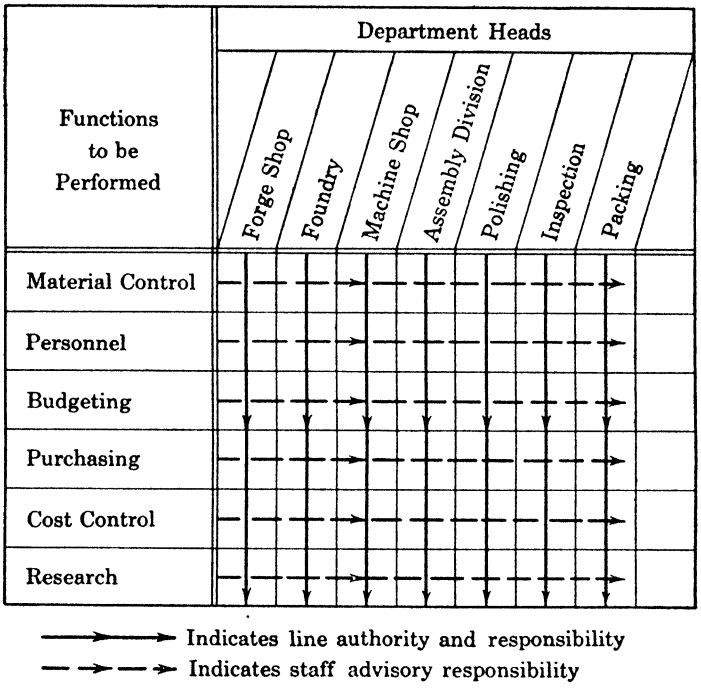


FIGURE 148. LINE AND STAFF ORGANIZATION

time specialists in selection, training, cost control, and a variety of other managerial functions. Each of these is functionalized under a separate person. Functional organization has many advantages: (1) One man devotes his entire time to doing one thing. (2) It does not hamper organization growth because each man grows in his own specialty. (3) Each person gives his best effort because he develops according to his best abilities.

Its disadvantages are: (1) It is confusing from the standpoint of procedures of control. (2) It is conducive to overlapping authority and lack of definiteness of fixed lines of responsibility, which may result in "buck passing." (3) It does not permit easy coordination of work and depends primarily for its success upon brilliant leadership which is not always present in modern business. Figure 149 shows the flow of authority and responsibility in the functional type of organization.

THE ORGANIZATION CHART

The purpose of an organization chart is to permit those at the top of an enterprise — management — to divide up the various duties so that they will be done effectively with a minimum of delay. The chart is a means of classifying the duties and responsibilities of all concerned so that time and effort are neither duplicated nor wasted.

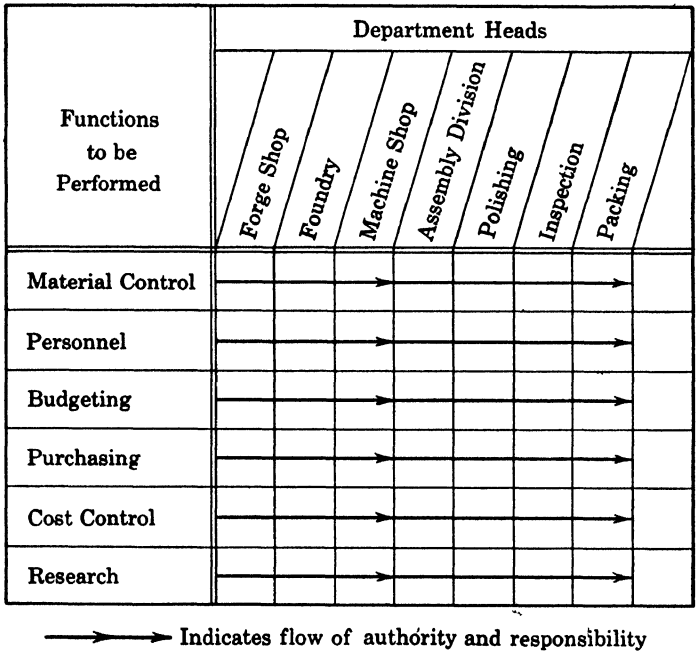


FIGURE 149. FUNCTIONAL ORGANIZATION

A well-planned chart will show all who work together in any undertaking, what each is to do, and to whom each is responsible. The organization structure, or framework, may be thought of as a communication system for assigning work — giving out jobs, delegating authority, fixing responsibility, and receiving information on results. In constructing the organization chart, the lines of communication — flow of authority and responsibility — should be direct and clear. The chart should be based on consistency of procedure also. This requires that in drawing up a chart those tasks falling into given categories be assigned to the departments or divisions most logically responsible for them. If exceptions and special arrangements are made when the chart is being drawn, confusion will be the result. The concessions needed to meet variations of individual capacities, personalities, and prejudices can be

made after the organization structure is properly conceived without distorting the basic pattern.

THE ORGANIZATION CHART AND TITLES

The designation of names of parts of work should be handled carefully. These are the bases for job titles and are the labels by which persons both inside and outside an organization are guided in their handling of the work and other relationships (Fig. 149A).

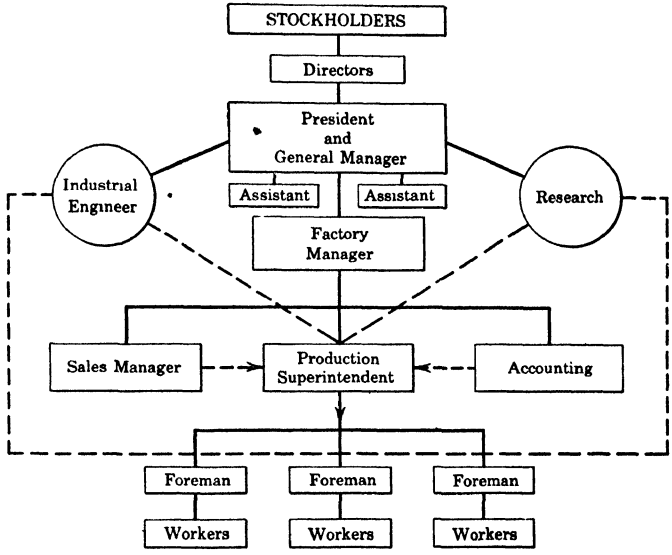


FIGURE 149A. HYPOTHETICAL ORGANIZATION CHART SHOWING LINES OF AUTHORITY AND RESPONSIBILITY

Unbroken lines show direct responsibility and authority. Broken lines show staff relationships.

Titles such as Production Manager, Factory Manager, Plant Superintendent, General Foreman, Foreman, Supervisor, and Department Head should be defined and placed in their proper relationship to the whole. Moreover, the functions to be fulfilled by workers in the various positions should be studied and their titles selected carefully. Nothing is more detrimental to organization harmony than ever-changing titles. Titles are labels which define segments of work. They should be helpful to those outside the organization and they should build an internal system of procedure.

It follows that a title held by a person in any organization should be a badge of ability. By giving a title, top management places a label on

an individual which says he is capable of certain responsibilities and, therefore, possesses a given type of ability. Responsibility and ability go hand in hand, and subordinates have a right to expect that titles of persons above them mean that these persons deserve the recognition accorded them. To give titles to those who do not justify them is an unkindness to the persons to whom they are given as well as to those who must work under them. It is one sure way to defeat the purposes of organization.

ORGANIZATION-CHART PRINCIPLES

Some principles of organization which deal particularly with the procedures of control as outlined in the organization chart deserve attention. These principles should be made standard practice in organization relationships. They follow:

1. Lines of Authority Should Be Observed by Top Management in Dealing with Subordinates

The machinery or procedure for handling work as designated by the organization chart should prevent executives and those at the top of the organization structure from going over the heads of immediate subordinates to give orders or instructions, or to obtain information. The established lines of communication as indicated in a completed organization chart should be followed. Persons who are by-passed are often humiliated. Executives who do this cannot expect to hold subordinates responsible for the work of those under them. (Of course, there are exceptions to the rule when persons in responsible positions do not produce results.)

2. Lines of Authority Should Be Observed by Subordinates in Dealing with Superiors

The organization should also prevent subordinates from by-passing their immediate superiors in dealing with persons over them. This practice can only arouse suspicion, jealousy, and breed organization disloyalty.

3. The Organization Chart Should Define Lines of Position

Care should be taken to avoid placing positions on the organization chart at the same structural level when they do not have either the same responsibilities or authorities. This leads to disputes and bickerings.

4. Balance of Organization Is More Important than Individuals

The organization chart or plan should be above personalities. The failure of a person to come up to expectations should be a cause for changing the person in the organization and not an excuse for warping the balance of the organization structure.

5. Organization Should Be Simple and Flexible

The organization pattern should be both simple and flexible to permit periodic modifications that may be required as the business or industry grows, declines in size, or changes its character. Whatever shifts are made, however, should not violate the basic principles already discussed.

ORGANIZATION-CHART LIMITATIONS

There are many industries or business organizations where a formal chart of organization is not needed. A person at the head of the business will perform nearly all the duties which are functionalized in the large firm. Then, too, it must be appreciated that organizations are composed of human beings. Concessions to personalities, peculiarities, and special abilities, must be made in order to expedite efficiency in the performance of work.

Not infrequently a job is created to utilize the special capacities of a particular man. When he leaves the organization, his exact work cannot be done as he did it. The creation of a special category for such persons is desirable and necessary. Their presence in an organization, however, should not preclude a careful demarcation of lines of authority and responsibility. The skeleton structure which shows *paths which work must follow* and *who does what* must still be in keeping with accepted principles of industrial management.

THE RELATIONSHIPS OF LINE AND STAFF ORGANIZATION

Unfortunately, those who work in a line capacity and those who serve as staff officials in industry do not always get along harmoniously. The persons in line authority often tend to resent interference or "meddling" in the work of their departments, and the staff men chafe at the handling of their "specialties" by those in line authority.

Ordinarily, those who hold staff jobs in industry usually have no authority over lines of supervision, and vice versa. There are some instances where special authority is given to one or the other and when this is done it should be made very clear to all concerned. By so doing, unnecessary friction will be avoided.

Actually, those with line and those with staff authority should complement one another in the performance of their work. Each is in reality dependent upon the other for help. The cost accountant cannot compute costs of manufacturing without information on manufacturing processes, and the foreman, in turn, needs to know what his costs are in order to measure his efficiency. Those who serve in a staff relationship should strive to gain the cooperation of those who are so-called line supervisors in order to put across ideas. The chief function of a staff man is to give a special service. The performance of this service, and not authority or prestige, should be the main concern of the staff official. His work alone will justify his role in the plant.

Line men should solicit the cooperation of the staff personnel as props to strengthen their jobs. By using the knowledge of the staff men, they will find that the efficiency of their own work is enhanced. Since staff specialists are usually more highly paid and have access to many departments of the organization, it is good business for those in line authority to gain all the knowledge they can through staff specialists. This is the surest way for many line men to improve their own jobs, enhance their incomes, or to become specialists themselves.

MORALE

Morale is the spirit which vitalizes an organization structure. It is composed of confidence, loyalty, and cooperation. Confidence and loyalty are closely related. Confidence in management gives rise to organization loyalty, while organization loyalty in turn bolsters the employees' confidence in those who control the organization itself. Both in combination result in cooperation between those who work for the organization and those who direct its activities.

Morale depends upon a great many factors. In its initial stages of development it is an expression of group opinion — the sum total of the feelings of all concerned. Viewed from top management it has two aspects: (1) the presence of good will among employees as demonstrated through participation in the work of the organization, and (2) good will on the part of the public. Both are a result of internal organization attitudes. They succeed or fail together, for the impression of the public is favorable or unfavorable as a result of relationships with those who are close to the organization — those who work for it. Employee contact with the public may be likened to the splash of a stone in a pool. The rippling circles on the surface spread outward. So does good will or ill will spread out from an organization. In dealing with customers employees are management's representatives and it is on the basis of these relationships that customers formulate their opinions about the organization and its policies.

It is important to examine carefully some management-employee relations that may make or break morale. An employee's loyalty and enthusiasm for his employer or firm is usually commensurate with his attitude toward his job. It is of foremost importance, therefore, that grievances and problems which are irksome to employees and which destroy morale should be recognized and adjusted. It is merely confessed management incompetence which minimizes these maladjustments in morale on the ground that friction must exist wherever human beings work together, or assumes that all matters requiring adjustment will eventually come to a head. Time and experience have demonstrated that most troublesome problems of employer-employee relations result from an accumulation of seemingly minor matters and lack of attention to what men are thinking and want from their jobs. Eruptions in human relations can be avoided only when managers understand workers' attitudes. It is worth while reviewing briefly what workers seek or expect of their jobs. The relative importance different groups will attach to these matters will vary, but most will include the following:

1. Leadership

All employees seek and respect intelligent leadership. The leader who inspires others to do for him is rapidly supplanting the hard-boiled supervisor. Supervisors are management's representatives to the worker and it is universally true that the loyalty and respect accorded the entire organization can be no better than that accorded to those who are directly in contact with workers. To be a good leader, one must have a good understanding of industrial psychology. It is essential that the leader understand impulses and instincts. This will help him understand the emotions and reactions of persons working under him. With this background he should be in a position to interpret the needs of his group and to direct their affairs so that they achieve the objectives they feel are significant and worth working for. Except as a leader can anticipate the needs of the members of his group and so direct his own activities that he becomes their interpreter to management and a sympathetic counselor in connection with their problems, he cannot build a firm foundation of morale.

2. Recognition — A Feeling of Worth-whileness

All people want to be recognized. They want appreciation for what they do as well as courtesy and consideration in everyday relationships. No matter how lowly his occupation, a worker likes to be regarded as an essential cog in the wheel, to be given recognition. Making employees feel that their work is a contribution which is appreciated is fundamental to every morale-building program.

Unfortunately, many managers are too preoccupied with their own positions to express proper consideration and courtesy to employees. They give short answers and orders without explanations, and as a result create a lack of respect. Those who receive the orders come to believe themselves regarded merely as animals comprising the living machine of industry. Like begets like, and only through outward demonstration of kindness and consideration can the best be brought out in associates. Those who have a friendly appearance, a ready smile, and who are slow to criticize, will find that others respond in the same way. On the other hand, persons who have a chip-on-the-shoulder manner and who find fault with those working for them will soon learn that such attitudes breed only contempt and discontent.

3. Organization Dependability

Perhaps above all else, workers want a reasonable expectancy of job security and regular pay. They want to feel also that they will receive deserved periodic increases. A sense of insecurity builds only discontent and indifference. Firms which have a high labor turnover usually have a very low morale, and it generally follows that the morale is high where turnover of labor is small. All workers feel that they have vested rights in their jobs and that they are making a contribution to organization welfare which deserves reward by way of assurance that their jobs are secure. In recognition of this fact, management is contributing another milestone in the development of sound human relations — good morale.

4. Definite Responsibility

No man likes to work for a multiplicity of bosses. Every man who is working for another has a right to know what is expected of him and who is to be the judge of what he does. Where several persons with conflicting authorities are to pass upon what any worker does, there can be only confusion and uncertainty on the part of both management and the worker with respect to job competence and satisfaction. There is no more certain way to destroy morale than to give workers assignments and then have them discover that their success is dependent upon pleasing not one but several persons with conflicting notions as to what constitutes a good job. Lines of authority and responsibility in this connection must be firmly established. This is an administrative problem which is discussed more completely under Administrative Organization as it relates to morale.

5. Equitable Pay

Every worker likes to feel that the pay he is receiving is a *just* compensation — that his pay is equitable in relation to that of others on

the pay roll. This means that the pay must represent a reward that is fair in terms of what various jobs require of those who fill them. Management must analyze job requirements as well as the qualifications of the men who fill them. Only thus can employees be assigned work for which they are qualified and then be paid accordingly. For many this means the examination of jobs and men through the use of two of management's newer techniques — job evaluation and merit rating. The former discovers what jobs require of men, and the latter measures how well men measure up to these requirements. (These techniques are discussed more completely in Chaps. XX and XXI.)

MANAGEMENT MISCONCEPTIONS CONCERNING MORALE

Most managers sincerely believe that their organizations are lacking in none of the requisites for good morale. They feel that their employees are wholly satisfied with the supervision they receive, with their pay for work accomplished, and with their relationships to their employers. With few exceptions, this is merely wishful thinking because managers really do not know the employee's attitude. They assume that an organization structure, often uniquely conceived, cannot fail to reveal all dissatisfactions and grievances. These are usually paper organizations in which authority, responsibility, and staff relationships are indicated by various colored lines and other similar devices. Although the recording of an organization structure on paper is desirable, the major fact is often overlooked that it is designed to keep orders flowing steadily in one direction. The organization is, therefore, a one-way street. Dissatisfactions, disagreements, or abuses do not dare venture the other way; it would be suicide — job suicide. Consequently, a host of maladjustments arise about which the worker can do little or nothing but which seriously impair his having a proper job attitude and good morale.

Chief among the reasons why an organization structure does not encourage and support morale are these: weaknesses of administrative organization, difficulties of personality, and nepotism (employment of relatives).

Administrative organization. Frictions arise most frequently where authority and responsibility are either indefinite or misplaced. When those at the top of an organization refuse to both delegate and define job categories carefully, discontent, undercurrents of friction, and disloyalty cannot be avoided. Officers and employees alike can neither do their best work nor feel free to offer needed criticism when they are concerned with their own status in relation to associates or even to job security. *When one's authority is definite and understood,* there is usually

little cause to exercise it. Both subordinates and associates know where they stand and act accordingly. When a man has responsibilities without authority, those who work for him and with him usually attempt to see how much they can get away with.

Personality difficulties. People work most efficiently and happily with those who have pleasant dispositions — cooperative attitudes and a toleration and respect for others. Organization morale would be an impossibility if the vast majority of workers did not have these qualities. Unfortunately, however, some persons have in their makeup attributes of conceit, jealousy, selfishness, and hypocrisy. When persons who demonstrate these characteristics to any marked degree are tolerated in positions of responsibility over others, they can only destroy morale. In extreme cases, their services should be dispensed with entirely in the interests of harmony in the organization.

Nepotism. The hiring of relatives is not objectionable in itself and may be readily defended from the viewpoint of work interest and dependability. The practice becomes really objectionable, however, when either blood or legal relationship is a basis for favoritism in matters of pay increases, promotion, and work assignments. Where these conditions prevail and employees really feel that "you have got to be in the family to get the breaks," dissatisfaction and poor morale are bound to result. Moreover, it is almost impossible for management to learn the truth about any difficult human relationships in which the family or closely related friends are concerned. In the end this spells inefficiency and low profits unless management can make very clear that there are no favorites on the pay roll.

MORALE AND EXPRESSED ATTITUDES

The attitudes of workers at every level of an industrial organization are in part a reflection of the ideas, mannerisms, and impressions they observe in their work situations. When those with genial natures dominate a situation, a friendly, cooperative attitude is likely to be fostered; similarly, disagreeable and irritable people create unpleasant working relationships.

It is often observed that subordinates reflect the attitudes of their bosses. Whenever a shop or office is under the charge of persons whose mannerisms are caustic and uninviting, the whole working force is apt to reflect this attitude. The attitude is absorbed through familiarity of association, and lowers the morale of all who must have contact with this part of the organization.

Responses of persons also have a direct bearing on morale. Some persons react to all proposals negatively. Their instinctive reaction is

"No, it cannot be done" or "Why should I do this?" Members of organizations who hold key posts and whose natural response is negative to all proposals, ideas, and requests for favors should be placed in jobs where they have little or no contact with others. The price paid in poor morale which results from placing negative persons in key jobs where the attitudes of others is affected is usually too great to justify keeping them there.

MORALE AND COMMUNICATION OF IDEAS

In communicating ideas opportunities are provided to build good morale. It is not always what is said, but how. The words used may not offend, but the facial expression or mannerism may. Those who supervise and lead others need to develop and practice the use of facial expressions, body mannerisms, and habits of action which convey correct impressions.

Communication is more than a matter of words. It is also what one does and how one appears. True meanings are expressed more often not by what is said, but by the way one acts. For example, a person may appear unimportant, and even though his ideas are excellent they will fall on deaf ears, but these same ideas expressed by one of attractive appearance are listened to eagerly by those who should be interested.

Confidence, cooperation, and loyalty, which are the cornerstones of organization morale, can be destroyed by incorrect use of words. Because the same words and phrases have several meanings and implications when emphasized differently and under different circumstances, it is most desirable for those whose job it is to convey correct ideas to others by means of words to see to it that they say what they mean as well as mean what they say.

In expressing policies, viewpoints, and discussion of grievances, there should never be any uncertainty in the written or spoken words of leaders as to just what is meant and where management stands on any matter. Morale is destroyed when people believe that there is a difference between the spoken or written word and the real meaning. It is true also that leaders who use extravagant praise or who speak glibly and freely with men can never build unswerving loyalty among their followers. Managers, and particularly those who are close to workers as leaders, must avoid being branded as insincere.

In the communication of ideas, it is seldom possible to convey one's meaning to others exactly as one wishes to have it understood unless the audience addressed — the listener — is receptive.

Persons are readily receptive to ideas which have their sympathy and which are in harmony with their emotional thinking. The emotions which rule the thinking of others can be understood by listening to their views and getting the best possible word picture of their feelings and sentiments. Top management and supervision in industry, therefore, cannot hope to have policies understood and supported except as they learn first of all to interpret them from the worker's point of view. This is a keystone of morale, because cooperation which is based on sympathetic understanding is the backbone of morale.

MORALE AND PUBLIC RELATIONS

The good will of present and potential customers is vital to the success of a firm and, in turn, to its morale. This involves much more than just "selling" the public particular products or services. It means the establishment of public "customer confidence" in those who manage or operate the business itself — an acceptance and respect for the sincerity of purpose, soundness of policy, and integrity in business dealings, backed by a desire to make customers rather than sales. Foremost in importance are courtesy, service, high value of products, and facts concerning their value. Employers must appreciate that these ideas are conveyed to a large extent by their own employees in dealing with the public. It is truthfully said, therefore, that sound public relations begin at home. If the management has the good will of the worker, the good will of the public will follow.

MORALE AND ABSENTEEISM

Absenteeism is closely linked with the hours of work devoted to production in the manufacturing plant. Workers who are discontented in their jobs will make the most of excuses not to attend work regularly and they will take time off on the least provocation. Those firms which have problems of absenteeism as a result of work attitudes should bend every effort toward improving morale and making the workshop an inviting, enjoyable place to be. Actually, persons spend more of their conscious hours in their workplaces than they do in their homes. Attention to esthetic surroundings as well as development of proper attitudes toward the job can be helpful in developing morale to reduce the amount of absence.

Absenteeism results also from physical fatigue due to increased working hours. This is particularly a problem during periods when production is at a peak and persons are called upon to work additional hours daily and to forego holidays and Sundays. How long a work week may

be under the strain of war production may be gauged from observations on absenteeism caused by the excessive demand on production workers engaged in factory war work during the first three years of World War II.

It is reported by British authorities [1] that hours of work in connection with Britain's war effort in World War II have often been too long. Quite apart from the well-being of the workers, it is deemed not worth continuing too long hours from the production viewpoint. The British Industrial Health Research Board recommends that a maximum working week of 60 hours for men and 50 to 55 hours for women is about a maximum for sustained efficiency. A number of British firms have reached the conclusion that hours even below these recommended maximums are much better for maximum production efficiency.

The experience of Great Britain demonstrates that absence from work is to be expected mostly among workers who have worked long hours over many months. Their desire to stay home is purely a result of fatigue and not defiance. The comment is made, however, that two-thirds of the absenteeism which British industries have experienced in World War II is said to be due to ill health and accidents rather than fatigue from long hours.

The general impression that high wages discourage people from carrying on their work is not borne out by conversations with British workers and their families. The primary causes of absenteeism are overstrain, fatigue, illness, and accidents.

CREATING AND SUSTAINING MORALE [2]

There are various methods or "agencies" for influencing morale and behaviour of others. Managers and supervisors should employ these in their daily contacts. Those more commonly used follow:

Example. Men tend to imitate their leader. The supervisor should never take liberties that are forbidden his men. If he is to lead, he must set a good example.

Praise. This is one of the most effective methods for building morale. Where credit is duly given, the desire for recognition is satisfied and further ambition is stimulated.

Patience. The manager or supervisor who displays self-possession and calmness toward his men relieves his department of unnatural strains and friction. Men work better in a stabilized "atmosphere."

[1] *The Christian Science Monitor*, Oct. 29, 1942, p. 1.

[2] The content of this section is taken from *Tips, Training in Progressive Supervision*, a publication of The Liberty Mutual Insurance Co., Boston, Mass. Reprinted by special permission.

Comparison. Most men have a desire to excel and usually react favorably to fair competition. The pride and self-respect that all men possess to some degree can be effectively used by the foreman to make them voluntarily raise their own standards of performance.

Courtesy. An atmosphere of mutual respect and consideration between the supervisor and his men is a strong factor in maintaining morale.

Fairness. Dealing fairly with men is frequently difficult. Personality, friendships, and skill can involuntarily influence a foreman's decisions. Nothing breaks down morale faster than injustice.

Interest. Every employee should be aware of his supervisor's personal interest in his job, as well as his outside problems. There is satisfaction in knowing that he is receiving a share of the supervisor's personal attention.

Responsibility. Giving a man definite responsibilities is an important aid in developing morale. A man responds quickly to opportunities to prove his ability. Responsibilities must be clearly defined.

Encouragement. Every man wants to progress and is grateful for help from his supervisor in guiding his effort to improve. The foreman who stimulates ambition keeps his department morale high.

Confidence. A foreman who trusts his men is trusted in turn by them. Confidence inspires the desire to make good on assigned duties.

Consistency. The supervisor whose temperament varies from day to day or with different individuals creates an atmosphere of uncertainty and mistrust. Cooperation can be encouraged by consistency of the supervisor.

Constructive criticism. The supervisor who merely analyzes a worker's methods, habits, or personality, accomplishes nothing unless he uses this information to improve the performance of that individual. When correcting a person, care must be taken to avoid "tearing down." The process should be one of "building up" in a friendly manner.

Sympathy. Complaints from dissatisfied workers require that a supervisor be a good listener. A sympathetic understanding of a man's problems increases that individual's confidence in his leader, particularly when corrective steps are immediately taken or a complete explanation is given.

MORALE AND INTERPRETATION OF COMPANY POLICIES [1]

Company policies clearly interpreted and understood by all employees are an important aid to a smoothly running organization. Regulations are usually adopted for the benefit of the employees, many of whom misinterpret the meaning of the regulation, and without questioning the purpose, condemn the principle. It is only natural that they do this since most people dislike being forced to conform with another person's law. If employees are given management's underlying reasons

[1] The content of this section is taken from *Tips, Training in Progressive Supervision*, a publication of The Liberty Mutual Insurance Co., Boston, Mass. Reprinted by special permission.

for a company regulation, they are more likely to understand and acknowledge the value of the ruling and to accept it graciously.

Management must depend upon the supervisor to put policies into effect and to interpret them in the spirit in which they were formulated. He should not attempt to offer his own opinions but rather should assume the position of interpreter.

The manager or supervisor must accept these responsibilities in the administration of a company policy:

1. Make sure he understands the regulation completely.
2. Explain clearly to each person concerned, giving reasons.
3. Point out the value of the rule to the employee.
4. Check back to eliminate danger of misinterpretation.
5. Enforce policies intelligently.
6. Live up to the policy himself.

The enforcement of company or department regulation requires the application of the methods for stimulating morale. The job is largely one of selling the idea to the workers in such a way that compliance is voluntary and the foreman's time is not required for constant follow-up.

Examples of Poor Morale	*Possible Corrective Methods*
Lack of interest	*a*) Show personal interest in workers. *b*) Delegate minor responsibilities. *c*) Stimulate ambition.
Poor workmanship	*a*) Appeal to worker's pride. *b*) Offer constructive criticism. *c*) Check working conditions.
Lagging production	*a*) Verify accuracy of schedules. *b*) Locate cause of delay — give assistance. *c*) Be fair and consistent in distributing work.
Increased accident frequency	*a*) Point out individual responsibilities. *b*) Emphasize self-preservation. *c*) Personally investigate accidents. *d*) Reinstruct — invite suggestions.
Poor housekeeping	*a*) Delegate responsibilities for improvement. *b*) Stimulate pride in orderliness. *c*) Demonstrate advantages of good housekeeping. *d*) Set a good example.
Misuse of equipment	*a*) Investigate causes completely. *b*) Be careful and thorough when instructing. *c*) Delegate responsibilities for control. *d*) Criticize constructively.
Friction among workers	*a*) Show personal interest in men. *b*) Get all the facts from each individual. *c*) Be sympathetic to their opinions. *d*) Bring men together for discussion.

Examples of Poor Morale	*Possible Corrective Methods*
Complaints	*a*) Be a good listener — get all the facts. *b*) Be frank in reasoning with workers. *c*) Take necessary action — use good suggestions. *d*) Make sure workers are satisfied with action taken. *e*) Check your own consistency.
Loafing	*a*) Assign a pacesetter to work with slow men. *b*) Increase responsibility. *c*) Encourage ambitions — arouse interest.

BUILDING MORALE THROUGH PLANT BROADCASTING[1]

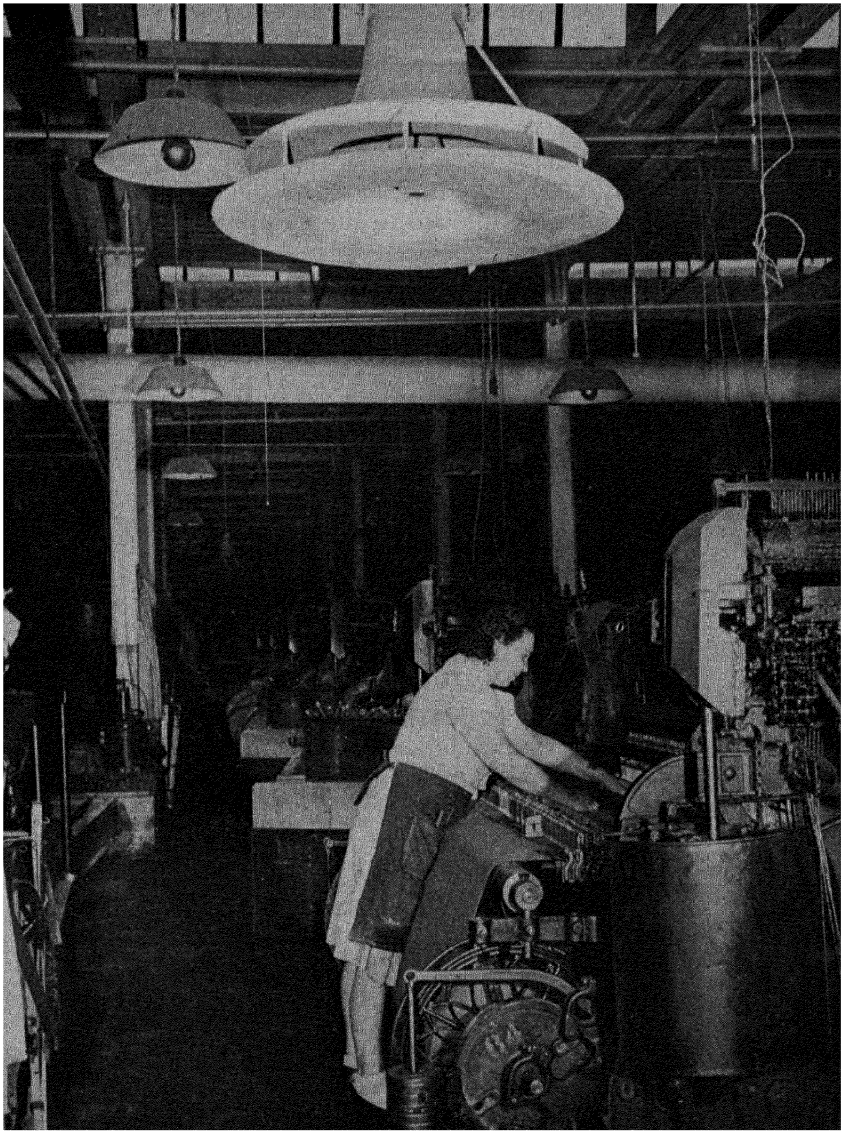
A sound system is an aid to management in building good morale. The spoken word is a powerful supplement to bulletin-board posters, handbills, printed messages in pay envelopes, or company magazines. Through the sound system, employees and employers may be brought into closer harmony. For example, brief messages can be broadcast concerning company activities and the importance of good work to company prestige, volume of business, wages, and hours. Explanation can be given of company policies. Just prior to mealtimes facts can be broadcast concerning proper foods to eat at home as well as on the job.

The selling of safety to plant workers is made easy through broadcasting. One firm broadcasts a jingle script similar to that of the famous Pepsi-Cola tune:

Safety first — please take care.
Safety first — please beware.
Safety first — please take care.
On the job, at home, or anywhere.
Beat the Axis, here's the way (whistle)
Safety first for the U.S.A.
Safety first — safety — safety first — safety (fade out)

Morale and music. The United States manufacturing industries are pioneering in the playing of music for workers as a means of building morale. Figure 150 shows a plant broadcasting installation. To do this requires the talents of both the engineer and psychologist. *The prime purpose of music is to boost morale and relieve fatigue.* The results are increased production. The right kind of music played at periods when workers are getting tired gives a "lift" over these low spots. Music can provide a soothing, relaxing atmosphere at rest periods and mealtimes. In plants engaged in war work, new shifts swing into action in the patriotic atmosphere of stirring martial music. During the day,

[1] Information provided by courtesy of the R.C.A. Corporation and based on a reprint of an article appearing in *Modern Industry* for Sept. 15, 1942.



Courtesy R.C.A. Manufacturing Co., Inc.

FIGURE 150. BROADCASTING INSTALLATION AT BOTANY WORSTED MILLS

Music is piped through to workers in noisy weave shed. Since frequency range of music is wider than that of factory sounds, music doesn't add to noise, but is heard plainly.

workers are allowed to request music which they like. The kind of music which seems best to improve industrial efficiency is the lively fox trot. "Hit Parade" selections, for example, are very popular and seem to give most workers in industry the kind of music they want. A great deal of work is being done by the R.C.A. Victor Corporation to classify music according to the industrial uses for which it is best suited. The R.C.A. Corporation is equipped to supply a nucleus library of 300 to 500 records, selected to fit normal needs of industrial plants, along with program recommendations. A monthly lease service supplies up-to-date records and any additional employee requests.

There is a difference of opinion as to whether or not music is as effective with men as it is with women workers. The experience of United States plants indicates that both enjoy music while working. The R.C.A. Victor Corporation reports an incident concerning a plant employing all men:

> This plant makes rolls — 2,000,000 every day for hotels, restaurants, and ships. For the men at the machines that turn out 400 dozen rolls per hour, the work is monotonous. But music was tried. Now management reports that morale is higher, labor turnover lower, and production better.

The possibilities of using music to improve morale in industry are tremendous. The idea is not new, but like many ideas it has been rediscovered during 1941–1942 under pressure of war production. Every sign indicates that progressive management should give attention to intraplant broadcasting as a valuable tool for increased production.

CHAPTER XVI

SAFETY AND HEALTH

SAFETY AND THE WORKER

The organization and conduct of a safety program may be said to have two broad aspects: (1) the organization of the physical plant as a safe place to work, and (2) the development of correct attitudes on the part of the workers toward avoiding bodily injury and preserving health — a problem of morale.

The majority of accidents in manufacturing industries are due more to human failure than to lack of machine guards and similar devices.

It is to little avail to spend time and money to build safety into the physical plant [1] through careful layout and planning unless the worker is willing to cooperate by observing safety practices and rules of conduct. Experience has proved that organized educational programs in industry will keep accidents at a low level, but when the enthusiasm for educational programs is allowed to fall off, there is a tendency for the number and severity of accidents to increase.

Accident prevention is as much a function of management as any other means of cost reduction. When management backs a safety program, the cooperation of foremen, supervisors, and others is more easily obtained. The effectiveness of a safety program, therefore, depends largely upon leadership in its promotion and the support afforded it by management.

ORGANIZATION FOR SAFETY

The organization needed to put across a safety program which is best suited to any given industry must depend upon the size of the industry and the emphasis to be placed on accident-prevention programs. Three types of organization have proved their value. These are: (1) safety-director type of organization, (2) line organization, and (3) safety-committee organization.[2]

1. Safety-director type of organization. The safety director's job is to function both as adviser and motivater of safety for an entire plant.

[1] See Chap. XIV.

[2] R. P. Blake, *Safety Organization*, Industrial Safety Subjects No. 18, Division of Labor Standards, U. S. Dept. of Labor, Washington.

He must work closely with supervisory forces without usurping their functions. Since he does not have direct charge of departments and must often obtain prompt correction of unsafe conditions, *he will be productive of results insofar as he can prove himself to be a leader of supervisors* and obtain the proper amount of responsibility from his own superiors.

The safety director functions as a staff officer and usually reports directly to the head of the personnel department, who in turn reports to top management. He is held directly responsible for all safety work and acts as an expert adviser to operating executives. His duties include:

a) Checking on safe practices and sanitary conditions and the need of various safeguards.
b) Educating foremen on the importance of safety and obtaining their cooperation.
c) Making recommendations regarding correction of unsafe conditions.
d) Examining specifications and drawings for new equipment and repairs to see that safety is properly provided for.
e) Supervising educational activities and bulletin-board service.
f) Arranging programs for safety meetings.
g) Investigating accidents and eliminating their causes.
h) Keeping records and preparing reports on accident experience.

The safety director should supplement his own work by a special committee organization. Among the committees which he will find helpful are the following: (1) a general or central committee for organizational purposes to be composed of representatives of the various management and production departments; (2) an inspection committee to make regular inspections of accident hazards, illumination, ventilation, sanitation, and safety in relation to maintenance; (3) a fire committee to inspect fire hazards and equipment; (4) a first-aid and sanitation committee in charge of medical and sanitation facilities; (5) a publicity and educational committee to maintain bulletin boards and publicity, and to plan and direct all safety instruction and meetings; and (6) an accident investigation committee to investigate and report on all serious accidents, their causes, and the methods of future prevention.

The size and number of these committees, as well as the frequency of their meetings, will depend upon the needs of the organization. A good plan to create active interest is to change the personnel of the committees from time to time, say every 3 or 4 months, in order that a large number of employees may serve on them and gain an inside view of the safety effort and thereby acquire an active interest in accident prevention.

The safety supervisor must at all times be in constant contact with all of the safety committees. He is the director of their activities and the responsibility for their performance rests on him. He will feel the need of outside information to assist him in his work, and fortunately there are safety service organizations established for just this purpose.[1]

2. Line organization. In plants where a full-time safety supervisor is not deemed desirable, those in charge of production may be made responsible for the safety program. This means that the supervisors and foremen must add to their regular production responsibilities the organization and conduct of a safety program. Before being asked to do this, however, top management should see to it that they are given proper instruction in the sound principles of safety and that they are assisted in every way possible to organize and conduct their programs. Fixing responsibility for safety on supervisors will tend to make for good housekeeping in each of the individual departments. Where safety responsibility rests with foremen, however, it is desirable to have a safety technician as a staff member of the organization. Otherwise, chief executives in the plant may find that they are devoting an unnecessary amount of time to safety.

The weaknesses of this type of organization is that supervisors are apt to be occupied with other production problems and, therefore, will find it difficult to acquire the special knowledge needed to achieve high safety standards in their departments. This may mean that too much of their safety knowledge will be gained from the accidents that occur. In brief, the principle to be recognized here is that "foresight is better than hindsight by a damn sight."

3. Safety committee organization. In plants which are small and which cannot afford a full-time director, the safety program is often placed in the hands of an administrative committee, the chairman of which functions as chief supervisor or director. Typical of this setup is that of having some major plant executive serve as chairman of the committee, and its membership composed of persons who serve as ad-

[1] National Safety Council, Inc., 20 North Wacker Drive, Chicago, is an association of manufacturing and industrial concerns, insurance companies, engineers, public officials, and others, publishes *National Safety News* (magazine), workmen's bulletins or posters, "Safe Practices" pamphlets on a variety of special subjects; holds annual congress, maintains information bureau; fosters local safety councils; also issues publications and interests itself in activities relating to public safety and industrial health.

Safety Institute of America, New York, publishes *Safety* (magazine), maintains a safety museum and special service to members.

American Society of Safety Engineers (Engineering Section of National Safety Council) is composed of individuals in safety work.

American Standards Association, New York, has general supervision over safety code work.

Underwriters' Laboratories, Chicago, tests, inspects, and labels safety and fire-protection equipment conforming to its standards.

visers. The committee membership should include a diversity of knowledge of methods, practices, and routines in the plant. If there should be but one committee it should have representatives from top management, supervisors, and workers. Where the committee form of control is used, continuity and consistency of policy regarding safety practices and programs will be helped when the following are set forth in writing: scope of committee activity, extent of committee authority, and procedure as to:

a) Time and place of meetings.
b) Frequency of meetings.
c) Order of business.
d) The records to be kept.
e) Attendance requirements.

When the type of organization is established it is important that top management fix authority commensurate with responsibility. When authority and responsibility go hand in hand one seldom has to exercise the authority. There is too often in industry a tendency for top management to retain authority and yet to parcel out responsibility rather generously. If a safety organization is to be effective, those in charge of it must have power to act and must be given the feeling that the top management is wholeheartedly supporting the safety program.

FUNCTIONS OF A SAFETY ORGANIZATION

Regardless of the type of organization, all safety programs should fulfill these functions:

1. Elimination of physical hazards through proper construction of buildings, layout of processes, guarding of machines.
2. Creation and maintenance of an active interest in safety.
3. Investigation and reports of accidents.
4. Follow-up of accidents and corrective action.
5. Education of employees to work safely.

1. Elimination of Physical Hazards

When the plant is organized for production, it is possible to reduce the number of accident health hazards by careful attention to construction, arrangement of production machinery, proper organization of the workplace, and correct stowage and piling. These topics are given separate treatment in Chap. XIV.

2. Creation and Maintenance of Interest

Those in charge of the safety programs may find that getting the cooperation of others is made easier if they use some psychology. In this

connection, some individual fears and desires can be used as incentives,[1] such as:

a) Self-preservation (fear of personal injury).
b) Personal and material gain (desire for reward).
c) Loyalty (desire to cooperate).
d) Responsibility (recognition of obligation).
e) Pride (self-satisfaction and the desire for praise).
f) Conformity (fear of being thought different from others).
g) Rivalry (desire to compete).
h) Leadership (desire to be outstanding).
i) Logic (special ability to reason).
j) Humanity (desire to serve others).
k) Patriotism (desire not to cause accidents to slow up production in times of national emergency).

In dealing with individuals, it may be desirable to analyze their traits of character in order to gain their interest and attention and determine which of the above appeals will produce best results. In maintaining the interest of management, statistics on accidents, lost time eliminated, and savings in costs over previous years before the safety program was installed, may be used to good advantage. The foreman can be appealed to on the basis that the accident record of his department is a reflection of his ability as a foreman. Foremen must be made partners, however, in the safety program and not just dictated to by those in charge.

3. Investigation of and Recording Accidents and Sickness

It is not sufficient in any safety program merely to establish protective devices in the hope of settling the matter once and for all. If the safety program is to be effective, it must be kept alive by periodic inspections of all departments to check safe practices and discover hazards. It is possible that accidents will happen where least expected. If accidents are to be prevented entirely, steps must always be taken when accidents do occur to see to it that they do not happen again. A report form should be completed, and information furnished in detail on these items:

a) Who was injured.
b) Time and place of injury.
c) Witnesses of injury.
d) Nature and severity of injury.
e) Machine or other agency involved in accident.
f) Nature of work employee was doing when injured.

[1] H. W. Heinrich, *Industrial Accident Prevention: A Scientific Approach*, McGraw-Hill Book Company, Inc., New York, 1941, p. 73.

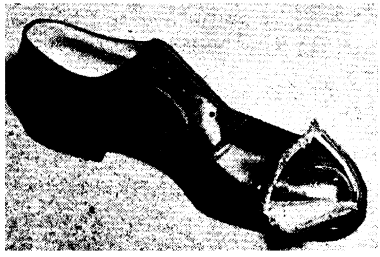
g) Type of accident.
h) Injured's report of accident.
i) Foreman's report of accident.
j) Mechanical or physical causes of accident.
k) Steps taken to prevent recurrence.

In completing the information under each of these headings, it is desirable to be as accurate as possible so that management can be notified of actual safety conditions existing and reliable data obtained for adjusting costs arising out of the accident.

It is equally important to report reasons for sickness, type of sickness, and length of sickness which workers experience as a result of their occupation. Lost time due to sickness is just as important as lost time due to accidents.

4. Follow-up and Taking Corrective Action

When accidents occur, it is the function of those in charge of the safety organization to determine their cause and take steps which will prevent their recurrence. Accidents may result from improper instruction or lack of any instruction whatsoever; disobedience, negligence, and horse play; haste and chance taking; improper illumination; defective design of materials and equipment; failure to use protective devices; the use of defective tools and equipment in doing work; and existence of unsafe floors or stairs, as well as unguarded openings in the building structure. They may arise also as a result of the poor physical condition of the employees; the wearing of improper dress or apparel (Fig. 151), or the exercise of poor judgment.



Courtesy Liberty Mutual Insurance Co.

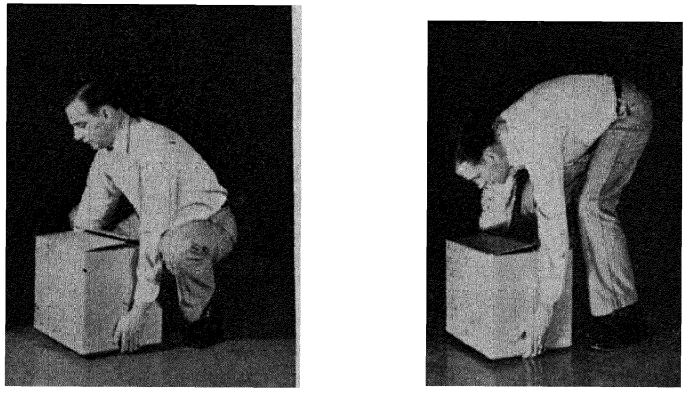
FIGURE 151. SAFETY SHOE. NOTE METAL CAP INSIDE OF TOE

When it is definitely known that an accident is traceable to one of these causes, every step should be taken to take proper corrective action. If instruction is needed, it should be given. If discipline is needed, it should be administered. If the employee is using defective tools or equipment, he should be taught the value of using safe tools. On occasion, desired results have been achieved just by giving orders that safety rules are to be observed, or that accidents are to be lessened. In general, however, this is not an effective means of obtaining desired results. It is usually found necessary to have some person or committee in charge of accident investigation and to collect the facts concerning

the cause of injuries or damage to equipment and machinery. When this information is turned over to the proper authorities (a person or committee in charge of taking remedial steps), the management has at least the assurance that it is doing its part in seeing to it that there are no recurrences of accidents. An ounce of prevention is worth a pound of cure. Good safety prevention results in fewer accidents and increased production.

5. Education of Employees to Work Safely

It is often said that work cannot be done skillfully that is not done safely. It is the safety committee's job to drive this point home and



Courtesy Liberty Mutual Insurance Co.

FIGURE 152. CORRECT (LEFT) AND INCORRECT WAYS TO LIFT

educate both old and new workers. It is desirable to give workers training in correct and safe methods, that is, the proper use of arms, fingers, and body in relation to their work. In the training of new workers, correct and safe methods should be taught from the start. In fact, the basic principles of safety can be ingrained in workers during their training period. Figure 152 shows correct and incorrect ways to lift.

Every worker should be given a safety handbook and made to familiarize himself with it.

In order to keep workers on the alert in safety, those in charge of safety education should make use of posters. These should be displayed prominently and changed frequently. Permanent notices and posters lose their punch and interest. Moreover, rule books are soon forgotten. It is recommended that posters be changed once a week to give at least 52 different warnings a year. Sample reproductions of posters

appear in Fig. 153. Posters usually contain the following educational material:

Slogans which give caution of consequences of accidents.
Warnings of the importance of first aid.
Pictures and cartoons of dangers of loose clothing near machinery.
Necessity for wearing goggles, protective clothing, and using mechanical guards.
The importance of keeping tools in good condition.
The need for keeping passageways clear.
Dangers from improper lifting.
Incidents and attitudes which cause falls.
Careless acts which cause fires.
Means and instruments of sabotage.
Importance of good lighting.

There are several auxiliary aids which can be used in training employees to work safely.

a) Audio-visual equipment may be used to good advantage with large groups. The wrong and right method of doing things can be brought out very forcefully through pictures (movies or slides) and coordinated voice instruction.
b) Industry can cooperate with trade schools in the development of instruction in safety techniques in the earliest periods of training. Demonstrations on safety can be given to good advantage also.
c) Safety can be taught at the same time that skills are imparted. Workers can be trained to visualize the actual hazards in their own lines of work. The best way to accomplish this is to have the foreman instruct his own men and supplement his instruction with printed matter which has been prepared by the safety education committee about correct methods of doing the job.

PREVENTION OF FALLS

Falls and automobile accidents account for two-thirds of all fatal accidents which take place each year. Many falls may be prevented by proper safety measures such as nonslip stair treads, proper lighting of aisles, stairways and passages, and correctly designed platforms. The most significant means of preventing falls, however, is the education of the individual himself, for it is the "human element" more than any other factor which is responsible for most falls.

The following are 20 rules for the prevention of falls:

1. Look where you are going to step.
2. Be especially cautious in dark areas.
3. Walk—don't run.
4. Avoid sudden motions and quick changes in direction while walking.

Courtesy National Safety Council, Chicago, Ill.

FIGURE 153. REPRODUCTIONS OF POSTERS USED FOR PROMOTION OF SAFETY IN INDUSTRIAL PLANTS

5. Don't let your shoes trip you—keep them in good repair.
6. Never carry bulky objects which prevent you from seeing ahead and down.
7. Avoid unprotected floor openings.
8. Never pull on anything unless you are securely braced.
9. Hold stairway hand rails.
10. Use elevators strictly according to rules.
11. Face direction of travel when alighting from vehicles.
12. Never get on or off moving vehicles.
13. Be a good housekeeper.
14. Before you climb a ladder be sure it is sound and securely placed.
15. If there is chance of falling from a height, protect yourself with a life line.
16. Keep alert and you will not fall.
17. Keep floors clean and free from trash.
18. Remove slippery material from floors immediately (oil, water, grease).
19. Do not fool while working.
20. Remember the rules!

PROTECTING EYES IN INDUSTRY

Actual figures are not available on the extent of eye injuries each year in industry, but conservative estimates place the number of persons blind in both eyes at 8000 and the number blind in one eye at 80,000 in this country at the present time. Over 2000 persons lose the sight of one eye each year at a cost of over $1,000,000 to industry.

Sources of eye injuries may be traced far more easily than other types of injuries.

Because the eye is such a highly specialized bundle of nerves it is easily injured by even very small particles, in fact, microscopic particles often cause more harm than larger particles which may readily be removed.

It is perhaps peculiar that any eye accidents occur at all because, unlike most accidents, all eye accidents may be easily prevented by the use of one simple device, inexpensive, yet highly efficient — goggles. (Fig. 154) While goggles are the chief agency for the reduction of eye injuries, there are other causes of eye injuries against which goggles cannot protect. These may be prevented, or at least controlled in part, by removal of toxic materials from the atmosphere, use of shields, prevention of fatigue and eyestrain by proper illumination, and avoidance of indiscriminate removal of particles from the eyes by fellow workers.

The greatest toll in eye injuries is taken by flying bodies, tools and machinery, splashing liquids, explosions, and infection. The following preventive measures may be taken against eye hazards:

1. **Flying bodies.** Proper instruction in use and care of tools used in hammering operations and strictly enforced goggle regulations.
2. **Tools and machine parts.** Tools should be carefully inspected. Workers should not be allowed to use tools with mushroom heads. Workers should not be allowed to use tools with which they are unfamiliar.
3. **Splashing liquids.** These may be controlled by proper type enclosed containers, correct instruction in the use of carboys, and the use of goggles.
4. **Explosives.** These may be controlled by proper instruction of workers; proper shields and guards, isolation of the explosives, and use of goggles.
5. **Infection.** This may be controlled by dust removal where grinding is done, by exhausting air over grates or by blowers. Proper first aid and eye examination by competent persons will help prevent eye infections.

Goggles are a preventive for nearly all eye injuries, but unlike other safety devices, workers themselves have the responsibility for using them. The great problem connected with the use of goggles is making workers wear them in dangerous operations. Many firms use different methods to make workers use goggles. There are various devices which

Courtesy Liberty Mutual Insurance Co.

FIGURE 154. SAFETY GOGGLES. WHEN FLYING OBJECTS STRIKE THE GLASS, THE GLASS SHATTERS, BUT DOES NOT BREAK, AS SHOWN IN ILLUSTRATION

force the worker to wear goggles before starting his work. For example, goggles may be attached to a switch which may not be turned on until the worker removes the goggles; this is used effectively on grinders especially.

In general goggles should meet the following requirements:

Where glare exists, properly colored lenses should be used.

Where danger of impact exists, lenses should be so strong and so framed as to reduce effectively the danger of eye injury from broken pieces of lens.

Lenses which interfere with vision because of starring or frosting, should not be used.

Frames should be light and adjustable to the face. In many, but not in all operations, frames should be equipped with side screens.

Where there are gases or fumes injurious to the eye, gas-tight goggles should be used.

Goggles which have been worn by one workman should not be reissued to another worker without first having them sterilized.

PLANT PROTECTION

Plant protection is not a concern of management solely because of foreign agents and spies; there are also frequent malicious acts committed by disgruntled employees for revenge or imaginary grievances.

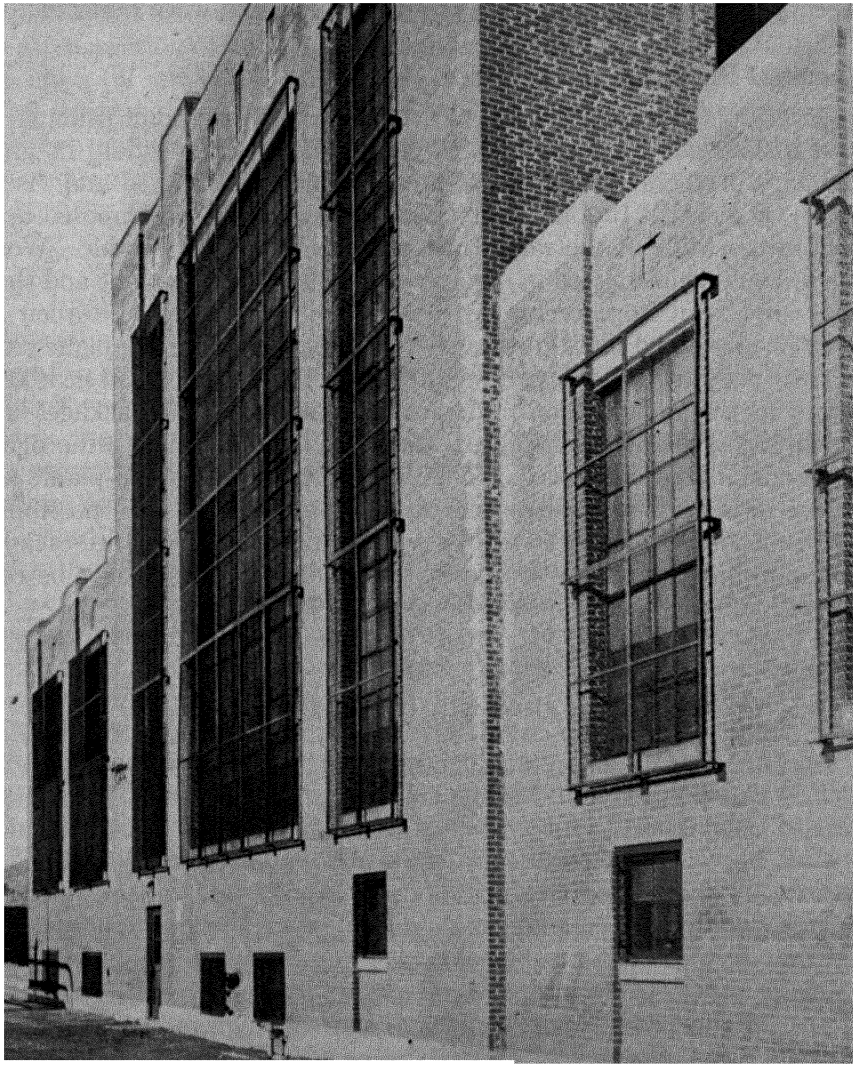
The provision of adequate plant protection is primarily a matter of organization of employees and giving educational instruction. Plant-protection programs are usually based on standard procedure calling for guards at all gates during the daytime and one or more watchmen covering specified beats during the night time and on holidays when the plant is closed. Some variations in extensions of this basic plan are: enclosing the entire plant area with a high fence; adequate lighting of all exterior property and passageways; flood lighting of certain areas and the adding of extra guards or patrols which supplement the regular night watchmen by operating on no fixed schedule.

In the establishment of a protection organization, it should be realized that the effect of a bomb, fire, or explosion is local and that there is less danger with decentralized operations. Wherever possible, plants should be prepared to protect themselves independent of outside assistance, but communication should be established with organized authorities for assistance when needed. The plant-protection programs divide themselves naturally into four divisions. Each should have a head responsible to a plant coordinator. The four divisions are fire, police, medical, and maintenance.

The maintenance division is responsible for protection of buildings, equipment, and supplies; survey of the plant preparatory to making

protection and installation of protection devices, such as window screening (Fig. 155), fences; control of wartime illumination; organization of emergency repair crews; making damage surveys and recommendations for repair work.

The fire-protection division is responsible for all types of fire-fighting equipment, inspection and survey of plant as a precautionary measure,



Courtesy Consolidated Expanded Metal Co.

FIGURE 155. WINDOW GUARDS FOR PLANT PROTECTION

removal of fire hazards, provision of adequate water supply, training men for fire-fighting and rescue squads.

The police division is responsible for all policing activities, maintenance of discipline and development of morale, supervision of guards and watchmen, observance and control of persons entering and leaving the plant, and control of traffic in keeping routes clear of obstructions.

The medical division is responsible for first-aid training and practice; establishment of first-aid stations; control of ambulance service; inspection of the sanitary conditions, garbage, and sewage removal.

General Protection Procedures

Every plant manager needs to determine at which point sabotage or a malicious act would disable his plant. These areas should be given primary protection. Vulnerable areas should be restricted and visited often by guards. It is necessary also that strict rules be imposed upon employees while at the same time maintaining a high morale. Workmen should be restricted in their movements within the plant and those who are absent from work repeatedly should be checked as to their activities. It should be required also that employees enter the plant property as pedestrians from parking areas which are not located near vital spots in the organization. Moreover, contents of all packages and lunch boxes should be inspected when they are carried into the plant. It should not be necessary for delivery men to enter the plant, and where necessary, a truck register may be established. The possibility of unauthorized entrances through coal chutes, skylights, fire escapes, water frontage, sidewalk windows, and unfenced areas should be considered and prevention measures taken.

GUARDS FOR PROTECTION

An important part of the plant-protection program is the use of efficiently trained guards to see that all protection plans and policies are carried out. Many companies have plant police, but guards are now trained to realize that plant protection and employee safety go hand in hand. An employee who violates a safety rule and causes injury or damage can do as much harm as a saboteur, therefore guards are trained not only in routine duties but also to watch for anything that is likely to cause delay, work stoppage, or danger to employees. Classes are often given in patrol work, espionage and sabotage methods, and the use of first-aid, fire-prevention, and fire-control equipment. Each member of the force is given a pocket-sized manual describing all duties in detail.

Control of the guard force comes through a regular police system with the flow of authority from a coordinator's office to the chief or captain, to the sergeant, and finally to the patrolman. The patrolman does the work of guarding gates and entrances, checking visitors, and inspecting contents of trucks and railroad cars.

Guards should be carefully picked with special attention given to past records. They must be fit for the job physically, mentally, and morally; personal factors such as ability to get along with others and to take orders deserve careful consideration. Discipline is obtained by careful inspection of uniforms and equipment and by frequent tours of inspection by sergeants. Guards are often given forms to be used on patrol work with spaces to be checked for rounds or stations missed, doors or windows open, visitors or trespassers, smoking violations, rule infractions, condition of fire-control equipment, water pressure or level, fire hazards, yard lights, and so on.

FIRE PREVENTION

A substantial part of fire prevention is (1) a matter of educating em ployees to avoid creating fire hazards, and (2) training workers to control fires when they do occur.

Most fires can be prevented. If a fire occurs, it generally indicates that someone has been careless and negligent in taking necessary precautions, or that conditions existed which might have been foreseen and eliminated. It is one of the most important duties of a foreman to prevent attitudes, practices, and conditions which might cause fires.

Good housekeeping is more important than any other one factor in the prevention of fires. Good housekeeping not only eliminates conditions which are favorable to starting fires but also helps eliminate accidents which may cause fires.

Many fires start from spontaneous combustion caused by waste, oily lint, or rubbish accumulated under benches, on machinery, behind radiators, in tool and clothes closets, or in other out of the way places. A fire once started from one of these sources spreads very rapidly. Every plant should have metal cans into which oily waste may be put so that it will not accumulate in piles on the floor or in corners.

Besides poor housekeeping, experience has shown that two of the worst fire hazards in the industrial plant are portable welding outfits and dryers and ovens. Portable welding outfits should not be used around combustible materials, or if it is necessary make sure that any combustible material is well protected from flying materials and hot metal. Dryers and ovens with open flames are often very carelessly located in the paint shop too near areas where paints are mixed with

volatile solvents. This may result in an explosion causing damage to life and property. Outdoor hazards such as piles of rubbish, dry grass, and waste should be removed. Stacks of lumber and combustible sheds should be protected and situated away from the manufacturing plant. Observance of the following rules will minimize the number and severity of plant fires and explosions:

1. Practice good housekeeping.
2. Provide adequate physical barriers to prevent the spread of fire.
3. Eliminate fire causes.
4. Place adequate fire-fighting equipment where it is instantly available.
5. Install automatic-sprinkler protection for combustible materials and spaces used for important materials and machines.
6. Make plant connections with a thoroughly reliable water supply having sufficient volume and pressure.
7. Restrict smoking in all except certain areas.

The oldest equipment known for fire protection, the pail of water, is still good in many cases to snuff a fire at its start, but modern manufacturing conditions require newer and better equipment as well as the training of personnel to use it efficiently. On the market today are many types of fire first-aid equipment. Common among these are soda-acid tanks which may be used to put out small fires at their start. The vast majority of plants are equipped today also with fire hoses distributed throughout the plant and permanently connected with the city water supply or a water tower on the roof of the plant. Other plants use water tanks with hand pumps which may be carried or wheeled to the fire. Paints, oils, and other inflammable liquids may be protected by *carbon dioxide extinguishers* which cannot harm the material as water would and does a much better job than water. An automatic water sprinkler system alone is said to represent nine-tenths of the possible complete fire protection. Seventy per cent of all fires occurring during the last 40 years under automatic sprinkler protection have been practically extinguished by the sprinklers alone. An additional 26 per cent were held in check. Efficiency of these sprinklers is somewhat better than 96 per cent perfect.

It is very important that all this equipment be kept in A–1 condition and that daily inspections be made. Soda-acid extinguishers must be recharged regularly, canvas and rubber hose must be pressure tested, automatic sprinkler systems have to be tested also and a check made to make sure that valves are open and have not been tampered with.

To have available an adequate amount of fire-fighting equipment hardly needs to be emphasized, although many plants take chances with insufficient equipment. The amount of equipment necessary varies

with the type of building as well as the kind of material used in it, and what personnel is available at any time.

Fire brigades in industrial plants have proved very effective in most cases. The Chrysler Corporation with this system reduced their fire losses 60 per cent in 3 years.

Although fire-fighting procedure varies with different types of industries and different plants, the general procedure is as follows:

1. The foreman turns in the alarm which calls the plant fire chief and the motorized equipment.
2. Brigades in other departments are warned to be on the alert, and the city fire department is called.
3. Workers use extinguishers as trained to do.
4. If automatic devices operate the crew stands by. Meanwhile another crew lays fire hose from standpipe or hydrant.
5. Salvage detail moves stock and covers machines with waterproofing.
6. Teams of men are assigned to shut off power machines, stand by sprinkler valves, close fire doors, and later open windows to ventilate areas.

SAFETY TRAINING AND FIRST AID

The chief factor concerned with safety training is the training of the employees in safety practices through some medium of education such as mass meetings, individual aid, or special schools in the use of safety devices and techniques. Even if workers become only slightly familiar with the practices, rules, and regulations of the safety training plan, there is sure to be increased efficiency and a decreased number of accidents.

The safety training plan should be headed by a competent safety inspector whose duty it is to inspect structures, machines, and various other types of equipment and recommend safety measures which may be taken. Supervisors should be appointed to work under the safety inspector to properly organize the workers. Almost all the tedious work falls upon the shoulders of the supervisors, and the success or failure of any safety program rests with these men. The success of any safety plan depends also upon the wholehearted cooperation of the superintendents, foremen, and employees with the safety plan organizers.

First-aid Training

First-aid training should be given under the immediate supervision of a regularly registered and qualified physician or authorized instructor. In order to have the best training in first aid, all examinations for first-aid certificates should be held under supervision of a physician or instructor. The need for first aid is unquestionable; the doctor and hospital are far from the scene of the accident; sometimes it is impossible

to reach the injured man and death may occur from bleeding or shock; a simple fracture may be converted into a compound fracture by ignorant or careless handling, and wounds may become infected. Many deaths have resulted in the past because there was no one to take care of the injured person. In case of any injuries there is a definite plan which should be followed. A few of the necessary things to be observed and followed are:

1. Find location of injuries; be calm; give orders.
2. Keep onlookers away from patient.
3. Look for red spurting blood.
4. Look for shock and fractures.
5. Never move a victim.
6. Never touch a wound with fingers or instruments.
7. Use resuscitation when possible.

All plants should have at least a common-sense minimum of first-aid equipment plus provision for medical and hospital service. The following is a list of minimum first-aid requirements for an average-size plant:

1. A first-aid cabinet kept continuously stocked with standard supplies.
2. A competent first-aid attendant should be available during all working hours. He or she should be properly instructed by a physician or some other recognized authority.

HEALTH AND THE WORKER

While many industrial organizations regard safety and first aid as essential for the welfare of employees, comparatively few provide as yet adequate medical and health service beyond emergency requirements. Among the firms having medical and health programs, some firms have completely equipped medical dispensaries and employ full-time physicians and nurses, and others make first-aid kits their sole provision for caring for injuries and health hazards. The emphasis during recent years on the benefits to be derived from attention to workers' health has provoked a growing interest on the part of industrial managers in industrial health programs. Foremost among the reasons are:

1. The realization that employees whose health is normal are more efficient and happy in their work than when they are below par physically.
2. Desire to reduce the high costs of lost time due to absenteeism caused by common illnesses and accidents improperly cared for. (It is estimated that workers in the United States as a whole lose approximately 280,000,000 days per year because of illness, averaging from 5 to 11 days per employee.)
3. Removal of the fear on the part of some managers that the motives of a health program might be misunderstood, even though manpower is recognized to be the most important asset.

4. Gradual recognition by the medical profession itself of the importance of providing health programs in industry.
5. An increasing appreciation of the economical importance of illness. Losses of time due to illness are just as important as those due to accidents; substitute workers are not so efficient as regular workers; and the costs of sick benefits, insurance, and medical expenses are among the larger costs to the company.

Functions of the Industrial Health Program

A complete industrial health service should fulfill these functions:

1. Determine the physical and mental fitness of employees.
2. Maintain a healthy and efficient working force.
3. Conduct health education inside the plant and in the worker's home.
4. Keep records of health and accidents of persons (requiring medical attention) in the employ of the company.
5. Reduce lost time of absenteeism caused by illness.

These functions should be achieved by means of providing the following services:

1. Prehiring examinations and periodic reexaminations for all employees.
2. Correction of physical defects of employees found upon examination.
3. First aid for accidents.
4. Control of occupational health hazards.
5. Provision of adequate emergency dispensaries and hospital facilities.
6. Supervision of sanitary facilities, lunch rooms, and drinking water.
7. Cooperation with family physicians, local hospitals, and clinics as well as specialists.
8. Giving special examinations when needed, such as eyes, ears and teeth, mental tests.
9. Group plans of insurance for hospital and medical service and rendering advice for assistance in securing competent hospital care.

Organization of the Industrial Health Department

The particular staff requirements which must be provided for industrial health service will depend on the size of the company and the community facilities available as well as the extent to which manufacturing operations are hazardous to the health and safety of the workers. In most organizations a part-time or full-time medical officer or physician and a full-time plant nurse comprise the industrial health staff; to these may be added the services of consultants, dentists, oculists, and clerical assistants.

The medical officer. In making provision for someone to operate an industrial health program it is desirable to obtain a person who is interested in industrial health service. The ordinary general practitioner does

not appreciate the special problems of industry as they relate to the administration and operation of a health program. If a medical officer is procured, his services should be regarded as sufficiently important to entitle him to executive rank in the organization. Needless to say, the medical director or his counterpart must have absolute and final control of policies and procedures relative to the operation of the industrial health program.

While it is desirable to have a full-time physician where possible, some quite sizeable plants have found a part-time service adequate for normal needs. A primary objection to this arrangement is that it eliminates the possibility of making outside contacts which are so valuable in developing a first-class program. A majority of small organizations, however, have to depend upon part-time service. This involves setting up a schedule of a few hours each day when the medical officer or physician is available to employees. His schedule should include time also for supervision of sanitation and inspection of the control of occupational health hazards. A partial list of causes of occupational diseases is given below.

Industrial health staff. A minimum staff in the industrial health department should include a full-time nurse to cover all shifts, and at least a part-time physician who keeps regular office hours at the plant. In some instances, night service may be provided by a male interne or by medical students taking advanced courses and who can sleep at the plant, being on call for emergencies.

If the size of the industry permits, it is desirable to have more than one part-time physician or specialist, and to make as much use of outside consultants as individual cases require. The types of specialists who can render valuable service are these: industrial hygienists, sanitary engineers, physiologists, and psychiatrists.

Industrial nurses can be very helpful in rendering first aid, as well as obtaining preliminary information for physical examinations. They can be very helpful in making laboratory analyses, sanitary inspections, promoting safety and health education, and keeping proper records.

OCCUPATIONAL DISEASES

Disease	*Cause*
Mercury poisoning	Mercury vapor, dust, or fumes
Chromium poisoning	Chromium and compounds, dust, vapor, or liquid
Industrial skin diseases (dermatoses)	Irritation by oil, chemicals, or solvents
Benzol poisoning (benzene)	Inhalation of benzol vapor
Wood alcohol poisoning	Inhalation of alcohol vapor
Nitrous fumes poisoning	Inhalation of nitrous fumes

Arsenic poisoning	Inhalation of dusts and absorption through the skin
Carbon monoxide poisoning	Inhalation of air containing the gas
Silicosis	Inhalation of air containing silica dust
Anthrax	Contact with germs through cuts and scratches
Metal fume fever	Inhalation of fine particles of burned metals
Ammonia poisoning	Inhalation of ammonia gas
Manganese poisoning	Absorption of manganese through lungs or skin
Lead poisoning	Absorption of lead through the skin or by inhalation or swallowing
Hydrogen sulphide poisoning	Inhalation of the gas (may be instantly fatal)
Carbon bisulphide poisoning (carbon disulphide)	Almost always by inhalation of the vapor

Some industrial nurses are expected to do outside visiting. If possible, it is wise to cover this service through group health and accident insurance, which provides that a visiting nurse of the insurance company will cover homes. The plant nurse must be a type of person of unusual ability and personality that will help in maintaining good employee relations. When the size of the organization permits, the staff of the industrial health department should include one or more clerks and typists to keep records and assist the industrial nurse in routine tasks.

The clinic or dispensary. Clinics and dispensaries should be located so they are readily accessible to new applicants for jobs, as well as present employees. It is also desirable to have them in the vicinity of the women's rest rooms, so that the nurse may give occasional attention to their sanitation.

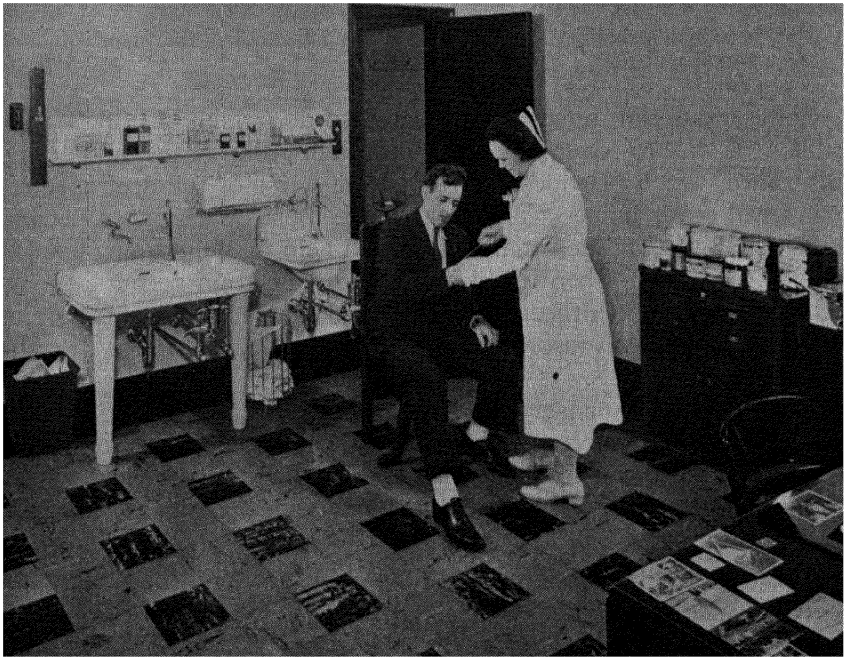
The amount and size of the equipment of the clinic must of necessity conform to individual plant needs. The minimum requirements for the size and equipment of industrial dispensaries may be obtained through "Health Service in Industry." [1] Needless to say, walls, floors, and furniture should be of modern sanitary construction and kept clean at all times (Fig. 156). A reception room, dressing room, consulting room, areas for hospital cots screened from the rest of the room, and separate baths and lavatories should be standard equipment. Doors should be wide enough for stretchers to pass through easily (Fig. 157).

The modern plant clinic or dispensary is called upon to provide the following services:

1. First aid for minor injuries and ailments; chronic conditions which require diagnosis are attended to by the physician.
2. Assistance in giving medical examinations and proper medical and hospital care.

[1] National Industrial Conference Board, "*Health Service in Industry*," New York, 1921, p. 26; "*Medical and Health Programs in Industry*," Studies in Personnel Policy No. 17, National Industrial Conference Board, New York, 1939, p. 10.

3. Records of medical service rendered to employees, as well as complete record of each employee.
4. Cooperation with the personnel department for maintaining safety, sanitation, good housekeeping, and related matters.
5. Assistance in the promotion of health education among employees.
6. Care for equipment and supplies used in the clinic.



Courtesy Lever Bros. Co.

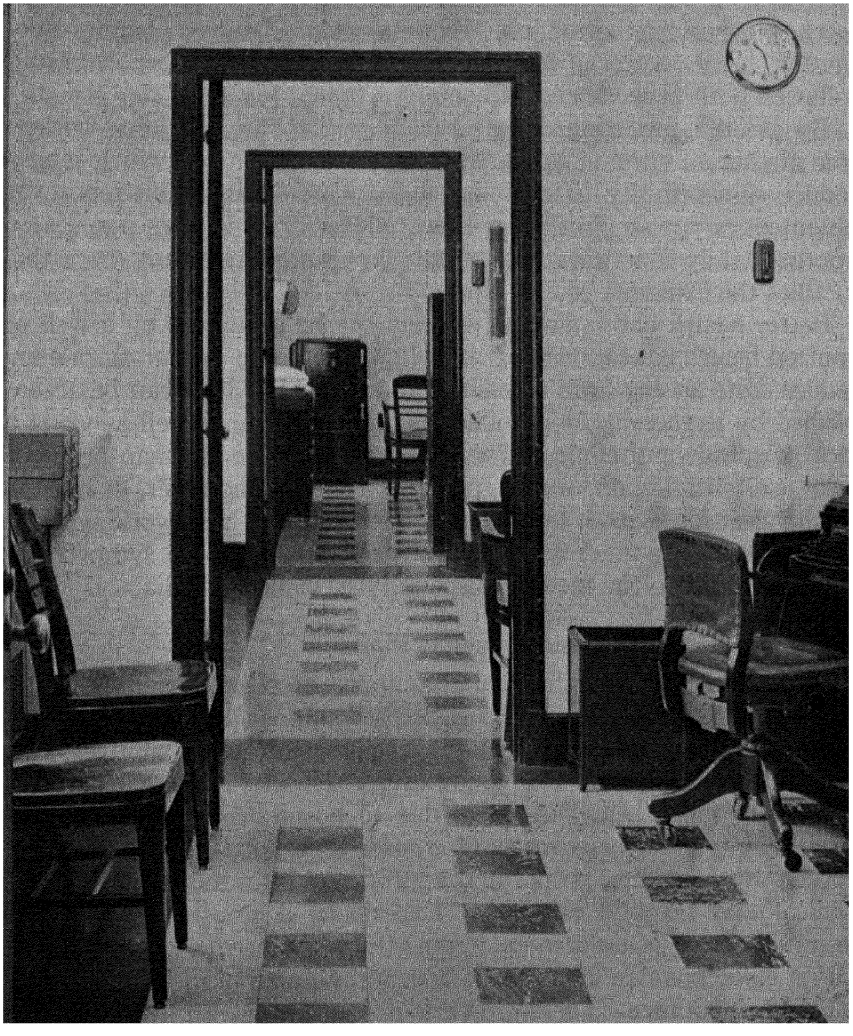
FIGURE 156. EQUIPMENT IN FIRST-AID TREATMENT ROOM. EMPLOYEES ARE SENT TO THE CLINIC PROMPTLY AS SOON AS THE SLIGHTEST SYMPTOMS OF ILLNESS APPEAR

Promotion of Health Habits to Minimize Absenteeism

Common among the causes of absence from work are common colds, digestive disturbances, tonsillitis, rheumatism, arthritis, and functional nervous diseases. Many of these are a result of fatigue. In this connection, it is important to encourage proper habits of living, rest, and recreation. Many workers blame industry for fatigue, whereas their home activities, lack of sleep, improper recreation, worry over financial problems may be the real cause.

In instances where there are mental problems which require special care, the services of a psychiatrist should be provided. The emotional

strains of industry as well as social factors influence a person's daily reactions and attitudes which often combine to contribute to mental upset. The wrong mental attitudes often result in violence, strikes, or sabotage. Many wrong attitudes can be corrected if persons are given proper values in relation to life and taught to live so as to minimize the



Courtesy Lever Bros. Co.

FIGURE 157. RECEPTION ROOM, TREATMENT ROOM, AND MEDICAL DIRECTOR'S OFFICE IN ADMINISTRATION BUILDING

effects of nervous strain from work. For example, much can be done by way of teaching workers to correct their posture while both at work and at home. Fatigue and physical disorders are directly traceable to bad posture. Correct sitting positions are important while on the job also. Posture clinics have proved successful in some areas, and persons needing assistance should be told about them.

Diet is another matter in which the industrial clinic can be of assistance. Poor food balance and malnutrition are evidenced by underweight, nervousness, and fatigue. Digestive disorders disturb the worker in performing his job. Workers should be given helpful information in the matter of food values and health and proper diets to be followed both at work and at home.

By way of minimizing absenteeism, some firms are providing workers, free of charge, vitamin tablets and special preparations which tend to reduce susceptibility to common colds. One organization reports its absenteeism per employee has been reduced from 9 days per year to approximately 5 as the result of this program. The result more than justifies the expense.

Better health habits among workers can be promoted by a well organized health education program. It will improve worker morale and reduce costs arising from illnesses and accidents. Much can be accomplished by lectures, posters, bulletins, and exhibits, as well as visits to local hospitals and clinics. The cooperation of the foreman or supervisor is essential in making the program a success; however, he must be on the alert for signs of fatigue and illness among those working under his direction. He must see to it that persons who reveal symptoms of illness are sent to the medical dispensary or clinic immediately.

Provision of Medical and Hospital Plans

Some industries have built and equipped excellent hospitals for the care of their employees. The cost per bed to provide satisfactory hospital care has increased in recent years to the point where an investment exceeding $8,000 per bed is not unusual. Persons at all salary levels hesitate to incur heavy expenses due to hospitalization and medical care. Plant managers can build considerable good will among their workers by providing proper and appropriate insurance against major medical and hospital expenses. Experience demonstrates also that hospital service is used more frequently when needed if payment of bills is made possible under some appropriate plan of insurance.

Health insurance. There are various forms of health insurance provided by mutual benefit organizations and insurance companies. The amounts paid usually cover disabilities for definite periods. Cash is paid to policy holders primarily on the basis of the illness or injury or

the length of its duration. Unfortunately, workers have a tendency to meet household bills with money received and forego the medical benefits they are supposed to receive. Consequently, many health insurance programs have not worked out too satisfactorily.

Group hospital service. Excellent hospital service is available today on the group payment basis. For modest sums, varying from $6.00 to $15.00 per year for individuals, plus additional appropriate amounts for members of employees' families, fairly complete hospital service can be obtained in most sections of the United States. Such plans should be called to the attention of the employees and if possible subsidized by companies in the interest of morale. These services are a great help to employees in the lower income groups.

Group medical plan. Group medical plans may be part or independent of hospital service. In some areas manufacturers use local hospitals and clinics, and in others use the facilities of local institutions for moderate fees. Salaried physicians and specialists provide services for prospective groups. These men are paid from the treasury of the group rendering the service.

CHAPTER XVII

SELECTION AND TRAINING

The employees of every progressive and prosperous manufacturing establishment represent a sizeable investment because considerable time, energy, and money have been spent to select and train them. Present-day industrial managers can neither afford to hire people who lack capacities to become competent employees, nor can they overlook the provision of proper training to bring out the best each can offer. No longer does industry just hire people, but instead every effort is made to select the most desirable among those available at any given time, and the ones selected are then given training to improve their abilities.

A shortcoming of industrial managers in the organization of their plants for production has been a tendency to focus attention on physical aspects while paying too little heed to the human side — the workers, supervisors, and managerial staff. It is just as important to select, train, and allocate competent personnel as it is to select and arrange machinery, equipment, and buildings. When the physical and human organization are given attention in proper balance, the result is a smooth-working production machine.

It is a primary concern of management to keep employment costs at a minimum while at the same time obtaining adequate and competent manpower to do the production job. This is a difficult task because a host of different factors cause considerable and constant labor turnover in nearly every plant. Some workers seek new employment; others prove to be misfits in the organization; and still others seek temporary work only from time to time. In the case of female workers, it is expected that their work will not be of long duration because the objective of most women is marriage and a family, and not a career in industry. When workers leave for any cause, however, new ones must be found and fitted into the organization to replace those lost as well as to take care of changing staff requirements.

The procedures and techniques requisite to securing and maintaining an efficient organization of human beings has been a subject of careful study among leaders in the field of scientific human relations for many years. Their observations and experiences have resulted in the development of basic principles.

SELECTION OF MANPOWER

The selection of workers to meet employee and staff requirements involves two basic steps: (1) the uncovering of sources of supply, and (2) the interviewing and picking out from among potential candidates for jobs those desired for employment.

Sources of Supply

The sources of supply for procuring competent manpower follow:

Present and former employees. Firms which have been in existence for some time and desire to obtain additional manpower will find the best source to be present employees. Workers in the employ of manufacturers know the policies and requirements of the firm and are in a position to recommend outsiders who possess the qualities needed to fill various jobs.

Every company which has records of former employees who have been dismissed or who have sought work elsewhere can rely upon these past records for information on possible job candidates.

Present workers are also the best source of supply for candidates to *fill supervisory and top-management positions.* It is always good policy to promote from within. Those who have been in the employ of an organization are familiar with its structure, routines, and procedures, and can best adapt themselves to changes in rank and responsibility. On the other hand, management should be in a position to observe personal strong points and shortcomings, thereby being able to select those best qualified for promotion to positions of responsibility over others.

Employment agencies. Among the best sources for hiring workers at all times are the public and private employment agencies. Their files, which contain names of persons who are seeking work, provide an excellent screen for potential candidates. Agencies maintained by the municipal, state, and Federal governments are particularly good sources because persons out of work and receiving unemployment benefits are listed with them for replacement. Their files of names cover a much wider area than local employment offices.

Advertising. Help-wanted ads in the newspapers and trade journals are a very good source of job candidates for industries which have established reputations as being good places to work. An advertisement provides an opportunity to set forth the specific qualifications needed to fill given jobs and thereby to arouse interest among persons who are out of work, as well as those seeking changes in placement.

Industries located in areas where labor is scarce have profited from advertising in the newspapers of cities situated at some distance and

having a plentiful supply of labor. Following the insertion of a suitable advertisement in the latter city, an interviewer can make arrangements to meet potential job candidates at a specified time in their own locality.

Colleges and universities. Organizations wishing persons with particular skills and training such as engineers, accountants, scientists, and others have found that college graduates are the most likely sources of supply. It is the practice of many firms to send to colleges and universities firm representatives who interview prospective candidates among both the members of the graduating class and the alumni. A common practice is to notify the university or college placement officers in advance of the type and number of persons required. The suitable candidates available are then selected for interviews at some appointed time by the representative of the prospective employer.

Labor unions. In some instances, management is obliged to obtain its employees through a labor union because of a contract existing between the firm and the unions of which its workers are members. Only when the unions fail to supply the labor needed is the company permitted to seek employees elsewhere. Where labor contracts exist, the company's first source of supply must be the labor union with which it has a contract. Aside from this type of arrangement, however, both craft and industrial unions can be very helpful in furnishing workers. Employment is one of the services which unions want to render to their members and consequently they are eager to cooperate with employers. Many union officials have demonstrated real competence in seeking out and providing suitable, desirable candidates. Of course, the companies are saved expense by having unions perform this service for them.

Unsolicited applications. Many persons who wish employment make a practice of filing unsolicited applications with the employment offices of firms for which they would like to work. This is particularly true when there is an oversupply of labor in any community or area. By interviewing such persons and keeping records of the jobs they are qualified to fill, a very substantial file of potential reserve candidates can be developed. Very few firms, however, rely upon applications at their employment office as a sole means of supply.

Scouting. When an available labor supply is scarce, or persons are needed who have particular skills, the only way to find them is often that of following a method known as "scouting." This involves making a widespread personal canvass for people who have particular abilities. Unfortunately, this practice often results in *labor pirating.* An employer who has given training to develop persons with particular skills loses them to another employer through the operations of the labor scout. The attraction for moving to another job is usually more pay. In this connection, many firms have established policies of not

competing in the matter of pay. Careful study of costs of replacement and training reveals that many industries would find it cheaper to increase a person's pay to meet a competitive level rather than to try to select and train new workers.

In the quest for competent managerial staff members for jobs which cannot be filled by promotion within the firm, it is usually necessary to seek persons who have special capacities and experience. The sole means available is to try to attract persons of known ability to accept a new post. Opportunity for additional pay, advancement, or better living conditions are used to attract those desired. While this is merely another form of scouting, it has a more general endorsement of approval than does scouting for shopworkers and those below the supervisory level.

The local community and labor supply. Industries seeking new employees must always examine their employment needs in the light of the available supply in the community where they are located. In towns and cities where the supply of persons with particular skills and abilities is inadequate, it becomes necessary to seek recruits outside the community.

It is incumbent upon management to see to it that persons with special skills are not sought outside of the community where the plant is located if persons exist in the community already who are unemployed and who have the qualifications necessary to meet general job requirements.

Local industries can benefit mutually from working closely with local employment offices, chambers of commerce, and other agencies to satisfy labor requirements. Every effort should be made to attempt to keep a balance of employment in the local community and to prevent temporary shifts and transfers from one community to another which only serve in the long run to disrupt the labor market and increase labor-turnover costs.

In instances where firms are seeking new locations in unfamiliar towns, it is very important that they make careful analyses of available labor. The examination of the labor supply should include not only the collecting of facts about the number of persons available, but also the kinds of required skills and training they possess. Manufacturers have changed locations to take advantage of a supposed plentiful labor supply based on unemployment statistics only to find that the workers available lacked the particular skills and experience needed for the industry concerned. Where this happens, the situation is apt to be aggravated further by the importing of laborers who serve only to upset local housing conditions, increase cost of community services for the city or town, and in the long run increase tax burdens for the industry itself.

Selecting the Worker

The process of selecting employees is one of deciding which applicants are best fitted for the work. In many organizations this is still a function of foremen and supervisors, but progressive firms have established personnel departments to serve in clerical and advisory capacities with respect to selection. The final decision is still made in most instances by foremen and supervisors.

In selecting job applicants, it is necessary to weigh carefully their qualifications with the job requirements. Care must be taken, too, to see to it that those hired have personal qualities which are in harmony with those of others already employed. Poor judgment in selection and placement can result only in discontented workers who lose interest in their jobs, spoil materials, and waste their own skill as well as the supervisors' time.

The selection and placement of workers is no longer a hit-or-miss procedure, but one which has been developed and perfected to the point of specific technique. Definite tools such as aptitude tests and interview rating sheets have been developed to implement the judgment of those who must do the selecting. Practices which have been found to be economical and effective are discussed briefly in the following paragraphs.

The application for employment. Those who seek employment are usually asked to fill out an *application form* which provides advance information about their personal history and record of experience. The completed application form serves as a basis for the conduct of personal interviews. The forms vary considerably in content, but usually include the following information:

- Date of application
- Applicant's name and address
- Job for which applicant is applying
- Other jobs which applicant feels qualified to fill

Personal history

- Date and place of birth
- Marital status
- Nationality and citizenship
- Physical characteristics
- Religious and church affiliation

Educational background and training

- Names of schools attended
- Number of years attended
- Degrees received

Record of experience

- Names of jobs held

Special experience
Special training courses taken
Personal and character references
Names and addresses of previous employers
Names of persons capable of testifying to character
Special information
Initial wage or salary desired
Professional affiliations, if any

The above information may be supplied on the application form by the applicant himself or filled in by an interviewer. When the applicant fills out the form, it serves as a sort of testing device of ability to follow instructions carefully and completely. Moreover, the time required to fill out the form breaks the monotony of waiting for an interview when there are a number of persons applying for the same or different positions.

If no jobs are available, the application form is filed. When an applicant is hired, this form becomes a part of his permanent employment record. The next step in employment is the personal interview.

Interviewing applicants. Interviewing procedure is now based on well-defined principles. Its purpose is to learn about the applicant and exchange information about jobs and the firm that is offering them.

When being interviewed, the job applicant is first put at ease. The interviewer then proceeds to ask specific questions designed to supplement the information provided on the application form. During the job interview, an impression can be gained of an applicant's ability of expression, capacities for handling people, personal appearance, voice, and general bearing. To a limited degree it is also possible to gain an over-all impression of whether or not the person is likely to fit into a particular job and work situation.

Every interview must be conducted frankly in a straightforward manner. This applies to both parties. The employer wishes to uncover everything possible about the job applicant, and the latter naturally wishes to learn about the company for which he may work. Misconceptions will be avoided if the job interviewer has in front of him a specification (Fig. 172) of the job which is to be filled. This will permit discussing in detail with the applicant the required skill, responsibilities, and conditions under which the work must be performed.

Such matters as hours of work, rest periods, work on holidays and Sundays, night work and overtime, should be carefully explained. It must be remembered always that the attitude of the interviewer has a great deal to do with the impression the job applicant will receive concerning the worth-whileness of the work he is being asked to do and the company as a place in which to work.

Preliminary and final interviews. The mechanics of interviewing can be greatly expedited if a practice is established of having preliminary and final interviews for all job applicants. In the preliminary interview, the essential facts about the applicant can be requested and he can be given certain mental and trade tests which have been found to be helpful in placing the employees within the organization. Only those applicants who qualify in the preliminary interview should be asked to return for the final one. The person who makes the final interview can then proceed to talk with applicants more intelligently because test information and other facts about the applicant are available. This will permit obtaining the maximum amount of information in a minimum amount of time.

For purposes of fitting the applicant into the organization, more specific personal questions can be asked in the final interview. (It is often deemed desirable to have female applicants interviewed by women and male applicants by men. Both seem to converse more freely with members of their own sex.)

Those whose responsibility it is to select job applicants for employment may be greatly assisted in the work if they have an understanding of the usefulness of various types of tests as used for selection and placement purposes. Progressive managers increasingly recognize the value of using tests to "get the right man in the right job."

TESTING FOR SELECTION AND PLACEMENT [1]

There are three possible uses of psychological tests in business and industry. They are (1) selection, (2) placement, and (3) guidance or adjustment. It is important for businessmen who are contemplating the use of tests to recognize that these three uses require entirely different techniques and different organizations of the testing program.

By far the simplest type of testing program is selection from a large labor-supply reservoir. That is, if an employer wishes to select the most able 10 per cent of a large group, his testing program can be relatively simple. When tests, however, are to be used as a routine part of employment procedure, and where the skills required for successful performance on a job are complex, the setting up of a testing program must be preceded by careful research to determine which testing instruments are most helpful in prediction.

The second use for tests — placement — implies that a given man will be employed by the company and tests are used to determine in what place in the company he can function best.

[1] The authors are indebted to Mr. Thomas M. Harris, Director Occupational Services, Boston Y.M.C.A., Huntington Avenue Branch, for preparation of the contents of this section.

The third use for tests — guidance and adjustment — refers to a clinical type of procedure in which tests are used to detect personal problems and in which the aim is the adjustment of problem employees.

To summarize, *selection* involves picking men for a particular job. The use of tests in *placement* involves decision where to put a man after he has already been selected on the basis of general qualifications. *Adjustment and guidance* involves helping a man decide what he can do best of all possible choices open to him, or if he is not able to do anything well, what he can do "least worst."

Development of a Testing Program for Selection and Placement

Selection and placement are the most important uses for psychological tests in industry. The industrialist who wishes to start a testing program for selection and placement should decide precisely what it is he wants tests to do for him. He must recognize too that there are numerous hazards in the use of testing techniques. A traditional and still unfortunate procedure is for the personnel man to look through the catalogs of the test publisher and decide on the basis of the names of tests which instruments to use. For example, an employment man who wishes to hire men who can learn to operate machines may feel that his selection and placement problem will be solved if he gets some tests of mechanical aptitude, administers them indiscriminately to applicants for the job, and then selects those applicants who make the highest scores. A great many of the unhappy experiences that industrial concerns have had with tests can be traced to this practice. The difficulty with such a procedure is that it fails to take into account the ambiguity that often lurks in the name of a test. Bingham has cited an amusing example of this ambiguity. One of the more common "tests of mechanical aptitude" has been found to be a better prediction of clerical ability than of mechanical ability and one of the most widely used measures of clerical aptitude has been found to be a highly successful instrument for selecting machinists' apprentices. The nub of this matter is that tests do not measure anything directly, hence the name that an author gives his test is based only on the experience that he himself has had with it. Also, there is a vocabulary difficulty. In a job analysis the investigator may use a phrase such as "manual dexterity" which may be functionally an entirely different sort of dexterity than a test author had in mind. So the employment man who picks a test on the basis of the author's title, assuming that the job he has in mind is the same that the test author had in mind, performs a logical jump that for the most part is unwarranted.

All good test programs have to be set up on the basis of careful research. There is no other way. Any program that is put together

on the basis of the employment man's hunches or on the basis of what he thinks the job requires in terms of test scores is foredoomed to failure. Certain necessary steps in this experimentation will be discussed later.

Testing instruments. There are many different kinds of testing instruments — hundreds of them designed to measure scores of abilities, aptitudes, and skills. The most usual classification of testing instruments divides tests into four main roots.

1. *Intelligence* tests, which for the most part have been constructed to measure scholastic aptitude. There are many types of intelligence tests. Some have to be individually administered by a specially trained examiner. Others can be given to groups by persons with less training who are willing to follow instructions carefully. Group intelligence tests are the most frequently used in industry. For the most part, these group intelligence tests contain a number of different kinds of problems or "items." They usually include some questions involving word knowledge, arithmetic problems, and questions involving different kinds of word and number relationships (Fig. 158).

In some of these group intelligence tests such as the familiar Alpha, there are a number of subtests — a group of arithmetic problems, a group of vocabulary questions, number series grouped together. Still other familiar types of tests scramble the different items. This latter procedure results in what is usually called an "omnibus" test. Although all such measuring instruments are indiscriminately termed "intelligence tests," actually they have for the most part been constructed to measure the type of intelligence that goes by the name of "scholastic aptitude." About all that is actually known about such instruments is that they can be useful in predicting how well people can do in school. It is true, of course, that at different occupational levels, different degrees of this kind of intelligence are required. The studies made of army Alpha during and after World War I demonstrate that the mean scores on intelligence tests by persons employed in different occupations vary very widely. Equally interesting, however, was the overlap between scores made by men in different occupations.

2. *Aptitude* tests are designed to measure a number of presumably native abilities that are supposed to have little or no relationship to what is called "intelligence." In the early days of aptitude tests, the assumption was explicit that these aptitudes — such as finger dexterity, clerical aptitude, structural visualization, and the like, could not be influenced by training. They were supposed to be a part of native endowment. This was a comforting assumption and one that lies behind many present-day attempts to build special aptitude tests, but unfortunately the assumption has proved to be largely a delusion.

OTIS QUICK-SCORING MENTAL ABILITY TESTS

By ARTHUR S. OTIS, PH.D.
Formerly Development Specialist with Advisory Board, General Staff, United States War Department

Gamma
AM

GAMMA TEST: FORM AM

For Senior High Schools and Colleges

Score.....

Read this page. Do what it tells you to do.

Do not open this booklet, or turn it over, until you are told to do so.
Fill these blanks, giving your name, age, birthday, etc. Write plainly.

Name..... .... Age last birthday .....years
First name, initial, and last name

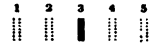
Birthday .....Teacher ....Date.....19.....
Month Day

Grade..... ...School.. ....City.....

This is a test to see how well you can think. It contains questions of different kinds. Here are three sample questions. Five answers are given under each question. Read each question and decide which of the five answers below it is the right answer.

Sample a: Which one of the five things below is soft?

① glass ② stone ③ cotton ④ iron ⑤ ice.....



The right answer, of course, is *cotton;* so the word *cotton* is underlined. And the word *cotton* is No. 3; so a heavy mark has been put in the space under the 3 at the right. This is the way you are to answer the questions.

Try the next sample question yourself. Do not write the answer; just draw a line under it and then put a heavy mark in the space under the right number.

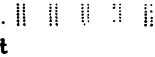
Sample b: A robin is a kind of —

⑥ plant ⑦ bird ⑧ worm ⑨ fish ⑩ flower....

The answer is *bird;* so you should have drawn a line under the word *bird,* and *bird* is No. 7; so you should have put a heavy mark in the space under the 7. Try this one:

Sample c: Which one of the five numbers below is larger than 55?

⑪ 53 ⑫ 48 ⑬ 29 ⑭ 57 ⑮ 16.....



The answer, of course, is 57; so you should have drawn a line under 57, and that is No 14; so you should have put a heavy mark in the space under the 14.

The test contains 80 questions. You are not expected to be able to answer all of them, but do the best you can. You will be allowed half an hour after the examiner tells you to begin. .Try to get as many right as possible. Be careful not to go so fast that you make mistakes. Do not spend too much time on any one question No questions about the test will be answered by the examiner after the test begins. Lay your pencil down.

Do not turn this booklet until you are told to begin.

Patent No. 1,586,628

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Courtesy World Book Co.

FIGURE 158. ONE TYPE OF INTELLIGENCE TEST WHICH IS WIDELY USED IN SELECTING AND PLACING EMPLOYEES

It has been found that aptitude test scores vary widely with training and experience and although such instruments are extremely useful in the employment office, it is extremely hazardous to suppose that they measure unchangeable native abilities. Figures 159 and 160 show aptitude testing in progress.

Courtesy Industrial Testing Division, Occupational Services, Huntington Ave. Branch, Boston Y.M.C.A.

FIGURE 159. TESTING MECHANICAL APTITUDE WITH THE MINNESOTA MECHANICAL ASSEMBLY TEST

3. *Interest* tests are of various types. The most common is the type of interest test in which the subject expresses likes or dislikes for a large number of different occupations, peculiarities of people, and so on. The test is scored by comparing the individual's responses with the responses given to the same questions by persons successfully employed in various occupations. Although it has been found that interest patterns vary widely from occupational group to occupational group, the usefulness of interest tests for employment purposes is quite limited.

4. *Personality* tests are for the most part of the questionnaire variety. The individual being tested is asked to respond "yes" or "no" or "true" and "false" to a number of statements about his social life, relations with his family, emotional reactions, and so on. These instruments are quite useful to a clinical psychologist and can give valuable

Courtesy Industrial Testing Division, Occupational Services, Huntington Ave. Branch, Boston Y.M.C.A.

FIGURE 160. TESTING MANIPULATIVE DEXTERITY BY MEANS OF THE PURDUE PEGBOARD

data when the subject is motivated to answer them as truthfully as he can. In the employment office, however, where the applicant is trying to make as good an impression as possible, he is likely to give idealized answers to such questions. He may do this either consciously or unconsciously, but in any event, the atmosphere of the employment office is not the kind of atmosphere that would encourage him to give utterly truthful replies to fairly intimate questions. A great deal of experimentation is now going on with types of personality tests in which the subject finds it almost impossible to figure out the most favorable re-

sponses. An increasing use is being made in industry of so-called projective tests in which the subject literally does not know what to repress.

Limitations of test measurement. In spite of the fact that there are thousands of different types of tests with hundreds of different names that are supposed to measure an almost infinite number of attributes, skills, and abilities, recent research seems to demonstrate that these tests overlap greatly and actually measure only a limited number of separate functions. As has been previously suggested, tests with different names often measure substantially the same thing. Many test psychologists now feel that a man's total ability can be broken down into a limited number of separate mental elements, just as a chemical compound can be broken down into its elements. The number of mental elements is probably not very large. Some of them have not been completely isolated as yet. It may be helpful to think of "total ability" as represented by a large circle. This large circle may represent the sum of a number of special abilities represented by smaller circles within the larger circle. The mental elements designated by the smaller circles are present in all individuals, but in varying amounts. It would be practically helpful if personnel men did not think of tests in terms of the traditional classifications. Such classifications obscure the extremely important fact of overlap. Also the arbitrary classification of testing instruments into intelligence, aptitude, personality tests, and the like, tempts one to feel that the functions which are being measured can be accurately named. Actually the naming of tests is of no significance. It does not matter what we call those smaller circles within the large circle. Perhaps it would be more convenient to designate them by numbers or letters. The point is that if a large amount of elements, *3*, *X*, and *R*, are found to be characteristic of workers who are successful in a certain type of job, but are not common to workers who are unsuccessful in their jobs, then tests measuring elements *3*, *X*, and *R* are very useful for selection purposes no matter how we label the tests. Since we cannot trust test names, our only recourse for discovering what mental elements a job requires is experimentation.

Importance of Research

The experimental research that must precede the setting up of a test-centered selection program must be carried out by persons thoroughly familiar with research techniques. This is not a job for an amateur and it is likely to be time consuming and often expensive. Practically, it is usually desirable to give a knowledge of different types of tests to men already employed on the job for which testing standards are to be set. The problem basically is to discover what mental elements are common in similar amounts to men successful on the job,

but are not common in those amounts to unsuccessful people or to people in general. New applicants are then selected on the basis of the possession of the desired amounts of these mental elements. In a sense, this sounds a good deal simpler than it really is. There are numerous hazards. The principal hazard is that in testing people who are successfully employed on a job, the tester is never sure whether the abilities so measured were developed after men came on the job or whether they were present before they had this experience. Therefore, the testing of men on the job is a preliminary step to further and more prolonged study. It is usually necessary to develop a group of tests on the basis of this preliminary study and then to try them out on successful job applicants before we can be sure that the tests really have predictive value. It is clear that when the tests are given to the first group of job applicants the scores should not be used to determine their fitness for the job. Instead, the tests should be given and promptly forgotten until data are available on how well the men have performed. Then it is necessary to study the test scores to see which tests would have had predictive value if they had been used. Even tests that appear to have predictive value sometimes do not work out very well. There is a mathematical reason for this. If we should take a handful of coins and toss them, we should expect to get approximately the same number of heads as tails, but on a "lucky" throw we might get a very large number of heads. For the same reason, we might find some tests that appeared on the basis of initial experimentation to be very diagnostic whereas they would not prove themselves to be so after successive trials. This example may suffice to explain why extremely careful experimental work has to be done before the validity of a group of testing instruments to be used for selective purposes can be finally established. The details of experimentation cannot be described here.

Research in Testing Not Always Necessary for Results

When tests are to be used over a long period of time, it is necessary that research of the type mentioned above be carried out. This research is not always practical and there are some occasions when it may not be necessary. For example, when an employment man has an extremely large labor supply to draw from and when he is not interested in special skills or precisely defined job requirements, he might, let us say, give an intelligence test to 100 applicants and arbitrarily select the 10 with the highest score. This procedure is not often applicable, but when it can be employed, it is sound; that is, if through interviews or through a study of experience records, these 100 applicants appear to be approximately equal, an intelligence test even of the simplest sort would help in separating the more bright from the less bright. Also,

most clinical psychologists have available enough data about standard tests now on the market to make a shrewd guess as to their possible value in a certain type of an employment situation. If a man is being considered for an important job, it is often worth while to have him thoroughly examined and interviewed by a clinical psychologist. The psychologist uses instruments with which he has had extensive experience and can draw inferences which are better than pure guesses as to their possible significance for the job for which the man is being questioned. These examples are not given to suggest that there is any substitute for the experimental method. They are intended rather to suggest that testing procedures may have some value in industry even when it is not possible to set up a research program.

Testing Programs Vary with Individual Firms

Unfortunately, each company has to do its own research work or has to have this work done for it by skilled technicians from the outside. This is true partly because requirements for jobs with the same name often vary widely from company to company. No two companies are exactly alike, so no two testing programs can be exactly alike. An even more fundamental reason is, however, that companies who have spent money in personnel research cannot afford to make their experiences available to others. Their investment in such research is usually quite large. Also there is an ever-present danger that applicants might see the testing instruments or hear something about them before they are tested. Unscrupulous people have been known to obtain copies of selection tests and have offered to train prospective applicants to pass these tests before the applicant takes the test at the employment office. Naturally, all experimentation is based on the assumption that the applicants will not have access to the testing materials in advance. If they do get such access, the whole experimental procedure must be radically altered and the money spent on research is wasted.

TRAINING

Scientific training is a cornerstone of sound management. Selection of the right employee for given tasks is only the first step in securing an efficient working force. Proper training is equally important in building a competent factory manpower organization. Fine buildings, modern machinery, and up-to-the-minute physical organization of the plant may be of little value in use unless the human machine is so trained that it can be effectively coordinated as part of the entire production machine.

New workers must be taught to do their jobs correctly from the outset; channels ought to exist to teach old employees new methods as

they are developed. Under scientific training, new employees are properly introduced to their work and given fair opportunities to meet performance requirements; those who fail at one task can often be salvaged for another. Moreover, a training program gives management an opportunity to explain carefully and clearly its policies, rules, and regulations. The employees get correct first impressions rather than false notions born of the petty grievances of those now working.

Tangible results of a training program include reduction in labor turnover, less spoiled work, less damage to material and equipment, and improvements in quality and quantity. Perhaps above all, good will is generated. When employees feel that they are treated fairly from the outset and not expected to accomplish the impossible, and when at the same time they know they are getting valuable instruction to place them on equal footing with fellow workers, there is bound to be generated a high regard for top management. In the final analysis, training programs are a reflection of management attitudes.

Training vs. Education

It will be helpful to the student of industrial management if a clear understanding is obtained at the outset as to just what industrial training involves. It is different from formal education which is carried on in the classroom and is perhaps designated as the *how* of doing something as compared to the *why*. The distinguishing characteristics are shown in the following table:

Training	*Education*
Application — how	Theoretical — why
Job experience	Classroom
Specific tasks	General projects
Personality adjustments	None
Paid to learn	Pay to learn
Definite objective	Opportunities — no special job in mind

Formal educational programs as carried on by colleges and graduate schools impart background knowledge of skills and to a degree give limited practice in them. It is the practical application of the skill, however, in which businesses and industries are really interested. Consequently, it is necessary to carry on organized training programs.

Types of Training

The training of industrial employees involves four broad types of training:

1. **The training of inexperienced operators.** In some organizations this activity is carried on only when new employees are brought in and in

others it is a constant process. In organizations where female labor exists to a considerable amount and the turnover is high, this type of training is a regular procedure.

2. **Versatility training.** Increasingly, industries are recognizing the value of having employees who can perform more than one skill. Versatile operators are valuable assets during both rush periods and periods when work is dull. Very often a specialist has to be laid off during a dull period but the versatile operator can be shifted to new work. In businesses where style changes are continually occurring, versatility training is a definite requisite of the training program.
3. **Retraining.** Operators who are transferred from one department to another very often must be retrained before they can begin productive work. In all industries where transfers are numerous, retraining is a part of the training program.
4. **Remedial training.** Remedial training is carried on to bring to old employees new methods of doing work and to teach them how to improve their performance. It is necessary to carry on remedial training also when employees have developed bad habits of work performance.

Training Methods

Organization for training varies from firm to firm, but the methods used are pretty much the same. The following enjoy widespread use and it is important to examine each briefly:

1. On-the-job training
2. Vestibule-school training
3. Training by experienced workmen
4. Training by supervision

On-the-job training. When employees are trained on the job they "get the feel" of actual production conditions and requirements. This avoids an extra transfer and adjustment from the training school to the actual production conditions following the training period. Moreover, the trainee learns rules and regulations and procedures by seeing their day-to-day application. The association with actual production workers serves as a stimulus to push the trainee along faster in his development. From the standpoint of management, training on the job affords an opportunity to size up trainees in their reactions to production conditions. Perhaps most significant is the fact that the trainee feels from the start that he is undergoing a training program, and he never gets the idea that his training is completed no matter how long he holds a job. Training on the job has the advantage of keeping costs at a minimum and it is necessary in the following instances:

1. When the cycle of work is long and complicated and where the operator must learn to handle situations which recur infrequently.
2. When the operator is required to perform a wide variety of duties. In

these instances training on the actual job is the only way training can be carried out.

3. When the number of trainees is too small to justify separate equipment and personnel. In such cases training on the job is again the only method to get desired results.
4. When the cycle of work is repetitive, short, and too simple to require a long training period.

Vestibule-school training. The "vestibule school" is a name for a training setup in quarters separate from the departments which carry on the regular production work. Both the equipment used and the instructional personnel are independent of production departments and manufacturing departments. Where vestibule schools exist, new employees are trained before they are inducted into actual manufacturing departments. This promotes confidence. In some instances the vestibule-school is modified so that it is really preassignment training. The trainee receives brief instruction in a separate training room under special instructors who are in turn under the supervision of the manufacturing department foreman. In the separate training school — or vestibule-school — these advantages usually exist: instructors are usually specially trained teachers; attentions are focused entirely on training routines; opportunities are afforded for making good job analyses for instructional purposes; instruction methods are thought out carefully and tried out before they are put into use; the new employee is prevented from learning short-cut methods as is often the case in on-the-job training. Quality and methods are emphasized, and this results in less spoilage than usually results from on-the-job training.

A vestibule-school type of training is required where shop conditions do not permit on-the-job training, and where large numbers of persons must be trained.

Training by experienced workmen. When employees are trained by fellow employees, the following advantages are applicable: no separate training staff is necessary; the trainee is more likely to ask questions than he is from a trained teacher or supervisor; the experienced operator appreciates the attitudes and feelings of the trainee and is in a position to put him at ease quickly; the experienced operator is usually quick to spot a misfit and those who are not qualified for further training can be eliminated quickly; the operators who do the training improve their own methods through teaching and in addition are forced to keep up to date on methods and standard practices; and finally, those operators who are used for training purposes usually develop into good material for promotion to the supervisory rank.

This type of training is particularly adaptable where experienced workmen need helpers. It fits in particularly well also in departments

where workmen advance through successive jobs to perform a series of operations. It is a necessary method in instances where equipment and processes cannot be duplicated economically for purposes of a training school and where new employees are added to an organization only a few at a time as needed.

Training by supervision. When supervisors do the training, responsibility for efficiency in their departments is placed directly on their shoulders. Trainees who work under supervisors are provided with good opportunities for getting acquainted with their bosses, and, in turn, the supervisor has a good chance to judge the abilities and possibilities of trainees from the job-performance standpoint. Significant too is the fact that supervisors are forced to keep up to date with the latest methods when they are responsible for the training. Here again a separate training staff is avoided. Wherever supervisors can give adequate time to training it is a most economical way of achieving satisfactory results.

Supervisors who train others equip themselves for more important jobs. Training by supervisors is adapted to those shops only which have ample room on the production floor to train new employees and where the supervisors have adequate time to give proper attention to trainees.

Training Procedures and Techniques

The procedures for carrying out a training program involve three basic steps. These are (1) the induction of new operators, which is perhaps of greatest importance; (2) the instruction of the operator in the work he is to do; and (3) the follow-up on the effectiveness of the training program.

1. The induction of new operators. It is impossible to place too much emphasis on the importance of carefully introducing a new employee to the job. The most essential part of the induction process is the responsibility of foremen and supervisors. Careful attention to this function will repay the supervisor many times because he obtains the respect, confidence, and good will of the new worker. The steps for induction of new operators are listed below in proper sequence:

a) New employee is hired and told briefly about his job. Skill requirements are outlined and employee is given clear picture of the nature of the work which he is expected to do. At this point also, the broad aspects of company policies are explained.

b) The new employee is given a short talk by a member of the employment department on matters such as the following:[1]

[1] *TIPS* — Training in Progressive Supervision, Liberty Mutual Insurance Company, Boston.

Personal	*Occupational*
Location of washrooms, lockers	Location of time clock
Emergency equipment, fire exits	Working hours
Employee social activities	Use of time or work cards
Benefit associations	Opportunities in job
Punctuality	Safe working methods
Disciplinary measures	Company policies and rules
First aid	Location of tools, stock, and equipment
Attitudes on cooperation	Cost and waste
Where to seek information	Housekeeping

c) The employee is received by the supervisor of his department and assigned to a job. The supervisor's responsibilities in installing a new employee in logical order are: [1]

(1) To discuss the scope and importance of work or job.
(2) To explain and familiarize with company literature, customs, safety rules, and so on.
(3) To conduct a tour of the department, and entire plant if possible.
(4) To assign locker space, time card, work cards.
(5) To introduce key men of department and fellow workmen.
(6) To provide necessary tools and equipment.
(7) To start instructions for job.

The supervisor must make every effort to see to it that the employee gets a correct first impression of his new job. A man who does not receive this impression is very apt to start off on the wrong foot, soon lose interest, and good will is lost.

d) The employee is assigned to whatever training program the company has in operation. In the event that it is a fellow-employee instructor, he is turned over to this person at this point. It is well for the instructor to repeat many of the items which have been covered previously and to explain again the company policy regarding work.

e) The employee is started on the training program, either in a special training unit or on the job. At this point, the instructor must give consideration to the following items: [2]

(1) Can the employee be expected to do the entire job or will he need assistance?
(2) Has he done this work before — what instructions does he need — should they be in writing?
(3) What amount of supervision will the job require — when should it be checked?
(4) Would it be better to break the job into simple fractional operations and use several men or does it warrant using a skilled mechanic?
(5) Should several jobs be assigned at one time?
(6) Can a time limit be set for the job?

2. Instruction period. During the instruction period, the employee must be acquainted with the following:

a) The nature of the product he is making and the purpose of the operations being performed.

[1] *Ibid.* [2] *Ibid.*

b) Equipment and materials to be used, the care and use of tools, safety rules and regulations, and particularly safety requirements in connection with the job for which the man is training.
c) The flow of work to and from the work station including information about requisitioning, handling materials, and processes.
d) Sources of information about the job, i.e., where to find data, what literature is available, what persons to approach to ask questions about the work itself.
e) Correct methods, short cuts, quality requirements.
f) The essentials of motion economy in general and as related to the particular job.
g) Further details on company policies regarding the facilities and performance of the work itself.

3. Follow-up. It is not enough to train an employee and then put him on his own. It is necessary also to follow up what the employee does and to obtain progress reports. These are in reality reports on what the operator has done during the previous day, week, or work period. The information needed may be obtained either from the payroll tickets or production reports as compiled by various supervisors. It is necessary to check in particular on (1) the quality of the work done by the new operator, (2) amount of spoiled materials which have resulted from his work, and (3) the probable errors in performance which may have caused the loss or damage.

JOB INSTRUCTOR TRAINING [1]

A complete training program involves more than just setting up procedures for training new employees at the operator level. It should provide also for the training of instructors who are expert in training new employees. Only in this way can the best results be achieved in employee training. Particularly outstanding in the development of procedures for job instructor training are the basic principles compiled during 1940–1941 for use in connection with the Training within Industry program as conducted by the Labor Supply Division of the War Production Board. The principles are those which have been used by a number of industries. Best practices have been combined to produce what is called the "principles of job instructor training." These involve four "get ready" points and four basic steps. Through courtesy of Training within Industry this information follows: [2]

[1] *Job-Instructor Training*, Training within Industry Branch, War Manpower Commission, Washington.
[2] *Ibid.*

How to GET READY *to Instruct.*

The four GET READY points to be taken care of before instructing are:

1. *Have a time table.*

   — how much skill do you want the man to have?
   — how soon?
   When faced with a "breaking in" problem, don't say what all too many of us say — "IT TAKES TIME — — —," or "HE JUST HAS TO LEARN."
   Say to yourself instead: "HOW *much* TIME — — —?"
   Here is an easy way to do it. Answer to yourself this statement: "(*employee*) should be able to (*do what job*) and do it (*how well*) by (*what date*)." Better yet, put down the names of your men on a piece of paper. Set yourself some dates when you are going to try to have them able to do the jobs they need to know. *Time is short.* Have a time table for yourself and your men.

2. *Break down the job.*

   You know that there is *one right way* to do every job. You know too that there are a few "*key points*" in every operation that make or break it. If these key things are done rightly, the whole operation is right. If *any one* of them is missed the operation is wrong.
   — if you put the job over to the worker with these key points made clear, he will really "get it."
   — he will do the operation right the *first time.*
   — he won't be "fighting" the work — making mistakes — getting hurt.
   There is an easy, quick way to get the job clearly outlined in your mind. Fill out a "Breakdown Sheet" for each of your operations. It only takes three to five minutes. This is for your own use. It is not to be given to the worker.

3. *Have everything all ready.*

   — the right tools, equipment and materials.
   When you so much as "touch" a job in front of a worker, set the *correct* example. Don't use the wrong tool. Don't fumble. Don't excuse. Don't miss a trick. When *you* have everything right, *he* is more likely to do the same.

4. *Have the work place properly arranged.*

   — just as the worker is expected to keep it.
   The same thing applies here as above. You must set the correct example. Put his bench, desk, stock pile or wherever he is to work, *in proper order,* before you start to put over the job to him. *He* won't do it if *you* don't do it.

How to INSTRUCT.

Here is what you should do every time you instruct a man or correct his work:

STEP I. PREPARE the worker to receive the instruction.

— put him at ease. Remember he can't think straight if you make him embarrassed or scared.
— find out what he already knows about this job. Don't tell him things he already knows. Start in where his knowledge ends.
— get him interested. Relate his job or operation to the final product, so he knows his work is important.
— put him in the right position. Don't have him see the job backwards or from any other angle than that from which he will work.

STEP II. PRESENT the operation.

— tell him, show him, illustrate, ask.
— "put it over" in small "doses." He (the same as all of us) can't catch but six or eight new ideas at one time and *really understand* them.
— make the "key points" clear. These will make or break the operation — maybe make or break *him.*
— be patient — and go *slowly.* Get accuracy now — speed later.
— repeat the job and the explanation if necessary.

STEP III. TRY OUT his performance.

— have him do the job, but watch him.
— then have him do it again, but have him EXPLAIN to YOU what he is doing and why. All of us find it easy to observe motions and not really understand what we are doing. YOU want him to UNDERSTAND.
— have him explain the key points.
— correct his errors, but don't bawl him out or indicate that he is "thick" or "dumb."
— continue doing all this until YOU know HE knows.
He may have to do the job half a dozen times.

STEP IV. FOLLOW-UP.

— put him on his own. He has to "get the feel" of the job by doing it himself.
— tell him to whom he should go if he needs help. Make this definite
— yourself or someone *you* designate. The wrong person might give him a "bum steer."
— check him frequently — perhaps every few minutes at the start to every few hours or few days later on. Be on the lookout for any incorrect or unnecessary moves. Be careful about *your*

taking over the job too soon, or too often. Don't take it over *at all* if you can point out the helps he needs.
— get him to look for key points as he progresses.
— taper off this extra coaching until he is able to work under normal supervision.

Greatly improved results can come from such a simple plan as the foregoing. It should be used, or whatever part of it applies, every time a new operation is to be carried out, a man's work is to be checked, or a change in work procedure made. The motto is:

If the worker hasn't learned, the instructor hasn't taught!

TRAINING OF SUPERVISORS

One of the crucial bottlenecks of production in times of emergency is the lack of adequate number of supervisors and managers to carry on an effective production program. As an organization grows, supervisors and managers cannot stretch their capacities beyond reasonable limits, except that the whole plant becomes increasingly less efficient. One way to expand the managerial organization is through training. The following are the steps recommended to manufacturers engaged in war production during World War II:

1. Increasing the responsibilities of present supervisors. When the volume of work increases in any manufacturing industry, it is usually necessary for the supervisors to take on more responsibilities. Each must supervise more men and equipment, and in many instances new departments, divisions, and sections must be combined. At times when supervisors are scarce, this way of expanding the supervisory force works to good advantage.

2. Upgrading. In the ranks of workmen, there are many persons who can be selected and elevated to become supervisors, and among the supervisors and department heads there are many who have the capacities for taking full charge of new departments, new plants, or to assume functions of new jobs that are created.

When any persons are promoted to new responsibilities, it is important to provide for their replacement and to make preparation for understudies. By doing this, the management avoids getting into a pinched situation when faced with large orders or important expansions. The members of the personnel or industrial relations department can be very helpful in developing plans preparatory to these changes. It is recommended that organization charts be developed to designate the persons who are to be given special training preparatory to taking over added responsibilities when changes and expansions must be made. In upgrading employees, these practices should be followed:

a) Older employees should be upgraded for promotion rather than hiring new men. Employees have a better morale when they know they can progress with an organization.

b) Persons who are to be upgraded should be given opportunities to learn by watching while performing minor tasks.

c) Those who are trained for more responsible positions should be rotated in jobs in order to make them more flexible, thereby avoiding crippling the organization when expansions occur. Lines of promotion should be established to be used as guides in making promotions and transfers.

Selecting and Training the Beginning Supervisor [1]

In selecting those who are to be upgraded for supervisory positions, emphasis should be placed on leadership ability rather than trade or professional ability. No particular group of persons should be earmarked for promotion, that is, engineers or technicians, as compared with less specialized persons. No single occupation or profession has a monopoly on the abilities required to lead others. However, when a supervisory job requires special technical knowledge, it is essential that the persons chosen have proper background.

As a result of the expanding needs for supervisory personnel to "man" industries producing war materials for World War II, some successful plans have been evolved to develop competent supervisors. The steps of a recommended training program are briefly as follows:

1. The new supervisor should be given elementary supervisory work to do for a period of 2 or 3 weeks. Then he should receive instruction in principles of supervision, dealing with labor and personnel policies. His first supervisory job should be handling the supervision of experienced workmen where special problems of discipline are not apt to arise. The new supervisor should be expected to handle routine duties such as time tickets, ordering materials, assigning and scheduling work. He should not be permitted to get into controversy over wage payments, grievances, or selection of persons for transfer or dismissal.
2. At the end of the initial training period, the new supervisor should be given intensive training. This should be designed to prepare him for handling difficult situations which many supervisors have experienced through a costly trial-and-error method. Problems of handling personnel are an excellent means of presenting these points. A recommended schedule of instruction follows:

   Supervisory job planning — 6 hours
   Theory and practice of instructing workers — 48 hours
   Personnel responsibilities — 6 hours
   Labor policies — 6 hours

[1] The material presented in this section is based on a bulletin entitled "Better Supervision" published by the Training within Industry Branch of the War Manpower Commission.

Supervisors in training should be taken off the job to undertake the above schedule rather than expected to carry it along with supervisory responsibilities. The long-term advantages outweigh the short-term inconveniences.

3. The new supervisor should be given a place of responsibility in a normal working group including some inexperienced workers. He should have contact with all supervisory problems and given full responsibility just as rapidly as he can handle it properly. At this point, it is suggested that new supervisors might well be given special assignments to instruct new workers.
4. Finally the supervisor should be put on his own. At this step, the supervisor will have full responsibility for his department under normal guidance of top management, staff meetings, and supervisors' conferences.

APPRENTICE TRAINING [1]

The objective of apprenticeship training is to develop all-round skilled craftsmen. The major part of apprentice training is done on the job doing productive work. Each apprentice is given a program of assignments according to a predetermined schedule. The well-balanced programs provide for efficient training in trade skills and permit a sufficient amount of time for the training to allow the apprentice to mature as a responsible worker. Apprentice programs are usually sufficiently flexible, however, to allow progress according to individual capacities. Some apprentices complete their entire training programs in shorter periods than others.

Some of the best literature available for manufacturing industries dealing with setting up and operating apprentice-training programs is that published by the Federal Committee on Apprenticeship which is a division of the Labor Standards in the United States Department of Labor. The Federal Committee defines an apprentice as follows:

> The term "apprentice" shall mean a person at least 16 years of age who is covered by a written agreement registered with a State Apprenticeship Council or the Federal Committee on Apprenticeship, providing for not less than 4,000 hours of reasonably continuous employment for such person, and for his participation in an approved schedule of work experience through employment, which should be supplemented by 144 hours per year of related classroom instruction.

The Federal Committee has also developed basic standards for apprentice training which are based on the best practices used by industries which operate apprentice-training programs.[2]

1. An apprenticeable occupation is considered one which requires 4,000 or more hours to learn.

[1] Bulletin No. 3, Training within Industry, War Manpower Commission, Washington.
[2] *Ibid.*

2. A schedule of the work processes to be learned on the job.
3. A progressively increasing scale of wages for the apprentice that should average approximately 50 per cent of the journeyman's rate over the period of apprenticeship.
4. Provision for related classroom instruction (144 hours per year of such instruction is normally considered necessary).
5. The terms and conditions of the employment and training of each apprentice to be stated in a written agreement and registered with the State Apprenticeship Council.
6. Review of local apprenticeship by a State Apprenticeship Council.
7. Apprenticeship should be jointly established by the employer and the employees.
8. Adequate supervision and the keeping of records should be required for all apprenticeship programs.

In the development of an apprentice program, the following steps should be observed:

1. Responsibility for the program should be given to one person qualified to handle it. Experience has demonstrated that a single supervisor produces the best results. This is usually a full-time job in large plants and a part-time job in small plants.
2. There should be an effort made to determine the skilled occupation to which apprentices will be assigned when they become journeymen.
3. There should be established a set number of apprentices in relation to the number of employed journeymen, anticipating normal losses, quits, and transfers.
4. The length of the apprentice-training period should be determined and based upon the number and complexity of the skills to be learned.
5. Provision should be made for the instruction on the job including selection and scheduling of work experience.
6. Classroom instruction should be made available in technical subjects related to the shop practice given apprentices.
7. Rate scales for apprentices should be established which correspond to the level of their skills and which recognize rates being paid to journeymen as well as the productivity which may be expected from those working as apprentices.

Selection of Candidates for Apprenticeship

The Federal Committee on Apprenticeship lists the following as fundamental considerations in selecting apprentices for training:

1. Selection of those candidates who have demonstrated they have the perseverance and qualities of character which will make it possible for them to continue and complete their apprentice training. Special attention should be paid to mechanical aptitude and intelligence. In this connection, the subjects studied by the prospective apprentice as well as the progress made in school should be examined.

2. Foremen should recommend likely candidates on the basis of their own observation and information available in the personnel department.
3. School authorities should be consulted for additional evidence of the attitude and suitability of those selected.
4. A probationary period should be established to place a double check on the suitability of those selected.
5. Where skilled craftsmen are urgently needed, candidates should be selected who have had some trade experience and can complete the training program in less than the full period.

TRAINING OF WOMEN FOR FACTORY WORK [1]

A large number of women are employed in manufacturing industries in normal times, but in times of national emergency an even larger number are required to take the place of men in carrying on war productivity. Fortunately, the curtailment of civilian production in time of war releases a number of women with varying degrees of skill for war production work. These women are available for retraining. The introduction of women workers into industries where they have not been employed previously and where they will be asked to do what is normally regarded as "men's work" requires special attention.

Selection and Placement of Women [2]

In selecting women for factory work, particular attention should be given to their education, training, and aptitudes. In this connection, housewives who are untrained and free for part of the day are perhaps less suited to serve for factory work than women who have been regularly employed. The housewife can replace regular female workers by doing civilian work, thereby making the latter available for production work. Many women have particular aptitudes for precision work. Those who have been engaged in occupations which require deft hand operations fall into this category. Experience demonstrates that with good training these women work to tolerances measured in ten-thousandths of an inch. It is also true that jobs which require "feel" such as fine assembly operations and adjustments are perhaps better filled by women employees than male employees. The shortcomings of women by way of mechanical aptitude should not be regarded as a lack of mechanical ability, but rather a lack of mechanical familiarity. Industries which have given mechanical training to women have found them to be just as effective as men in the performance of mechanical

[1] Bulletin No. 7, Training within Industry Branch, War Manpower Commission, Washington.
[2] *Ibid.*

operations. The training procedures which should be followed in introducing women to industrial occupations are just the same as those followed for men.

Special Considerations Regarding Factory Women Employees[1]

Factory managers must give particular heed to "protective" legislation which has been established for female workers. Some states have rather strict standards and where it is necessary to modify these standards to meet the needs of war-production programs, the industrial commissioner or secretary of labor of the individual state should be consulted.

Physical limitations. Female workers have specific physical limitations. These may be overcome by using mechanical conveyors, load-lifting devices, pedestals, and so on. In some instances, tools must be revamped and scaled so as to be more easily handled by women, and benches made lower for female assembly workers. Women are inclined to observe safety rules more carefully than men. Some special precautions need to be taken, however, in connection with safety for women. Women working in industry should be required to wear caps if their hair is long, jumpers or slacks instead of skirts, and short sleeves rather than long sleeves if working around belting and gears.

Absence. The absentee records for women are worse than those of men. Little can be done to avoid this because a number of uncontrollable factors contribute, such as responsibilities in connection with the home. Manufacturers are urged to have substitute workers available to replace women who are absent from regular work.

Turnover. Contrary to popular opinion, many women in industry do not change jobs so often as men. If they are given good supervision, good working conditions, fair wages, and fair treatment, they will hold onto their jobs, thereby decreasing labor turnover.

Supervision of Women Employees

While some organizations feel that women employees should be under a woman personnel supervisor, experience of industry demonstrates that this is not at all necessary. In the shop, however, women should be encouraged to become first-line supervisors because this will serve as a promotion incentive and at the same time will avoid by-passing women supervisors to go directly to the man whom they feel is the real boss.

[1] Bulletin No. 7, Training within Industry Branch, War Manpower Commission, Washington.

TRAINING AND MOTION STUDY

An important adjunct to any training program is giving instructions in the principles of motion study. Correct methods result in increased output at lower cost, a lessening of fatigue on the part of the operator, as well as greater earnings with less effort. The principles of motion study which should be used in training are discussed in Chap. XVIII. Training programs as set up in modern industry either incorporate motion study as part of the training program or it is carried on as a follow-up.

Where no motion-study programs exist and a training program is to be introduced, it is possible to take motion pictures of old methods as now used. New methods can sometimes be developed from the application of motion-study principles and these should be photographed also. By means of showing employees so-called before and after pictures — the old and the new way — employees become motion-study conscious and very often bring about improvements in their own work.

CHAPTER XVIII

MOTION STUDY AND THE WORKER

The principles of motion study as applied to plant layout are treated as a part of the physical organization of the plant. These principles bear directly on physical arrangements of productive machinery, workplaces, and service areas.

It would be futile for management to spend time, energy, and money in perfecting the efficiency of the physical side of its plant organization and then to overlook the efficiency of the workers who are to use the plant. The principles of motion study which apply to workers are different in emphasis from those which apply to plant layout. The management advantages to be derived from their application are:

1. **Better employee training.** Through the elimination of waste motions and the introduction of improved work methods, standard procedures may be developed which not only simplify the job for the individual workman and increase production volume, but also make possible a development of uniform training procedures. This in turn minimizes the time for induction of new workers and makes them productive sooner than when no standard procedures exist. Moreover, workmen who are trained to do jobs properly usually work safely, spoil less material, and are less subject to fatigue. Motion pictures of jobs which are taken for micromotion analysis purposes are very useful in showing large groups of workers how work is done correctly.
2. **More equitable wage rates.** The development of standard practices leads to standards of performance — descriptions of what is expected from employees in terms of physical, mental, and other requirements of the jobs. This information is helpful in equalizing wage rates as part of a job-evaluation plan. Even when job evaluation is not used, standards of performance are useful in deciding upon standard times that are reasonable for the performance of work.
3. **Increased output at lower costs.** Workers who are taught to perform tasks according to the best principles of motion study and who work in places that incorporate motion-study principles as applied to plant layout should be capable of increased output at lower costs. When motion-study principles are applied a production volume is to be expected that is above that of organizations in which motion-study techniques are not used. Except in unusual instances, an increase in production volume lowers the overhead cost per unit as well as the labor cost.

Motion Study — Skill and Fatigue[1]

Human motions are made by parts of the body. These parts function most efficiently in doing particular tasks only when they have attained skill and learned to function with minimum fatigue. The study of human motions is primarily concerned with the achievement of skill and the elimination of bodily and mental fatigue, one in conjunction with the other. Brief consideration of each of these topics is introductory to statement of the laws of motion study applied to the worker.

Motion study and skill. Skill is an indication of trained muscular performance. It is the quality which ensures accuracy and precision of movement as well as rapidity of movement. A skilled worker is able to do relatively complicated things easily and well. Basically, skill in movements of parts of the human anatomy is the result of high accomplishment in any one or a combination of the following:

1. Sensory capacity — development of the senses such as touch and sensitivity of finger tips in making small, fancy articles or doing delicate assembly work.
2. Manipulative ability — fine control of movements in which tools become extensions of the fingers as in the case of writing and artistic painting. This involves also flexibility of wrist movements such as turning in using a screw driver; flopping in doing paint and varnish work and typing; and movements from side to side in writing and drawing.
3. Rhythm of movement — repetitive action without the stimulation of repeated impulses.
4. Precision — development of this skill produces a combination of accuracy and speed in doing work.
5. Ambidexterity — either hand or more than one part of the body is trained to do the same or similar things.
6. Coordination — the functioning of two or more anatomical members of the body both efficiently and simultaneously.

It is difficult to conceive of many skills where some or all of the foregoing are not involved to a degree. Speed and accuracy, for example, result from a high development of precision. When accompanied by rhythm and ambidexterity as well as coordination this skill becomes automatic and one which is easily transferable from one job to another.

Motion study and fatigue. Among the first to study fatigue in industry as a factor retarding production were Frank and Lillian Gilbreth.[2] In fact, it was their interest in this particular topic which led

[1] Discussion of skill and fatigue based on Stephen B. Sponder, *Laws and Principles of Motion Study*. Special publication of the Society of Industrial Engineers. (Now Society for the Advancement of Management.)

[2] Frank B. and Lillian M. Gilbreth, *Fatigue Study*, Sturgis and Walton Company, New York, 1918.

to some of their pioneering work in motion study. The most common causes of fatigue are poor lighting, excessive noise, poor air conditioning, monotony, and improper posture.[1] Each of these deserves attention, not only in the interests of employee well-being, but also as obstacles to efficient productive effort on the part of human beings. Fatigue elimination is a primary function of motion study as applied to the worker. To minimize if not eliminate fatigue causes is a first responsibility of every motion-study analyst.

ANATOMICAL MEMBERS OF BODY
INVOLVED IN MICROMOTION TECHNIQUE

1st, 2nd, 3rd, & 4th Fingers

Left hand	Thumb Palm Wrist Lower arm Upper arm	Right hand
Left leg	Thigh Knee Calf Ankle Heel Toes	Right leg

TRUNK

Forward bend	Backward bend
Left sideways	Right sideways
Left twist	Right twist

HEAD

Hump	Shrug
Forward bend	Backward bend
Turn to left	Turn to right

Mouth

EYES

See left — See center — See right

MISCELLANEOUS FUNCTIONS PERFORMED

Sit	Stand
Stoop	Kneel
Smell	Taste
Hear	Blow

Count

FIGURE 161

[1] See Chap. XVI and Chap. XI.

PRINCIPLES OF MOTION STUDY APPLIED TO THE WORKER

The basic laws of motion economy as applied to the worker and which affect his bodily movements are again a result of research work carried on by the Gilbreths.[1] It must not be assumed that motion study applies solely to hand motions because much work entails use of all anatomical members of the body and still other motions are performed entirely by parts of the body other than the hands. For example, when we walk we use our legs. (During the First World War, the Gilbreths devoted research to study of parts of the body used in doing jobs in order to place crippled workers. Operations were analyzed in order to determine what parts of the body were required to perform them and workers having the anatomical members needed were assigned to these jobs. Thus a person with one leg would be placed on a job which included only hand motions.)

Figure 161 names some parts of the body, some types of movement, and miscellaneous bodily functions. These are useful guides in analyzing motion picture reproductions of jobs — known as the *micro-motion technique.* Improved methods result from applying the laws[2] of motion economy which follow:

1. Both hands should preferably begin the motions simultaneously. This ensures rhythm and eliminates loss of time due to overlapping motions.
2. Both hands should preferably complete motions at the same instant. Here again rhythm is an important factor.
3. Both hands should not be idle during the same instant except during rest periods. The idleness is either avoidable or unavoidable. If avoidable, it should be eliminated. If unavoidable, a mechanical means of doing the job should be developed to absorb the lost time.
4. Motion of arms should be in opposite and symmetrical directions and should be made simultaneously. When both arms are moving in the same direction, the worker is off balance. This results in fatigue and loss of muscle control. In addition, it is unnatural from a physical standpoint.
5. The performance in proper sequence of the fewest fundamental motions is the best way of doing work, *in reality the basis of motion study.*
6. Motions should be made within the limits of the area of the normal work place. The normal work place is the most convenient zone within which hand, wrist, and arm motions may be made with a normal expenditure of energy. There is a normal area for both hands. This is shown in Fig. 162. (Supply units should be placed preferably in this area at an elevation of 30 degrees on a horizontal plane. Tools of produc-

[1] Frank B. and Lillian M. Gilbreth; Chart of Therbligs reproduced by courtesy of Lillian M. Gilbreth.

[2] Courtesy of Lillian M. Gilbreth.

tion should be similarly placed. Every effort should be made to eliminate bending over, moving around, and reaching long distances.) [1]
Tools and materials should be prepositioned as much as possible to reduce the need for searching and selecting. This can be handled by using hoppers for feeding parts, devices to suspend screw drivers in the air on springs, gravity containers, and so on.

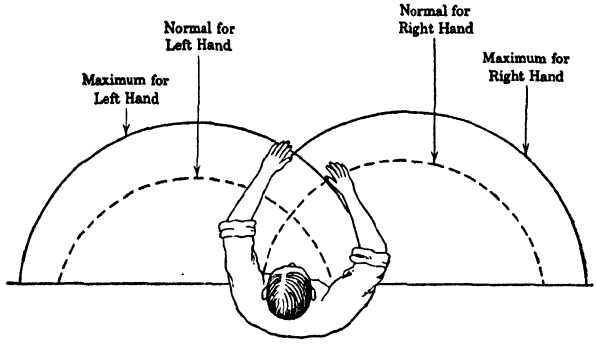


FIGURE 162. NORMAL WORK AREAS FOR LEFT AND RIGHT HANDS

7. Motions should be confined to the lowest possible classification in order to reduce fatigue. This means that as few parts of the body as possible should be used to do work and the use of larger parts reduced to smaller ones. For example, in place of using the upper arm and lower arm, an effort should be made to use wrist and finger movements.
8. Hands should be relieved of all work that can be done by feet or other parts of the body. Foot pedals should be incorporated wherever possible to operate mechanical units that are part of the job setup, and as devices for unloading jigs.
9. As the paths of fast motion are different from those of slower motions, the fast motions should be taught first.
   This means that the worker should be started in on the method he will use when he becomes expert and be taught to do it correctly even though he does the fast motions slowly at first.
10. The sequences of motions should be arranged to build rhythm and automaticity into operations. When automaticity is attained, the worker is relieved of necessary conscious mental direction.

In addition to the foregoing laws, the following Pendulum Law was developed by Dr. Lillian M. Gilbreth in cooperation with a motion-study group working at Montclair, New Jersey.

Each anatomical member has a natural path of motion fixed by its length and center of gravity. The motion requiring the least effort and causing the least fatigue will be for any member that which is performed in a period

[1] See *Motion Study and Plant Layout*, Chap. XI.

comparable with a physical pendulum. There is superfluous fatigue if a wrong path is used. The distribution of time along the wrong path does not correspond with a simple harmonic motion.

THE TECHNIQUES OF MOTION STUDY

Motion-study laws are put into practice by application of techniques. These include:

1. Understanding and using therbligs.
2. Construction and analysis of motion-cycle charts.
3. Obtaining a knowledge of special equipment to implement the construction of motion-cycle charts by therbligs and to carry out recommended procedures which result from study of these charts.

Therbligs

Frank and Lillian Gilbreth, who pioneered in the motion-study practices of modern industry, classified bodily movements into *18 elements of motion.* Each of these is represented by a therblig symbol which is carefully defined. The word "therblig" comes from a reverse spelling of the name *Gilbreth.* Each therblig has a color, abbreviation, and symbol. These are shown in Fig. 163. Definitions of the therbligs follow:

Therblig	*Description*
1. Search	It is recommended that the three therbligs, "Search" — "Find" — "Select" be combined into one therblig in that the limits of each are not clearly discernible and defined. Seldom do they occur in such relation that a separation is possible. Another difficulty with this classification is that they are not distinctly hand motions. Inasmuch as the third, SELECT incorporates the first two, it is recommended to cover this classification.
2. Find	
3. Select	
4. Grasp	The motion beginning at the time the hand or any part thereof comes in contact with the object being grasped, until the object starts to move in the performance of the following therblig.
5. Transport loaded	The motion executed in moving an object from one location to another.
6. Position	The motion that is used in laying an object in a place to which it has a definite relation so that it can be used in that location. In all cases it is an accurately controlled and constrained motion, differing in this respect from and following "transport loaded." It usually precedes "use" and occurs in the "get ready" part of the cycle.
7. Assemble	Starts the instant the hand begins to move an object or part of an object into or onto or together with another cooperating object of which it is an integral part, and ends when the hand comes to rest or goes on to another therblig.
8. Use	Begins the instant the hand applies itself in moving a device in such a way that the device is functioning for the intended purpose. It ends when this motion of application comes to rest or is changed to some other motion.

Therblig	*Description*
9. Disassemble	Starts the instant the hand begins to separate an object or part of an object from another cooperating object of which it is an integral part, and ends when the hand comes to rest or changes to some other motion after the separation.

Symbol		Name of Symbol	Explanation	Color	Color Symbol	Dixon Pencil Number	Eagle Pencil Number
	Sh	Search	Eye turned as if searching	Black		331	747
	F	Find	Eye straight as if fixed on object	Gray		399	747½
	St	Select	Reaching for object	Gray, light		399	734½
	G	Grasp	Hand open for grasping object	Lake red		369	745
	TL	Transport loaded	A hand with something in it	Green		375	738
9	P	Position	Object being placed in hand	Blue		376	741
#	A.	Assemble	Several things put together	Violet, beam		377	742
U	U.	Use	Word "Use"	Purple		396	742½
#	D.A.	Disassemble	One part of assembly removed	Violet, light		377	742
	I	Inspect	Magnifying lens	Burnt ochre		398	745½
	PP	Pre-position	A nine pin	Sky-blue		394	740½
	R.L.	Release load	Dropping content from hand	Carmine red		370	744
	TE	Transport empty	Empty hand	Olive green		391	739½
	R	Rest for overcoming fatigue	Man seated	Orange		372	737
	UD	Unavoidable delay	Man bumping nose	Yellow ochre		373	736
	AD	Avoidable delay	Man lying down on job	Lemon yellow		374	735
	Pn	Plan	Man thinking	Brown		378	746
	H	Hold		Gold ochre		388	736½

FIGURE 163. THERBLIGS

Courtesy L. M. Gilbreth

10. Inspect	Time taken in comparing an object with a predetermined standard.
11. Preposition for next cycle	This therblig is the same as "position," having of course the same limits of beginning and ending, with the added fact that the object prepositioned is placed in a predetermined location in such a manner that it may be grasped in the position in which it is desired to hold it when it is needed, making positioning unnecessary after it has been grasped.
12. Release load	The motion that takes place from the instant any part of the hand leaves the object grasped until the instant all parts of the hand have left it. The time of this motion is so short we arbitrarily assign one "wink."
13. Transport empty	This motion starts the instant a hand begins to reach for or go to an object. It ends the instant a part of the hand comes in contact with the object. It may involve another object or other objects being held in hand while moving to the next object.
14. Rest for overcoming fatigue	Rest for overcoming fatigue is "delay" allowed to give the worker relaxation to recover from the fatigue of his work.
15. Unavoidable delay	A delay is unavoidable when it occurs as a part of the process or brought about by an unpremeditated failure occurring in the system, influencing the work.
16. Avoidable delay	Absence of useful motion within the control of an operator.
17. Plan	A delay in motion in order to derive a method, distinguished from necessary "planning" done before the operation is performed. This therblig may occur in any place in the sequence and is usually "paired" with the "inspect" therblig of "make ready."
18. Hold	This therblig has been added recently by some workers in motion study. It is defined as the retaining of the piece after a grasp has taken place that is not followed by a change in position or transport of the object.

The therblig "use" is the most productive and therefore the most important of all. It is the most difficult to learn in mastering an operation or trade. Other therbligs are desirable and necessary only so far as they facilitate, prepare for, or assist the therblig "use." "Use" is the highest paid therblig because it requires the most skill. The more therbligs of "make ready" and "put away" are performed by less skilled and consequently lower paid workers, the better for workers and industry alike. Each will be employed at the task for which he is most capable individually and the product will be made at a lower cost.

Classes of Motion

Application and study of the 18 fundamental elements of motion are facilitated when they are reclassified and grouped according to the type of motion which they entail. These are mental motions, physical motions, and classes of delay. The mental motions are:

Search	Inspect
Selection	Preposition
Find	Plan
Position	

The physical motions are:

Grasp	Transport empty
Transport loaded	Release load
Assemble	Hold
Disassemble	Use

The three classes of delay are:

Rest for overcoming fatigue
Avoidable delay
Unavoidable delay

Motions may be considered also as belonging in the classes of [1] major motions, minor motions, assisting motions, single motions, compound motions, and synchronized motions.

1. *Major motions* are those that consume the most time of the task being performed or operation cycle. For example, if one therblig occupies a third of the time for doing the job, the first step in the study of this job is to devise the means to reduce the time for this therblig.
2. *Minor motions* are those which require the smallest parts of the total time for doing a job. These should be analyzed last. They must not be overlooked, however, because analysis of them often contributes considerable reduction in total time.
3. *Assisting motions* are those performed by an anatomical member of the body in helping to assist another motion. The eye, for example, assists completion of the "grasping" therblig.
4. *Single motions* are those which are performed individually by either hand. The therbligs of "selection," "grasp," and "release load" are usually single motions in that they are most efficiently performed when done one at a time.
5. *Compound motions* are when more than one motion at a time is performed by the same anatomical member. For example, flopping over a jig and loosening a nut at the same time would constitute a compound motion. Both are performed together in the same time as one.
6. *Synchronized motions* are major motions performed simultaneously by more than one part of the body. Holding something with the hand and stepping on a pedal with the foot constitute synchronized motions.

Motion-cycle Charts

The motion-cycle chart makes possible the recording of a more detailed analysis of manufacturing operations than is possible with the process-chart technique described in the chapter on Motion Study and Plant Layout. Motion-cycle charts fall into two classifications: (1) the simple motion chart and (2) the micromotion chart.

[1] Sponder, Stephen B., Laws and Principles of Motion Study. Special publication of the Society of Industrial Engineers. (Now Society for the Advancement of Management.)

MICRO MOTION TRANSFER SHEET

Film No. Telechron Motor Asm.
Date Filmed 1/2
By ASK

Operation Old Method
Operator Babcock
Department

Sheet No. 2
Date Made 1/4
By W. C. T.

Clock Reading No. Frames	Subtracted Time	Therblig Symbol	DESCRIPTION LEFT HAND	Clock Reading No. Frames	Subtracted Time	Therblig Symbol	DESCRIPTION RIGHT HAND	Clock Reading No. Frames	Subtracted Time	NOTES
844	6	RE	Reach for name plate asm.	844	6	AR	At rest			
856	12	G	Take hold of asm.	865	21	RE	Reach for field coils			
862	6	MP	Move part to asm. pos. & position	888	23	G	Take hold of field coils			
906	44	H	Hold, assisting with thumb	891	3	MP	Move part to asm. & position			
2362	1456	MP	Move part (asm.) to bench	903	12	#	Place in asm.			
392	390	RL	Drop part (asm.)	966	63	RL	Release field coils			
396	4	RE	Move hand to start next asm.	969	3	RE	Reach for armature			
				978	9	G	Take hold of armature			
				982	4	MP	Move arm to asm.			
				1008	26	#	Place in asm.			
				61	53	RL	Release arm			
				64	3	RE	Reach for brush			
				78	14	G	Take hold of brush			
				1081	3	MP	Move brush to asm. & prepos.			
				100	19	#	Place brush in asm.			
				153	53	RL	Release brush			
				156	3	RE	Reach for brush			
				168	12	G	Take hold of brush			
				171	3	MP	Move brush to asm.			
				200	29	#	Place in asm.			
				218	18	RL	Release brush			
				222	4	RE	Reach for back plate			
				250	28	G	Take hold of back plate			
				272	22	MP	Move back plate to asm.			

FIGURE 164. THIS MICROMOTION TRANSFER SHEET IS TYPICAL OF MOTION-CYCLE ANALYSIS SHEETS USED TO RECORD DATA OBSERVED IN ANALYSIS OF MOTIONS USED IN PERFORMING WORK

The *simple motion-cycle chart* is one which is made purely by visual observation and deals with the movements of the body, hands, and arms in operations such as bench assembly work, handling of materials, and working on machines. Each movement involved is termed an "element" and is recorded by therblig symbols with a brief explanation placed beside it. Beside each symbol also is placed a time factor for each element under observation. Ordinarily, stop-watch observations are satisfactory for this purpose. Figure 164 shows a form for recording these data.

The *micromotion chart* is one which is developed from a motion-picture analysis of work or operations being done. By taking motion pictures at a constant speed, and including a so-called microchronometer in the background of the picture (see Fig. 166), it is possible to measure the time lapses during bodily movements, and in particular, hand and finger movements which are too quick for time measurement by ordinary observation. These charts are used very effectively where rapid and skilled motion is used.

The technique of this procedure is as follows:

1. Make a motion picture of the entire cycle of the manufacturing operation to be studied (see Fig. 165).
2. Project the developed picture on a screen and analyze the entire cycle, frame by frame, as shown in Fig. 165.
3. Decide carefully where each therblig (motion) begins and ends, for example, in an assembly operation, when the hands first reach for the parts, determine when the fingers stop *transporting empty* (⌣) and begin *grasping* (∩).
4. Record each successive detailed bodily movement by a symbol and write beside each symbol a brief description of what it means. This can be done most conveniently by use of a *motion-cycle analysis sheet* as shown in Fig. 164.
5. Make clock (microchronometer) readings for the beginning and end of each of the bodily movements as defined in step No. 4. Record this information also on the motion-cycle analysis sheet. The microchronometer measures time in 0.002 minute (approximately $\frac{1}{33}$ of a second), each of which is called a "wink."

The information now recorded on the motion-cycle analysis sheet (Fig. 164) is the *data* necessary to construct a *simultaneous motion-cycle chart* which is popularly called a "simo-chart" (Fig. 165).

When constructed this chart portrays the entire work cycle in the colors which represent the therbligs. It is customary to use cross-section paper to construct simo-charts. Paper which has 10 squares to the inch vertically and horizontally allows the use of 1 square to represent each $\frac{1}{2000}$ minute or wink. A column of any width desired

Courtesy Northeastern University Industrial Engineering Department

FIGURE 165. MOTION STUDY LABORATORY

Students of motion economy are shown taking motion pictures of circular work bench operation (upper right), constructing a so-called simo-chart (lower right), splicing film (center), and projecting operation already photographed (lower left). Attention is called to the completed simo-chart on the walls of the upper left corner.

(usually 5 to 10 squares) running the length of the paper is marked off vertically to represent lapsed therblig times — one vertical square, one wink; each area so marked has a therblig symbol placed beside it. When the simo-chart is completed the colors are studied carefully in the light of principles of motion economy as applied to the worker. This is done with a view to eliminating or shortening those parts of the vertical color bars on the chart which represent undesirable therbligs or waste motions. The following should be looked for in making a study of a simo-chart:

1. Possibility of combining the last element of one operation with the first element or therblig of the next one — particularly where duplications are found.
2. The number of therbligs required to do a job should be counted. The sequence of the fewest therbligs is nearly always the best way to perform work.
3. An effort should be made to understand the reason for each element of time recorded for doing the job. Hesitations should be analyzed and studied, causes accounted for, and, if possible, eliminated. Lateness of one part of the anatomy as compared with others should be recorded wherever delay occurs. The advisability should be considered of providing some optional work that will permit utilizing the time of delay if desired, or making a study of the intervals where duplication is found.

Motion study analysis will frequently result in radical departure from old methods and often develop entirely new ones. The new motions to be performed should be in keeping with best motion-study practice. Only when this is done can standard tools, standard methods, and standard conditions be developed. In order to develop new methods, trial motion studies and trial time studies may have to be taken. During this time details of work manipulation may be perfected and tested by comparing times. When no further improvements seem to be possible, final records of time may be recorded. It should be borne in mind that the one best method found is usually the result of collective opinions and ideas of several different people, the ideas of any one of which would not suffice alone. Figure 167 shows a revised method for performing the operations shown in Fig. 166.

MOTION–STUDY EQUIPMENT

A view of a motion-study laboratory is shown in Fig. 165. This particular laboratory was built after study of existing laboratories in industry and in educational institutions conducting work in this field.

The satisfactory conduct of a motion-study program is aided greatly when those responsible for it have access to a well-equipped laboratory.

Not only is it difficult to carry out experiments in the midst of regular work in the shop, but the experimentation often required can be done to best advantage in a laboratory. The cost for space and equipment devoted to this purpose is a sound investment for most industries. Following is a list of necessary equipment.

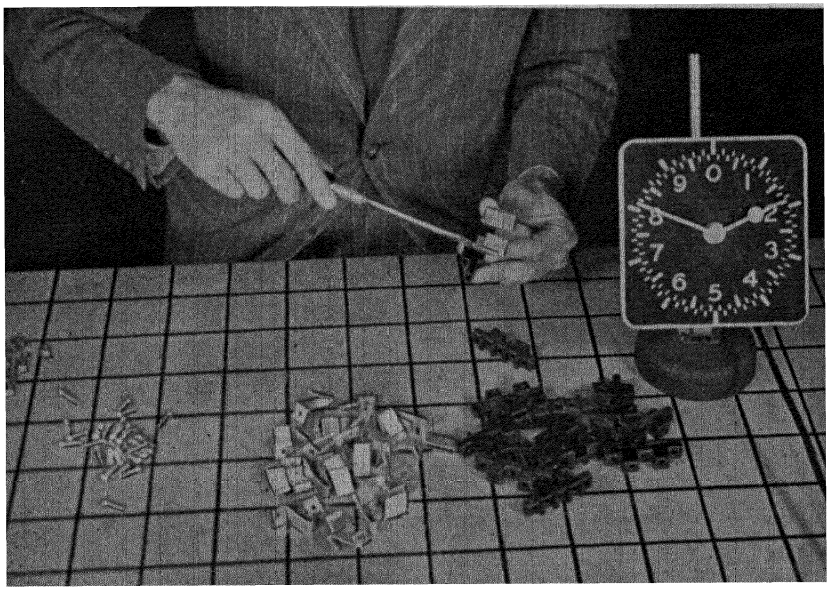


FIGURE 166. ILLUSTRATION OF MICRO-CHRONOMETER OR "WINK" CLOCK USED TO MEASURE TIME LAPSES IN MOTION ECONOMY IN INTERVALS OF TWO-THOUSANDTHS MINUTE

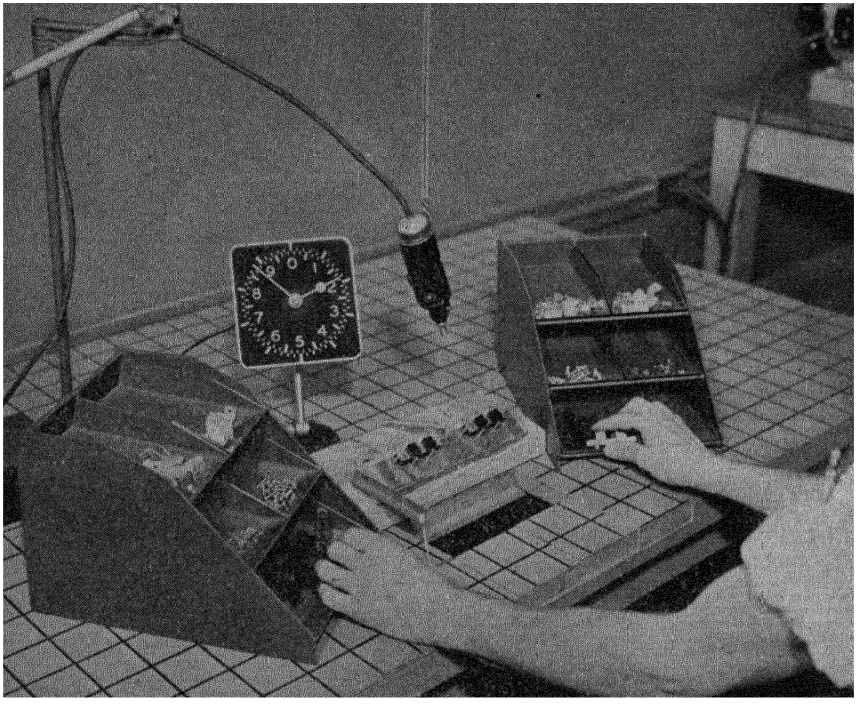
GENERAL MOTION-STUDY EQUIPMENT

1. Miscellaneous wood- and metal-working tools to build special equipment, jigs, and fixtures and to make special bench setups
2. Circular workbench (Fig. 165)
3. Motion-study measuring table (Fig. No. 167)
4. Lathe with set of tools
5. Drill press (Fig. No. 165)
6. Work tables (masonite top, 39 inches high)
7. Workbenches and tool cabinets (Fig. No. 165)

MICROMOTION EQUIPMENT

1. Motion-picture cameras (F1.9 lens recommended)
2. A camera table on wheels with elevator top to facilitate moving about in laboratory in order to take motion pictures at any place in the laboratory where a job study setup is located.

3. Reflectors with floodlight bulbs to provide proper light intensity to make good pictures.
4. Exposure meter (photometer) to adjust the lighting in relation to speed emulsion of the film being used.
5. Film splicer set.
6. A wide-angle lens to give width and detail at the same time (15 millimeter)
7. Telephoto lens.
8. Special film for making the motion picture. 16 millimeter is recommended for use in taking pictures for motion-study analysis because it is better adapted than 8-millimeter film for work with large numbers of people; moreover, it is easier to edit and handle. Supersensitive film is also recommended, and its fine-grain emulsion and greater speed gives



Courtesy Northeastern University Industrial Engineering Department

FIGURE 167. REVISED METHOD FOR ASSEMBLING CONTRACTOR ASSEMBLY

This photograph shows the new job technique resulting from motion study analyses of operation shown in Fig. 166. Note the arrangement of hoppers to facilitate the use of both hands, suspended electric screw driver, and foot-operated lever on fixture which tips completed units out of fixture down into the drop delivery chute. The table used is a measuring table with top lined in 2″ squares.

sharper pictures over a wider area of lighting conditions. Agfa Hypan film has these qualities also.

9. A microchronometer (with interchangeable dials and case) to record time in connection with the timing involved in the operation being studied (see Fig. 166).

AUXILIARY MOTION–STUDY EQUIPMENT

1. Assembly racks and bins.
2. Adjustable posture chairs.
3. Therblig drawing tables (These are especially designed tables with racks to hold the therblig pencils used in making simo-charts.)
4. Film cabinet file.

MOTION STUDY AND COST CONTROL

Motion study is not an end in itself. It is a means to increased output, greater efficiency in plant organization, less human fatigue, and lower costs of production. These objectives are accomplished by the use of the tools already discussed. A knowledge of these tools is not sufficient, however, if motion-study practices are to be most serviceable in the development of an efficient industrial organization. They must be combined with an appreciation of (1) how motion study affects various items of the manufacturing statement and (2) how they tie in with the control of overhead expenses. Motion study and cost knowledge go hand in hand in these connections:

1. The making of estimates for bids or special orders. Not infrequently, companies receive requests to design new products or to modify existing ones within given cost limits. If the products in question are to be made in any quantity, the motion-study analyst can work out the most effective way for making them. Since these jobs are usually to be done quickly, the application of motion-study principles in the light of what costs are focuses attention on the elimination of the costly steps or elements in the manufacturing processes. In some instances, entire new methods result from these analyses, as well as new equipment and new training procedures.

2. Anticipating results from application of motion economy. Plant managers are very cost conscious. They want to know how motion study can assist them in making economies and lowering costs. (Many motion-study men often fail in their attempts to sell management on the value of motion economy by talking tools and techniques rather than savings in manufacturing expense.) The manager can obtain a

Through motion study jobs are broken down into their component parts, studied, and correct methods developed for performing them. This usually requires retraining the employees, and the job information obtained through motion study provides the necessary data. When a micromotion analysis has been made of any operation or process, it is possible to use the motion picture to show employees "before and after" pictures of their jobs. This drives home the things that are done wrong. The workers see how they perform operations as compared to what sound motion-study practice requires.

Motion study is useful also in helping the job instructor to obtain information needed to decide upon the proper sequence for teaching each step in a job to a beginner.

Progressive manufacturers are recognizing that motion study is not only useful in providing training information, but also that employees who are taught the principles of motion economy become "motion minded," and frequently make improvements in their own work and that of fellow employees. These increase output, lower costs, and lessen fatigue. In order that every employee may appreciate the importance of correct work methods, it is now considered a "must" of progressive training to include as part of the induction and training program for new workers brief instruction in motion study. Many of these same companies have also adopted policies of holding classes in motion economy periodically for the regular working force.

Motion Study and Safety

Another valuable aspect of motion-study training for employees engaged in production work is that persons who are motion minded are usually safety conscious. Unsafe acts on the part of individuals constitute by far the largest source of accidents which result in lost production time. Eighty per cent of accidents in industry may be attributed to unsafe acts of individuals, while the other 20 per cent may be attributed to mechanical defects in machinery. Unsafe practices include:

1. Reaching over and under moving equipment and objects.
2. Reaching beyond fields of vision.
3. Motions made in off-balance positions.
4. Motions made too rapid for conditions.
5. Lifting or handling objects when posture is incorrect.
6. Motions made in crowded work places.

All of these motions are regarded as undesirable, and sound motion-study practice teaches their elimination. The incorporation of motion study as a part of a training program, therefore, will contribute toward the achievement of the type of safe working practices which are the objective of every worth-while safety program.

good picture of the value of a motion-economy program by using a manufacturing statement which shows details of expense items. These steps may be followed:

a) Cost items on the manufacturing statement which are most subject to modification through motion-study work (direct labor, material-handling costs, overhead costs for space occupied by work areas) may be segregated.

b) The possible savings to be expected from application of motion economy to each of these may be estimated.

c) A revised estimated manufacturing statement may then be constructed to show comparisons of costs as they are at present, and as they may be expected to appear following the application of motion-study principles. In this connection, savings in overhead expenses must not be overlooked. For example, when process-chart analyses reduce floor area required for manufacturing or lessen the number of machines to be used, there are savings in overhead costs such as building expense, taxes, insurance, and depreciation. In order to calculate these and estimate possible savings in them, the motion-study analyst needs to understand cost finding or the distribution of overhead expense.

3. Understanding limitations of motion study. Motion study in practice has some specific limitations. Outstanding are:

a) All industries do not lend themselves readily to cost reductions through motion-study work. Some manufacturing plants have a high labor cost as compared with others whose costs are primarily overhead expenses. A manager who needs to reduce his expenses of operation and whose labor costs do not exceed 10 per cent of the total cost of making his product cannot expect to achieve any sizable over-all economy through motion study as applied to labor economy.

b) Within any given plant not all operations and processes permit spending time on them profitably. Most tasks which are performed only occasionally do not warrant expenditure of time or money in motion study.

c) The cost of obtaining savings in some instances exceeds possible amounts to be saved. Every manager or supervisor responsible for motion-study work needs to decide how much time can be spent profitably in making particular studies and whether or not it is likely that expensive jigs and fixtures can be paid for in savings; and always it must be decided whether it is wise to use process charts or the more expensive time-consuming micromotion pictures. (In general motion pictures of operations are taken to teach employees the importance of motion economy by showing "before and after" pictures.)

MOTION STUDY AND TRAINING

Motion study has dual relationship with training. It is at the same time a source of information for training and a part of progressive employee-training programs.

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CHAPTER XIX

TIME STUDY

Motion and time study in reality go hand in hand. Some firms use the word "motion study" to include both the analysis of operations and rate-setting. Others use "time study" to signify the same thing. Motion study, however, frequently disregards time elements — focusing attention on methods of simplification and improvement. Subsequently, time economies which result from the simplification of operations are recognized and accounted for specifically, but not in the same manner as taking observations to calculate time standards.

Time study is commonly regarded in United States industry as synonymous with rate-setting. Industrial operations are timed and systemized, and standard times set for their performance. These standard times are then used as a basis for pricing the work. The process is carried on in an essentially mechanical fashion because most time-study engineers are trained in mechanical sciences. They are concerned almost solely with output and devote attention to the techniques of doing the work that will provide an expected volume at a price which management can afford to pay, or one which seems reasonable in terms of the value of the product.

Time study is used in a much broader sense by industrial psychologists. They recognize that efficiency of human beings in doing work is closely tied up with the biological functioning of the human body. Industrial psychologists recognize the mechanical approach as important to improve work efficiency but attempt to supplement this with their background of biological training. Attention is focused on discovery of the proper muscular processes involved in jobs so as to involve a minimum of fatigue on the part of the operator. Time study has given the industrial psychologist a means of measuring the value of work. Similarly, the industrial psychologist uses time study — stopwatch measurement — to measure performance to analyze the nature and degree of fatigue caused by an industrial task.

Workers appreciate better than anyone that their own efficiency in doing tasks changes considerably from morning until night as well as from the beginning to the end of the week; there are periods of warming up, high-level performance, and slowing down. The performance of

any given individual may vary from hour to hour, depending upon the condition of the human body, room temperatures, mental attitudes, and so forth. This knowledge, combined with distrust of rate-setting as carried on in some organizations, makes many industrial workers uncharitable toward time-study work as a necessary and useful tool of management.

The work of the industrial psychologist has served in many instances to justify the suspicions of labor regarding rate-setting. The psychologist has found that some rates are unreasonable and result in fatigue or injury to the health of the worker if he attempts to work at the pace set by the rate setter. In future years, industrial psychologists and time-study engineers should combine efforts to make a better science of time study. Industrial psychologists whose subject is the human mind and its functioning on the job will understand how to deal better with many of the problems of human beings in relation to their work than the engineer whose subject is mechanics. The latter will continue to be indispensable in making improvements in methods employed to do the work.

Time Study and Labor Relations

Outstanding among the reasons why time study has been a source of irritation among workers in industry are (1) an erroneous notion that time study and resulting systems of wage payment are the whole system of scientific management; (2) foremen have not understood the procedures used in arriving at rates of pay; and (3) unions have not been encouraged by management to cooperate in setting rates and very often union representatives have failed to comprehend time-study methods and objectives.

1. Frederick W. Taylor, the father of scientific management, commented as early as 1911 on the tendency of top management to confuse a "pay system" with management itself. Mr. Taylor wrote: [1]

> Under the ordinary type of management the necessity for offering the workman a special inducement has come to be so generally recognized that a large proportion of those most interested in the subject look upon the adoption of some one of the modern schemes for paying men (such as piece work, the premium plan, or the bonus plan, for instance) as practically th whole system of management. Under scientific management, however, the particular pay system which is adopted is merely one of the subordinate elements.

Following the pioneering work of Frederick Taylor and Frank B. and Lillian M. Gilbreth in the early part of the twentieth century, there

[1] Frederick Winslow Taylor, *The Principles of Scientific Management*, Harper & Brothers, New York, 1916, p. 34.

was a low-water mark period in the development of time study as a useful tool of rate-setting. This occurred from approximately 1916 to 1925. Many persons who had no particular training for doing time study entered the field and posed as experts. Their activities served only to antagonize workers whose rates of pay they set. The feeling still prevails in many quarters and can be overcome only by demonstrations of competence and fairness. Many labor unions insist on checking time standards and prefer to have rates set by their own time-study engineers because they have a general distrust of some of the professional experts employed by industrial managers.

2. The failure to educate foremen and supervisors in the techniques of rate-setting has been a fault of top management in many organizations. The foremen need to know not only how to set rates of pay for work for which they are responsible, but also how to explain and justify them to their subordinates. Perhaps even more important, foremen should be in a position to discover and remedy rates promptly that are either unfair or "too tight," as often expressed in time-study parlance. This means that it is management's responsibility to see to it that foremen are given proper training in rate-setting. It means also that foremen should be given authority to challenge rates which they believe unfair.

3. Labor, too, should have a voice in setting rates, because this can become a very effective way of eliminating strong feelings and even work stoppages that often result when rates are deemed unfair. Programs which ignore the labor viewpoint and which reserve rate-setting information exclusively for management are pretty apt to be both ineffective and costly in the long run. Union participation in rate-setting should be encouraged. This is particularly desirable if any feeling exists that there is secrecy surrounding the bases for establishing pay.

The intelligent industrial manager is one who expects to give a fair day's pay for a fair day's work. He understands that all people do not and cannot work at the same rate of speed and effectiveness all the time. He recognizes also that the slower workers often set the pace in the shop — the potentially fast workers tend to slow down, appreciating that their extra exertions are not always compensated. It has been entirely proper, therefore, that management has sponsored systems for measuring the time needed to do jobs in order to decide what to pay for them. *Whether or not the managers actually time jobs and calculate pay rates they need to know how it is done.* There can be no intelligent discussion of pay matters unless managers understand time-study procedures as well as their end results. A lack of understanding is a poor excuse for the existence of unfair standards of time.

TIME-STUDY PROCEDURES

In the timing of jobs, two separate practices are followed:

1. Jobs are timed as a complete performance and one total time taken for all jobs from start to finish. This is known as *over-all timing.*
2. Jobs are broken down into *elements* or separate operations and each element is timed. Care must be taken to see to it that elements are not too short in time duration. Generally speaking, an element of less than 0.04 minutes duration is too small for accurate timing.

In carrying out the time-study process it is customary to have the time-study engineer stand behind the worker to his right or left and observe operations as they are normally performed. In some instances, the times are taken on work now done, but it is generally preferred to make some motion study of the work before times are taken with a view to improving methods.

The observed time lapses are recorded on a sheet as shown in Fig. 168. While taking the times the time-study engineer compares the performance of the operator under observation with his own concept of proper performance. This is done to arrive at a so-called rating factor, which may be expressed as an efficiency point hour, unit hour, or percentage. This rating factor is used later to "normalize" the time-study data recorded, that is, to bring them into line with the observer's concept of proper performance.

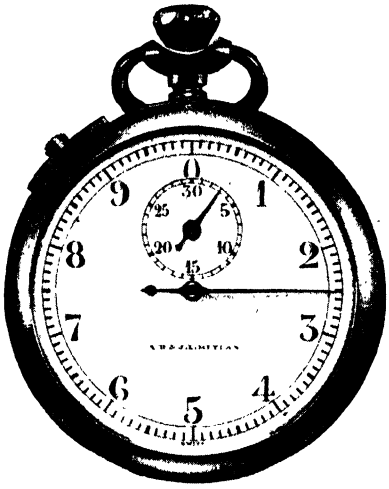
The equipment used by the time-study engineer is simple. It consists of a time-study board, a stop watch, a pencil, and a time-study sheet (Fig. 168). The hour decimal watch with the time-out feature shown in Fig. 169 is the type most commonly used, although there are several other serviceable types.

TIME-STUDY ELEMENTS

Whenever possible time studies should be made by timing each element of a job. For element timing, the snapback method is convenient to use — the watch is read when each element is completed and the hand of the watch is returned to zero. The number of pieces which are studied when element times are used will vary according to the length of the individual operations. On short operations, many pieces are studied. On long operations only a few, and on one-piece orders, one entire cycle. Since many elements are very fine and the accuracy cannot always be 100 per cent, it must be remembered that the times recorded are just those taken, and all of them are probably not fair times to use in reaching time standards. An appraisal of the effort expended by the operator should be made during the study. Effort

rating at best is very difficult. Effort varies from day to day, and even from morning until night.

The analysis of elements of different jobs will reveal several of them to be what are known as *constants* and others *variables*. The *constant* elements are those whose times remain the same from operation to operation; that is, for some motions, the path of movement and the time required to complete them does not vary in performing the same or similar work. In a drill-press operation, picking up the material to be drilled, placing it in the jig, and tightening the jig are all separate elements. The times for these particular elements will be the same from operation to operation, and are known, therefore, as *constant* times and can be selected by careful study of times recorded for many jobs. The *variable* elements are those which require different times. These may be the same as in the drilling operation on the drill press. The size of the hole and types of metal, however, will alter the time necessary to complete the actual drilling.



Courtesy A. R. and J. E. Meylan

FIGURE 169. MINUTE DECIMAL STOP WATCH WITH "TIME OUT" FEATURE

When the elements of a task are studied and timed separately, the standards computed are known as *element standards*. The times recorded for each element are called *actuals*. The efficiency of the operator is rated and element standards are then computed as follows:

Actuals × Rating Factors + Allowances = Element Standards.

It will be helpful to the student to have a picture of the steps carried out by the time-study engineer in arriving at standard times. Each step is discussed briefly in proper sequence below:

1. The work upon which times are to be taken is selected. In most instances, this is work where a number of operators are involved and work which is of a repetitive nature. It should be the type of work where labor cost is an important part of the total cost of production. Except as this is the case, there is little point in making time studies. For example, if labor is not more than 10 per cent of the total cost of manufacturing the product, a time study will save relatively little cost of manufacturing. (Even if labor costs are cut to the extent of 20 per cent of their total there is a saving of only 2 cents on each dollar of manufacturing cost.

It may turn out that attention could be focused to much better advantage on the material-handling methods, obtaining price concessions in the purchase of materials, or cutting down waste and spoilage.)

2. The jobs selected for study are broken down into elements or steps for purposes of timing. The time-study engineer may determine the elements to be used on the basis of present methods of doing the work, or he may devise an improved procedure for doing the jobs involved.
3. The time-study engineer observes the work as performed by operators selected for observation and reads his stop watch, recording times as already explained. Ten or more stop-watch readings of each operation are made. In recording the times, the time-study engineer may use one of two methods. Under the so-called snapback method, the watch is allowed to run until the operator finishes an element or cycle. The stem of the watch is then pressed to return the large hand (see Fig. 169) to zero. The time which elapsed before pressing the stem is recorded on the time-study sheet. Under the so-called continuous-reading method, the watch is allowed to run continuously and readings are made as elements are completed and at the end of each work cycle. The times recorded are then subtracted to obtain the elapsed times for doing various tasks.
4. During the process of making time studies, the time-study engineer makes notes on all of the following:
   a) Foreign elements such as unnecessary motions or operations that would not occur during the efficient performance of an operation. These include the dropping of tools, nervous movements, and disposing of spoiled materials.
   b) The nature of the parts being assembled, arrangement of the work place, and ease with which the operator performs his work.

At this stage the recording of times is completed, and the balance of the steps in the calculation of standard time may be performed by the time-study engineer at his own desk. In doing this he proceeds as follows:

5. During the time-study operation, the operator was *rated* as to his observed efficiency in performance by the time-study engineer. The rating will recognize continuity of speed, effort expended, and consistency of movements. On the basis of this information, the *rating factor* will be decided. This may be expressed in a percentage, B hour, or point hour, which indicates how good an operator is in terms of the average run of his fellow workmen. In this, he may be either below or above. For example, a 70% efficiency rating would mean that an average or representative operator would require 70% of the time taken by the particular operator observed in order to complete the task the latter is performing. A rating of 110% would mean that a representative operator would require 10% more time than the operator observed in order to do a given job. These effort ratings may be expressed in other ways, but this particular

method simplifies the adjusting of times recorded so as to make them reasonable for representative workers. In the computing of time standards, it is only fair to use representative workers rather than exceptionally fast or slow workers.

6. The information now recorded on the time-study sheet is computed into a standard time.
   a) First of all, the very high and very low times for performing each element are discarded because they are not representative of expected performance and they tend to distort the averaged results.
   b) The usable times are averaged. The average obtained is multiplied by the rating factor to determine an adjusted time in which the operator should perform the work under normal conditions. For example, if the average time of an operator for doing a task is 40 seconds, and he is found to be 70 per cent efficient, the time in which he should do the task is 0.70×40 or 28 seconds. The 28 seconds represent the adjusted time, or that required for the representative operator.
   c) Allowances are added to this adjusted time. These include allowances for fatigue, personal requirements, and preparation of materials.
   d) The adjusted time and allowances are added together to find the standard time.
7. The prevailing rates of pay for the nature of work being done are used in conjunction with the *standard* time to determine the rate of pay for the work involved.

Assuming that time studies are taken as follows for three separate elements of a job

Element 1.	30	(22)	24	25	(37)	29	30	35	(38)	31
Element 2.	31	28	27	24	25	31	30	(37)	29	32
Element 3.	28	27	(21)	30	(41)	33	(39)	31	32	28

the circled times are discarded because they are too high and low to be used in making averages.

When averaged these become:

Element 1.	29.14 minutes
Element 2.	28.55 minutes
Element 3.	29.86 minutes
Total time/cycle	87.55 minutes

Assuming a rating factor of 110 per cent

$$\therefore \text{Adjusted time} = 87.55 \times 110 = 96.31 \text{ minutes.}$$

8. The allowances to be added are recorded and calculated separately.

Name of Allowance	*Per cent of Adj. Time*	*Total Time/ Cycle*	*Additional Time Allowed*
Personal	2	96.31	= 1.92
Fatigue	5	96.31	= 4.82
Preparation	5	96.31	= 4.82
			11.56

Standard time = 96.31 + 11. 56 = 107.87 or *108*

LIMITATIONS OF TIME STUDY

It has been stated already that workers have very often challenged and even stopped working because of rates of pay based on time studies which they believed to be unfair to themselves. They have objected to "stop-watch technicians" and so-called one-horse specialists who have demonstrated that they are too often more interested in establishing rates which will please management than those which are fair to workers. Frank B. and Lillian M. Gilbreth wrote an indictment of stop-watch study in December, 1920, many of the underlying principles of which have application today. Under the title of *Time Study and Motion Study as Fundamental Factors in Planning and Control,* the Gilbreths called attention to the fact that many of the original data used by time-study engineers in establishing times are inaccurate. In this connection, they observed: "Final averages are no more accurate than the data from which they are derived." [1] The Gilbreths knew from experience that the reading of a stop watch is not in itself a wholly accurate procedure because the watch moves too quickly for wholly accurate observations. They recognized too that errors may occur in recording data and that selection of times to be used is largely a matter of judgment.

The Gilbreths advocated the application of their standard, "the one best way to do work," based on the use of more accurate methods of measurement developed by themselves. These are already known to the student as tools of micromotion which include the use of the micro-chronometer and motion pictures to record accurate time data. Unfortunately, micromotion has proved too expensive for a large portion of the work requiring simplification in present-day industry. The results do not justify the costs entailed. Most industries appreciate, however, the value of micromotion (motion-picture technique) as a means of teaching operators the correct method, and it is used widely for this purpose (see pages 370–372).

[1] Frank B. and Lillian M. Gilbreth, *Time Study and Motion Study as Fundamental Factors in Planning and Control;* paper presented before New York Section of The Taylor Society, Dec. 16, 1920; p. 3.

CHAPTER XX

JOB EVALUATION

Job evaluation is primarily a tool of personnel administration, but because it deals with jobs and what is paid for them, those classified as managers at every level of the organization should have a clear understanding of how it works. The emphasis on labor relations during the past ten years has brought about a widespread interest in and adoption of job evaluation as a basis for deciding what jobs are worth. Significantly, too, some officials of the more progressive unions look upon job evaluation today as the best means available for determining rates of pay that are fair to all concerned. In brief, both management and labor are recognizing more and more that decisions in pay matters can be made only when definite facts are known about jobs and what they require.

Application of the principles of job evaluation is not confined to the shopworker. In many organizations it includes every employee from the janitor to the president. It may include an entire organization or be confined to certain groups of employees within an organization. Moreover, job evaluation is not restricted to organizations of any particular size or type. It has usefulness in any establishment where people work for wages and salaries. Regardless of how large or small a firm may be, its supervisors and foremen can profit from knowledge of job-evaluation principles. If nothing else, it will give them a greater understanding of the jobs they are supervising and make them better supervisors as far as directing their employees is concerned.

Job evaluation in use is a valuable aid to better industrial relations. The detailed information about every job which is necessary to run an evaluation plan provides information that is useful in hiring new employees as well as making transfers and promotions; the facts uncovered about jobs may be used as the basis of instruction and desk manuals. The job specifications which are part of its basic information are also basic to employee-rating programs which are designed to judge how well employees fill the jobs they hold. In this same connection, job evaluation goes hand in hand with merit rating as a guide for supervisors in upgrading and training subordinates.[1]

[1] See A. S. Knowles, "Merit Rating of Supervisors, Foremen and Department Heads," Bulletin 4, Northeastern University, Boston, Mass., November, 1940.

Above all else, job evaluation is useful in eliminating many of the evils to which nearly all systems of wage and salary payments are subject. These are (1) payment of high wages and salaries to persons who hold jobs and positions not requiring great amounts of skill, effort, and responsibility; (2) paying beginners less money than they are entitled to receive in terms of what is required of them; (3) giving raises to persons whose performances do not justify them; (4) deciding rates of pay and increases in pay on the basis of seniority rather than ability; (5) payment of widely varied wages and salaries for the same or closely related jobs and positions; and (6) the payment of unequal wages and salaries because of race, sex, religion, and political differences.

JOB EVALUATION DEFINED

A definition of job evaluation follows:

1. The work requirements of all jobs are expressed in common factors — responsibilities, skills, effort, and working conditions.
2. These common factors are used as a measuring stick by which all jobs are appraised — that is, the relative requirements of the jobs, one in relation to the other, are decided.
3. The relative values decided upon are converted into point ratings.
4. The point ratings become the basis for deciding what amount of the total pay roll each job is entitled to command — the amount that each job justifies for anyone who can meet its minimum requirements.

The sole purpose of job evaluation is to divide up any given pay roll so that all jobs are paid for according to their relative difficulties. *It is not a system for arriving at the total amount of a firm's pay roll.* In practice, job evaluation assumes that the total pay roll (wages and salaries) which any company can afford to pay has been arrived at. If this total amount is regarded as a big pile of money in a corner, job evaluation then becomes a scheme for determining the extent to which each job holder is entitled to dip into the pile. For example, the job of a machinist and that of an electrician may appear to be quite different, but if they are of the same relative difficulty, both should be paid at the same rate.

The reader must not confuse job evaluation with employee rating. The latter has to do with the rating of employee performance in filling jobs. Job evaluation has to do with the amount of pay employees may receive for meeting the minimum requirements of jobs, expressed as base rates. Additional amounts may be added to base rates to be paid as differentials representing job performance. This differential is often determined by means of a point system of employee rating.

PRINCIPLES SAME FOR ALL JOBS

Unfortunately, two different terms have sprung up to designate application of the principles of job evaluation to jobs of hourly workers and salaried workers: (1) "job evaluation," to designate the application of the principles to jobs of shopworkers — machinists, mechanics, machine operators, and others in the manufacturing plant; and (2) "salary evaluation," to designate application of the principles to clerical or office jobs and in general all others outside the shop classification, including jobs of top executives.

Since the principles are the same for both groups, a more satisfactory designation for this tool of management is *job evaluation.*

DEVELOPMENT OF PROGRAM

There is no one job-evaluation plan that will fit all types of organization or even all the firms within one classification of industry. There is no ideal system, even though a number of management consultants in this field attempt to tell industrialists that there is. Until job evaluation progresses to a much more advanced stage of development than it has yet achieved, the very best method of procedure for any firm wishing a job-evaluation plan is to develop one for itself which is workable and in which all employees have confidence.

The best means of developing a job-evaluation plan, and to administer it after it has been developed, is to have it handled by a committee organized from management and supervision. Such committees perform most efficiently if they are appointed when the program is started. The real function of the committee is, of course, the formation of the job-evaluation plan and not the actual evaluating of the jobs. Others in the organization will be asked to do this when the plan is in operation. Every committee should be as inclusive as possible. Recommended members are representatives of the standards department, personnel department, industrial engineering department, factory and divisional superintendents and foremen, together with key workers and union representatives, if the last are available. (From time to time the committee may need to appoint advisory members of specialists in certain classes of work.) Inclusion of employee representatives on a job-evaluation committee is a good policy. When employees are asked to cooperate in the formation of a plan they understand it when it is completed, and sell it to their associates. In fact, this procedure more or less assures acceptance of the idea from its beginning. If soundly developed, job evaluation should appeal to every employee in every organization, for it is a beautifully logical system which makes an honest effort towards lessening inequalities of pay.

WORK OF COMMITTEE

Careful analysis of practices of companies which have successful job-evaluation plans in operation reveals that a job-evaluation committee will proceed most logically and save the greatest amount of time by giving careful attention to these topics:

1. The analysis of jobs:
   - Collecting facts and obtaining employee cooperation
   - The job description
     - Recording job data
   - The job specification
   - Standardization of titles
   - Preparation of bench and desk manuals
2. The selection of factors common to all jobs:
   - Definition of factors
   - Factors used
   - Relative importance of factors
3. Selection of plan to evaluate jobs:
   - Job classification
   - Factor comparison method
   - Job rating
     - Weighted point rating
4. The actual evaluation process:
   - Checking point ratings
   - Converting point ratings into wages and salaries
   - Comparative advantages of point ratings
   - The development of a job schedule
5. Formulation of policies relative to wage and salary adjustment:
   - Adapting the plan to changes in organization
   - Frequency of ratings
   - What jobs should be evaluated
   - Determination of who is to do the evaluating
   - Determination of policies regarding the use of results.

THE ANALYSIS OF JOBS

The first task of a job-evaluation committee is job analysis. This involves three steps: (1) collecting facts about jobs; (2) writing *descriptions* or detailed stories on the basis of the facts collected; and (3) preparing *specifications* which are brief definitions of job requirements. In the small- or medium-sized organization it may be possible to make a study of every job, but in larger industries the time factor makes it more desirable to study and define only the so-called key jobs. When this is done, the other jobs may be compared and related to key jobs for

purposes of evaluation. Key jobs are those which have these characteristics:

1. Cover a large portion of the population of the company.
2. Have counterparts in other companies and therefore permit cross comparisons.
3. Are stabilized as to duties and not in a state of flux.
4. Are familiar to the entire organization.
5. Are distributed over the entire range of pay of the company.

Since the job-analysis process is really the backbone of job evaluation it is worth while to review briefly the techniques involved.

COLLECTING FACTS AND OBTAINING EMPLOYEE COOPERATION

In order to collect information about jobs, the first step is to obtain the cooperation of the employees who fill them. They know best what their jobs require and are in a position to give necessary information quickly. An effective way to gain acceptance for a job-evaluation program and to obtain employee cooperation is to call employees together and explain to all just what job evaluation is. Such a meeting should be held on company time and should be handled by someone competent to answer questions concerning its benefits and general fairness. Many job-evaluation programs have broken down at the start because of misunderstandings and the customary unfavorable propaganda so apt to obstruct new plans of procedure.

There are several ways of getting information from employees after their cooperation has been gained: (1) They may be asked to prepare by themselves at their workplaces complete information about their jobs and what they require to fill them adequately. (2) They may be asked to write out this information in some area specially provided away from the regular workplace. (3) A job analyst may interview and ask employees leading questions at their workplaces and then record the data on a properly prepared form. It is possible also to have information prepared by supervisors who are familiar with the jobs under their control. Job information which will result from all of this is likely to be somewhat disorganized. In reality it may be nothing more than sheets of paper filled with a lot of disjointed information which needs to be organized and expanded to be meaningful. This is done by making job descriptions.

THE JOB DESCRIPTION

The description sets forth in story form the work which is done by the employee who is now filling the job. This is prepared to explain in detail what the job requires and is presented in an organized manner.

SAMPLE JOB DESCRIPTION

Office Boy

Under general supervision of the office manager, but with some latitude for the exercise of independent judgment, the office boy performs the following duties:

Duties	*Time, Per Cent*
1. Opens and sorts incoming mail *a.* This requires knowledge of the departmental personnel and locality of mail boxes of each. *b.* Mail must be ready for delivery by 9 : 00 A.M. each day. *c.* Must know what mail not to open and must know to what department to refer letters addressed to company. *d.* Supervises subordinate in sorting duties.	30
2. Delivers mail to executive departments *a.* 20 delivery points *b.* Mail delivered three times daily	10
3. Picks up outgoing mail *a.* This includes interdepartment and U. S. mail. *b.* Must be sure that all branch mail is properly addressed.	10
4. Sends out U. S. mail *a.* Includes over 250,000 units of mail per year at a postage cost of $10,000 — bills, notices, checks, orders, bids for contracts, etc. The office boy must know this part of his job exceptionally well and must have capacity for responsibility. *b.* Occasionally runs postage-meter machine.	20
5. Messenger duties *a.* Picks up canceled checks at banks. *b.* Makes cash and check deposits (cash deposits as large as $2000). Note: The office boy is bonded. *c.* Picks up special orders at other business establishments. *d.* The office boy must know the city and environs well.	25
6. Other duties *a.* Moving file boxes for secretaries. *b.* Training assistant (see Notes). *c.* Delivering rush notes and telegrams. *d.* Replenishing postage in postage meter. *e.* Maintaining petty cash fund for postage ($50).	5
	100
NOTES: Supervision over one subordinate Training time — three weeks	

FIGURE 170

JOB DESCRIPTION DATA SHEET

Name of Position..... Approved by.....

Occupant..... Reviewed by.....

Describe location and conditions under which work is done (noise, hazards, clothes spoilage)	
Describe contacts with fellow employees, supervisors, subordinates, public, and customers.	

Describe in Detail Tasks and Duties Performed under Headings Listed Below

Name of Duty or Task	*Description*	*When Performed*	*Per Cent of Total Time*	*Remarks*

FIGURE 171

(Completed job descriptions are useful as information for desk manuals and instructions to new employees.)

In writing job descriptions, no attempt is made to classify the types of skill and effort needed to perform the work. Sufficient information is included so that this may be done later. A sample form of a description for a salaried worker is given in Fig. 170.

Descriptions must be prepared to represent a true picture of the work as it is performed. When descriptions are written by analysts, they reflect both the worker's opinion of his work and what the analyst observes while talking with him.

From the standpoint of the company, it is probably more desirable to have the job analyst collect facts and make descriptions. Less time is required, because the analysts know what they are seeking and there is no need to prepare manuals and special forms to instruct employees as to what information is sought and how it will be used. It must not be assumed that job analysts know jobs better than the workers, but they do know the points which must be considered for evaluation purposes. One large company states that it believes the employees have been treated fairly regarding the appraisal of their work when they have been given an opportunity to discuss it. The good job analyst can combine collecting facts and making a description because one really grows out of the other. To do this, it is convenient to have a form which will help get the needed information quickly. Figure 171 shows a job description data sheet suggested for this purpose.

Recording job data. In using the job description data form, the job analyst of today has considerable advantage. Sufficient work has now been done in the field of job evaluation to permit firms that are just beginning programs to anticipate in advance the *common factors* most likely to be used in their final program for rating jobs. This means they know in advance the type of information they are seeking in regard to particular skills, responsibilities, working conditions and types of effort required. In the early stages of the development of job-evaluation programs, however, job descriptions had to be used to pick out the common factors needed to evaluate jobs. (Many companies may still need to do this in order to obtain the right set of factors for their own use.) Knowing in advance the common factors that are likely to be used, job analysts starting from scratch can ask leading questions to seek data they require. When their description data sheet is completed it can be checked by supervisors and necessary modifications made. A comparison of the point of view of the employee with that of the employer as represented by the department heads or supervisors contributes much to making fair descriptions. The completed description is sent to the wage and salary unit of the company.

JOB SPECIFICATION

Job Title: Apprentice Machinist — Class: .....

Factors	*Basis of Rating*
SKILL A. Manual 1. Dexterity	Speed and coordination for semicomplex operations done on lathes, shapers, milling machines, and band saw.
2. Versatility	Ability to use precision gauges and instruments competently so that operations may be completed without any assistance.
B. Mental 1. Ability to do detail work	Interpretation of blueprints and working knowledge of precision gauges and instruments necessary. Educational equivalent — 1 year college.
2. Resourcefulness	Very little initiative and resourcefulness required since most of work is planned by superiors.
C. Social	Cooperation with foremen and fellow workers important since their aid is often necessary for lifting stock and work into machines.
RESPONSIBILITY FOR A. Physical property 1. Material or product	Possible waste, damage, or loss is confined to low value, since most stock is small and is for precision work. ($50.00 max.)
2. Machinery and equipment	Possible waste, damage, or loss not exceeding $250.00, since most machines are available to worker yet supervision at unfamiliar machines is constant.
3. Plant and services	No possibility of damage to building and service equipment.
B. Safety of others	Slight care necessary to prevent minor injuries, as small cuts and abrasions.
C. Work of others	Responsible for own work only, as employee is lowest ranking in machine shop.
EFFORT A. Mental	Continual coordination of eyes and muscle necessary to do precision work on nonprecision machines.
B. Physical	Ordinary light physical exertion necessary in lifting, with occasional heavy lifting with assistance of others.
WORKING CONDITIONS A. Environment	General shop environment — slight dirt and grease with low clothes spoilage. Illumination, however, is very bad and there is no air conditioning, with the result that it is very cold in winter and very hot in summer.
B. Health hazards	Minor cuts and abrasions possible, with a lack of safety devices, such as goggles.

FIGURE 172

If employees are to be asked to make job descriptions by themselves, a form should be used containing necessary leading questions in order to obtain the desired information.

THE JOB SPECIFICATION

The description is the basis for the preparation of a specification. A specification rewrites description information and classifies it according to skills, responsibilities, types of effort, and working conditions. Complete specifications are really a definition of jobs written according to a standardized form. A sample specification form for hourly employees is shown in Fig. 172 and one for employees paid on a salary basis in Fig. 173. It should be noted that special headings are used in the specification. These conform to the names of the job factors and their subdivisions, and facilitate use when jobs are being evaluated. In the specification, the language of the description has been interpreted to have meaning in terms of the factors by which jobs are appraised.

Completed specifications become a part of an evaluation program. As stated already, persons evaluating jobs use the specifications as a source of information upon which to base ratings. (If need be, raters should have access to the job descriptions also.) By making specification headings conform to the names of the job factors and their subdivisions as they appear in a rating manual and rating sheet, the time involved in the mechanics of making the actual job evaluations is kept at a minimum. (Vocational guidance conducted by the personnel department should be predicated upon specifications — the abilities needed to perform work rather than descriptions of what is done.)

Care must be taken to make specifications both concise and clear. Writing them becomes a fairly routine procedure for a competent job analyst who has had some practice in this work. In the final analysis, the specification can be no better than the data as revealed through the description prepared by a job analyst, employee, or supervisor. It is the description, therefore, which must be given the most attention.

Standardization of titles. When job specifications have been prepared it is desirable to undertake a standardizing of titles. Titles of jobs in any organization should be descriptive of the work to be done. It is not uncommon to find in the same organization several titles attached to the same type of work. For example, in the hourly field there are many varieties of mechanics, and in the clerical field, a billing clerk is often called a bill clerk or junior clerk. There can be no uniform understanding of jobs for making comparisons except as these discrepancies in titles are eliminated. Standard titles facilitate also cross comparisons of jobs among departments and different companies. Organizations

JOB SPECIFICATION

Job Title: Chief Office Boy Class:.....

Factors	*Basis of Rating*
I. SKILL A. Mental 1. Resourcefulness	Aggressiveness desirable. Occasional need for formulating a method for own work, though this is purely on own initiative.
2. Analytical ability	Slight analytical ability required in mailing methods, choice of class of mail to be sent.
3. Ability to make decisions	Must make decisions as to layout of work and work of one subordinate. Must have average sense of judgment.
4. Ability to do detail work	Work is mostly detail, examples of which are sorting of mail and delivery of mail to the departments and Post Office.
B. Manual	Must do simple routine tasks and be able to run a postage meter. Uses mailing machines which do not require much manual skill.
C. Social 1. Capacity for getting along with others	Must be neat, affable, and courteous. Must get along well with associates.
2. Capacity for self-expression	Few chances for self-expression except when problems arise and opinion is requested.
II. RESPONSIBILITY A. For determining company policy	No determination of company policy, but may make changes within mailing department which affects its policy in a minor way.
B. For work of others	General supervision over office-boy assistant who works on his own initiative for the most part. Occasional need to train assistant.
C. For good will and public relations	Public relations may be hindered by mailing errors; must guard against these closely.
D. For company cash	Handles large cash deposits (up to $2000) and keeps small petty-cash fund for stamps. Actual cash expenditures either made or authorized amount to about $50 per year. (Note: the office boy is bonded.)
III. EFFORT A. Mental	Occasional mental-visual attention in sorting mail, much mental-visual attention in putting outgoing mail through postage meter.
B. Manual	On feet most of day; constant and repetitive work on sorting and mailing.
IV. WORKING CONDITIONS	Average general working conditions, but monotony of work and fatigue are caused by routine nature of position and long hours during which the position holder must be on his feet.

FIGURE 173

which are growing must be alert constantly to reclassify their titles and keep them in line with standard terminology. Periodic review of jobs on a semiannual or annual basis will make this possible.

Preparation of bench and desk manuals. Job-description data are very useful in instructing new employees in what they are to do in particular jobs. By reorganizing the information, it is relatively easy to prepare bench or desk manuals which are in reality instruction manuals and reference books for both new and old employees. A manual is a by-product of an evaluation program. One large firm has found job-description data extremely useful in the preparation of desk manuals used for instructional purposes and believes that its evaluation program is justified for this advantage alone.

THE SELECTION OF FACTORS COMMON TO ALL JOBS

The basic factors used in an evaluation program consist of the qualification requirements common to all jobs. These are necessary to permit measuring one job in terms of others and are selected from an analysis of key jobs. The so-called common factors recognize types of skill and responsibility rather than the different tasks to which they may be applied. For example, the operation of an adding machine and a telephone switchboard both require a specialized development of manual skill which is not interchangeable, but the relative degrees of manual skillfulness for each job may be compared. The common factor is manual skill and not ability to perform the particular task involved. Similarly, the relative degrees of skill required of a turret-lathe operator and a grinding-machine operator may be compared.

Definition of Factors

In selecting and defining the factors that make up the requirements of the various jobs, unnecessary duplication and confusion may be avoided by grouping them under one of three major classifications: the *skill*, the *responsibility*, the *effort* required. All of the qualifications necessary to fill any job may be placed in one of these broad major categories. To these three is usually added *working conditions*, as they influence the remuneration which the occupant of the job should receive. Analysis and definition is further simplified by selecting the most important subdivisions under the major factors. Skill, for example, may be broken down into mental, manual, dexterity, and social skills. The more specific abilities listed under General Classifications help to define them because the general classifications establish limits for each group of factors, and the nature of the other factors within a group places a further limitation upon the interpretation to be given any one.

For example, the ability to get along with others may be listed under social skill. The major classification definitely separates this factor from others, such as resourcefulness, a mental skill, which may at first appear difficult to distinguish from the social skill because both resourcefulness and social skill are needed at the same time. Grouping all the social skills together also helps to define each, because any one of them might be broadly interpreted as representative of the whole field and, in the absence of any of the others, quite correctly so. But the presence of other adjacent factors narrows the interpretation that may be given to any one factor. If *ability for self-expression* were the only social skill listed, all social considerations would have to be entered under this factor, but the presence of the other factors narrows the interpretations of ability for self-expression down to the requirement that a person be able to say what he wants to say. Of course, he should want to say the right thing at the right time, but this is taken care of by the other social skills.

This method of defining by outlining the whole range of factors and noting the related position of each item in the outline gives a clarity of definition not attained by the use of synonyms alone. In many cases, however, the outline method of definition may be supplemented to advantage by using synonyms for each item or factor. Care should be taken to avoid different terms which have essentially the same meaning. For example, it is not uncommon to find such factors as "ingenuity" and "resourcefulness" used jointly. These terms have the same essential meaning.

In attempting to define job factors it will be found helpful to examine accepted definitions used by industries having job-evaluation plans in operation. Typical of these are the following:

Skill is the ability to use instruments, tools, and equipment; the ability required to plan ahead, visualize tasks, and to master detail. It involves also capacities needed to get along with people (social skill). Handling materials and tools competently requires various kinds of dexterity and exercise of some degree of accuracy and precision. (These result from experience and training.) Planning demands resourcefulness and ingenuity, and in order to handle people effectively one must possess abilities for self-expression, poise, and judgment.

Responsibility entails the requirements of jobs in relation to proper care of materials and products, as well as plant machinery, equipment, and services. This is viewed in terms of loss or damage and production delays which might result except as proper care is exercised. Responsibility entails also the care required to avoid injury to others, and the supervision and training necessary to use the abilities of subordinates effectively.

Effort entails (1) the amount of mental concentration and attention required to fill a job, and (2) the muscular expenditure necessary to perform the work. Varying degrees of coordination of senses and muscles are needed to produce accuracy; and physical strength is needed in varying amounts to do different kinds of work.

Working conditions as defined in job evaluation are word definitions of the hazards of the workplace and possible injuries to which workmen may be exposed in doing their jobs. It includes also the relative disagreeableness (monotony, noise, and dirt) or pleasantness of surroundings in which work is to be done.

A rewording of these definitions becomes what are called "major factors" and "subfactors" of job evaluation (see Figs. 174 and 175.) The main and subheadings are those which define the range of factors to be used for the evaluation of any group of jobs. (They are also the headings and terminology used for the specifications of various jobs. Except as the main and subheadings of a job-specification form correspond to these, the specification is difficult to use when making evaluations.)

Factors Used

One company says that it does not matter what factors are used so long as they cover the positions and so long as they are carefully defined and uniformly understood. The management believes that there are so many interpretations of skill, dexterity, and such factors that standard definitions should be set up and strictly adhered to. Further, definitions should be simple, complete, and easily understood by employees and management alike.

Figure 174 shows the factors considered by firms having evaluation plans to evaluate the jobs of machine operators, skilled craftsmen, and so on.[1] Most of the factors listed vary only in definition and scope. Consequently, it is possible to regroup the job factors reported into two general classifications: (1) major and (2) subfactors. The major factors are listed in order of the importance attached to them by these seventeen firms and indicated under the column heading, "Number of times reported." Particular attention is called to the wide range of the subfactors included. Figure 175 shows the major factors and subfactors used by the companies replying to a questionnaire survey on plans used to determine salaries of executive, supervisory, and clerical jobs.[2] The factor "working conditions" is omitted by many firms because

[1] See Asa S. Knowles and F. W. Means, "A Survey of Job Evaluation to Determine Base Rates," *N.A.C.A. Bulletin*, Vol. XX, No. 7, December, 1938.

[2] See Asa S. Knowles, *Salary Evaluation*, Bulletin No. 7, Northeastern University Publications, Boston, Mass., November, 1941.

MAJOR AND SUBFACTORS USED

JOBS COMPENSATED FOR ON HOURLY BASIS

Basic Factors	*Subfactors Included*	*Times Reported*
I. RESPONSIBILITY	For equipment For materials For safety of others Supervision (given and received) Initiative — honesty Discretion — integrity Leadership — count	17
II. SKILL	Dexterity — precision Versatility — accuracy Variation — sense of time and space Sense of weight — steady nerves Accuracy of { Calculation, Measurement, Reading, Record, Selection, Weight }	14
III. MENTAL EFFORT	Talent — blueprints Ingenuity — pace Complexity of operations Management ability Memory — observation Originality — planning Analysis — adaptability Setups	14
IV. PHYSICAL EFFORT	Acuteness — strength Endurance — difficult pace	14
V. EQUIVALENT EDUCATION REQUIRED	Knowledge — judgment Ability — mental development	13
VI. WORKING CONDITIONS	Hazards — accident, health Clothes spoilage — disease Internal injury — fumes Heat { air, contact, radiation }	13
VII. EXPERIENCE REQUIRED	Time required to break in Service — age Previous experience Length training period	12

FIGURE 174

MAJOR AND SUBFACTORS USED
JOBS COMPENSATED FOR ON SALARY BASIS

Factors	*Number of Times Reported*
I. SKILL	44
Mental	42
Resourcefulness	16
Analytical ability	17
Decisions	10
Adaptability	2
Vision	2
Manual	33
Dexterity	12
Physical requirements	6
Social	31
Getting along with others	25
Self-expression	15
Managerial ability	3
Clerical supervision	1
II. RESPONSIBILITY	44
For company policy	14
For work of others	23
For good will	21
For company cash	19
Safety	2
III. EFFORT	24
Mental	17
Mental-visual demands	17
Accuracy	21
Manual	14
IV. WORKING CONDITIONS	18
Noise	9
Fatigue	9
Monotony	11
Variety of duties	3
V. OTHERS	
Education	8
Experience	6
Training time	6
Service with company	2
Dependability	2
Promotion lines	2
Initiative	5
Equipment	1
Technical ability	2
Ingenuity	2

FIGURE 175

they believe that environment and surroundings for the types of work involved are in general agreeable. This is not always the case, however; many routine positions must be performed where noise, monotony, and fatigue are prevalent. A business-machine operator, for example, may operate a machine which requires relatively little skill, responsibility, and effort, but the machine itself may be located in a noisy environment, making its operation both tiresome and monotonous. Working conditions may constitute an important part of job make-up and cannot be overlooked when evaluating many types of work.

In appraising working conditions of salaried positions, however, it is important to recognize that they are improved by modern lighting and ventilation, correct posture chairs, specially built desks, noiseless business machines, and so on. In addition, the rest periods allowed most office workers, as well as the lack of rigidity in the work schedules of supervisors and executives, relieve fatigue and monotony.

Relative Importance of Factors

In selecting factors for any evaluation program the most important ones will presumably be thought of first and, as the list is reviewed, additional ones may be added. If all the factors are given equal weight, the importance of the first ones will be diminished as additions are made to the list. In other words, the importance of each factor will be arbitrarily determined by the number of other factors included with it on the same list. The solution to this inconsistency lies not in arbitrarily limiting the number of factors that they may be listed, but in giving all the pertinent factors their relative importance, both in terms of the others and in terms of the total. For example, in terms of the other factors, it might be decided that the voice of a telephone operator is more important than any three other factors used in a salary-evaluation program, and in terms of the total that voice should be about one-quarter of the total requirements for the position. Unless there are seven other factors of equal weight it will be necessary to modify the importance of voice either in respect to the other factors or in respect to the total. While this adjustment may at first appear burdensome, its consideration will force the evaluator to give the work the careful study which is necessary for its success.

SELECTION OF PLAN TO EVALUATE JOBS

When specifications for jobs are completed they must be interpreted into wages and salaries. The systems used to translate specifications into wage and salary figures fall into one of three major divisions: (1) job classification; (2) factor comparison; and (3) job rating. In the

first method jobs are classified into groups according to the difficulty of meeting their respective requirements, and wage or salary ranges are assigned to each group. The factor-comparison system evaluates the factors directly in terms of dollars according to their relative difficulties. Job rating first measures the difficulty of job requirements in terms of points according to a definite numerical scale, and then translates the total points for each position into monetary figures.

The method to be used to evaluate jobs as adopted by a given company will depend upon the nature of the particular organization, the time available for organizing and setting up a job-evaluation program, the objectives of the project, and preferences of the persons in charge (the job-evaluation committee). It may well be a combination of features taken from all of the systems listed above.

Job Classification

The simplest form of job classification is sometimes termed "ranking." Specifications are studied by several persons and jobs are then listed in the order of their importance. The rankings are then averaged to obtain a composite of opinions of all those who made the rankings. Wage and salary figures are arbitrarily assigned in the same order. All the elements of each job are considered as part of the whole and the rank of each job is based on the over-all requirements. The ranking approach is essentially a repetition of the unsystematic manner in which wages and salaries are assigned to jobs where no evaluation plan exists. Its value lies in that it provides an over-all review of all wage and salary figures at one time, and may be used as a starting point in devising a more systematic analysis.

A more scientific plan of classification consists of placing all jobs in a list of predefined classes or grades that are arranged in order of importance. The Western Electric Manufacturing Company classifications of its salary positions are typical. They are divided into seven groups defined as follows: [1]

1. Unskilled	The positions of this group, mostly clerical in character, require accuracy and dependability, but no extended training. Office boy, record clerk, and file clerk.
2. Skilled	The positions of this group, mostly clerical in character, require in addition, training of hand or mind. The group includes such positions as stenographer, production clerk. . . . Among the nonclerical positions of this group are laboratory assistant, demonstrator. . . .

[1] *Westinghouse Manual.*

3. Interpretative	The positions of this group call for ability to classify work and apply established procedures to its accomplishment. Many of the positions are clerical, such as correspondents, but others are nonclerical, such as foremen, laboratory assistants, and layout draftsmen. In most positions of this group the work is nonsupervisory in character. In the highest positions of the group the work is supervisory and involves little or no substantial amount of work of the same kind as that done by those supervised. Illustrations are: chief clerk, office manager, foreman.
4. Creative	The positions of this group are those of creative character, such as engineer, salesman, staff supervisor, attorney, system designer, and working group leader and section supervisor within these fields of activity.
5. Executive	Positions of this group are those of department manager, local sales manager, superintendent, general foreman, and the assistant managers and superintendents of large departments. The function is that of departmental management in the broad sense.
6. Administrative	The positions of this group involve responsibilities of large magnitudes or over-all character or for mixed functional divisions such as division manager, district sales manager; of high-order functional character such as accounting director, chief or consulting engineer, director of research, treasurer, general manager of purchases and traffic, and general works manager.
7. Policy	The positions of this group are those of the senior elected policy officers of the company.

When the classes have been defined, job specifications are studied and each job is placed in the class which most nearly summarizes its requirements. Pay ranges are then established for each class. The following requirements must be balanced when defining these ranges.

1. Rates of pay which are established by forces beyond the control of the individual company must be recognized when determining the range of pay for the class in which these positions fall. These rates may be established by labor unions, by community tradition, by the competitive bidding of neighboring industries, and in some instances by government regulation.
2. The cost of living of the social class to which the occupant of the position is likely to belong.
3. The difference between the wage and salary ranges of successively higher classes should be commensurate with the increased importance of the classes.

4. The difference between the limits of the ranges themselves should indicate the added worth of an individual as he gains more experience and improves his qualifications while filling the same position. In this connection it may be noted that in some cases the upper limit for one class will be below the lower limit for the next higher class.

Factor-comparison Method

In the factor-comparison method each factor in the requirements of key jobs is evaluated in terms of monetary units, and the total wage or salary is the sum of the values of all the factors.

The process of evaluating the factors includes the following steps:

1. Each member of the evaluating committee studies the job specifications and then ranks the jobs under each of the factors, so that he has as many ranking lists as factors. The lists made by the different members are then compared and major discrepancies are ironed out.
2. The average ranking of each job under each factor is then calculated and tabulated. For example: three raters might give one job among several the following rankings under the factors skill and effort:

Skill	*Effort*
1	5
1	7
2	6

The average rank for the skill factor in this position is 1.3; for the effort factor, 6.

3. The rate of pay for each job is then divided among the factors in proportion to the importance of each factor as shown by its average rank. For example: the following table shows average rankings for the job of bookkeeper and the corresponding allotment of a $20 salary:

	Average Rank	*Remuneration*
Mental skill	9.4	$6.27
Manual skill	5.0	3.33
Effort	6.3	4.20
Responsibility	5.7	3.80
Working conditions	3.6	2.40

After this distribution is made, it must be checked to see that differences in pay for the same factor in different jobs reflect the differences in the original ranking, and that the total for all factors of each job remains the same as the existing salary.

The monetary worth of each factor for all the key jobs is used to make up a *job comparison scale.* A vertical scale is marked off in monetary units and the factors are listed horizontally so that the job may be listed in vertical columns, one for each factor, according to the value of the factor represented by the particular column. Figure 176 shows a

job-comparison scale for salaried workers. (Scales for hourly workers may be constructed in the same fashion.)

When this comparison scale has been correctly established, it is used as a basis for evaluating the wages or salaries which should be paid for other jobs. Those who do this must be familiar with the specifications of key jobs already evaluated, as well as those of the new job, so that they may judge the relative amount that should be paid for each factor, in view of the amounts that are paid for the same factor in key jobs. For example, knowing the skill needed and its rate of pay for the jobs listed in Fig. 176, the pay for the skill of an elevator operator is made commensurate with this established scale.

JOB COMPARISON SCALE

Dollars per Week	*Skill*	*Effort*	*Responsibility*	*Working Conditions*
10	Typist		Typist	•
5	File Clerk	Bookkeeper File Clerk	File Clerk Bookkeeper	Bookkeeper File Clerk
0	Bookkeeper	Typist		Typist

FIGURE 176

In a large organization, departments or sections are generally dealt with separately rather than attempting to make a single comparison scale for all the jobs in the company.

It should be noted that this method assumes that the key jobs selected as a basis for the job-comparison scale are already being paid fairly. The wages and salaries paid other jobs are brought into line with these selected key jobs. The procedure will become unwieldy unless the number of factors used is limited to about five, such as mental skill, physical skill, effort, responsibility, and working conditions.

Job Rating

Job rating is accomplished by means of assigning point values to various major factors and subfactors. This system makes full recognition of the fact that no two jobs are ever exactly alike in their requirements. Each demands a little more or less of respective skills, responsi-

bilities, effort, and working conditions. In order to decide just what each requires, each factor is broken down into so-called degrees, that is, graduations of difficulty of each major factor and subfactor are defined in word definitions. Each factor is then allotted points according to its degree of difficulty. Figure 177 shows a manual chart for jobs paid on a wage basis; Fig. 178 shows a similar chart for jobs paid on a salary basis. Suggested definitions are given for 5 degrees of 11 and 14 factors, respectively, under 4 major headings. These definitions are a result of a study of many evaluation plans in existence and are not a direct reproduction of any particular plan. *They are intended to be used merely as guides in setting up similar charts for actual use.* It is recommended that the chart form shown in Figs. 177 and 178 be used in the setting up of a job-evaluation program. This particular form gives a bird's-eye view of the core of the system; it also facilitates making actual evaluations of jobs when used with job specifications whose headings correspond to those on the manual charts.

The maximum number of points for each degree is also included. The use of a scale marked with both word definitions and point values such as those shown in Figs. 177 and 178 has these advantages: (1) variations between the degrees are more readily expressed in terms of points than with qualifying adjectives, and (2) the points become a shorthand which is also amenable to mathematical treatment. Some systems have worked out maximum point values for each factor and subfactor which are always assigned as the same set amounts in favor of any jobs which require the factor being considered. For example, if "mental skill" is termed to be worth 50 points and "responsibility for others" 30 points, any jobs requiring these factors are given the maximum point value for each. This particular use of points does not allow for the fine distinction among degrees which is possible when they are interpreted into numerical definitions. The whole range of points from "0" first degree to the maximum number for fifth degree should be used in selecting the point values which best express just how the job fits into the word definitions. (See page 409, *Actual Evaluation Process.*)

Weighted point rating. If each degree of every factor is given the same number of points, all factors will have equal importance and the influence of an individual factor will diminish as more factors are added. However, in many cases it will be apparent that some factors are more important than others, and this difference is translated into point ratings by giving more points to each degree of the more important factor. In the final analysis, the difference between the total possible points for each factor reflects the scarcity of the qualifications demanded by the factor. In Figs. 177 and 178 the points allowed by the degrees of each factor are weighted. For example, the degrees of mental effort have

more points than corresponding degrees of any other factors, indicating that jobs which require mental effort are worth more to the company than those in which some other qualifications are required.

It does not particularly matter what total amount of points is selected to be distributed among all the factors and their respective degrees, 500, 1000, 1500, and so on. The important thing is to have the range of scale and the distribution in balance. A factor worth 100 of a total of 500 would be assigned 200 and 300 respectively in point scales of 1000 and 1500. Once it is decided what total number of points will be distributed among the various major and subfactors, the technique for splitting up the points among the degree definitions of each factor is as follows:

1. Decide the total maximum amount of points to be allowed each major factor and all its subdivisions. (This will be all subfactors combined.) If the total of points to be distributed is 1500, the division might be: skill, 500; responsibility, 400; effort, 400; and working conditions, 200.
2. Split up the total amount allowed each major factor and its subdivisions according to estimated relative values of subfactors, that is, mental skill, 200; manual skill, 200; and social skill, 100.

Steps 1 and 2 can be carried out easily in the maximum point column of the chart shown in Figs. 177 and 178.

3. Assign each successive degree a proportionate progressive maximum number of points so that the fifth degree point value for each major and subfactor is the maximum allowed for the factor as in Step 1. For example, if the total value of a subfactor is 100, the maximum degree values will be:

Degrees	1	2	3	4	5
Points	20	40	60	80	100

When the maximum value for the fifth degree is 75, the distribution is:

Degrees	1	2	3	4	5
Points	15	30	45	60	75

There follows a table showing the maximum weights assigned typical job factors as applied to workers paid on an hourly basis by seven different manufacturing establishments. This demonstrates clearly the extent to which the same job factors vary in their importance as related to different jobs; it reveals also the need for agreement on uniform definitions of job factors among manufacturing firms. For example, some firms regard "previous experience" as an attribute of skill. It will be noted that firms B and C weight most heavily the factor "skill," giving no points to previous experience as do the others.

MAXIMUM WEIGHTS GIVEN TO FACTORS BY VARIOUS COMPANIES[1]

(Basis of 1000 Points)

Factor	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Average*
Responsibility	230	129	112	240	195	100	134	163
Skill	110	483	406	230	255	300	201	283
Mental effort	60	64	63	100	109	86	201	98
Physical effort	60	64	63	60	136	155	101	91
Equivalent education	140	130	156	100	123	138	113	129
Working conditions	140	130	200	150	91	121	116	135
Previous experience	260	—	—	120	91	100	134	101
Total	1000	1000	1000	1000	1000	1000	1000	1000

Some companies represented in the above table distribute 1000 points over the factors, some 500, some 800. For the purpose of comparison, all have been converted into ratings on the basis of 1000 points. Thus, some of the above point assignments seem to be in very odd amounts.

ACTUAL EVALUATION PROCESS

Jobs are rated on sheets similar to that shown in Fig. 179. To be used for an hourly worker, the written job specifications should have headings to correspond to those on the manual charts (Figs. 177 and 178). The specifications are read and checked against the degree definitions on the manual chart which applies to the job, that is, hourly or salaried. The degree is decided upon and noted on the rating sheet. Following this, the number of points to be allowed for each degree is decided upon (see Fig. 179, sample form).

Point rating is a device to facilitate the comparison of the relative importance of factors and jobs. The points are not ends in themselves, and are meaningful only when interpreted in the light of the scale and similar jobs that are rated on the same scale. There is always danger that points will be assigned without careful thought, in the same way that an indiscriminating person may lavish words of praise upon a mediocre piece of work. The value of the point ratings, like that of words, depends upon the qualifications and careful thought of the person making them.

Checking point ratings. When the point ratings for any job have been completed, the *number of points allotted to each factor should be checked from four different standpoints:*

1. The number of points allotted to one factor of a job as compared with those given to each of the other factors.

[1] Asa S. Knowles and F. W. Means, "A Survey of Job Evaluation to Determine Base Rates," *N.A.C.A. Bulletin*, Vol. XX, No. 7, December, 1938.

2. The points allotted to one factor of a job as compared with the points allotted to the same factor of other jobs.
3. The points given to each factor as compared to the total number of points given the same job.
4. The total points for each job as compared with the total points for other jobs.

JOB RATING SHEET

Job Title: *Chief Office Boy* Dept. *General*

Code No. *0–21* Division *Home Office*

FACTORS	RATING	
	Degree	*Points*
I. SKILL		
A. Mental		
1. Resourcefulness	*2*	*33*
2. Analytical ability	*2*	*58*
3. Ability to make decisions	*1*	*10*
4. Ability to do detail work	*2*	*30*
B. Manual or motor	*2*	*14*
C. Social		
1. Capacity for getting along with others	*3*	*61*
2. Capacity for self-expression	*1*	*6*
II. RESPONSIBILITY		
A. For determining company policy	*1*	*1*
B. For work of others	*2*	*42*
C. For good will and public relations	*2*	*32*
D. For company cash	*2*	*14*
III. EFFORT		
A. Mental	*2*	*55*
B. Manual	*3*	*60*
IV. WORKING CONDITIONS	*2*	*25*
TOTAL POINTS		*441*

RATED BY *T. M. L.*

REVIEWED BY *P. O. M.*

FIGURE 179

The first two of the above comparisons will be facilitated by a chart similar to the key job-comparison scale used in the factor-comparison method, except that the vertical scale is in terms of points rather than dollars.

Converting point ratings into wages and salaries. The total point ratings represent the relative worth of a job to a company in terms of the other positions that have been rated on the same scale. The next step is to translate these point ratings into wages and salaries. Graphic analysis by means of a scatter diagram is helpful at this stage. Point ratings are assigned to the horizontal scale and wage or salary figures to the vertical scale. When point ratings are plotted against the present

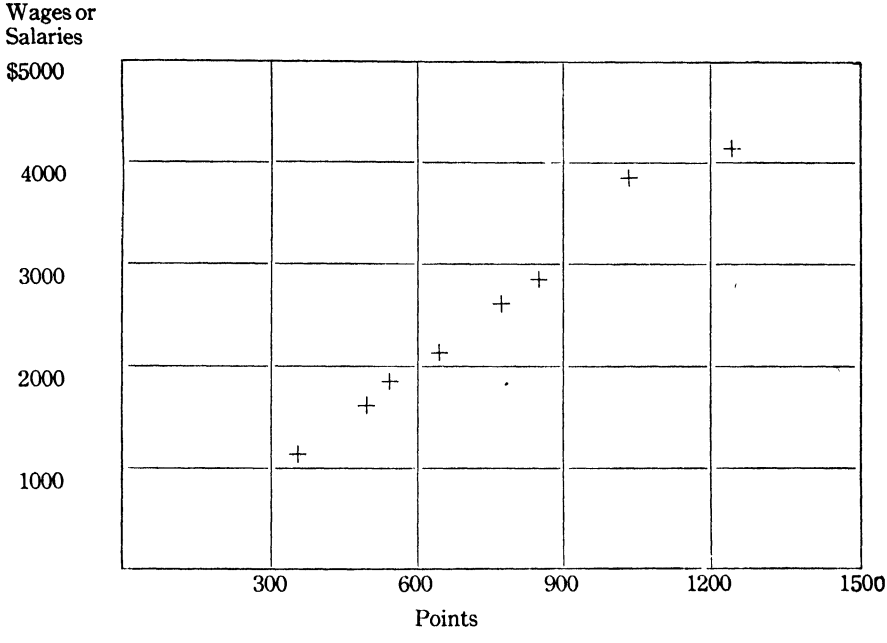


FIGURE 180. SCATTER DIAGRAM SHOWING GOOD CORRELATION BETWEEN WAGES OR SALARIES AND POINT RATINGS

wages and salaries paid for the jobs, the extent to which the present wage and salary schedule is in line with the findings of the evaluation committee will be evident. If the dots (or crosses) tend to form a line which starts with low wages or salaries for low-point ratings and ends with high wages or salaries for high-point ratings (Fig. 180) there is little need for further adjustment. When there is a low correlation between the difficulty of the job and the wages or salary being paid, the dots will be widely scattered (Fig. 181) and a detailed study must be made to uncover desirable adjustments.

The usefulness of a small scatter diagram is limited at this stage because there is no direct means of identifying the dots with the positions they represent. It is therefore recommended that a large scatter diagram be laid out on a bulletin board or blackboard so that labeled

pins or stickers may be used rather than dots. The name of each job may then be located with respect to the two axes, and the whole wage or salary situation given a visual significance that is impossible with a small scale. In making tentative adjustments, particular attention must be given to key positions whose wages and salaries are fixed by custom or union agreement, and they may be made graphically prominent by the use of a color code for the labels.

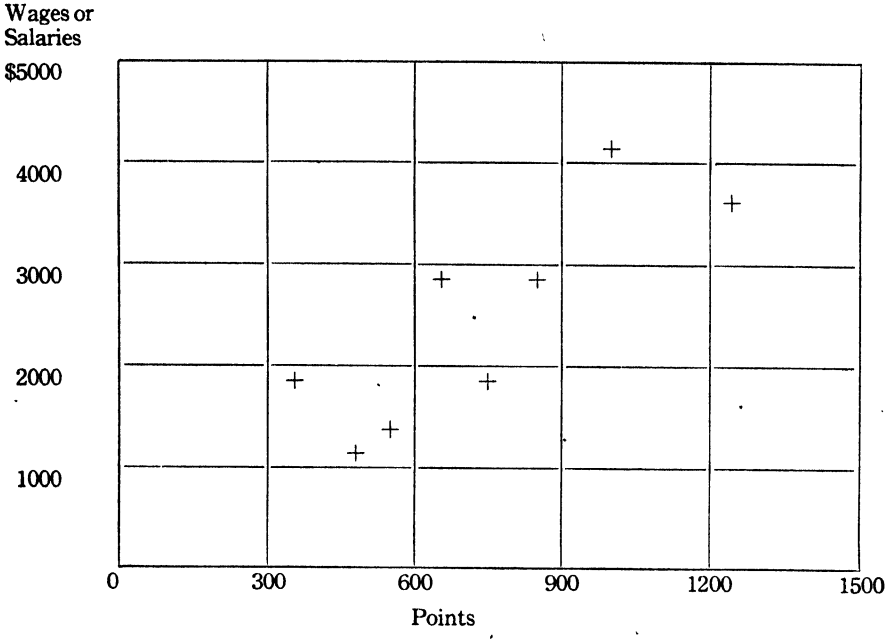


FIGURE 181. SCATTER DIAGRAM SHOWING POOR CORRELATION BETWEEN WAGES OR SALARIES AND POINT RATINGS

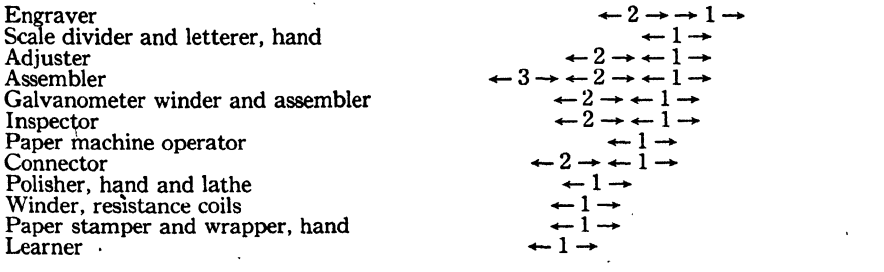
It should be emphasized that this graphic device, as well as numerical points, is only a means to an end, and only as reliable as the quality of thought developed to its use. The function of the large scatter diagram is to provide a common denominator for group discussion and a visual check upon the accuracy of the conclusions. After studying the scatter diagram and correcting the wages and salaries that are out of line, wage and salary ranges for each job, or for groups of jobs, may be defined as discussed under job classification.

Comparative Advantages of Point Ratings

1. The use of points to express the relative importance of jobs forces the evaluator to discriminate carefully in all the statements he makes. He cannot get away with saying that one factor is "probably more

SCHEDULE FOR JOBS COMPENSATED ON AN HOURLY BASIS

NOTE 1: "S and O" indicates "Set up and Operate" as contrasted with "Operate only."



NOTE 2: The numbers appearing between the arrowheads represent grades or skill bands by classes.

FIGURE 182

important than another," but must make the best estimate he can of just how much more important it is than the other one. Furthermore, the use of points does not limit the comparisons to simple multiples or fractions, such as three times as important, or half as important.

2. Comparison of factors is more accurately accomplished by the use of points than by means of ranking or classification. Ranking gives no indication of whether the differences in rank are caused by large or small differences in importance, and classifications must of necessity establish arbitrary dividing lines.

3. The use of abstract points rather than monetary units for the comparison of the relative importance of factors is advantageous because:

a) Bias is reduced. Monetary units immediately infer a comparison with customary wage and salary rates or standards of living, whereas points have no connotations irrelevant to the comparison of the relative importance of the factors they represent.

b) The value of monetary units changes with general business conditions, the value of the work done changes with the selling prices of the company's products, and total rates of pay for certain jobs may be changed by outside influences such as unions, or competitive bidding by other companies.

c) Where the relative importance of factors is measured in terms of monetary units only, it is necessary to change the figures to keep them in line with changes listed above.

d) When points are used to express the relative importance of factors, adjustments need be made only for actual changes in this relative importance, and not for changes in the unit of measure.

e) Once a point scale is well established, it is a permanent measuring device.

The development of a job schedule. When the jobs have been evaluated, they may be arranged in the form of a schedule which lists them from least to most difficult. Figure 182 shows a job schedule as established by a small company and expressed in cents per hour. This company has determined the upper and lower limits for each class of work and uses ratings to determine where, within a certain class, each man falls.

From this job schedule, charts of advancement and promotion may be readily developed. The use of such charts, together with a job schedule, will aid in accomplishing the following:

1. Show relative value of jobs.
2. Define lines of organization and responsibility.
3. Serve in making wage and salary adjustments and discovering radical variations.
4. Establish a basis for comparing company rates with outside rates of pay.

5. Facilitate recognition of merit and promotion, thus stimulating ambition.
6. Facilitate setting lines of job progression so that future executives may have a well-rounded experience background.
7. Furnish a basis for training employees for greater efficiency and positions of greater responsibility.

Figure 183 shows a job-evaluation summary sheet as used by a large corporation. The letters at the head of the columns stand for common job factors which are:

1. Mental requirements
2. Skill
3. Responsibility
4. Mental application
5. Physical application
6. Working conditions

FORMULATION OF POLICIES RELATIVE TO WAGE ADJUSTMENTS

After all jobs have been rated, they should be plotted against the standard rate curve. Many rates will be found slightly out of line with the new standard, some markedly. It is a simple matter to adjust upward those below the curve.

Those jobs decidedly above the curve may be there because of length of service, size of family, or some other personal reason. This should not invalidate ratings. The schedule of jobs will serve a very definite purpose here in pointing out which are the blind-alley ones. It should serve as a guide for transfer and promotion. In instances where employees' wages and salaries are inadequate for their needs, a definite effort should be made to educate and train them in order that they may meet the requirements of a position in the next higher wage bracket and thereby improve their earnings. During the training period for these people, however, the jobs above standard on the chart should be circled in red so that they will not be forgotten, and so that the correct pay rates will be established when the worker begins his new task.

When men are working on jobs for which prevailing rates are above standard on the chart, their pay should not be reduced immediately unless there is good reason. A sound wage policy commonly followed is to refrain from changing wages and salaries except as there is a general change in an entire plant or department, at which time it is usually possible to bring all base rates into line with least friction.

Adapting the Evaluation Plan to Changes in Organization

As an organization expands and changes in personnel are made, it becomes clear that all men do not possess exactly the same combination of abilities. The tasks to be performed by particular occupants of jobs

JOB-EVALUATION SUMMARY SHEET

Code		*Points*						
		M	*S*	*R*	*MA*	*PA*	*WC*	*Total*
0705	Gateman, directs visitors	35	60	25	20	0	0	540
0705	Watchman, unif. patrol, traffic	35	60	25	20	15	10	565
0910	Crane, 30 to 200 T. sin. hook	35	80	45	25	5	0	590
0910	Crane, 200 T. double hook	35	120	70	30	10	0	665
0931	Truck driver, gas, plant	20	60	35	20	15	10	560
0931	Truck driver, gas, licensed	35	100	45	25	15	10	630
0932	Truck driver, shop, elec.	20	60	20	20	20	0	540
1100	Electrician, 1st, leading man	80	260	60	30	25	20	875
1225	Plumber and steamfitter, 1st	60	240	40	25	30	25	820
1234	Machinist, 3rd, ordinary repairs	50	200	35	10	30	10	735
1234	Machinist, 2nd, large machines	65	240	40	20	30	10	805
1234	Machinist, 1st, diagnose	80	280	55	30	30	10	885
1260	Sheet metal, 1st, L/O develop	65	240	30	30	25	15	805
1263	Carpenter, 1st, finish work	60	220	25	30	25	20	770
1301	Laborer, inside	5	20	5	10	40	0	480
1302	Sweeper, sweep, remove chips	0	0	0	5	35	0	440
1306	Janitor, office lavatory	20	20	10	10	15	0	475
2000	Bor. mill, 3rd, rough and fractional	50	160	20	15	25	0	670
2000	Bor. mill, 2nd, loco. wheels, spiders	70	220	40	25	15	0	770
2000	Bor. mill, 1st, 16-ft. stator frame	85	280	70	40	10	10	890
2102	Planer, under 7-ft. motor frames	50	180	45	25	15	10	725
2102	Planer, 7-ft. and over fab. frames	70	240	60	35	10	10	825
2303	Lathe, Eng. 3rd, rough off stock	30	80	5	15	10	5	545
2303	Lathe, Eng. 3rd, for grind	50	180	20	20	10	5	685
2303	Lathe, Eng. 1st, intricate	70	240	30	30	10	5	785
2401	Screw mach., auto. no set up	35	80	10	20	20	5	570
2401	Screw mach., auto. die head and s.u.	60	220	30	30	20	5	765
2420	Lathe turret, irreg. complic.	60	220	30	30	15	5	760
2430	Screw mach. bar mic. and s.u.	60	200	30	30	20	5	745
2502	Milling machine, clearances	20	100	10	10	15	5	550
2502	Milling machine, fractional	25	120	15	10	15	5	590
2502	Milling machine, in fix. close	35	160	30	20	15	5	665
2502	Milling machine, irreg. close	50	180	30	20	15	5	700
2502	Milling machine, ordinary, index	60	220	30	30	10	5	755
2502	Milling machine, complic. index	60	240	35	35	10	5	785
2703	Drill rad., clearance holes	20	80	10	10	20	5	545
2703	Drill rad., med. jig work	35	140	20	15	20	5	635
2703	Drill rad., compl. L/O	50	160	25	20	20	5	680
2721	Drill sensitive, compl. layout	40	140	20	20	20	0	640
2721	Drill sensitive — simple	10	20	0	5	20	0	455
2930	Grind precision, 2nd, arm. sh.	50	180	35	20	20	5	710
2930	Grind precision, 1st, gas, eng. cr.	60	220	40	25	20	5	770
3000	Punch press 80–150 arm. p.	35	80	25	20	30	15	605
3000	Punch press over 200, irreg.	45	140	60	20	30	15	710
3001	Punch press, repet, strip or roll	20	60	0	10	30	0	520
3900	Assem. bench, 2nd, general	40	160	25	25	25	0	675
3900	Assem. bench, 1st, fit, scrape	60	220	35	30	20	0	765
3910	Assem. conveyor, simple	10	40	0	0	30	0	480
4300	Assem. floor, 1st, align. large	60	200	40	30	30	5	765
4511	Toolmaker, 3rd, templates	65	220	45	20	20	0	770
4511	Toolmaker, 2nd, compl. fixtures	85	260	45	25	20	0	845
4511	Toolmaker, 1st, compl. jigs	90	320	50	40	20	0	920

FIGURE 183

must vary with their own ability, the abilities of others in the organization, and the work that must be done according to current business order and general conditions.

A good man with a special combination of abilities will create an important job for himself. If the need arises to replace him, it may not be possible to do so with someone who possesses exactly the same qualifications; instead it will be necessary to modify the requirements of several other jobs in order that the work may be adequately performed.

A job-evaluation system should allow good men to make their own jobs and not cramp good talent into inflexible categories and titles.

Frequency of Ratings

The frequency of making job ratings depends upon the stability of the individual enterprise. When job requirements are constantly changing or new jobs created, rating becomes a continuous procedure. Particularly in the growing firm, are there always changes in the volume of work, personnel, organization, methods, procedure, and equipment that can be taken care of only by a continuous audit of job requirements.

What Jobs Should Be Evaluated?

The wide scope of job evaluation revealed by survey results does not seem to indicate that management believes there are limitations as to its coverage, and evidently many factors are considered common to all supervisory, executive, and clerical jobs.

Job-evaluation plans are applied to the appraisal of all types of jobs from the lowest-paid clerks through the executive board. Figure 184 shows at a glance the scope of job evaluation as conducted by 45 firms replying to a questionnaire survey on the evaluation of salaried jobs. In addition to the report shown in this table, one company states that it evaluates jobs from the executive board down to jobs paying $45 per week.

The usual procedure is to start the evaluation with the routine jobs and proceed to the more complex ones. It is generally agreed that the more routine the work is, the less difficult the job will be to evaluate. Objective judgment can be used effectively in appraising repetitive work, whereas subjective judgment is usually necessary in evaluating the more complex jobs.

Determination of Who Is to Do the Evaluating

The personnel department usually possesses more knowledge of jobs than any other single department. Job evaluation should therefore be undertaken under its direction or by its wage and salary division. A

survey of firms having job evaluation in operation reveals that the job evaluation administration unit is the personnel department in 37 cases, a special planning committee in 5 instances, and is composed of a neutral committee in 3 systems. In the latter two instances, the personnel department works in cooperation with the job-evaluation unit.

SCOPE OF JOBS EVALUATED

(Based on Questionnaire Survey of Job Evaluation as Applied to Jobs Paid on a Salary Basis)

Group	*Number of Times Reported*
Executives	
Senior	14
Junior	23
Supervisors	
Department heads	28
Assistant department heads	28
Subdivision heads	29
Others (salaried foremen)	3
Engineers	
Industrial	18
Sales	10
Desk	12
Technicians	2
Research	2
Inspectors	1
Salesmen	15
Accountants	34
Purchasing agents	2
All clerks	45

FIGURE 184

Determination of Policies Regarding Use of Results

In initiating a job-evaluation program, each firm must determine the particular combination of objectives sought and design its system accordingly. The primary objective of all programs is to determine fair and equitable rates of pay. In addition, the system may be designed to produce the following:

1. Information useful in the selection and placement of employees (job specifications).
2. Information useful in negotiating pay adjustments with union officials and others.
3. Information useful in guiding the rating of employee performance.

4. A basis for coordination with merit-rating systems to indicate advanced jobs which an employee is qualified to fill.
5. Information for development of standard practice instructions, work manuals, bench, and desk manuals.
6. A means of familiarizing supervisors with work expected of subordinates. (Supervisors are forced to study jobs for which they are responsible.)
7. Disclosure of unnecessary routine, red tape, and duplication of effort.
8. A basis for improved organization of personnel, and division of authority and responsibility.
9. A system useful in budgetary control respecting wage and salary matters.

Company policies vary regarding the publications of wage and salary ranges based on the evaluation program. A survey of practices reveals that completed job evaluations are shown to job holders in approximately one-third of the firms having plans in operation; they are shown on request in several companies; and the evaluation results are not shown to employees in some instances. Many companies, however, notify an employee when he has reached the maximum wage or salary for the job.

When a wage or salary schedule is established, it often becomes apparent that certain wages and salaries are out of line; that is, the pay for some jobs is too high and that for others too low. Some companies make adjustments immediately; others more gradually; still others do not make changes until promotions or new hiring take place.

SUMMARY OF PRINCIPLES

Job evaluation has to do with jobs and not men. It is a method for determining the relative worth of each job. This job worth is that portion of the total wage or salary which is paid for the occupational requirements and is known as the *base rate.*

Before base rates can be determined, it is necessary that thorough job analyses be undertaken and specifications developed. These should be based on carefully established standards of output and procedure. This is important, because the amount of skill and mental and physical effort cannot be truly evaluated unless job conditions and output standards are set at a fair and logical value first. Specifications should be prepared so as to be most useful in the actual evaluation process; the headings and terminology used on specification forms should correspond to the major and subfactor definitions.

It should be evident from the previous discussion that no one man or department should have entire charge of evaluating jobs. Only through the combined judgments of a group of competent men can these evaluations be justified. The detailed work may be done in one

department but questions of policy and evaluation of key jobs should be done by a committee.

The mere rating of jobs without consideration of the fundamental factors involved will yield but superficial results at best. The common factors and their definitions by degrees, together with the weights assigned to each, must be determined by the committee. The next logical step is the development of manual charts to record definitions and point values. These are the so-called manual charts (Figs. 177 and 178).

Rating the key jobs and indicating to what extent each factor is present will follow. When point ratings are determined, it is necessary to convert them into monetary values. A rate curve of labor costs as budgeted may be used to convert these point ratings into dollars and cents.

The job schedule, together with promotional charts, may be developed as a logical outcome of this work, resulting in definite improvements in employee morale and efficiency. At this time it is also essential that policies in regard to rate changes (made necessary if this evaluation of jobs is to be of real worth) be determined. For those employers who desire to make an allowance for employees who more than fulfill the job requirements, an employee-rating plan at regular intervals is the answer. Factors such as quality of work, versatility, and initiative may be considered. A certain maximum, such as 10 per cent of the base rate, may be allowed. The portion of this which will be assigned to each man is determined by the employee rating.

The results to be expected from any job-evaluation plan are:

1. A complete, accurate, and impersonal description of all classes of work within the plant will have been obtained.
2. The relative value of all jobs within the plant will be known.
3. Lines of organization, responsibility, and channels of authority will be more clear.
4. Job information in convenient form for the use of the employment office, in deciding both initial employment and transfer possibilities, will be available.
5. Fair maximum and minimum job pay rates will be known.
6. Wage and salary adjustments will be facilitated and inequalities in payment will become obvious.
7. A basis of comparison when checking company wages and salaries with those paid generally for the same kind of work in the community or industry will have been realized.
8. Employee ambition will be stimulated because of recognition of merit and promotion to positions of larger responsibilities on this basis.
9. Job evaluation, through the job schedule, will facilitate setting lines of job progression, so that when an employee attains a job of high

responsibility his experience and background will be as rounded as possible.

10. The two aforementioned results will furnish a basis for training employees for greater efficiency and for positions of greater responsibility.

Job-evaluation information can be used advantageously by managers in all manufacturing industries regardless of size or type. The small company manager and supervisor will find his judgment on pay matters enhanced by possessing knowledge of job evaluation. Officials of medium-sized and large firms will have particular advantage in adopting actual systems.

A LOOK AHEAD

Job evaluation is destined to be applied on an extensive scale. This will probably be best accomplished by trade associations, acting in the capacity of a coordinating agency for their member firms wishing to take part in this work. When this happens, these benefits may be realized by each of the industrial groups participating in the program:

1. The determination of similar names and definitions of jobs so that rate and employment data can be more easily and accurately collected.
2. The standardization of labor as well as other costs. This will assist trade associations in voluntarily policing their industries in regard to fair trade practices toward labor (provided interference from government agencies can be avoided) and thereby make possible the elimination of unfair competition from the sweatshop type of employer.
3. The development and possession of information that will enable businesses to deal more fairly with labor organizations — and know what they are talking about.
4. The creation of conditions that will be conducive to greater stability for industry and greater security for labor.

CHAPTER XXI

MERIT RATING — MEASURING MANPOWER PERFORMANCE

Merit rating may be defined simply as a system for discovery and classification of the individual differences among employees [1] — a tool for appraising the relative qualities of their personalities with respect to the jobs they fill; while job evaluation is the analysis of the job itself to learn what it requires of whoever fills it and, therefore, its relative "worth" in comparison with other jobs in the plant.[2]

Job evaluation and merit rating have different objectives, but they go hand in hand in determining what a worker should be paid. The former is a means of arriving at a base rate for the job itself — an amount automatically paid anyone meeting its minimum requirements — and the latter reveals the differences in individual capacities on the job, thereby determining the pay *differential* to which each is entitled.[3] When used in conjunction, therefore, these tools are very helpful in arriving at an equitable rate of pay for given labor situations: the job itself and the efficiency of the individual assigned to it. The situation pictorially is as shown in Fig. 185.

Merit rating has become a requisite of good employer-employee relations in nearly all types and sizes of industrial organizations, because it provides an effective medium for avoiding arbitrary supervisory attitudes toward labor. For the large firm its use partially overcomes the lack of familiar contacts found in the smaller shops, which are so essential if men are to be properly appraised and employed to best advantage. It has similar advantage in the medium-sized shop, depending upon the degree to which supervisors and employees can develop mutual understandings. In the small organization, however, its value is largely restricted to the category of useful knowledge — the small

[1] The content of this chapter is based, in part, on material compiled by the Bureau of Business Research of Northeastern University and included in Bulletins 1 and 4 of the Northeastern University Publications, Northeastern University, Boston, Mass. February and November, 1940

[2] Asa S. Knowles and F. C. Means, "A Survey of Job Evaluation as Used by Industry in Determining Base Rates," *N.A.C.A. Bulletin*, Vol. XX, No. 7, p. 384.

[3] To the base rate and pay differential may be added a third pay element in the nature of a reward for productivity or superior workmanship. In the final analysis the essential elements in pay determination are not altered by the method of payment.

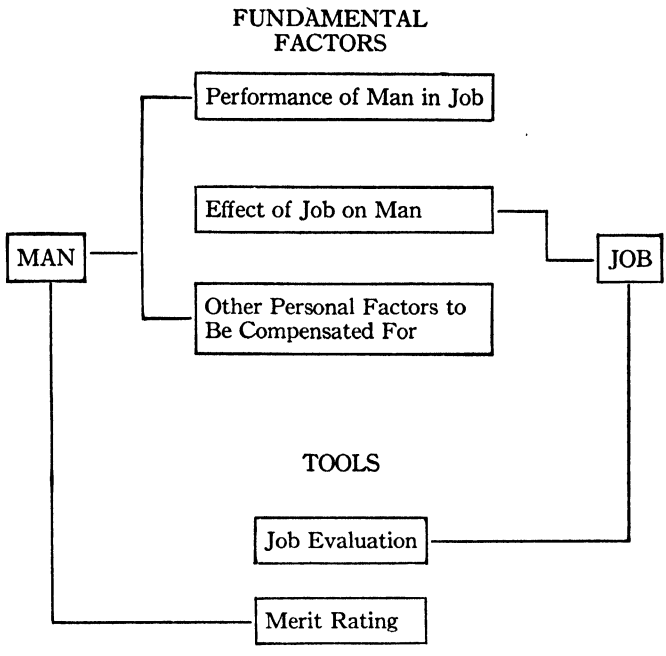


FIGURE 185. CHART SHOWING THE RELATIONSHIP BETWEEN MERIT RATING AND JOB EVALUATION IN DETERMINING AN EQUITABLE RATE OF PAY FOR A JOB

business or industry has a natural advantage in close relationship between management and labor.

The current emphasis on merit rating grows out of an attempt on the part of industrial managers to seek scientific means to achieve these advantages: [1]

1. *Better understanding of work and men.* The development of rating programs has forced those responsible for jobs and men to study them carefully. The outcome is a better understanding of both the jobs to be done and those attempting to do them.
2. *Increased production.* Employees who are rated appear to accept the existence of a rating program in the spirit of competition. An added incentive for superior achievement is thereby derived. In addition, those whose productivity does not come up to standard are uncovered and replaced.
3. *Uncover special abilities of employees.* The appraisal and comparison of employees in terms of prescribed standards have brought to light men having special abilities. This has facilitated selections both for promotion and transfer.

[1] Asa S. Knowles, "Measuring Salesmen's Performance," *Advanced Management*, S.A.M., New York, April–June. 1941, Vol. 6, No. 2, p. 50.

4. *Minimize prejudice and bias.* Merit rating reduces guesswork and snap judgment. In the appraisal of employees, objective measures are substituted wherever possible, and those who rate are asked to deliberate in arriving at decisions.
5. *Establish fair and equitable pay.* Merit rating makes possible fair rates of pay because all employees are appraised in terms of the same specific factors, and completed ratings are reduced to numerical values. To this extent they are comparable when used for determining pay.

It is highly important for those who are just getting acquainted with merit rating to recognize that it has definite limitations. Regardless of the degree of development of any plan being used, the results achieved can never be better than the judgment, honesty, and fairness of the men operating it. Furthermore, no rating system can ever replace leadership — there is no adequate substitute for an ability to inspire men to do their best. Merit rating is merely a tool which when properly wielded provides composite opinions of employees based on uniform, scientific procedures rather than the snap judgment of individuals. It is a means, not an end in itself.

Finally, it is not a mechanism for setting wage rates but rather a tool for testing their adequacy, determining whether or not employees measure up to the minimum requirements of their jobs in performance. When a merit program is used in conjunction with job evaluation, it is the basis for arriving at wage differentials to which employees are entitled on the basis of individual differences in job performance.

CLASSES OF EMPLOYEES RATED

There is a growing tendency to rate both plant and office employees. Firms cooperating in a recent merit-rating questionnaire survey reported these groups as being subject to rating systems (figures represent number of times mentioned in replies): [1]

Plant		*Office*	
Direct laborers	31	Office workers	15
Indirect laborers	26	Salesmen	8
Supervisors	16	Executives	8
Salaried clerks	1	Engineers	1
All hourly paid help	2		
All Employees	4		

BASIC PRINCIPLES APPLIED TO ALL TYPES OF RATING

There are basic principles of rating employees which apply to the organization and conduct of rating programs at any level of an organization. Whether employees are shopworkers, or supervisors and execu-

[1] Asa S. Knowles, *Merit Rating in Industry*, Northeastern University Publication No. 1, Boston, Mass. February, 1940, p. 12.

tives, the development and operation of a rating program to measure performance in filling a job requires techniques and procedures which are essentially the same for all. These will be presented in detail and the exceptions discussed in connection with suggested rating plans.

DEVELOPING EMPLOYEE-RATING PROGRAMS

Employee-rating programs are best developed on the individual firm basis. Existing plans seldom fit the needs of particular firms. The development of the program itself cannot fail to arouse in those doing the rating, as well as in those rated, more interest in making the plan work — not only do they understand better the capacities of workers, but supervisors and top management alike become interested in the rating program and want it to be productive of desired results.

A committee should be appointed to develop and operate the rating system. Its chief duties will include careful consideration of each of the following steps:

1. *Job Specification.* Establishment of requirements [1] for jobs to be rated if they do not already exist.
2. *Purpose.* Formulating the aims and uses of the rating program.
3. *The Rating Sheet.* Developing the *rating* form, selecting the *type of form* to be used; deciding upon the traits or characteristics to be measured in the light of job analyses; developing a procedure for *scoring* (assigning point values to rating); determining a proper system for weighting *individual traits* in relation to jobs; consideration of *application of objective measures.*
4. *The Rating Procedure.* Determination of:
   a) Who will do the rating.
   b) What instructions and training will be given those doing the rating.
   c) How often ratings will be done.
   d) Who will check completed ratings.
5. *Use of the Results.* Formulation of policies regarding availability of ratings for general use of top executives, and reaching a decision as to how they shall be used to assist those rated to improve their job competence.
6. *Training of Raters.* Establishing and conducting a training program for those who are to make ratings.
7. *Educational Program.* The organization and conduct of an educational program among those rated regarding the foregoing.

Typical rating committees now existing in industry are composed of representatives from personnel departments, administrative staff members (top executives), and supervisors (foremen) when shopworkers are to be rated. Occasional committees, composed differently, con-

[1] Where job evaluation plans are in use, the specifications will be readily available.

sist solely of representatives from one category, such as top executives; and still others comprise members from many different sources, including subordinates of persons being rated.

1. Job Specifications

The appraisal of a person's effectiveness in any job can be truly meaningful only when there has been careful definition of the scope of the job, its limitations, and the demands it imposes on anyone who is to fill it properly. A good rating form, therefore, is one which attempts to measure a person's performance in terms of what the proper fulfillment of his job demands. The selection of job requisites which apply in particular instances is best done by men familiar with the job under consideration, that is, those working on the job, those who supervise the job, and top management. A careful job specification will assist particularly in the accomplishment of the following:

a) Determining the purpose of the rating program.
b) Deciding the characteristics and traits to be measured.
c) Providing a *fair* basis for comparing the measured performance in relation to that expected.

A sample job specification is shown in the chapter on Job Evaluation, page 394. Where firms do not have job specifications available, the following is a somewhat inclusive list of the type of information which must be sought in order to compile proper job specifications.

Factors to be considered in developing job specifications.

a) *Skill and experience* — dexterity and accuracy; the degree of proficiency in manual and mental skills required; quickness, deftness, coordination of eye and muscles demanded.
b) *Educational development and intelligence needed* — education required to fill job expressed as equivalent to grammar school, high school, or college.
c) *Responsibility* — demands imposed by job regarding safety of others, direction of subordinates; care that must be exercised in use of tools, equipment and machinery; degree to which accountable for process development and efficiency.
d) *Physical effort needed* — the muscular effort and strength required to fill job properly.
e) *Personality factors required* — appearance, carriage, voice, tact, ability to get along with others, cooperation demanded, character, common sense, intelligence.
f) *Leadership qualities needed* — initiative and ingenuity, originality, patience in dealing with others, capacities for growth.
g) *Teaching abilities required* — requirements for training others and instructing subordinates; capacities for learning; demands job (or posi-

tion) imposes in learning new methods, meeting new situations, grasping new ideas.

The following apply particularly to supervisory and executive positions:

h) *Personal productivity* — amount of work job requires to be done personally; diligence and care that must be exercised in fulfillment of duties.

i) *Productivity required of unit (department, firm) for which responsible* — amount of output of satisfactory quality required to meet production schedules, departmental standards.

j) *Personal efficiency demanded* — care and accuracy needed to complete necessary records and reports; importance of promptness in completing own work as related to job.

k) *Efficiency demanded of unit for which responsible* — extent to which economy and prevention of waste time, material, and equipment must be achieved; need for orderliness of equipment, tools.

l) *Special requisites* — age limitations, citizenship, special language abilities.

2. Purpose of the Rating Program

The usefulness of the results of any rating program is enhanced through restricting its purposes to as few as possible — preferably only one. Rating programs are used most commonly to aid in making decisions regarding these matters; determining the differential to be added to job-evaluation base rates in wage and salary determination, promotion, transfers, hiring, layoff, and discovery of individual weaknesses. Occasionally ratings are used as a guide in rehiring employees who have been temporarily discharged, but this is not a common use.

3. The Rating Sheet

No two rating forms are exactly alike in appearance, but all attempt to measure the presence or absence in individuals of the characteristics which are essential to meet the requirements set forth in job specifications. In the interest of a simple and clear rating form, however, the specification factors must be rephrased and regrouped, and terminology developed that will cause the rater to think of the factors in terms of the capacity of an individual to meet them. Not only is it desirable to obtain the essential information through measurement of as few traits as possible, but also to describe the traits to be measured in simple language. Unless great care is taken in both connections, there will be confusion in the minds of the raters which will correspondingly lessen the value of the completed ratings.

Type. Regardless of the characteristics to be measured and the intended purpose of a rating program, the rating form used will necessarily be modeled after one or a combination of these four general types of construction:

a) *Graphic Rating Scale.* The graphic rating scale is one of the more accurate methods of rating currently in use but has not been adopted widely. It is recognized by its distinguishing feature, a line about 5 inches in length for each of the traits to be measured; at regular intervals beneath this line short descriptive phrases signify different degrees of the trait; and at one end of the line is printed one of the following: (1) the name of the trait, (2) the name and a short description of the trait, or (3) merely a short description with the name of the trait left out. The last has the advantage of forcing the rater to read the description, meanwhile preventing him from utilizing any preconceived conception of the trait on the basis of its name.

A space is customarily reserved on the reverse side of the sheet for comments, general remarks, or in a few cases, specific reasons justifying the ratings. When the ratings are completed, they are returned to the personnel department to be scored by use of a master stencil (see Fig. 192). This gives, if desired, a numerical rating for each employee and makes possible statistical corrections for the tendencies of the individual raters. Moreover, in devising the master stencil various factors may be weighted properly both without inconvenience to the rater and influence on his judgment. (The rater tends to avoid exceptionally high or low ratings of heavily weighted traits.)

Many employers feel that the graphic rating scale is more accurate than necessary and, therefore, are unwilling to devote the additional time its use requires. Furthermore, those who score it must have access to much confidential information and this is regarded by many as a potential danger.

An example of this type of rating sheet is shown in Fig. 186.

b) *Rating by Letters.* The use of letters to rate individuals is probably an outgrowth of school marking techniques; it simply names and describes the traits to be measured and classifies the employee by letters (E, G, F, P) into arbitrary groups. While it is one of the more popular methods now in use, its only recommendation is simplicity in use.

Since one of the chief functions of merit rating is the minimizing of subjective judgment, there is little to commend a system which groups employees into classes of excellent, good, average, below average, and unsatisfactory. Varying conceptions of these terms make comparison of different ratings nearly worthless. (In addition, the method possesses all the disadvantages of No. 3.) A sample form using this method is shown in Fig. 187.

c) *Rating by Grouping.* Rating by grouping is the most popular of rating methods currently in use. It is an extension of "rating by letters." Employees are again divided into groups, but instead of using

just letters (or the equivalent, as E for excellent) to differentiate them, the groupings are *more or less* carefully described. In the final analysis, the success of this method depends upon the accuracy of these definitions.

Figure 188 used by the A–C Spark Plug Division of General Motors is an excellent example of this type of rating procedure. Because of the wide use of "rating by groupings," it is desirable to consider briefly its underlying theory; those who support it assert that by making ratings one is in general attempting to measure certain traits which are "nonmeasurable," and the presence or absence of which in human beings is due to the interaction of heredity and environment, while the actual extent to which the traits have any bearing on job performance will depend, in addition, upon the amount and kind of supervision.

This fundamental statement is followed by an acceptance of the hypothesis that the frequency of occurrence of certain intelligence levels will follow a bell-shaped curve, and since, in general, the traits which we attempt to measure are governed to a large extent by the same factors, it is assumed that the frequency with which degrees of these traits occur will be shown by the same curve *as it has been modified by social conditions.* (For example, in the case of regularity of attendance one might find that early public-school training has skewed the curve, but it is still a curve.)

Figure 189 shows an evaluation of rating people by grouping. In effect, this procedure establishes an arbitrary system of zoning which differentiates widely between the two individuals whose abilities would place them on lines A and B, when in reality the difference is so slight as to be negligible.

It is not, therefore, wholly fair to all who are being rated and introduces additional inaccuracies into a process which by nature can never be wholly accurate. Its advantages are ease of rating, greater accuracy than rating by letters, and simplicity of installation.

d) *Specific Items.* The newness of this rating technique has prevented its wide adoption as yet and, therefore, it is subject to development. Rating is accomplished by use of a form listing several items to be checked as either existing or not in the individuals under consideration. Its underlying theory is similar to that of the behaviorgram,[1] specific items being selected to serve as indicators of the presence or absence of more general traits.

The specific-item method introduces speed into rating procedures, but its success or failure depends upon the care with which the rating form is prepared and used. A thoughtfully developed form may serve

[1] Defined by Bradshaw, "a narration of instances, supporting facts, or anecdotes illustrative of the behavior of the person being rated." From *Psychological Aspects of Business*, E. K. Strong, McGraw-Hill Book Company, Inc., New York, 1938, p. 442.

SERVICE RATING SCALE

INSTRUCTIONS FOR USE. On this rating form there are eight qualities on which to rate each employee. Obviously, some qualities have more importance than others. You do not have to be concerned with their relative weights, but are asked to rate on each quality as independently and exactly as possible. Ask yourself how this employee compares with all other State employees doing similar work. Rate him by making a check (√) at that point on each scale where, in your judgment, he stands. Think of the employee always in terms of the whole group with the average or typical employee rated at the exact center of the scale. Please be sure to record your rating of the employee on each of the qualities. Do not omit any. If the employee has made no impression on you whatever, either favorable or unfavorable, so far as one of these qualities is concerned, rate him at the midpoint of that particular scale.

DO NOT ATTEMPT TO RATE AN EMPLOYEE UNLESS YOU HAVE ADEQUATE KNOWLEDGE ON WHICH TO BASE YOUR RATING — If you rate an employee below 1 or above 4 on any quality, please write your specific reasons for this in the space provided for comments on the other side of this page. This is important since dismissal from the service or promotion to a higher grade may be dependent on your rating.

1. QUALITY AND QUANTITY OF WORK ACCOMPLISHED — Consider amount of work accomplished and ability to maintain a high degree of accuracy.

1	2	3	4	5
Unsatisfactory performance	Very slow, but fairly accurate	Completes regular work in reasonable time without undue error	Completes more than average amount of work with great accuracy	Completes large amount of work of highest quality

2. INDUSTRY AND INITIATIVE — Does employee apply attention, energy, and persistence to his work? Does he need constant prodding or does he go ahead with his work and follow it through to completion?

1	2	3	4	5
Lazy, needs much prodding	Rather indifferent, needs occasional prodding	Does ordinary assignments of own accord and fairly well	Industrious and energetic, completes suggested supplementary work	Does far more than is expected. Sets and completes additional tasks

3. DEPENDABILITY AND INTEGRITY — Consider the dependability of the employee in the discharge of every duty. Does he carry his full share of responsibility? Can you depend on him to be punctual? Is he honest in his dealing with the administration and his fellow employees?

1	2	3	4	5
Indifferent, does as little as he can, needs constant watching	Sometimes unreliable. Avoids responsibility. Satisfied to "get by"	Works acceptably. Honest and willing. As a rule responsible but needs some direction	Very dependable and honest. No disciplinary supervision required	Highly dependable. Thoroughly honest. Consistently constructive force in his group

4. KNOWLEDGE OF JOB AND ABILITY TO LEARN — Consider extent of knowledge of his own job and related jobs, the ease with which he learns new methods in his own job, and details of jobs related to his.

1	2	3	4	5
Does not understand own work and unable to learn	Has fair understanding of own job, but unable to adapt to new conditions	Thoroughly understands own job, but slow to adapt to new conditions	Understands own and related jobs and will be promotional material	Understands all jobs in division and is good promotional material

5. COOPERATION — Consider his attitude in acting jointly with associates and superiors for the benefit of the unit. Does he fit easily into the group?

1	2	3	4	5
Cooperates grudgingly. Inclined to make trouble	Gives limited cooperation	Usually cooperates willingly	Cooperates willingly and fits easily into group	Cooperates cheerfully and consistently and inspires cooperation

6. JUDGMENT — Does he impress you as a person whose judgment is dependable even under stress? Is he hasty, erratic, biased, swayed by his feelings?

1	2	3	4	5
Notably lacking in judgment	Shows some tendency to react impulsively	Acts judiciously in ordinary circumstances, may be hasty in emergencies	Habitually shows good judgment	Shows unusually sound judgment under all circumstances

7. ATTENDANCE — Consider regularity of attendance and the employee's attitude toward time lost from work. Does he consistently take time out for trivial reasons or is he absent only when absolutely necessary?

1	2	3	4	5
Takes advantage of every opportunity to take time out	Frequently absent	Average attendance, absent only when there is a good reason	Rarely absent	Always on the job

8. VALUE TO THE DIVISION — In the light of all the evidence regarding this person's characteristics (whether mentioned above or not) how do you rate his personal value to the division?

1	2	3	4	5
Low	Below average	Average	Above average	Superior

Date

Signature of Rater

FIGURE 186. GRAPHIC RATING SCALE MERIT-RATING FORM

ESTIMATE OF QUALITIES

Date..... Report On.....

Dept.....

This rating should be made with great care and fairness, for the best interest of the Company and the employee, being careful to avoid overratings from mistaken motives of kindness and underratings from prejudice. Be prepared to justify your ratings should occasion require.

The facts disclosed are valuable to the employee as well as to the Company. The employee should be encouraged to show improvement in those qualities which are rated low.

In each group, the employee should be given an appropriate rating (either 1, 2, 3, 4, or 5) for each subdivision thereunder, after which an "X" should be marked in the column that indicates a fair general average for the group. Estimates should be based on a comparison with other men in a similar status.

Qualities to Be Considered	1 *Outstanding (Exceptional)*	2 *Good (Above Average)*	3 *Satisfactory (Average)*	4 *Fair (Below Average)*	5 *Poor (Unsatisfactory)*
GROUP 1 — Ability to do his work:					
Quality of work (accuracy and neatness)					
Quantity of work done (industry, promptness, volume)					
Ability to quickly understand and follow instructions					
General ability					
GROUP 2 — Knowledge:					
Knowledge of his own work					
Knowledge of department operations					
Knowledge (engineering)					
Knowledge (manufacturing)					
GROUP 3 — Work habits and personal characteristics:					
Punctuality					
Attendance					
Deportment (self-control, courtesy)					
Alertness					
Interest in work and earnestness in doing it					
Dependability when working without supervision					
Habit of keeping busy and avoiding idleness					
Cooperativeness (willingness to assist others)					
Loyalty to Company's interests					
Orderliness (in working methods and care of equipment)					
GROUP 4 — Special qualities:					
Initiative					
Judgment					
Adaptability					
Trustworthiness					
Originality (inventive ability)					
GROUP 5 — Supervisory ability:					
Capacity for taking responsibility					
Ability to plan work					
Ability to execute work					
Ability to train others in proper working methods					
Ability to lead others and secure cooperation					
Knowledge of the Company's business					
GROUP 6 — Best fitted for:					
Sales					
Manufacturing					
Development					
Engineering					
Summary rating of all qualities — general value to company					

FIGURE 187. FORM FOR MERIT RATING OF EMPLOYEES WHICH INVOLVES SAME PRINCIPLES AND METHODS OF CLASSIFICATION AS RATING BY LETTERS

as a reasonably accurate method even though accomplished rapidly, while a carelessly prepared form, allowing full play of prejudice and bias, will be of little value. Those who contemplate using this method should devise the form and then test its reliability by comparing the results obtained with another rating blank of known reliability. Figure 190 shows a modified sample form.

Scoring (assigning point values to ratings).[1] To be most useful, completed ratings should be comparable. This requires the adoption of a common unit of measure, that is, a scoring system. When dealing with human behavior, however, we have no convenient physical units of measurement, as in the physical sciences where various scales, conversion factors, and statistical measures are readily available. Ratings of individuals must be made as a matter of judgment rather than by means of an accurate scale. Numerical scales and weights function in employee rating as a device to facilitate more exact appraisal of personal traits by making possible comparisons of total scores computed for the individuals rated.

In reality a rater is told to be precise when asked to evaluate an employee by a numerical scale (8 for "superior," for example). But since the selection and use of the scale involve individual judgment, the scale can only supply a common term for the expression of this judgment. *A primary requisite in setting up such a scale is that the designation for each separate rank between imperfection and perfection must be in proper relationship to the whole scale.* The particular arbitrary scale as selected is unimportant compared with a proper understanding of the scale by the raters and the interpretation of the final scores by executives.

Weighting individual traits.[2] Particular traits are not always of equal importance in the performance of jobs and positions. This is particularly true in the case of supervisory and executive positions. Where traits have unequal significance in relation to proper filling of the jobs under consideration, it is necessary to construct *weights* which will give proper significance to each as related to the job, that is, various factors should be recognized as *essential, desirable,* or *unimportant* in the performance of a job. A weighting scale must be devised to weight the significance of each trait in filling the particular position held to give a proper balance in each of the categories (essential, and so on) as related to the job. For example, if no points were given a trait relatively unimportant to a particular job, but generally desirable in the character of

[1] Asa S. Knowles, "Merit Rating of Supervisors, Foremen and Department Heads," *Personnel*, American Management Association, New York, November, 1940, Vol. XVII, No. 2, p. 12.

[2] *Ibid.*, pp. 12, 13.

EMPLOYEE'S RATING CHART
AC SPARK PLUG DIVISION
GENERAL MOTORS CORPORATION

Date .. .... Employee's Name.... ....Clock No.....
First Middle Last

Rating for Period from .....to.....Occupation Rated on.....

Quality Rated	Details of Quality	Put Cross in Section Which Most Accurately Describes Detail in This Employee					Detail Total	Quality Total	Remarks
		Unsatisfactory Negative Qualities		Average	Satisfactory Positive Qualities				
Quality of Work	Accuracy of production	Many errors and spoiled work	Careless	Average	Careful	Most accurate			
		4	2	6	2	4			
	Care of working space	Slovenly	Careless	Average	Keeps space clean	Very clean and orderly			
		2	1	3	1	2			
	Handling of material	Rough	Careless	Average	Careful	Very careful			
		2	1	3	1	2			
Quantity of Work	Speed of production	Very slow	Slow	Average	Fast	Very fast			
		4	2	6	2	4			
	Use of working time	Very wasteful	Loaf with others	Average	Good	Very busy			
		2	1	3	1	2			
	Use of materials	Extremely wasteful	Careless	Average	Good	Very careful and considerate			
		2	1	3	1	2			
Ability to Do Other Work	Ability to learn	Dull	Learns slowly	Average	Learns quickly	Brilliant			
		1½	½	2½	½	1½			
	Acceptance of responsibility	Buck passer	Evades it	Average	Likes it	Seeks it and handles it well			
		1	½	1	½	1			
	Initiative	Lives in a rut	Seldom offers suggestions	Average	Resourcefully suggestive	Very original			
		1	½	1	½	1			
	Ability to direct the work of others	Antagonizes	Hinders	Average	Helps	Excellent leader			
		1	½	1	½	1			

	Attendance	Very poor	Poor	Average	Good	Excellent			
		4	2	6	2	4			
Cooperation	Attitude towards company	Actively antagonistic	Passively antagonistic	Neutral	Cooperates passively	Cooperates actively			
		2	1	3	1	2			
	Attitude toward superiors	Disregards wishes	Follows orders like soldier	Neutral	Follows orders cheerfully	Tries to help make good			
		1	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	1			
	Attitude toward fellow workmen	Puts blame for errors on them	Looks down on them	Neutral	Helps them when told	Extremely considerate			
		1	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	1			
Safety Habits	Attitude toward safety program	Destructively critical	Follows rules disinterestedly	Neutral	Offers a few suggestions	Extremely helpful			
		3	$1\frac{1}{2}$	5	$1\frac{1}{2}$	3			
	Observance of safety rules	Openly disregards	Believe disregards when not watched	Average	Observes all major rules	Observes all and has own			
		3	$1\frac{1}{2}$	5	$1\frac{1}{2}$	3			
	Accident record	Major injuries through carelessness	Many minor injuries	Average	Few minor injuries	Never gets minor injuries			
		$1\frac{1}{2}$	$\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$			
Personal Habits	Moral character	Known very bad	Questionable	Average	Good	Outstanding			
		2	1	3	1	2			
	Physical condition	Very poor	Many minor ailments	Average	Good	Very good			
		1	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$			
	General appearance	Slovenly and dirty	Careless	Average	Neat and clean always	Exceptionally pleasing			
		1	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	1			

← *Total Numerical Grading*

Rated by – (Foreman) _____ Assisted by – (Title) _____

Checked and approved by – (Superintendent) _____ Numerical grading by _____

FIGURE 188. FORM FOR RATING EMPLOYEES BY GROUPING

all employees, this trait would be omitted from the rating. In fact, no irrelevant characteristic should be listed on a rating sheet.

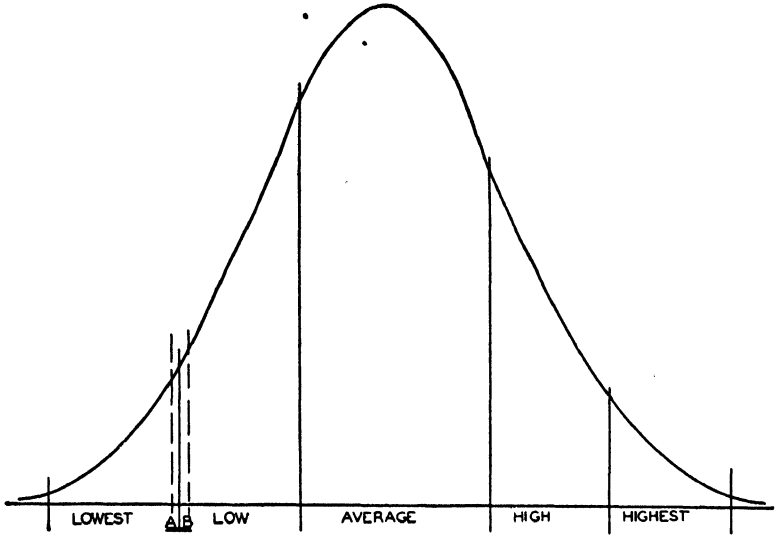


FIGURE 189

Three possible scales for weighting the importance of traits with regard to jobs follow:

	1	*2*	*3*
Essential to fill the job	2	3	4
Desirable to fill the job	1	2	3
Unimportant to fill the job	0	1	2

Presumably, each of these scales supplies numerical units representing varying degrees of significance of traits with respect to jobs from *unimportant* to *essential.* In any such scale it is advantageous to have the distance between each of its designated degrees in proper relation to the whole range. For example, the distance between *desirable* and *essential* on the first scale is one-half the whole scale, which makes too wide a gap. In turn, this tends either to penalize or value too highly certain traits, the possession of which as essential or desirable in filling a job may be questionable. The second scale somewhat lessens this gap and gives the same trait, considered as *desirable,* one-third less weight than it would receive were it weighted as *essential* to a supervisory job. The third scale appears to be fairest in weighting traits in relation to jobs because it narrows still further the gap between *essential* and *desirable,* that is, to one-quarter the total scale.

The smaller the gap between the numerical weights in relation to the whole scale, the less will be the distortion of the total point ratings for

EMPLOYEE RATING SHEET

Name..... Dept.....No.....
Present Job..... Date.....
Rated by.....Foreman Total Service.....Yrs.....Mos.....Days
Checked by.....Supervisor From **Employment Record Card.**
Approved by.....Superintendent By.....Employment Dept.

I. CUMULATIVE SERVICE

1 Yr.....	1	22 Yrs.....	11
2 Yrs.....	1	24 Yrs.....	12
3 Yrs.....	2	26 Yrs.....	13
5 Yrs.....	3	28 Yrs.....	14
8 Yrs.....	4	30 Yrs.....	15
10 Yrs.....	5	32 Yrs.....	16
12 Yrs.....	6	34 Yrs.....	17
14 Yrs.....	7	36 Yrs.....	18
16 Yrs.....	8	38 Yrs.....	19
18 Yrs.....	9	40 Yrs.....	20
20 Yrs.....	10	42 Yrs.....	21

II. DEPENDENTS

4 Persons	4
3 Persons	3
2 Persons	2
1 Person	1

III. MARITAL STATUS

Married man	1
Single woman	1

IV. CITIZENSHIP

Citizen	5
Alien (service 25 yrs. or more) with or without 1st papers	5
First papers	3
Alien (service 20 yrs. to 25 yrs.)	2
Alien (service 15 yrs. to 20 yrs.)	1

V. ATTENDANCE

Perfect	4
1–2 absences	3
3–4 absences	2
5–6 absences	1
Over 6 absences	0

VI. QUANTITY

Day workers

Above average	6
Average	4
Below average	2
Unsatisfactory	0

Bedaux workers

80 Pt. Hr and Over	6
70–79 Pt. Hr.	4
60–69 Pt. Hr.	2
Below 60 Pt. Hr.	0

VII. QUALITY — *Ans.* (√) — *Pts.*

A. To what degree is the product of the employee up to the department's accepted standard of quality?
1. Above standard requirements? Yes.....1
2. Meets standard requirements? Yes.....1
3. Not more than occasionally below standard requirements? Yes.....1
4. Is this person employed on a job of high-quality requirements? Yes.....1

B. Workmanship
1. Is this person one who is orderly and handles tools and equipment properly? Yes.....1
2. Does this person handle materials economically? Yes.....1

C. Degree to which Supervision check is necessary to maintain quality?
1. Needs little or no checking? Yes.....1
2. Needs no more than average checking? Yes.....1

Factor VII Total Credit.....

VIII. VERSATILITY, ADAPTABILITY, SKILL
1. Has this person learned new work within the expected time? Yes.....1
2. Is this person able to fill satisfactorily 2 major jobs without training? Yes.....1
3. Is this person able to fill satisfactorily 3 major jobs without training? Yes.....1
4. Can this person readily adjust to radical changes in the requirements of his present job? Yes.....1
5. Does this person show the capacity for learning different work? Yes.....1
6. Would this person adjust readily to transfer to another major job? Yes.....1
7. Can this person actually fill the job he is on with more than ordinary skill? Yes.....1
8. Can this person perform a highly skilled job with apparent ease and dexterity? Yes.....1

Factor VIII Total Credit.....

IX. CONDUCT, COOPERATION
1. Is this person one who does not play pranks that might endanger other workers? Yes.....1
2. Does this person refrain from objectionable language or actions on the job? Yes.....1
3. Is this person always willing to carry out instructions and requirements of job? Yes.....1
4. Is this person always willing to try new methods? Yes.....1
5. Does this person use a helpful attitude in notifying Supervision regarding conditions that require attention? Yes.....1
6. Does this person call to attention of Supervision defective work received? Yes.....1
7. Is this person one who does not offer excuses or alibis to avoid accepting his proper responsibilities? Yes.....1

Factor IX Total Credit.....

Total Rating .....

REGULATIONS GOVERNING SERIOUS MISCONDUCT

Any serious violation of the rules of conduct involving intemperance, dishonesty, or other misconduct not covered by the above question shall justify in addition to proper disciplinary action or discharge, a deduction of five points from the employee's current rating on Factor IX. Such action, however, shall be taken only after review and approval by the Manager of Industrial Relations.

REGULATIONS GOVERNING TARDINESS

Two points may be deducted from Factor V in the case of an employee who is habitually late.

FIGURE 190. EMPLOYEE RATING FORM BASED ON SPECIFIC–ITEMS METHOD OF RATING

various individuals. Application of these principles is made in the suggested supervisory rating form shown on pages 448–450.

Traits may be weighted also in the assignment of point values to them. Different point values are applied to traits to make ratings and to score the results. In establishing the maximum points to be allowed any trait, the rating committee recognizes the differences in importance of traits as related to the proper fulfillment of jobs. As reflected in a final composite score of an individual who has been rated, the various traits are weighted.

4. The Rating Procedure

Who will rate. Among the typical firms having considerable experience in rating, the actual rating is done by those next in rank above the persons rated, or by top executives. (Of 14 firms replying to a questionnaire on this point in relation to supervisory ratings, only one stated that rating is done exclusively by the personnel department. In the rating of supervisors organizations ask supervisors of the same rank to rate one another. Where this is done great care must be taken to check the results for possible prejudices and bias.)

Instructions. It is most important that uniform instructions be given those who are to do the actual rating. Unless the same terminology and rules are applied by all who rate any individual, the results achieved will not be comparable and the persons rated may suffer from unfair treatment. Instructions for rating are frequently stated at the top of a rating sheet or on its reverse side.

Frequency of ratings. While new employees are rated semiannually, occasionally the practice is to rate all employees once a year. Those cooperating in the special questionnaire study on rating practice noted these special occasions:

Change of position.
When some occasion suggests desirability.
Prior to any change in supervision for supervisors.

Checking and reviewing. Most firms agree that it is good practice to have the completed ratings checked or reviewed by members of the personnel department or some officers higher than the persons doing the rating. Moreover, it is generally thought the new rating should be compared with previous ones. The comparisons are usually made by the personnel department, where data regarding individuals are on file. The principal value of reviewing is to reveal any great discrepancies in ratings and to ascertain whether or not the persons being rated are making progress. It appears to be the belief of most industries that reference to previous ratings can only arouse prejudices and biases and prevent giving credit for corrected faults.

5. Use of the Results

Completed ratings are most useful when they are analyzed to show how well individual employees meet the requirements of their jobs as defined in the specifications for their positions. With few exceptions, the firms whose plans have been studied discuss completed ratings with the persons rated. A primary purpose of rating programs is to uncover any individual shortcomings and to use completed ratings as a basis for making constructive suggestions. Ratings should never be concealed lest some of those rated come to doubt their real purpose. Secrecy regarding the results can only breed distrust and poor morale.

6. Training of Raters

Rating programs produce the best results when both the raters and those rated have a clear understanding of their purposes and the techniques by which rating is to be accomplished. Too little attention has been given to proper education to introduce and assure success of rating programs. Most rating sheets contain brief prefatory instructions which help to ensure uniformity in procedure.

Almost without exception, those who rate are instructed to deliberate in making ratings. This is sound practice and is particularly productive of results when raters discuss among themselves the persons being rated. The discussion method is principally used, however, in modifying separate ratings already made privately, or when ratings are reviewed by the next higher official.

The purpose of rating is to minimize prejudices and bias so prevalent in subjective judgment everywhere. Every effort should be made not only to present clear instructions but also to encourage deliberation and open discussion in order to provide a truly composite picture of an individual's real worth. The best results from a rating program will be obtained in those industries where adequate training courses and discussion groups consider rating from every possible angle. It should be the function of the committee in charge of the rating program to meet periodically with those who do the rating and provide opportunities for discussion of the program in use. Such discussion groups could be the nucleus for the development of a rating manual to be used by others less familiar with the rating program who may be called upon to participate in it.

7. Educational Program

All employees (shopworkers, supervisors, and executives) should be thoroughly acquainted with the factors by which they are appraised in order that they may make the best possible showing with respect to each. The method of weighting and scoring the rating form should be

explained to them, and they should be allowed to criticize features of the rating form which they believe to be unfair. Furthermore, the success of the program is by no means certain unless those rated are given these assurances regarding the rating program: (1) ratings are to be made fairly and without discrimination; (2) all ratings will be reviewed by impartial judges; (3) ratings will be used to improve a man's worth to the firm and not as a weapon of dismissal; (4) each man rated will be given a clear picture of his rating and an opportunity to defend himself if he is convinced that he has been treated unfairly.

Dangers of Rating

The primary sources of danger in any rating program are the rater himself, the rating form, the frequency of making ratings, secrecy regarding the results, and inadequate education.

The rater himself. The results to be achieved from any rating program can be no better than the judgment, honesty, and fairness of those who administer it. In order to protect persons rated against possible dangers which may arise in this connection, it is desirable that the rater be required to justify his ratings. Moreover, care must be taken to assure that ratings are always reviewed by superiors and compared with previous ones.

The form. Too much care cannot be exercised in the selection of traits to be measured and the formulation of clear definitions. If this is not done, rating results are likely to be unsatisfactory. Forms should be printed attractively on good paper so that those who are to rate will attach due importance to what they are doing. (A mimeographed form has a bad psychological effect.)

Frequency. When ratings are made too often, they become irksome and the results suffer from haste on the part of the raters. The committee in charge of developing rating must see to it that ratings are made with sufficient frequency to be useful and comparable, but it must guard against too frequent ratings.

Secrecy. The primary purpose of ratings is to correct shortcomings of those who are rated. Each employee rated is entitled to a frequent impersonal, constructive discussion of his rating. Unless this is done, animosity and distrust will be aroused and forestall intended benefits for both top management and those who are rated.

Inadequate education. Possibly the greatest danger to any rating program is lack of understanding of its purposes and uses. No matter what amount of care is exercised in developing a system and how fair it is in execution, unless its purposes and intended uses are made very clear to those who are affected by it, the program will be enshrouded with mystery and give rise to suspicion and distrust.

RATING PLAN FOR SHOPWORKERS

Selection of Traits

One of the most difficult requirements of a committee on merit-rating procedure is to select the traits which are to be used to measure worker performance. The problems encountered are as follows: uniformity of definition, significance of relationships of the traits, and prevention of overlapping.

The traits commonly used to rate shopworkers may be grouped under headings for purposes of clarity.

1. **Performance.** The traits which measure what the worker does on his job: accuracy or quality of work, speed or quantity of work, efficiency or use of working time, and job knowledge.
2. **Potential.** Traits which measure the worker's aptitude, inherent abilities, ability to progress, intelligence, and leadership.
3. **Behavior.** Traits which show the attitude of the individual, his influence on general morale, and application in his work: versatility, attitude, safety record, and attendance.
4. **Labor's factors.** Traits which are of importance in considering an employee's responsibilities and which represent the employee's point of view: citizenship, number of dependents, length of service.
5. **Personal factors.** These traits include those which have a direct bearing on an employee's work through his attitudes and capacities for getting along with others: cheerfulness, initiative, loyalty, enthusiasm.

These specific traits, listed in each of the foregoing general categories, may be reclassified again as objective and subjective, that is, those which lend themselves to specific objective measurement and those which are purely matters of opinion. Traits which lend themselves to objective measurement are accuracy or quality of work, speed or quantity of work, safety record, attendance, citizenship, number of dependents, and length of service. The traits which must be measured subjectively or appraised by judgment are efficiency of use of working time, job knowledge (these may be reflected in accuracy and speed), intelligence, ability to progress, leadership, versatility, attitude, cheerfulness, initiative, loyalty, and enthusiasm.

Suggested Rating Sheet for Shopworkers

All rating sheets are very much alike and each represents the personal idiosyncrasies of those who have prepared it. For purposes of persons interested in checking existing rating plans or inaugurating a new rating system, Fig. 191 presents a rating form which represents the best practices of representative firms having rating programs in use. It is a rating sheet which recognizes the use of subjective and objective measures.

RATING SHEET

Employee..... Clock No..... Job No.....

Foreman..... Dept..... Date.....

Consider His Reaction to Shop Life and His Effect on the General Morale in the Following Circumstances

Score

1. ATTITUDE TOWARD COMPANY

actively antagonistic	passively antagonistic	cooperates passively	✓ cooperates actively

2. ATTITUDE TOWARD SUPERIORS

disregards wishes	follows orders but grumbles	follows orders cheerfully	✓ tries to help make good

3. ATTITUDE TOWARD FELLOW EMPLOYEES

puts blame for errors on them	looks down on them	✓ helps them when told	extremely considerate

4. OBSERVANCE OF SAFETY RULES

openly disregards	believe disregards when not watched	observes all major rules	✓ observes all and has own

Consider His Ability to Plan for Himself and to Execute Such Plans

lives in a rut	has few suggestions	offers many suggestions, some good	✓ offers many suggestions, many good

Consider the Degree to Which He Favorably Influences the Thoughts and Actions of Other Employees

follows	thinks for himself, lets others do likewise	helps mold opinions of small group	✓ has wide influence

	Rating	
QUALITY	*50*	
QUANTITY	*75*	
CITIZENSHIP	*10*	
NUMBER OF DEPENDENTS	*15*	
SERVICE	*22*	
ACCIDENTS	*40*	
ABSENCES	*18*	*230*
	Total →	

Put Reasons for Ratings on Other Side

FIGURE 191. RATING SHEET FOR SHOPWORKERS

The subjective part of the sheet (upper portion) may be filled in by a foreman, and when completed represents his opinion of an employee's attitude or initiative and leadership. The rating sheet shown in Fig. 191

requires use of a stencil to score upper portion where traits are measured subjectively. A typical stencil for doing this is shown in Fig. 192.

The lower half of the sheet contains objective measures and may be completed by clerks in the personnel department or in the office of the person in charge of rating. The objective measures used are quality, quantity, citizenship, dependents, service, accidents, and absences. The means of computing point values for each of these is as follows.

Quality. The determination of the score for quality depends largely upon the detail of spoilage records available. Where records are com-

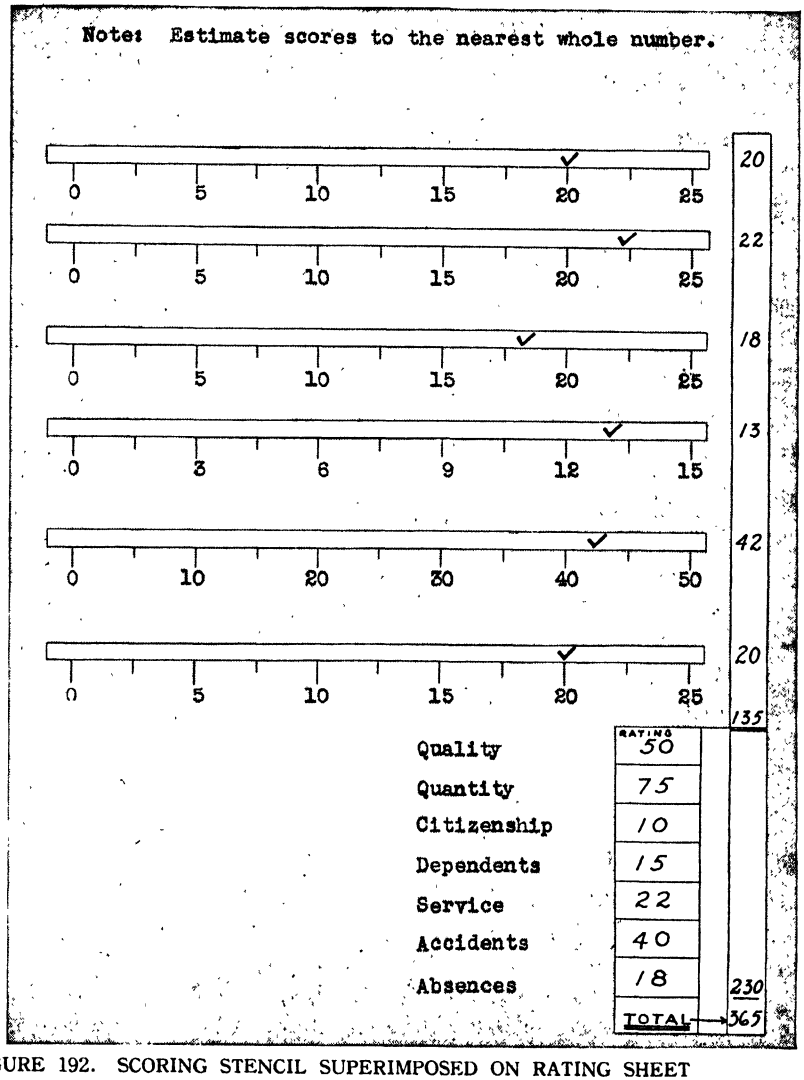


FIGURE 192. SCORING STENCIL SUPERIMPOSED ON RATING SHEET

plete, a spoilage median for each job should first be figured. By dividing each employee's per cent spoilage into the per cent normal, and subtracting from the normal, a per cent deviation for each employee is obtained. This should be entered on the rating sheet.

10	55	45	35	25	15	5	0	0	0	0	0
20	60	50	40	30	20	10	0	0	0	0	0
30	65	55	45	35	25	15	5	0	0	0	0
40	70	60	50	40	30	20	10	0	0	0	0
50	75	65	55	45	35	25	15	5	0	0	0
60	80	70	60	50	40	30	20	10	0	0	0
70	85	75	65	55	45	35	25	15	5	0	0
80	90	80	70	60	50	40	30	20	10	0	0
90	95	85	75	65	55	45	35	25	15	5	0
100	100	90	80	70	60	50	40	30	20	10	0
	− 10	− 8	− 6	− 4	− 2	0	2	4	6	8	10

Per cent deviation from normal spoilage.

FIGURE 193. QUALITY SCORING

To convert this figure into rating points, a chart similar to Fig. 193 may be constructed. To secure the rating for an employee working with material valued at 60 cents per unit, whose deviation is − 4 per cent, the scoring clerk would look at the interception of the vertical column at − 4 and the horizontal column at 60. By use of this table, an employee who saves the company money by reducing his spoilage below the average for his job will be rewarded in proportion to the value of the material with which he works.

The primary difficulty encountered in the foregoing is in determining the employee's median spoilage. In order to reduce the amount of clerical work necessary to obtain this number, it may be computed for a typical week or a group of days selected at random. If the number varies from the normal by a very large amount, out of fairness to the employee another sample should be taken to check the first.

Quantity. The same problem must be solved in computing the median production of the employee for the period. A per cent efficiency, from which the rating can be figured from the curve in Fig. 194, may be obtained by dividing this number by the standard production.

Citizenship. In the evaluation of citizenship, the employee is given 10 points if a citizen of the country and none if not. If desired, this may be broken down and a credit of 5 points given if the employee has taken out his first papers.

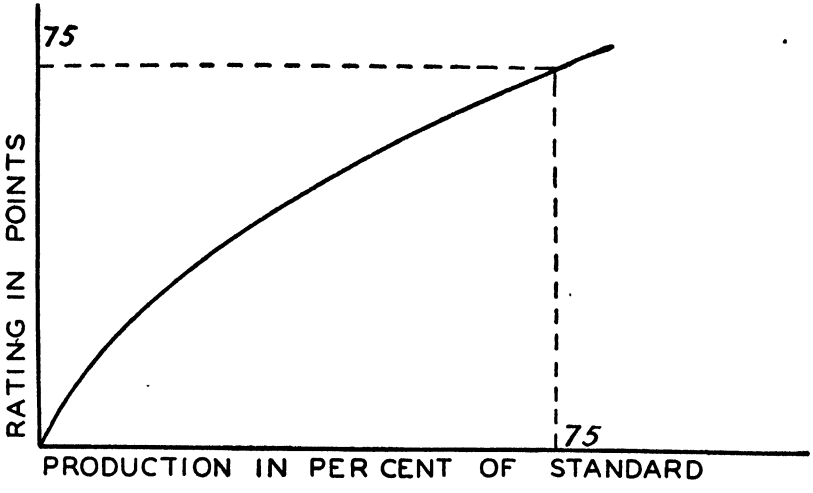


FIGURE 194. QUANTITY SCORING

Dependents. The score for the number of dependents is taken from the following table:

No. of Dependents	*Score*
0	0
1	10
2	15
3	20
4	25

Service. The score for the number of years continuous service is taken from a table similar to:

No. of Years	*Score*	*No. of Years*	*Score*
0	0	6	15
1	2	7	17
2	5	8	20
3	7	9	22
4	10	10	25
5	12		

Accidents. The scoring table for the number of accidents chargeable to the employee may be constructed as follows:

No. of Accidents	*Score*
0	50
1	40
2	25
3	5
4 or more	0

Absences. Score for the number of unexcused absences is based upon:

No. of Absences	*Score*
0	25
1	22
2	18
3	13
4	7
5 or more	0

RATING PLAN FOR SUPERVISORS

Supervisor rating is comparatively new. Every progressive manager recognizes that where competent shop leadership is lacking, it is impossible to achieve maximum efficiency. Regardless of the care exercised in the selection of supervisors, the acid test of the value of each to his employer is demonstrated in job competence. Consequently, the use of merit-rating systems is a definite aid to management in appraising the effectiveness of a supervisory force.

The term "supervisor" is used in this report to include foremen, gang bosses, superintendents, department heads, department managers, and even top executives of industrial firms. *In brief, anyone who is responsible for the work of others.*

Selection of Traits

In the selection of traits by which to measure supervisors, it is necessary to keep in mind that the supervisor is responsible both for his own work and the work of others. The factors of most concern to management regarding any person in a supervisory capacity may be grouped under three major headings.

Personality. Those factors that have to do with the capacities for working cooperatively with others are appearance, ability to get along with others, character, and intelligence.

Performance. Traits which bear directly on what the supervisor does on his present job are present productivity (use of own working time), productivity of unit for which supervisor is responsible, personal efficiency in using own time, and efficiency of unit for which responsible.

Executive capacities. Traits which show the potentialities of growth: initiative, organizing ability, leadership, and cooperation.

Application of Subjective and Objective Measures [1]

For the most part, supervisory rating must be done subjectively, that is, various individuals must attempt to express their judgment of

[1] Asa S. Knowles, "Merit Rating of Supervisors, Foremen and Department Heads," *Personnel*, American Management Association, New York, November, 1940, Vol. XVII, No. 2, p. 12.

how well supervisors fill their jobs. Unfortunately, supervisor rating does not lend itself so readily to objective measures as does the rating of shopworkers. In this connection, some executives have suggested that supervisory and junior executive performance and capacities might be measured more specifically if provision were made to determine the degree to which supervisors meet standard costs as established for the work which they do themselves or for which they are responsible. There is no doubt that the demonstrated ability of supervisors and junior executives to keep actual costs in line with recommended or established standard costs is a fair indication of a type of efficiency, particularly in those organizations where standard costs have been in use for a considerable period and are therefore entirely fair.

It is significant, however, that at the present time none of the firms studied appears to recognize the comparison of actual and standard costs as a measure of the effectiveness of supervisors in their jobs except as it may be considered indirectly in gauging quantity and quality performance. Undoubtedly, many could do so to advantage.

Careful reflection reveals some objections to using comparisons of actual and standard costs as measures of performance and ability.

1. When supervisors are subject to appraisal on the basis of their relative abilities to keep within the bounds of established or recommended standard costs, they are immediately dependent on the whims and accuracy of the Accounting Department. For example, accountants do not always agree on the classifications of expenses, and standard costs systems will vary from plant to plant and even in subsidiaries of a single organization. An appraisal of the results achieved by supervisors through comparison of their actual cost records with standard costs may lead to unfair criticisms and conclusions.
2. Many industries where supervisory rating is sorely needed do not lend themselves to the effective use of standard cost systems. This is particularly true of industries that must constantly retool or change product lines. Standard cost data either do not exist or are not sufficiently reliable to justify use in a rating system. (Firms having no standard costs and considering the adoption of supervisory rating might be less inclined to adopt it if it appeared to involve the establishment of a standard cost system.)
3. The use of a standard cost system can never measure the abilities needed to cope with the imponderables which arise in handling people and unusual events, which are perhaps the most important items to measure in a supervisory rating program.

Suggested Rating Sheet

A supervisory rating form is shown in Figs. 195 and 196. With minor modifications to suit particular needs, the form might well be used for any or all of the following:

1. The measurement of how well supervisors fill their present positions; and to call attention to individual weaknesses that can be corrected.
2. The selection and guidance of men for promotion (in particular, those capable of filling executive posts).
3. Guide in the determination of supervisors' salaries.
4. Calling the attention of management to particular factors in individual cases, that is, special abilities, capacities for special job assignments.
5. Providing information of value in deciding upon transfers.

The form is to be filled out by the immediate superior of the person rated and by fellow supervisors on a semiannual or annual basis. Instructions for using the rating form appear at the beginning of the sheet. These are numbered to correspond with the columns. In Col-

RATING REPORT FOR SUPERVISORS, FOREMEN, AND DEPARTMENT HEADS

Name..... Division..... Date.....

Position..... Department..... Code.....

Note: Numbers in instructions correspond to column head numbers.

1. Read carefully the descriptions of the traits to be evaluated under each heading. Place a check mark in Column 1 under the heading of the division which most nearly expresses your considered judgment of each trait as applied to the person you are rating, i.e., Superior ( ), Above Average ( ), etc.

2. List in Column 2 those considerations stated under each trait which you believe to be deficiencies or weaknesses of the individual you are rating, i.e., neatness, voice, etc. Correction of the items you list will improve the individual's rating for this trait.

3. Each trait does not have equal bearing on all positions. To assure greater usefulness of the final results, raters must state their considered opinions of the relative significance of each as requisite to the job now held by the person rated, i.e., appearance, ability to get along with others, etc. Post in Column 3 the weight you accord each item as follows:

For items:	Assign weight of:
Essential to fill position properly	4
Desirable to fill position properly	3
Unimportant to fill position properly	2

4. To determine the point rating for each trait (R × W), multiply the point value of the rating recorded in Column 1 by its assigned weight in Column 3 and post in Column 4. Rating values are as follows:

Superior	8	Average	4
Above Average	6	Below Average	2
	Unsatisfactory	0	

5. Column 5 is for use of the Personnel Department in reviewing and re-grading point ratings.

FIGURE 195

	1					2	3	4	5
	Superior	*Above Average*	*Average*	*Below Average*	*Unsatisfactory*	*Remarks*	*Weight*	*Point Rating ($R \times W$)*	*Review*
I. PERSONALITY:									
a) Appearance Consider dress, manner, physique, neatness, voice.									
b) Ability to get along with others Consider courtesy and tact, temperament, and self-control.									
c) Character Consider dependability, sincerity, courage, and consideration for others.									
d) Intelligence Consider ability to learn, mental alertness, judgment, imagination, flexibility in handling new problems, ability to reason logically.									
Total Personality Point Rating:									
II. PERFORMANCE:									
a) Personal productivity Consider use of own working time and amount of work done personally (not by unit for which person rated is responsible); consider also diligence in fulfilling duties.									
b) Productivity of unit for which responsible Consider amount of output or accomplishment of satisfactory quality.									
c) Personal efficiency Consider promptness in completing work for which person rated is personally responsible; care and accuracy in completing necessary records and reports.									
d) Efficiency of unit for which responsible Consider economy in operation; prevention of waste of material, time and equipment; accident record of subordinates; care and orderliness of equipment and tools.									
Total Performance Point Rating:									

FIGURE 195, *continued*

	1					2	3	4	5
	Superior	*Above Average*	*Average*	*Below Average*	*Unsatisfactory*	*Remarks*	*Weight*	*Point Rating (R × W)*	*Review*
III. EXECUTIVE CAPACITIES:									
a) Initiative Consider energy, ingenuity, self-starting ability.									
b) Organizing ability Consider ability to select effective personnel, to plan and coordinate systematically, to determine policies, and make clear assignments of responsibility and authority.									
c) Leadership Consider ability to influence others by examples of good work, qualities for inspiring others, teaching ability, patience and firmness in dealing with subordinates, freedom from prejudice and bias.									
d) Cooperation Consider capacities for teamwork, freedom from jealousy, willingness to subordinate personal desires, loyalty to fellow supervisors, company officials, etc.									
Total Executive Capacities Point Rating:									

DO NOT FILL IN THIS SPACE

Rating Summary:

	Over-all Rating Scale (Expressed as percentage of total possible score)
I. Personality.....	88–100.....Superior
II. Performance.....	63–87.....Above Average
III. Executive capacities.....	38–62.....Average
	13–37.....Below Average
	0–12.....Unsatisfactory

Total Point Rating:

Rated by..... Reviewed by.....

Position..... Filed.....date

FIGURE 196, *reverse side of Figure 195*

umn 1 the person rated is checked as "superior," "above average," and so on, with respect to the traits listed. Column 2 provides space for recording the rater's observations of weaknesses or shortcomings of the individual under each trait. These remarks will prove helpful when referring to the form at some later time, and serve indirectly as a means of *justification* of each rating.

Provision is made in Column 3 for weighting each trait as essential, desirable, or unimportant to the particular job held by the supervisor being rated. Column 4 records the total point rating, calculated by multiplying the assigned weights by the rating values shown under Instruction 4. In keeping with desired practice, Column 5 provides space for the personnel-department review of the ratings.

The rating sheet demands that supervisors be rated on a scale ranging from 8 points for superior, to 0 for unsatisfactory in performance of various characteristics. The rater is then asked to consider each characteristic or trait as essential, desirable, and unimportant, and these are weighted essential, 4; desirable, 3; unimportant, 2. This does not mean that these values are to be accepted universally by companies as fitting all needs; they should be used only as a guide for those who are undertaking the establishment of a supervisory rating program. The point values and weights used by various companies having supervisory rating programs are meaningful only as they are carefully defined by those who use them.

This rating sheet recognizes that total ratings for various supervisors must be comparable or they will possess little value, that is, individual ratings must be reduced to total scores which may be compared with similar ratings. Provision is made to do this on the reverse side of the form, Fig. 196, under the heading: "Over-all Rating Scale (Expressed as percentage of total possible score)."

Since the form in Figs. 195 and 196 provides for weighting each trait according to its importance to the job held by the supervisor, it is necessary to eliminate from consideration the importance of each trait in relation to particular jobs (shown in Column 3) if the ratings made on this particular form are to be numerically comparable. This may be accomplished by multiplying the sum of the weight column by the maximum possible rating of 8, and then using the result as a base to find a percentage which expresses the total point rating attained as related to the maximum attainable, that is, $\frac{\text{total point rating score}}{\text{maximum possible score}}$, or $\frac{R \times W}{8 \times W}$. The percentages for determining whether the over-all rating given any individual is Superior, Above Average, and so on, are shown on the form.

Uses of the Completed Rating Form

The primary uses of the rating sheet are (1) the uncovering and correction of individual weaknesses, (2) selection of men for promotion, and (3) guidance of men in their self-development.

Column 2 of the rating sheet provides the opportunity for recording the subfactors which define each of the traits listed and which are lacking or unsatisfactory in the person rated. These weaknesses are naturally reflected in the effectiveness with which supervisors fill their jobs. They should be made known to them in order that they may bend every effort toward improving their worth to their employers.

A rating sheet of the type shown in Figs. 195 and 196 provides valuable information which can be used to determine the promotional potentialities of supervisors. The following steps of a clerical nature are requisite to the achievement of this end:

1. Standard weights for each trait as related to a specific supervisory job should be established. The weights recorded for the traits listed on the rating sheet show what raters believe to be their relative importance to the supervisory position. These should be used to establish composite *standard weights*, which will be different for each supervisory position under consideration.
2. The *point ratings* for each trait given supervisors by raters in checking Column 1 should be averaged separately. The average score for each trait should be entered on a permanent file copy.
3. When occasion arises to select a man for promotion (or transfer), the data compiled in steps 1 and 2 can be used in conjunction to determine which supervisors are best suited for the positions involved: that is, the *point ratings* of supervisors can be multiplied by the *standard weights* established for the traits as related to the particular position. This will give a score which can become an important guide in determining the degree to which each supervisor may be expected to meet the qualifications demanded by the position to be filled.

Completed ratings may be used to advantage also in aiding ambitious employees who wish to prepare themselves for positions above their present rank. Multiplication of any supervisor's point ratings by standard weights assigned the traits requisite to fill positions above his rank provides a tool by which top management may give intelligent guidance to subordinates. Careful study of the resulting scores will indicate the kind of work for which each supervisor is best suited, and, consequently, the training that he should undertake.

CHAPTER XXII

EMPLOYEE COMPENSATION

At the dawn of history man made or killed whatever he needed and it was his. He either worked or starved, and was of necessity self-sufficient. Then came the beginnings of specialization, with one man a farmer, another a hunter or herder, and another a potter or perhaps a weaver. Through barter of his own surplus goods, each man gained from the others those things which he needed and could not provide for himself.

As civilization progressed, not only individual men became specialists in hunting or herding, but whole tribes, under the direction of a chief who told his followers what to do and divided up the gains among them. It is with the introduction of group work that the problem arises as to how much of the gain obtained by the group should go to any one individual member. It is the same fundamental problem as that of wage determination in our industrial system. Unlike the primitive hunter, a man does not own the fruit of his labor, and he may not even own the tools with which he works; it becomes difficult to determine what he should receive in compensation for his work. When one man carries out the complete productive process, such as farming or chopping wood, the procedure has often been to give him a certain portion of the total product — so many cords of wood or bushels of wheat. But as the division of labor increased many different workers and types of work became involved in such production; further, the individual receiving even a part of the total product would then be forced to exchange it in order to obtain the variety of food and clothing required. A man cannot specialize in chopping wood and survive unless he is able to exchange part of his share of the wood for food and clothing.

Problems of this type eventually result in a medium of exchange — money. With this more convenient substitute as a means of paying men for their work, there arose so-called entrepreneurs who were to make their living not alone from their own toil, but also through the toil of others.

Until recently, most employees have been paid on a time basis. They have been paid so much per hour, day, week, or year. Thus in part employees have been deprived of incentives to work which existed

when what they did was their own gain. The payment of wages in money tended to fix prices for different classes of labor subject to the law of supply and demand and to eliminate considerations of individual differences and efficiency. Some workers found that from a short viewpoint, at least, it was not always necessary or advisable for them to work at capacity. As long as industries remained small, self-respect and community standing as well as owner management served to check the foibles of each worker and prevented any too obvious soldiering on the job.

With the advent of the Industrial Revolution in the eighteenth century and the rapid growth of both cities and factories, problems of how much to pay various workers for different kinds of work became a major problem of factory managers.

DETERMINING HOW MUCH TO PAY

Wages still constitute one of the most controversial problems of industrial management. Typical questions to be answered are: How much pay should an employee receive? What is a fair day's pay for a fair day's work?

It is very difficult to decide the value of work at the time it is performed. For example, the value of a hammer cannot be determined by looking at it. Only by continually using the hammer until it breaks can we make a fair decision. Yet it is necessary to pay wages immediately to the workman who made the hammer. In the same way, it is impossible to measure the success of a football coach until the close of the entire season, yet he must be paid by the month during the season. This is also true of managers, foremen, and workmen. The value of their work depends largely upon the success of the whole business undertaking, and this cannot be known until considerable time has elapsed since the work was performed. Another parallel is that of artists who live in poverty, only to have fabulous sums paid for their work after they are dead. The problem of making immediate payments for work narrows down to finding a convenient measure of what the work is probably worth.

The total wages a man receives is equal to a *basis of pay* multiplied by a *rate*. The basis of pay is some measure of his work — the number of pieces completed or number of hours worked. The rate is the worth of the unit of measure selected as the basis of pay. For example, if a man is paid on a time basis at a rate of $0.50 an hour, and works for 8 hours, his total pay is $4.00. Another example, if a man is paid on a quantity basis, receiving $0.02 per piece, and makes 300 pieces, his total pay is $6.00.

All discussions of wages should include both factors: (1) basis of pay, and (2) rate. The basis of pay must be selected first because the rate is stated in terms of the basis of pay, that is, number of dollars per hour or per piece. The considerations involved in selecting each are different and will be examined separately, but the final determination of wages brings both factors into play and requires that they be coordinated with each other.

As soon as a basis of pay has been selected, the rate may be adjusted so that the total pay amounts to any desired figure. For example, if it has been decided to base a mechanic's pay on the number of valves he grinds, and he usually grinds 60 a day, at the rate of $0.10 per valve, he would receive a total pay check of $6.00. If this total amount is too high or too low, it may be changed by simply increasing or decreasing the rate. In the same way, payments made upon an hourly basis may be adjusted by altering the hourly rate.

Rate of Pay

Since the rate of pay may be easily changed to give any desired amount, the determination of wage rates — either piece rates or hourly rates — determines the total amount of payment. Management is interested in the total paid to all workers, which is the labor cost of manufacturing. Each individual worker is interested in the total amount he receives, which is his total income.

The following factors enter into the establishment of the rates of pay:

1. **Financial condition of the company.** A company which is in a strong financial condition can afford to pay relatively high wages, and consequently, its rates may be higher than those of companies which are not in good financial condition. Nearly all manufacturers must determine what part of the expected income can be paid in wages and salaries; in the majority of instances this amount is the difference between the combined sum of material costs and the cost of overhead charges (excepting wages and salaries) and the cost of total sales of the products manufactured. This is expressed in the following formula:

   Salaries and wages = costs of sales − materials and other expenses

   Other considerations may enter into the determination of this total amount of money to be paid for wages and salaries, such as scarcity of labor required, demands of organized groups (unions) for an increased total increment to labor, and so on. When labor demands more than the amount management can afford to pay in wages and salaries and still stay in business, or when management tries to withhold part of this total amount, labor strife becomes most bitter.

   When industry has a monopoly or some special advantage — secret processes, patents, advantageous location — the share of its total income which it is willing to pay to labor is less subject to controversy than in

the more highly competitive industries. Only when demands for increased wages start to raise costs to the point where profits are seriously endangered or increase prices so far as to be detrimental to sales volume, would there be a problem concerning the determination of the total wages to be paid.

2. **Equitable distribution among employees.** The rates for different types of work should reflect the varying degrees of requirements of different jobs; and the rates paid individual workmen should also recognize payments for loyalty, service, experience, and so on. These considerations are treated at length in the discussions of Job Evaluation and Merit Rating.
3. **Current market rates.** Like all prices, current market rates express the value which is generally accepted by society. This value is the result of previous bargaining between buyers and sellers, or employers and employees in this case. Some companies who wish to boost employee morale make a practice of paying slightly more than the current market rate.
4. **Individual bargaining.** In the past, most wages which have not been a reflection of current market rates have been determined by bargaining between management representatives and individual employees. The resulting rates have been decided in favor of the company, frequently because its representatives have been expert at making bargains and because the company could easily afford to lose just one worker, whereas the worker's very livelihood was at stake.

   It is the recognition of this fact, that the individual worker is at a great disadvantage if he must bargain individually with the company and its representatives, that has led to successful organization of labor unions despite the opposition of many manufacturers.
5. **Collective bargaining.** With the advent of craft and industrial unions, many rates are now decided by the process of collective bargaining. That is, industrial workers as a group are represented by union officials who bargain with management to decide upon wage rates.

   All rates in the last analysis are the result of some type of bargaining. Collective bargaining sets up definite machinery in an attempt to make resulting rates as fair as possible. Rates established by collective-bargaining agreements should also reflect the other factors listed above.

BASES OF PAY

The two principal bases of pay have been indicated previously — *time* and *quantity* of work. The second really amounts to *speed*, as will be explained in the following paragraphs which consider each of these bases in detail.

Time as a Basis of Payment

The time which a man spends on a job is very easy to measure. Any convenient unit of time may be used. Labor is paid by the hour; office and clerical workers, by the week; supervisors and executives, by the

month or year. When the staff is paid on the weekly basis, it is only necessary to know what time a man is present on the job and multiply this by the rate.

The time basis of payment is very satisfactory if the rates reflect the value of the time spent on the work. If the total value of a piece of work is known, then the hourly rate may be found by dividing the value by the number of hours. In most cases the total value of the work is difficult to determine, particularly at the time when it is done, and the rates are the result of other factors previously discussed.

The disadvantage of this basis is that *time itself* does not measure effort or results, but only the presence of a man on the job. While the value of the work done should be reflected in the rate which he is paid for his time, the rates tend to be "sticky"; as soon as they are set, they tend to remain as they are. Rates are determined largely by judgment and bargaining, and the effort involved in adjusting rates causes them to remain constant.

Consequently, individual employees may feel it is not worth while to work harder than fellow employees because their additional effort will not receive immediate recognition in the pay check. Their wages remain the same as long as they are merely present on the job; their attitude often expressed is: "So why not take it easy?"

When there is a limited amount of work to be done after which an employee may be discharged, the time basis of pay encourages a "stretchout" of the work to make it last as long as possible, so that earnings will be greater. Even when there is no threat of discharge, workers can "soldier," that is, relax on the job, and still receive the same amount of money.

Since the time basis of payment does not encourage men to work hard, it becomes the responsibility of foremen and supervisors to keep men working. The foreman must act as a policeman, checking up on the men to see that they are busy as well as telling them how and what to do.

One of the distinct advantages of the time basis of payment is that it gives the worker some security against sudden reductions in his income. Workmen cannot make investments in homes or automobiles, if they fear constantly that their incomes may be reduced because of any one of many causes. In addition, the time basis of payment protects the worker against reductions in income due to temporary reductions in personal efficiency, whether this results from unavoidable accidents and sickness, or fatigue from outside activities.

The time basis of payment recognizes that it is necessary for the company to have skilled and trained employees even when there are not jobs enough to keep them working at full speed. The worker is

paid what he is worth to the company from a long-time standpoint, rather than the estimated worth of the work he does at any one time. He is treated in much the same way as a semifixed asset. The financial costs — overhead expenses — of machinery are paid whether or not its full capacity is utilized, and even if it is temporarily broken down. In the same way the worker is paid what he is generally worth to the company over a long period. Besides protecting the worker against sudden reductions in an income, this also protects the company against the loss of a valuable asset — skilled labor — during slack times. This is one reason why executives and those with special skills or valuable knowledge are usually paid on a time basis, and retained on the pay roll during good and bad times.

The basis of payment also affects the procedure for estimating and recording costs. When time basis is employed, the hourly costs of manufacturing are constant, but the unit costs will vary. If the work is done rapidly, the cost of each unit will be smaller than if the work is done slowly.

Job and man rating provide key to time basis of payment. In the opinion of the authors, the time basis of payment is the most desirable provided it is used only after careful determination of job requirements and the measurement of worker performance in relation to these established requirements. In the determination of job requirements and the measurement of performance the techniques of job evaluation and merit rating should be applied. Job evaluation may be used to determine the *base* rate or that portion of the wage system which is paid any person who meets the minimum requirements of a job. It is the portion paid for the job and not the employee who fills it.

To this may be added a *differential* which is the portion of the wage which makes allowance for individual differences in filling a job. It distinguishes between job requirements included in the base rate and what the worker is, how completely he fills the job, and his general value to the company — attitude, versatility, loyalty, and so on.

If careful records of each man's activity are kept and periodic adjustments made in the wage rate, the so-called measured day work results.

When job evaluation and merit rating are used as a basis of determining rate of pay, the steps to be followed are:

1. Motion study to establish standards of output and procedure.
2. Job analyses and specifications to establish job requirements.
3. The use of job evaluation to determine the relative importance of job requirements and the base rates to be paid for these.
4. Employee (merit) rating to allow for individual differences in fulfilling job requirements.

Job evaluation and merit rating in practice demand a periodic review of base rates and differentials because jobs change and individuals change in the performance of their duties.

The authors recommend the use of the weighted point system to arrive at base rates. The principles for doing this are presented on pages 407–409. Weighted points should be used also in determining the amount of pay which will comprise the differential to be given employees on the basis of their performance. When job evaluation and merit rating are used in conjunction each must be coordinated and worked out to provide proper balance between the maximum of base rates and the maximum of differentials. In some organizations, the maximum of the differential to be based on merit rating is made purposely not to exceed 10 per cent of the total pay a worker can receive.

When job and man rating are used to determine pay, wage rates should be reviewed periodically, and as much use as possible made of nonfinancial incentives. These include recognition in the company paper, praise, provision of attractive working conditions, awarding medals, inspiring leadership, and so on.

Speed as a Basis of Payment

The tendency of some workers to soldier on the job has caused some manufacturers to develop a different basis of payment. The objective has been greater accomplishment. The piece-rate plan of payment is based on the idea that men are hired to work, not to stand around, and so their pay is based on the quantity of work they complete satisfactorily. If a man is hired to grind piston rods, his pay depends on how many rods he grinds, so that his weekly pay check reflects the amount of work he accomplishes during a week. In other words, the basis of pay is quantity — the number of pieces produced — and the rate is called "piece rate."

These terms, "quantity basis" and "piece rate," would have the proper implications if the worker had all the time he wished in which to work. He could then continue to work until he had made enough pieces to bring his total pay check up to any amount he desired. However, in our industrial system, men work in a factory building for a definite number of hours each day or week, and they use machinery and equipment owned by the company. The expense of maintaining and operating this productive capacity is paid by the company and profit workers who can maintain a reasonable speed. If the workmen were free to use the manufacturing facilities as long as they wished, the business would have no control over its overhead costs. When a worker takes his own time to do a job on a machine, the number of jobs that can be done on the machine are reduced, increasing the over-

head costs which are a part of the total cost of the product. This may cause the company to lose its competitive position. *Sound management, therefore, is concerned not only with the amount of work a man does but also with the time in which he does it.* Workers paid on a piece-rate basis are really paid according to what they do during a pay period. In reality they are paid according to the speed at which they work, the amount of work per week, not merely the amount.

Speed may be used as a basis for payment only when the quantity of work may be easily measured. Number of pieces completed is a good basis if the pieces are identical, but if each is different, involving various degrees of difficulty and size, there cannot be a uniform unit of measure. While payment based on speed provides an incentive for greater volume, it discourages quality and judgment. It also becomes necessary for supervisors to inspect the work carefully, since the system encourages the sacrifice of quality for quantity. *It was necessary for supervisors to encourage speed under a time basis; it becomes necessary for them to maintain quality standards under a speed basis.* The costing procedure is basically different when speed is used as a basis. The cost per unit tends to be constant but the total cost of manufacturing may fluctuate.

The procedure under discussion assumes that the rate per piece is the same regardless of the worker's speed. This assumption is not always true and different types of rates are discussed below.

Constant rates. The simplest form of piece rate pays the same amount for each piece completed during the week (or other time period). This means that a man's pay is directly proportional to his speed, and that an increase in speed will be rewarded by the same percentage increase in pay. For example, on the assumption that a man is making 100 pieces a week at a rate of $0.30 a piece, he receives a total pay check of $30. If he increases his output by 25 units, a percentage increase of 25 per cent, his pay will also be increased 25 per cent, becoming $8.00 rather than $6.00. In each case the increase is $\frac{1}{4}$ or 25 per cent of the original size. The constant rate is shown graphically in Fig. 197. The speed in pieces per week (or other time period) is measured along the horizontal scale, and the total pay per week (or other time period) is found on the vertical scale. The straight line commencing at the origin, or zero point of both scales, and moving upward to the right, indicates that total pay is directly proportional to speed. Any other straight line moving upward to the right but not passing through the

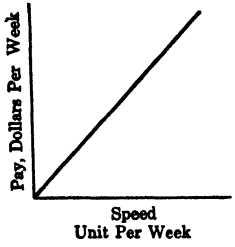


FIGURE 197.
CONSTANT RATE

Straight line passes through origin and slopes upward to the right.

origin would indicate that pay increases as speed increases, but that the pay is not directly proportional to speed. For example, many sales clerks are paid an hourly rate plus a small percentage of their sales. The relation between speed of making sales and total pay is shown in Fig. 198. The line is still straight, indicating that the constant rate is used for that part of the total compensation which depends upon speed. The line does not pass through the origin because part of the total pay depends upon time and not speed.

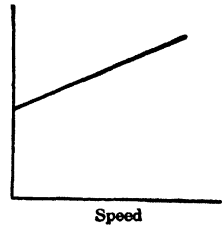


FIGURE 198.
HOURLY RATE PLUS PIECE-RATE COMMISSION
Straight line intersects vertical axis.

Increasing rates. Under increasing rates, the rate per piece increases as the worker's speed increases. For example, a man producing 20 units per day might be paid at a rate of 10 cents per piece, but if he speeds up to 25 units per day he would receive 12 cents for each piece completed.

In contrast with the straight line of a constant rate, the graphic appearance of an increasing rate is a curve which becomes steeper and steeper as it goes to the right. Upon examination of Fig. 199 it will be seen that the same increase in speed will receive greater compensation if it is an increase over a speed which is already high.

When constant rates are employed the increases in pay are directly proportional to increases in speed, but they are not proportional to increases in effort. As a man works faster and faster, each increase in speed requires successively greater increases in effort. An example from athletics illustrates the same principle. A man who can run 100 yards in 13 seconds can bring his time down to 12 seconds by diligent practice, but it is practically impossible for a 10-second performer to reduce his time to 9 seconds. This principle is comparable to that of diminishing returns — equal successive increments of effort are accompanied by decreasing increments of results.

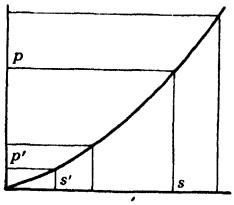


FIGURE 199
The same increase in speed receives a greater increase in pay (p) when the speed is already high than when the speed is low (p').

It is impossible to have the total pay vary directly with both effort and speed. From the standpoint of the ambitious and skilled worker, it is advantageous to have rates which increase as speed increases, and so that total pay tends to be proportional to effort. On the other hand, such rates are apt to be resented by average and inferior workers, because of the resulting difference between their total pay and that of superior workers.

An increasing piece rate is justified from the management's standpoint whenever the demand for the product is greater than the average

output. By encouraging labor to work faster, the productive capacity of the physical plant may be increased without additional investment in physical property. The labor costs per unit are increased in order to obtain a greater volume of total output.

Decreasing rates. It is also possible to decrease the rate as speed increases. As a man works faster, he does receive more pay, but his pay increases less rapidly than his speed. This is shown graphically by a line which starts upward from the origin and curves to the right (Fig. 200).

FIGURE 200

There is little justification for decreasing rates. In the past it has been disguised under various complicated methods of payment used by unscrupulous managers in order to reduce labor cost and at the same time make the men work faster. This is one of the reasons why some labor unions are strongly opposed to any method of payment which is based on speed.

Pay is for work and not the speed itself. It is important to remember that the use of time or speed as a basis of wage payment does not mean that the company is interested only in the time on the job or speed of work, but that one of these has been adopted as a *measure of work* for determining pay. Whatever one is adopted will have disadvantages which must be recognized by supervisors. Time rates encourage loafing, and piece rates encourage quantity to the detriment of quality and perhaps even the physical wellbeing of the worker. The nature of supervision must be adapted to these weaknesses which arise because neither basis is a perfect measure of a man's work.

Applications of Time Basis

When workers are paid on a time basis they are paid by the hour, week, day, month, or year. The time basis is almost universally used for clerical positions, supervisors, and executives in manufacturing industries. These include the factory office clerks, general office clerks, secretarial staffs, foremen, department heads, and those in the general management group — production managers, personnel managers, sales managers, the comptroller, treasurer, president.

The time basis is also widely used for shopworkers. In fact, about three-fourths of manufacturing industries still use time basis of wage payment instead of the piecework or incentive system. The time basis is more satisfactory in shops where any of the following conditions prevail:

1. **Mechanical pacing.** The speed at which the employee works is governed by a machine, assembly line, or material-handling system which determines how fast work must be performed.

2. **Delays in work inevitable.** Where manufacturing must stop or slow down through no fault of the worker, it is unfair to use a piece-rate system of pay. Therefore, the time basis is more equitable to all concerned.
3. **Quality is the primary requisite of production.** In instances where the management is more interested in the quality output than a particular volume, it is also desirable to use the time basis of wage payment.
4. **Beginning wages.** The time basis is nearly always found to be more satisfactory for the beginning worker.

Time wages have some disadvantages, however. When they are constant for all workers, there is a tendency for the speed of the whole shop to strike a general average. This tends to discourage the more efficient worker, and does not give proper recognition of ability. The success of time wages depends upon the management's ability to measure the work to be done and establish equitable hourly rates. When standards of performance are properly determined it then becomes the supervisor's job to see to it that output is satisfactory. The amount of work expected can be established and those who fail to achieve whatever amount is expected must not expect to remain on the pay roll. As stated already, those industries which have a good system of job evaluation can set hourly base rates and then use a merit rating system to measure individual performance, which in turn may be reflected in pay.

In addition to penalizing good workers and discouraging extra effort, time wages make for difficulties in estimating labor costs, except when mechanical pacing takes place. In fact, labor costs become almost unpredictable. The same men will vary their output from day to day because there is a tendency to soldier, talk on the job, and periodically leave the regular workplace. In the final analysis, all this is just so much lost production time which reflects itself in production volume.

Applications of Speed Basis

Firms wishing to use speed as the basis for calculating compensation should be able to meet the following requirements:

1. **Definite units of output.** This requires that units be subject to being counted, weighed, or otherwise measured.
2. **Uniform working conditions.** When men are doing the same or similar work they should not be expected to work under widely differing conditions or workplaces which are not on the same level of efficiency.
3. **A smooth flow of work.** There must be no production delays if a speed system is to be used because this hampers the worker's effort and is unfair in this respect.
4. **Output dependent upon the person who receives the incentive.** The pace at which employees work should not be subject to what others do,

other processes and operations over which they have no control, or mechanical pacing of machines if they are to be paid on an incentive system.

5. **Quality not a requisite.** As stated already, time is the best basis of pay when quality output is expected. Workers must not be expected to achieve high standards of quality and speed in order to get a fair day's pay.

Some labor officials object to piece-rate systems and incentive plans because of the health factor of the so-called speed-up. There is a definite tendency on the part of workers to expend too much effort to get a high day's pay when piece rates make this possible. In a number of instances workers have injured or jeopardized their health by putting forth every effort in the interests of a few extra dollars per week or month only to find that the price in health more than offsets the gain in financial income.

The labor leader fears speed-up because he recognizes that there is a tendency on the part of management to lower rates of pay when the earnings of those on piece rates get out of line with workers who are on the time or hourly basis. This results in forcing laborers to do more and more to achieve the same amount of pay and is therefore described as speed-up.

Group Piece Rates

The piece rate is most favorably used where employees work on an individual basis, that is, each is dependent upon himself for his output and earnings. Some types of work, however, do not lend themselves to division and therefore the objectives of increased output which are achieved under the individual piece rate are sought on a group basis. Employees are asked to work together and are paid on a per unit basis. At the end of the work period the earnings are divided equally, or according to some basis which is satisfactory to all concerned. In the use of piece-rate systems for groups there is always danger of rivalry and bickering within the group, if all the workers are not of equal ability. In addition, the effectiveness of the group depends largely upon the pace set by its leader.

Summary — Comparative Advantages of Time and Speed

Time	*Speed*
Stimulation of Worker	
The system itself does not provide an incentive for men to work after they have arrived at the working place. Supervisors must maintain quantity and quality standards.	The system itself encourages quantity. Supervisors must check for quality and spoilage.

Time	*Speed*
Requirements upon Management	
The system itself does not force management to study the methods of doing the work, but only to check up to see that the men are busy.	Management is forced to know something about the methods of doing the work, as piece rates which are too high or too low make management appear incompetent.
Effect upon Employee Morale	
Workers are protected against sudden drops in their income.	Many workers are antagonistic because management has misused the system in the past, reducing the rates as the men have learned to work faster. Worker is immediately penalized if no additional work is available. Superior effort is immediately rewarded.
Effect upon Costs	
Labor costs unpredictable.	Labor cost per unit is constant if piece rate is constant.

The relative advantages of time and speed as bases of wage payment suggest a compromise between them that will combine the good points of each. Systems which attempt to do this are generally known as "incentive plans," and there are many of them.

INCENTIVE PLANS

Incentive systems as used in present-day industry have roots that are firmly planted in the early history of the scientific management movement in the United States. Until the first decade of the present century, few of the principles of scientific management as we know them were even thought of. Such phrases as "standards of performances," "motion and time study," "job analysis," "job evaluation," and "employee rating" are of comparatively recent origin. Until World War I, production-control systems, improved layout techniques, and the principles of material handling were still "frills" to be looked into by most plant managers. Furthermore, the methods of work used in the shop were primarily those which had been followed since the inception of the factory system of production. Modern mass production was still to be discovered, and so-called handicraft skills were the chief means of output. Quite naturally, therefore, labor was looked to as the principal source of any increase in production and improved efficiency. Before 1900, England and some nations on the continent of Europe had made attempts to speed up labor by using systems of wage payment which rewarded productivity. American industrialists were quick to see advantages in such wage systems and developed wage-

payment systems of their own. The objects were to make workers do more work in the same time. One unique feature of the American system was an attempt to improve methods along with the introduction of new standards for performing tasks under the new systems of wage payment.

Among the first to achieve a national reputation in developing increased output in industry was Frederick W. Taylor, now widely acclaimed as the father of scientific management. He saw clearly the need for improved techniques and better definitions of jobs to be done. In describing his idea of scientific management, Mr. Taylor wrote in 1911,[1]

> The particular pay system which is adopted is one of the subordinate elements. . . . Perhaps the most prominent single element in modern scientific management is the task idea. The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work. And the work planned in advance in this way constitutes a task which is to be solved, . . . not by the workman alone, but in almost all cases by the joint effort of the workman and the management. This task specifies not only what is to be done but how it is to be done and the exact time allowed for doing it.

Taylor tried to bring management to think of more than mere systems of payment for work. Both management and labor alike were suspicious of the new techniques which he proposed. Of these early efforts, Taylor commented that the offering of special inducements and particularly the adoption of a scheme of wage payment was regarded by most managers in the early 1900's as practically the whole system of management.[2] Many so-called efficiency men and consultants in management working in industry at this time were quick to adopt systems of wage payment which each tried to sell under his own name. Some of these were not particularly well conceived and all were very much alike in principle.

It should not be concluded that wage systems are of no consequence in present-day industrial management. They have a definite role to play in providing many plants with incentives for output, furnishing rewards for superior productivity and workmanship, as well as assuring management that it pays only for what it receives in output.

Taylor's fundamental concepts are still true, however. Wage systems by themselves mean very little in the way of scientific management.

[1] Frederick Winslow Taylor, *The Principles of Scientific Management*, Harper and Brothers, New York, N. Y., 1911, pages 34 and 39.

[2] *Ibid.*, page 34.

Their use must be coordinated with the other elements of standards of performance already considered — motion and time study, job evaluation, and merit rating.

The abuse which incentive plans have received from labor, management, and management consultants does not mean that they lack merits. The system of wage payment is an important cog in successful industrial management, and many times one of the so-called incentive plans may be used to advantage.

Although the basis of payment may be phrased in terms of a premium, time saved, a bonus, or a differential piece rate, these various terms should not be allowed to disguise the fact that the basis of payment is actually speed as well as time. The other terms have been devised partly to overcome the workers' antipathy toward the speed, or straight piece-rate basis of payment. Outstanding examples of different types of incentive plans are discussed below. Each discussion is accompanied by a sample calculation and each is compared with the others in the table on page 471.

Halsey plan. The Halsey plan is a relatively simple combination of the time and speed bases of payment. The worker is paid at an hourly rate for all the time during which he is working. Speed or quantity standards of production are also established, and if his speed exceeds the standard speed, in terms of quantity per day, he is compensated for the time saved. This compensation is a percentage (30 to 50 per cent) of the value of the time saved as measured by the hourly rate. His total pay is the sum of the guaranteed hourly rate times hours worked, plus a predetermined percentage of the hourly rate (30 to 50 per cent) multiplied by whatever time he has saved by working faster.

Time saved is arbitrarily defined as the difference between the time that would be taken by working at the standard speed, called "standard time," and the time actually taken by working at speed greater than the standard. The time actually taken is, of course, the time spent on the job — the length of the working day or week. The standard time is found by multiplying the standard time per piece by the number of pieces completed. For example, if the standard time is 1 hour and a worker completes 10 units in an 8-hour day, then the time saved is 2 hours. It would have taken a "standard" worker 2 more hours to complete the 10 units which were finished in 8 hours. The wages saved are equal to the time saved multiplied by the hourly wage rate. Under the Halsey plan, a predetermined portion (30 to 50 per cent) are shared with the worker by the management.

In effect, the compensation for time saved is a straight piece rate which the worker receives in addition to his hourly earnings, but does not begin until the standard speed has been attained. This piece rate

is disguised by the term "time saved" in order to make the system more attractive to workers who object to a speed-up.

SAMPLE CALCULATION OF HALSEY PLAN

Data: hourly rate, $1.00; time in hours, 8; standard time per piece, 1 hour; premium percentage, .50; number of pieces completed, 10.

Total Earnings = (Time) (Hourly Rate) + (Premium Percentage) (Time Saved) (Hourly Rate) = (8) ($1.00) + (.50) (2) ($1.00) = $9.00

One hundred per cent premium plan. The mechanics of the 100 per cent premium plan are similar to those of the Halsey plan except that the worker receives the full value of the time saved, not a portion of it. The time saved is multiplied by the full value of the hourly rate. In other words, a rapid worker is paid a guaranteed hourly wage, plus the additional amount that a slower, standard worker would have eventually received upon completing the same quantity of work.

In effect, this plan is a straight piece rate together with a guaranteed rate per hour, which is paid regardless of speed. After the standard speed has been attained, then the total pay is exactly the same as if a straight piece rate were used. Increases in total compensation are directly proportional to speed, as they were in the straight piece rate discussed on page 460. Above the standard, the total earnings under the 100 per cent premium plan could also be calculated by multiplying the quantity by a piece rate, which is the standard quantity divided by the standard time. The more roundabout method of adding the full value of time saved to the regular hourly wage is employed to avoid some of the implications that are associated with piece rates.

SAMPLE CALCULATION OF THE 100 PER CENT PREMIUM PLAN

Data: hourly rate, $1.00; time in hours, 8; standard time per piece, 1 hour; number of pieces completed, 10.

Total Earnings = (Time) (Hourly Rate) + (Time Saved) (Hourly Rate) = (8) ($1.00) + (2) ($1.00) = $10.00

In contrast with the 100 per cent premium plan, the increases in earnings under the Halsey plan are not directly proportional to increases in speed after the standard has been exceeded. This is because speed is only one factor in the basis of payment — a man's wages are determined by both the number of hours he works and the speed at which he works. The balance between these two factors may be adjusted by changing the percentage of the hourly rate (usually 30 to 50 per cent) which is used to calculate the premium for time saved. Increasing the percentage increases the importance of the factor *speed*. Of course the rate and the standard may be adjusted so that the total wages of any

one speed will be the same regardless of the balance between the bases of pay (time and speed). Since most workers soon attain a speed which is maintained regardless of the financial incentives for them to increase, the *adjustments of pay rates and quantity standards are usually more important than the details of the balance between the time and speed basis of payment.*

Graphically, the importance of the speed basis of payment is shown by the slope of the line after it has crossed the standard. The steeper the line, the greater the influence of speed, and if, when extended, the line would pass through the origin, then the basis of pay is entirely speed. A horizontal line on the same type of chart, on the other hand, indicates that payment is based entirely upon time, and speed is not considered.

Gantt task and bonus system. Like the Halsey plan, the Gantt task and bonus system provides hourly wages for slower workers and a piece rate for fast workers, and in addition makes a definite distinction between those who can attain the standard speed and those who cannot. All workers who do not meet the standard are guaranteed an hourly rate. If a man achieves the standard speed, he is immediately paid a bonus of 20 to 50 per cent, and above the standard his pay continues to increase on a piece-rate basis. Following Mr. Gantt's procedure of calculating wages at the standard and above, the worker is paid at an hourly rate for the standard time for doing the work, and a bonus of 20 to 50 per cent is added to this. The measure "standard time" actually functions as a unit of speed — the quantity of work a man does is measured in terms of time required by a standard worker rather than in terms of the number of physical units produced. A fast worker can produce more standard hours of work during the day, and so receive more pay in the same way that he would under a piece rate.

Because of the sharp discrimination between the worker who attains the standard and the one who just falls short, the standard under the Gantt system should be based upon careful time study so that it can be attained by persistent application of the principles of motion economy. Like all systems, its success or failure depends largely upon the manner in which it is administered, and in this case the determination of the standard speed is particularly important.

As originally conceived, the Gantt system also provided that the foreman should share in the distribution of the value of the time saved, as well as the worker and the company. This was to encourage foremen to give more attention to slow workers and help them improve, thus achieving greater capacity utilization of physical property. In some plants the foreman has been given an additional bonus if all the men under him attained the standard.

SAMPLE CALCULATION OF THE GANTT TASK AND BONUS SYSTEM

Data: hourly rate, \$1.00; time in hours, 8; standard time per piece, 1 hour; number of pieces completed, 10; percentage bonus, 25 per cent

Total earnings below task = (Time) (Hourly Rate) = (8) (\$1.00) = \$8.00

Total earnings, task and above = (Standard Time) (Hourly Rate) (Bonus Percentage) = (10) (\$1.00) (.25) = \$12.50

The Bedaux system. When incentive plans are used for a variety of different types of work in the same factory, management has the problem of setting comparable standards for all jobs. It must not be easier for workers in one department to earn a bonus or premium than for those in another, and where it is necessary to interchange workers between departments there must be no pay system penalties because of the shifts. To avoid these pitfalls, all standards which are paid at the same rate should be of the same difficulty of attainment, and the managers who are setting standards need a common denominator for measuring the difficulty of work.

Under the Bedaux system, a point or Bedaux, abbreviated as a "B," is defined as the work which a man should be able to perform in 1 minute. The difficulty of a job is then measured in terms of its number of B's. The B contains an allowance for normal rest and fatigue, so that the standard is a normal one and not one which only exceptional workers can attain. The difficulty of a job is measured by the number of B's assigned to it, and the standard time for the job allows a minute for each B. Each 8-hour day contains 480 B's, and a worker meets the standard if he completes 480 B's of work during the day. Below the standard he is paid a guaranteed hourly wage. Above the standard, he receives a premium, usually 75 per cent of the value of the time saved. The principle of using both time and speed as a basis of determining wages is exactly the same as in the Halsey plan, and if the standards, hourly rates, and premium percentages are the same, earnings under the Halsey plan and the Bedaux system will be exactly alike, and provision may also be made for the foremen to share in the bonus. The distinctive feature of the Bedaux system is that it provides for comparable standards throughout the entire factory.

SAMPLE CALCULATION OF THE BEDAUX SYSTEM

Data: Standard for 8-hour day, 480 B's (60 × 8); standard rate per B, \$0.01⅔; B's completed during day, 600; premium percentage, 75 per cent.

Total Pay = (Standard B's) (Rate) + (Premium Percentage) (Actual-Standard) (Rate) = (480) (\$0.01⅔) + (0.75) (600 − 480) (\$0.01⅔) = \$9.50

A comparison of the methods of wage payment discussed in the foregoing paragraphs is shown in chart form in Fig. 201.

Worker	Time Length of Working Period (Hours)	Speed Quantity per Working Periods (Pieces per Hr.) Std. — 16 per Day or .5 Hr. per Piece	Standard Time for Quantity Produced (Hours) Std. Time per Piece × Number of Pieces	Time Saved Std. Time Less Actual Time (hr.)	Earnings				
					Hourly Wage at $1/Hour	Piece Rate Wage at 50 Cents per Piece	Halsey 50 Per Cent Premium	100 Per Cent Premium Premium Total	Gantt Task, and Bonus 25 Per Cent Bonus
A	8	12	6	0	$8.00	$ 6.00	$8.00	$ 8.00	$ 8.00
B	8	14	7	0	8.00	7.00	8.00	8.00	8.00
C	8	16	8	0	8.00	8.00	8.00	8.00	10.00
D	8	18	9	1	8.00	9.00	8.50	9.00	11.25
E	8	20	10	2	8.00	10.00	9.00	10.00	12.50
F	8	22	11	3	8.00	11.00	9.50	11.00	13.75

FIGURE 201. COMPARISON OF WAGE PAYMENT PLANS

There are many other plans besides those discussed in the preceding paragraphs. Some of them have a guaranteed hourly wage up to a standard speed, and then superimpose upon the time basis or replace it with either increasing or decreasing piece rates. They are essentially the same in principle, and differ only in the details of how difficult the standard should be, and the balance between the time and speed basis, the abruptness of the break at the standard and/or between the time and speed bases. A detailed analysis of these plans is beyond the scope of a book which deals with basic principles. As indicated at the first of this chapter, the intricacies of various wage systems should not be allowed to detract attention from other more important topics. Any simple wage system should prove satisfactory provided it is *intelligently designed and administered with satisfactory rates and standards.*

QUESTIONS

CHAPTER XV. (ORGANIZATION AND MORALE)

1. What are the steps in organization development?
2. What is the significance of titles in the organization chart?
3. State the principles of organization chart development.
4. Define an organizer.
5. Outline briefly the principles of organization.
6. Why is organization important?
7. Explain what is meant by type of organization. Define each briefly.
8. Explain the term "relationships of line and staff organization."
9. Define nepotism.
10. Define morale.
11. Explain the management misconception concerning morale.
12. How is morale affected by expressed ideas?
13. What do employees seek in their job relationships?
14. How is morale a factor in public relations?
15. What are the methods that may be used to influence morale?
16. In what way is a plant broadcasting system a help in building morale?
17. Describe the significance of morale as a factor in interpreting company policies.

CHAPTER XVI. (SAFETY AND HEALTH)

1. Describe the types of *safety organization* that may be used to advantage.
2. Explain the relationship between health habits and absenteeism.
3. How are most eye injuries caused?
4. When should eye goggles be worn?
5. Outline in detail what is embraced in a plant-protection program.
6. How are safety posters used? Give ten rules to prevent falls.
7. List the information to be collected about accidents when they occur.
8. Explain the importance of first aid training in a safety program.
9. How should an industrial health department be organized?
10. State the functions of an industrial health program.
11. Why are manufacturers showing an increased interest in employee health?
12. Define dispensary or clinic, medical director.
13. What is health insurance?
14. Define group hospital service.
15. What are the functions of a safety organization? List the fears and desires that may be used to promote a safety program.

CHAPTER XVII. (SELECTION AND TRAINING)

1. Name the steps in the selection of workers.
2. List the source of supply of manpower.
3. What is the significance of a final interview?
4. How important is research in good testing?
5. Explain the distinction between training and education. State briefly the types of training.

6. Why do testing programs vary from company to company?
7. What are the principal testing instruments?
8. Distinguish between an intelligence and an aptitude test.
9. Explain the problem of "labor supply and the local community."
10. What information should be contained on an application form?
11. How should a testing program for selection and placement be developed?
12. State briefly the basic standards of apprentice training.
13. Define upgrading.
14. What is an apprentice?
15. Outline briefly the procedures for inducting new employees.
16. What are the four training methods?
17. What is the importance of training supervisors?
18. Describe the job instructor training program of T. W. I.
19. Explain the problems of selecting and placing women in factory work during a war period.
20. How should women workers be supervised?
21. How is motion study a factor in training?

CHAPTER XVIII. (MOTION STUDY AND THE WORKER)

1. What are therbligs? Name and define the therbligs.
2. What is meant by "techniques of motion study"?
3. What are the advantages to management to be gained from a motion-study program?
4. What is skill?
5. How is fatigue eliminated by motion study?
6. Name and explain briefly the principles of motion study applied to the worker.
7. Describe a simple motion-cycle chart. Describe a micromotion chart.
8. How is motion study related to safety?
9. What equipment is needed to organize a motion-study laboratory?
10. Explain the relationship between motion study and cost control.
11. Explain what is meant by major — minor, assisting, single, compound, and synchronized motion.
12. Classify the 18 fundamental elements of motion according to (1) mental, (2) physical, (3) delay.

CHAPTER XIX. (TIME STUDY)

1. Why should foremen and supervisors understand time study?
2. Explain the term "time-study element."
3. Define rating factor.
4. How does time study affect labor relations?
5. List the procedures of time study.
6. Define time study.
7. Outline the steps for making a time study.
8. Explain the limitations of time study.
9. What are allowances? How are they calculated?
10. Distinguish between snapback and continuous reading methods of timing.
11. What is "over-all timing"?

CHAPTER XX. (JOB EVALUATION)

1. Define job evaluation.
2. Explain the relationship of job evaluation and salary evaluation.
3. What are the advantages of a job-evaluation system?

4. What steps need to be taken to set up and put into operation a job-evaluation system?
5. What does job analysis involve?
6. Why is it necessary to obtain the cooperation of employees?
7. What are the characteristics of key jobs?
8. Define (1) job specification, (2) job description.
9. Explain major factors, subfactors.
10. What is a bench or desk manual? How may it be developed through job evaluation?
11. Define skill.
12. Define responsibility.
13. Define effort.
14. Define working conditions.
15. What is a job factor? Distinguish it from a common factor.
16. To what extent is job evaluation helpful in developing standard titles for jobs?
17. What factors are used commonly to evaluate jobs paid on an hourly basis?
18. What is job classification?
19. How is a position-comparison scale used?
20. What factors are used commonly to evaluate jobs paid on a salary basis?
21. Outline the technique of the factor comparison system of job evaluation.
22. Define job rating.
23. Explain the use of a manual chart.
24. Why does weighted point rating assist in accurate evaluation of jobs?
25. Explain how points may be distributed over degrees of major and subfactors.
26. Describe the steps for converting point ratings into wages and salary.
27. What is meant by checking point ratings?
28. Outline "the actual evaluation process."
29. What are salaried jobs? What are hourly jobs?
30. What should be the policies on the use of the results of a job-evaluation program?
31. Describe the development and use of a job schedule.
32. What jobs should be evaluated?
33. Who should evaluate jobs?
34. How may a job-evaluation plan be adapted to changes in organization?
35. What should be the frequency of job ratings?
36. How may trade associations cooperate to put across job evaluation?
37. What results should be expected from a job-evaluation program in operation?

CHAPTER XXI. (MERIT RATING — MEASURING MANPOWER PERFORMANCE)

1. What classes of employees may be rated in any organization?
2. How are job evaluation and merit rating related?
3. What is the role of job specifications in merit rating?
4. What advantages may be obtained from a merit-rating program?
5. Name the purposes of a merit-rating program.
6. Outline the steps for developing a merit-rating program.
7. Define graphic scale rating.
8. Outline the procedure of rating by letters.
9. How is rating by grouping accomplished?
10. What is the specific-items method of rating?
11. What is a rating sheet?
12. Name the four systems of rating employees.
13. Who should rate employees?
14. What characteristics or traits are used in rating the performance of shopworkers?

15. Explain the procedure for scoring ratings.
16. How is quality of output rated?
17. What characteristics or traits are used to rate supervisory performance?
18. What are subjective measures?
19. Explain the significance of objective measures.
20. How can an employee-rating program be used for guidance and training?
21. Who should check and review ratings of individuals?
22. How should completed ratings be used?
23. How would one train raters to do merit rating?
24. What differences exist between rating of shopworkers and rating of supervisors?
25. What are the dangers of rating?
26. What is the importance of an educational program about rating?
27. What is the importance of instructions in merit rating?

CHAPTER XXII. (EMPLOYEE COMPENSATION)

1. Explain what is meant by bases of pay.
2. What determines the rate of pay of any company?
3. Define basis of pay, rate of pay.
4. Explain the meaning of constant rates.
5. How does speed affect wage payment?
6. Outline briefly the significance of job evaluation as the key to the time basis of payment.
7. When is the speed basis of pay used to advantage?
8. Explain the meaning of incentive plans.
9. Under what conditions is the time basis a more satisfactory basis of pay?
10. Describe the Halsey plan.
11. Explain the use of the Gantt task and bonus system.
12. What are the underlying principles of the Bedaux system?

PROBLEMS

Problem 1. The National Industrial Management Society

Development of an Organization Chart

The National Industrial Management Society consists of a national organization and thirty individual chapters located in key industrial cities throughout the United States. The conduct of the affairs of the national society is vested in the following officers:

1. Board of Directors, composed of one representative of each chapter nominated as a national director.
2. National officers as follows: president, vice president, secretary, treasurer.

The function of the board of directors of the organization is to control policies and approve actions of an executive committee which is composed of national officers. The executive committee consisting of the national officers acts for the board of directors on matters of routine procedure. In actual practice, the board of directors meets not more than once or twice a year to approve acts of the executive committee.

The duties of the officers are as follows:

The president of the society is chairman of the executive committee and the first administrative and coordinative officer of the society as well as ex officio member of all committees.

The secretary is a member of the executive committee, has charge of membership promotion, the conduct of the affairs of existing chapters, and the development of chapter growth.

The vice president of the society is vice chairman of the board and executive committee. He is responsible for new chapter development and also serves as coordinator for vice presidents of the following operating divisions which represent the areas of administrative work involved in conducting the affairs of the Society:

Vice President of Student Branches
Vice President of New Chapter Development
Vice President of Eastern Region
Vice President of Western Region

The Society also has several functioning committee chairmen whose task it is to meet the needs of different branches of the professional fields represented by members in the Society. These are as follows:

Personnel Administration
Motion and Time Study
Administration (policy making functions)
Financial Management
Property Management (including maintenance and problems of selection)
Plant Organization and Layout

Each of the chairmen of functional divisions has direct relationship with chapters of the Society and promotes the work of his particular field in each of the chapters.

Develop an organization chart which will show the relationship of authority and responsibility in the conduct of the affairs of the national society.

Problem 2. A New Process

MORALE AND LEADERSHIP

A new process was being installed. As a preliminary, one group of 12 operators had been selected for the purpose of proving the final practicability of the new methods. This particular project was important because it affected a product that needed a reduction in cost in order to compete with other manufacturers. Eventually, it would be applied to the work of a hundred operators. Great care had been exercised in analyzing the work by the engineers who were sure that there were no flaws in the methods. Notwithstanding, the unit did not operate efficiently. Upon careful investigation, it was found that all operators were disgruntled and that they had determined to make the project unsuccessful.

It was necessary to discover the leader, as all such situations usually are initiated by one or two individuals. It was found that one operator had caused the dissatisfaction. This operator believed that her division of the labor had been poorly assigned and that she was compelled to do work beyond her normal limitations. She was an intelligent individual, outspoken, and fair if treated likewise. Great care was employed to make sure of arousing no fear in her mind. Her complaint was considered constructive and justified until it had been proved otherwise. The operator was promised an immediate investigation in which she would participate. The engineers directing the project, the operator's supervisor, the operator, and the head of the department who acted as an arbiter, met in privacy. At the meeting, the complaint was frankly discussed. It was agreed that the necessary equipment should be brought into the room in order that every detail of the job might be reviewed. Although the job had been studied meticulously, yet it was discovered that some important details had been overlooked by the engineers. The operator received hearty praise from all present for the discovery of the errors. When the necessary adjustments in methods had been completed the project proved successful. This investigation lasted 5 hours — a small amount of time when compared with the accomplishment.

This case presents important phases of good morale and leadership. What are they?

Problem 3. Miss X

ORGANIZATION AND MORALE

Miss X had been absent from work for 26 days, during which time she had undergone an operation. A rule of the organization for which she worked permitted an employee a period of 30 days absenteeism without a severance of employment. Upon reporting to her foreman she was told that her employment had been canceled and that he had no work for her at present. She had the courage to ask him why he had done this and received the reply that the following week he would be on vacation. In order to leave a clean desk he had canceled several operators who had been absent for a period of time. She asked about the 30-day clause. The foreman replied that he knew of no such rule and he had no way of transferring the employee who had taken her place.

Miss X had worked in this organization for 8 years and knew other supervisors in whom she had confidence. She sought advice and was directed to the personnel manager. He explained to her that an error had been made and at the same time endeavored to excuse her foreman. However, Miss X's attitude was adamant — and rightfully so. She said that this foreman was anxious to oust employees with service and hire in their places bright, young girls. This fact, she said, was considered true by other employees.

Unfortunately, it was necessary to return Miss X to the same department. She has always been a faithful and efficient employee but with such a feeling it is questionable

if she will perform her work efficiently or maintain an attitude of loyalty and gratitude. The attitude of the foreman should be investigated and the destructive action pointed out to him.

What principles of organization and morale are involved?

Problem 4

The assembly of a small motor by a skilled worker was observed carefully by a time-study engineer. He recorded these elements for the left hand:

Release load	Hold
Unavoidable delay	Position
Grasp	Assemble
Transport empty	Transport loaded

Show the therblig for each element.

Problem 5. The Delta Company

APPLICATION OF MOTION-STUDY PRINCIPLES

The Delta Company includes in its list of manufactured plumbing supplies a $\frac{3}{8}$-in. valve, shown in Fig. 202. When shipped to purchasers from the factory, these valves are completely assembled. The assembly is done for convenience in packing and adds no value to the product itself. The packaging operation consists of picking up the body of the valve in one hand and placing a wheel on the valve stem (see Fig. 203). The hexagonal nut is then screwed to the stem and made tight with a wrench which is a specially designed tool.

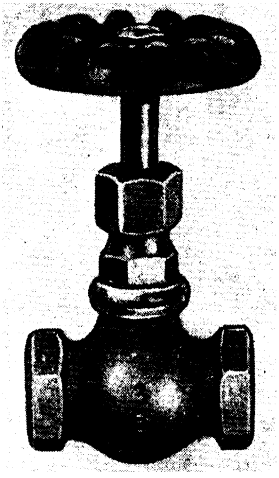


FIGURE 202. THREE-EIGHTH-INCH VALVE

At present the assembling and packing is done by 6 girls, paid 48 cents per hour. Each girl assembles and packs an average of 35 valves per hour. The management of the Delta Company wishes to reduce the cost of this assembly to an absolute minimum. For this purpose a member of the staff of the methods department has been requested to make a complete study of present assembly operations and to recommend improvements.

a) Determine the present labor cost of assembling these valves.
b) Develop a solution to the assembly problem based on the best principles of motion study. (Draw a sketch of a simple jig or fixture for making the assembly, or, if possible obtain specimen valves of this nature and build a fixture to solve the problem.)
c) Determine the quantity to be assembled with the new procedure.

Problem 6. Modern Electric Supply Co.

APPLICATION OF MOTION-STUDY PRINCIPLES

The Modern Electric Supply Company manufactures electric appliances and parts. A standard item which is produced regularly in large quantities is an old style inexpensive flatiron plug, No. 26. Because the same type of plug is manufactured and sold by

all competing appliance manufacturers as a service item, there is great need to keep the cost of manufacturing at a minimum. The present costs of production are:

Materials and parts	$ .01
Labor	
Productive	.01
Assembly	.005
Overhead expenses	.000625
	$0.025625

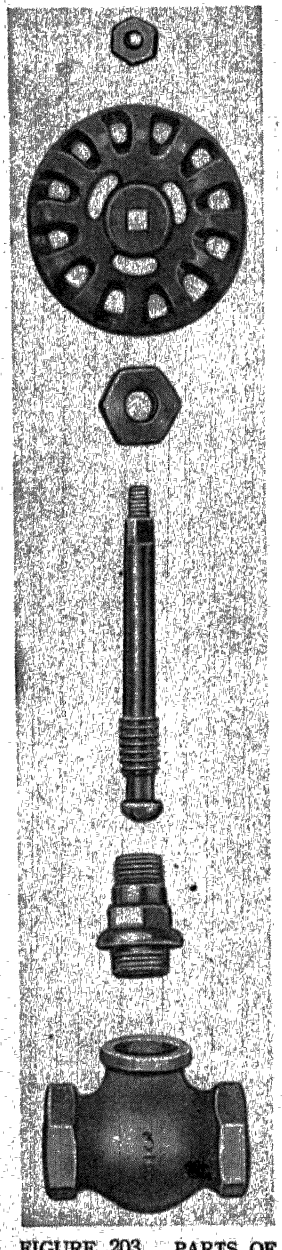


FIGURE 203. PARTS OF THREE-EIGHTH-INCH VALVE TO BE ASSEMBLED

Since the regular manufacturer's price to wholesalers for No. 26 plugs is $0.03, the management has decided to discontinue the manufacture of this item unless the cost of production can be lowered. This would entail dismissal of a sizable number of workers and the management wishes to make every effort to lower the cost of production in order to continue manufacturing operations. The production manager has recommended that a motion-study analysis be made of the No. 26 plug in the hope of making economies that might permit the continuation of the manufacturing or even a small profit.

In making a study of the product and its process of manufacture, the motion- and time-study department has found that the cost of the parts used is essentially the same for all purchasers of the No. 26 plug. They have concluded also that the overhead expense per item offers little opportunity for savings. In analyzing the labor costs, however, it has been found that the cost of assembling the plug offers some opportunity for savings. Further examination reveals that girls are now being paid 40 cents per hour to assemble approximately 100 plugs each per hour. An examination of the methods used to do the assembly reveals the following steps:

1. One plug shell is laid on a table.
2. Contacts and stem are inserted in the shell.
3. The second shell is put in place.
4. Two screws are dropped into holes in the upper shell.
5. Entire plug is picked up and turned over and held in one hand while nuts are dropped into holes in the shell through which the bolt ends protrude.
6. The entire assembly is now turned over in one hand and a small screw driver used to tighten up the bolts, making the entire assembly complete.

Figure 204 shows the assembled plug and Fig. 205 shows its parts exploded.

a) Make an analysis of the present method of assembly and a new method for completing the assembly.
b) Time the present method of assembly.
c) Devise a new method based on some principles of motion economy.
d) Calculate the quantity to be manufactured, as well as the unit labor cost of the revised assembly procedure.

FIGURE 204. ASSEMBLED FLATIRON PLUG

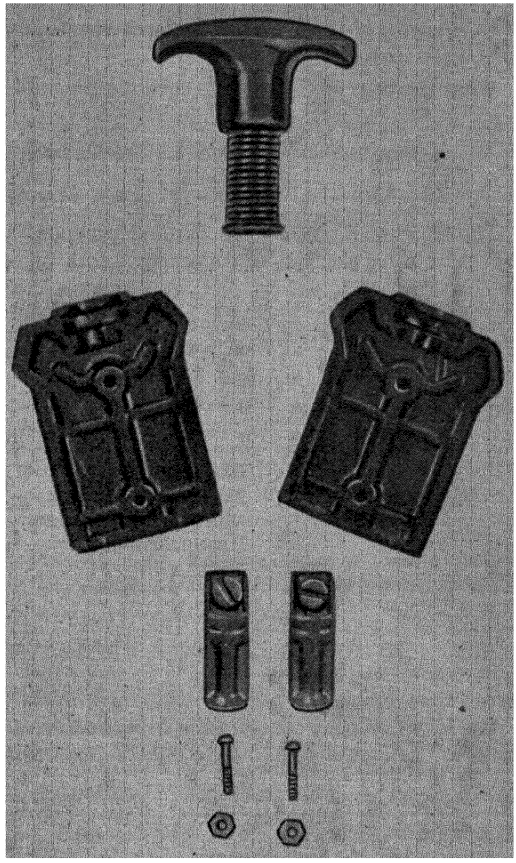


FIGURE 205. FLATIRON PLUG PARTS

Problem 7. The Thun System

COMPARISON OF FUNDAMENTAL MOVEMENTS AND THERBLIGS

The name and definition of each fundamental movement of the Thun system of motion economy follows:

1. *Observation:* This includes all the fundamental movements which denote the receiving of a sense impression.
2. *Grasping:* Movements designed to effect a junction between, or to separate some part of the body and an object.
3. *Movement in Space:* Movements of parts of the body not immediately connected with an object except observation, grasp, and position.
4. *Displacement:* Movements of parts of the body directly connected with or resulting in the displacement of an object, insofar as such movements are not in direct execution of work.
5. *Rest:* Absence of any movement connected with work, unless they are movements of observation.

6. *Change of Position:* Movements producing a change of position of the body.
7. *Handling of Tools:* Preliminary movements are also included, as the insertion of a screw driver.

What therbligs are included in each fundamental movement?

Problem 8. The Emerson Company

CALCULATION OF A STANDARD TIME

The Emerson Company standards department has recorded these times as being correct for three elements of performing a task (in hundredths of minutes):

Element No. 1: 21, 22, 19, 17, 20, 22.
Element No. 2: 19, 20, 21, 20, 22, 21.
Element No. 3: 20, 23, 21, 18, 22, 23.

The operator is rated as 75 per cent efficient.
The job allowances are:

	Per Cent
Fatigue	4
Machine preparation	6
Material preparation	10
Personal allowance	12

Determine the standard time for the task.

Problem 9. The Kay Company

CALCULATION OF A STANDARD TIME

The Kay Company standards department has recorded these times as being correct for three elements of performing a task (in hundredths of minutes):

Element No. 1: 21, 22, 19, 17, 20, 21, 16, 18.
Element No. 2: 19, 20, 21, 20, 22, 22, 18, 26.
Element No. 3: 20, 23, 21, 18, 22, 20, 21, 25.

The operator is 80 per cent efficient in terms of standard figures. The job allowances are:

	Per Cent
Fatigue	10
Machine preparation	2
Material preparation	3
Personal allowance	2

Show the standard time for the task.

Problem 10. The Baxter Corporation

JOB EVALUATION

The Baxter Corporation has adopted a program of job and salary evaluation to determine the base rates of pay for both its factory and clerical workers. Job analyses and descriptions have been prepared as a basis for writing job specifications to be used as information sheets in evaluating all jobs and positions.

For purposes of educating supervisors in the principles of job rating, each has been asked to evaluate three jobs paid on an hourly basis and three paid on a salary basis.

JOB SPECIFICATION

Job Title: Apprentice Machinist — Class: .....

Factors	*Basis of Rating*
SKILL A. Manual 1. Dexterity	Speed and coordination for semicomplex operations done on lathes, shapers, milling machines, and band saw.
2. Versatility	Ability to use precision gauges and instruments competently so that operations may be completed without any assistance.
B. Mental 1. Ability to do detail work	Interpretation of blueprints and working knowledge of precision gauges and instruments necessary. Educational equivalent — 1 year college.
2. Resourcefulness	Very little initiative and resourcefulness required since most of work is planned by superiors.
C. Social	Cooperation with foremen and fellow workers important since their aid is often necessary for lifting stock and work into machines.
RESPONSIBILITY FOR A. Physical property 1. Material or product	Possible waste, damage, or loss is confined to low value, since most stock is small and is for precision work. ($50.00 max.)
2. Machinery and equipment	Possible waste, damage, or loss not exceeding $250.00, since most machines are available to worker yet supervision at unfamiliar machines is constant.
3. Plant and services	No possibility of damage to building and service equipment.
B. Safety of others	Slight care necessary to prevent minor injuries, as small cuts and abrasions.
C. Work of others	Responsible for own work only, as employee is lowest ranking in machine shop.
EFFORT A. Mental	Continual coordination of eyes and muscle necessary to do precision work on nonprecision machines.
B. Physical	Ordinary light physical exertion necessary in lifting, with occasional heavy lifting with assistance of others.
WORKING CONDITIONS A. Environment	General shop environment — slight dirt and grease with low clothes spoilage. Illumination, however, is very bad and there is no air conditioning, with the result that it is very cold in winter and very hot in summer.
B. Health hazards	Minor cuts and abrasions possible, with a lack of safety devices, such as goggles.

JOB SPECIFICATION

Job Title: Machine Operator and Setup Man Class:.....

Factors	*Basis of Rating*
SKILL	
A. Manual	
1. Dexterity	Coordination and speed necessary for reaction in doing repetitive work.
2. Versatility	Ability to handle many different operations competently. Use tradesman's tools, gauges, and instruments on wide variety of tasks.
B. Mental	
1. Ability to do detail work	Must interpret and make calculations based on instruction. Working knowledge of use of precision instruments necessary. Education equivalent 4 years technical school.
2. Resourcefulness	Must anticipate changing conditions. Casual supervision necessary. Must plan own work for most part.
C. Social	Cooperation with foremen and workers important.
RESPONSIBILITY	
A. Physical property	
1. Material or product	Possible waste damage or loss confined to low value ($50 max.).
2. Machinery and equipment	Possible damage limited to $500.
3. Plant and services	Possible damage not exceeding $50.
B. Safety of others	Constant attention to avoid injury to self and others.
C. Work of others	Responsible for own work only.
EFFORT	
A. Mental	Continual coordination of eyes and muscles to avoid accidents.
B. Physical	Ordinary light physical exertion necessary in lifting (not over 30 lbs.).
WORKING CONDITIONS	
A. Environment	Slight dirt or grease. Low clothes spoilage.
B. Health hazards	Possibility for extremely serious bodily injury but no disease.

JOB SPECIFICATION

Job Title: Second-class Toolmaker Class:.....

Factors	*Basis of Rating*
SKILL A. Manual 1. Dexterity	Frequent use of two controls simultaneously to move cutting tool in angular direction. Fast reaction time necessary for starting and stopping feeds, etc. Work to 0.0001 in. in some cases.
2. Versatility	Use of milling machines, lathes, drill presses, shapers, grinders, verniers, and micrometers, surface and planer gauges.
B. Mental 1. Ability to do detail work	Working knowledge of use and special techniques associated with use of above machine tools in tool making. Knowledge of setups of above machine tools. Ability to read complex blueprints.
2. Resourcefulness	Plan repair of jigs and fixtures involving a variety of operations on three or four machine tools plus hand operations.
C. Social	Must cooperate with foreman in receiving and carrying out assignments.
RESPONSIBILITY FOR: A. Physical property 1. Material or product	Material here includes jigs, fixtures, gauges, and tools. Some tolerances to 0.0001 in. so work easily damaged. Damage may result in delay of material (production) and/or men costing not over $200.
2. Machinery and equipment	Possible damage to machine tools listed not over $250.
3. Plant and services	Very little chance of damage. Possible damage will not exceed $50.
B. Safety of others	Surface grinders dangerous. Great care necessary in changing wheels and guards and in use of grinders to prevent injury from broken wheels.
C. Work of others	Responsible for own work only.
EFFORT A. Mental	Very little use of stops on automatic machine feeds. Setups take longer than operation.
B. Physical	Some lifting of index heads, chucks, and large fixtures (up to 50 lbs.). Some difficult working positions. (Cutting threads, lapping, etc.)
WORKING CONDITIONS A. Environment	Noisy and slightly dirty. Slight clothes damage.
B. Health hazards	Exposure to minor accidents (burns, cuts, and bruises). Subject to eye strain.

JOB RATING SHEET

Job Name ..... Dept. .....

Code No. ..... Division .....

Factors	*Rating*	
	Degree	*Points*
SKILL		
A. Manual		
1. Dexterity		
2. Versatility		
B. Mental		
1. Ability to do detail work		
2. Resourcefulness		
C. Social		
RESPONSIBILITY FOR:		
A. Physical property		
1. Material or product		
2. Machinery and equipment		
3. Plant and services		
B. Safety of others		
C. Work of others		
EFFORT		
A. Mental		
B. Physical		
WORKING CONDITIONS		
A. Environment		
B. Health hazards		
TOTAL POINTS		
LABOR GRADE		

Rated by .....

Reviewed by .....

FIGURE 206

JOB SPECIFICATION

Job Title: Chief Office Boy Class:.....

Factors	*Basis of Rating*
I. SKILL A. Mental 1. Resourcefulness	Aggressiveness desirable. Occasional need for formulating a method for own work, though this is purely on own initiative.
2. Analytical ability	Slight analytical ability required in mailing methods, choice of class of mail to be sent.
3. Ability to make decisions	Must make decisions as to layout of work and work of one subordinate. Must have average sense of judgment.
4. Ability to do detail work	Work is mostly detail, examples of which are sorting of mail and delivery of mail to the departments and Post Office.
B. Manual	Must do simple routine tasks and be able to run a postage meter. Uses mailing machines which do not require much manual skill.
C. Social 1. Capacity for getting along with others	Must be neat, affable, and courteous. Must get along well with associates.
2. Capacity for self-expression	Few chances for self-expression except when problems arise and opinion is requested.
II. RESPONSIBILITY A. For determining company policy	No determination of company policy, but may make changes within mailing department which affects its policy in a minor way.
B. For work of others	General supervision over office-boy assistant who works on his own initiative for the most part. Occasional need to train assistant.
C. For good will and public relations	Public relations may be hindered by mailing errors; must guard against these closely.
D. For company cash	Handles large cash deposits (up to $2000) and keeps small petty-cash fund for stamps. Actual cash expenditures either made or authorized amount to about $50 per year. (Note: the office boy is bonded.)
III. EFFORT A. Mental	Occasional mental-visual attention in sorting mail, much mental-visual attention in putting outgoing mail through postage meter.
B. Manual	On feet most of day; constant and repetitive work on sorting and mailing.
IV. WORKING CONDITIONS	Average general working conditions, but monotony of work and fatigue are caused by routine nature of position and long hours during which the position holder must be on his feet.

JOB SPECIFICATIONS

Job Title: Receiving Clerk — Class:.....

Factors	*Basis of Rating*
SKILL	
A. Mental	
1. Resourcefulness	The receiving clerk is mostly on his own and is required to do tasks as they present themselves. Work is determined by amount of incoming materials.
2. Analytical ability	Must be able to spot priced goods, special orders, and rush orders coming in. Layout of own work is important.
3. Ability to make decisions	Makes decisions affecting all general receiving operations, though supervisor is consulted on major problems.
4. Ability to do detail work	Large portion of work requires careful attention to pricing and listing.
B. Manual	Fills out standard forms; uses decimals and small calculations frequently.
C. Social	
1. Capacity for getting along with others	Few contacts with associates, only when problems arise.
2. Capacity for self-expression.	Expresses opinions to office manager and department heads when questions concerning work of receiving department are asked.
RESPONSIBILITY	
A. For determining company policy	Little opportunity or need for expressing or altering policy of company. Action for the most part comes from superiors.
B. For work of others	No supervision administered; works under general supervision.
C. For good will and public relations	Contacts with delivery men only.
D. For company cash	Only cash risk is errors in pricing, which are easily rectified by the accounting department.
EFFORT	
A. Mental	Occasional mental and visual attention required in pricing and checking orders.
B. Manual	Lifts large bundles and boxes; much physical exertion in carrying and placing material on shelves.
WORKING CONDITIONS	Slight tiring from standing and walking. Discomfort from lifting and carrying. Normal clothes spoilage.

JOB SPECIFICATIONS

Job Title: Production Trouble Shooter Class:.....

Factors	*Basis of Rating*
SKILL A. Mental 1. Resourcefulness	Must work steadily alone and must organize own work in coordination with others.
2. Analytical ability	Must analyze blueprints, piecework slips, and examine numbers of castings to find errors or omissions. This is not constant but occasional.
3. Ability to make decisions	Must lay out own work so that jobs are done on time. Decisions affect his work directly but others indirectly.
4. Ability to do detail work	Errors are costly in that time is lost through negligence.
B. Manual	Must have basic knowledge of simple mathematics. Must use adding machine and tabulating card index of minimum difficulty.
C. Social 1. Capacity for getting along with others	Many contacts with production men in plant and with office manager. Neatness and cooperation desirable.
2. Capacity for self-expression	Self-expression through talks with production men and office manager in order to keep work at maximum efficiency.
RESPONSIBILITY A. For determining company policy	Makes suggestions as to changes in procedure of department. Changes are minor in most cases but may have widespread significance.
B. For work of others	No supervision over others.
C. For good will and public relations	Customers' good will depends on delivery dates, which dates depend on when materials are found and machined. Cooperation with production departments makes this relatively important.
D. For company cash	No direct cash handling, but errors may cause cash losses on orders.
EFFORT A. Mental	Reading blueprints, piecework slips, and casting numbers requires constant mental-visual attention. Finding and searching require patience and method in work.
B. Manual	Constant standing and walking. Fatigue is high.
WORKING CONDITIONS	Machines noisy while in production units, considerable heat on warm days, some dirt and discomfort, average clothing spoilage.

JOB RATING SHEET

Job Name..... Dept.....

Code No..... Division.....

Factors	*Rating*	
	Degree	*Points*
SKILL		
A. Mental		
1. Resourcefulness		
2. Analytical ability		
3. Ability to make decisions		
4. Ability to do detail work		
B. Manual		
C. Social		
1. Capacities for getting along with others		
2. Capacities for self-expression		
RESPONSIBILITY		
A. For determining company policy		
B. For work of others		
C. For good will and public relations		
D. For company cash		
EFFORT		
A. Mental		
B. Manual		
WORKING CONDITIONS		
Total Points		
Labor Grade		

Rated by .....

Reviewed by.....

FIGURE 207

To do this, each has been given two rating sheets (Figs. 206 and 207), one to be used in rating the three factory jobs as a group, and the other the three clerical jobs. In addition, each has been furnished with complete job specifications as follows:

Hourly jobs: apprentice machinist; machine operator and setup man; second-class toolmaker.

Salary jobs: chief office boy, receiving clerk, production trouble shooter.

a) Construct two facsimiles of the rating sheet shown in Figs. 206 and 207.

b) Determine the degree and point value for each major factor and subfactor included in the following job and position specifications. For this purpose use the

manual charts shown in Figures 177–178. (Do not alter or change any of the data included in the following specifications to make them comply with personal experience in connection with the types of work described.)

Problem 11. The Bruce Company

DEVELOPMENT OF A MERIT-RATING SHEET

The Bruce Company is a firm of management consultants engaged in installing job-evaluation and merit-rating systems. A client has requested that special rating sheets be developed for rating personnel in the following professional fields: accounting, factory management, mechanical engineering, marketing, and advertising. The rating sheets are to be used by professional organizations in measuring the capacities of their staff members to do professional work in these fields. The Bruce Company wishes to develop a merit-rating form which will be a means of evaluating professional competence.

a) On the basis of the information contained in the chapter on merit rating, develop a rating form for one of the above professional groups.

Problem 12. The Maxwell Corporation

UP-GRADING PERSONNEL THROUGH MERIT RATING

As part of a program to obtain additional supervisors, the Maxwell Corporation has undertaken a system of up-grading. In connection with this, it has introduced a system of merit rating designed to measure the personalities, potential executive capacities, and personal efficiency of present workers. The form to be used is one which will incorporate proper weights for characteristics to be measured, a column for remarks to show why persons are rated down and a column for scoring ratings.

a) On the basis of information contained in the chapter on Merit Rating, develop a rating form which should uncover persons having the qualities requisite to become supervisors.

b) Have another person use this form to rate yourself in terms of your own capacities to fill a supervisory or executive job.

Problem 13

How many units must a workman make in an 8-hr. day to save 10 per cent of the working time when the standard output is 810 units per day?

Problem 14

Find the total day's pay and standard:

Output: 1600 units
Rate of pay: 40 cents per hour
Working day: 8 hr.
Bonus: 60 per cent of time saved
Bonus received by worker: 60 cents

Problem 15

Standard time for a task is 22.5 sec. A worker completes 1620 task accomplishments in a working day of 8 hr. He is paid at the rate of 40 cents per hour and receives a bonus of 20 per cent of the time saved. What is his total daily wage?

Problem 16

A worker earns $4.48 per day. His output is 2100 units during 8 hr. and his rate of pay is 50 cents per hour, plus 80 per cent of the time he saves. What is the standard task and the time saved?

Problem 17

A workman produces 1400 units during an 8-hr. day and receives 50 cents an hour. When the workman exceeds the standard output for the day, which is set at 1250 units, he receives 40 per cent of his time saved. What is the wage of the workman who makes 1400 units?

Problem 18

A worker earns $4.80 per day. His output is 1600 units during 8 hr. and his rate of pay is 50 cents per hour, plus 60 per cent of the time he saves. What is the standard task?

Problem 19. Easyflow Incorporated

ADAPTION OF WAGE SYSTEM TO EXPEDITE PRODUCTION

The Easyflow Ink Corporation manufactures ink in several different colors. The manufacturing process divides itself into three parts: (1) mixing the ingredients, (2) filling the bottles, (3) preparing the filled bottles for shipment.

After mixing the ink, the operations in detail are as follows: Each bottle is filled and corked by machine. It is then labeled, packed in a tube, and placed in wooden boxes for shipment. (Each bottle is labeled in respect to the color of the ink, its quality, and the size of the bottle.)

Easyflow ink-bottle labels are printed in long strips which are rolled up for use in a mucilage machine, which spreads glue on the reverse side of the label. Labels are passed from the machine and cut by the operator just prior to being affixed to a bottle. A girl can affix about 175 labels to ink bottles of any size in an hour, working at a pace set by herself. At present the two girls affixing Easyflow labels are paid at the rate of 40 cents an hour for 40 hr. a week. Production is arranged so that during a given day all bottles coming into the labeling room are uniform in size.

Machines can be procured to affix Easyflow labels at an initial cost of $1250, installed. These machines are capable of affixing a maximum of 300 labels an hour. The cost of operating each machine, including all charges, is estimated at 14 cents per hour. In addition, there will be required one operator to attend each such machine installed and put into use. The wage customarily paid machine attendants in the Easyflow plant is 32 cents an hour for each hour worked. No pay is given for idle time.

The average number of bottles received in the labeling room during ordinary production periods has never been greater than 2800 bottles during any one day. (The bottles are filled and corked by a machine, hence a day's supply of bottles for labeling is usually delivered during the first 3 hr. of each day.) It is planned by the Easyflow management to increase the production volume to average 4000 bottles per day during a 5-day trial period. It is not expected that this number of bottles will be completely labeled every day, but will be provided to avoid the possibility of idle time through an insufficient supply.

The management is considering the desirability of purchasing and using the new equipment as compared to keeping on the present labor force working under a wage-incentive plan.

The standards department has concluded on the basis of several time-study observations that workers in the Easyflow label room could increase the average number of bottles labeled during a working hour by 20 per cent or more above the present level of output and still not feel driven in their work. It is believed that the hourly wage plan encourages deliberate soldiering which a wage system properly installed could overcome. (Machine installation would set the pace for the workers and there could be no soldiering on the job.)

The company has under consideration three wage-incentive plans. They are as follows:

1. The Halsey premium plan.
2. The Gantt task and bonus plan.
3. Straight piece-rate plan. Under the straight piece-rate plan, a worker is guaranteed no wages per day and his earnings will depend mainly upon his own effort.

The Easyflow plant works 8 hr. a day for 5 days a week. The standards department has concluded that each label girl ought to attain an efficiency of 225 bottles (average output) an hour before being paid a bonus. This standard corresponds with those set by competitor plants.

A week of experimenting on the new standards prior to determining upon the bonus plan to be used disclosed the labeling room output per hour (average output for each worker) to be:

	Labeled Bottles per Hour
Monday	250
Tuesday	235
Wednesday	221
Thursday	242
Friday	247

The management decided not to increase the hourly rate of pay, and if the Halsey plan were adopted, to give the workers 80 per cent of the savings resulting from their increased output. It was decided that if the Gantt system were used, the workers should have a bonus of 20 per cent of the standard. Under the straight piece rate, it was concluded to pay the worker \$0.0072 per label affixed to a bottle.

a) Should the company buy the machines to do the labeling or use a bonus system?
b) On the basis of the experience of 1 week which wage plan, if adopted, would be the most beneficial to the management? To the worker?
c) Determine the results that would be attained under each plan for the first week.

PART V

PRODUCTION CONTROL

Another section of this text has dealt with the organization of the physical plant and problems of manpower administration.

At this point in the organization and enterprise, the manager encounters problems which arise in connection with establishing and administering operating controls. The topics treated are these:

1. **Introduction to production control.** Every manager needs to understand the processes of manufacturing as they relate to control of his plant. He must be able to distinguish also some basic concepts of individual control as compared to group control. Then, too, it is necessary to understand the importance of control in relation to the size of the organization.

   Following treatment of the above topics, the introductory chapter on Production Control gives the student of management a brief preview of the four types of manufacturing processes as classified for purposes of production control. Finally, the chapter presents an approach to the analyses of manufacturing processes and other considerations which determine the type of production control best suited to achieve desired results.
2. **Nomenclature.** The first requisite of production control is a system of identification and classification of the materials and parts which flow through the plant during the manufacturing processes.

   The system for numbering materials and parts which may be used in any manufacturing plant is presented in detail. This system is applied in connection with control procedures outlined and illustrated in the remaining chapters of this part of the text.
3. **Storeskeeping control.** Whereas the problems of storeroom organization from the plant-layout standpoint are treated in detail in the chapters on Organization and Layout for Storeskeeping, the procedures of controlling a storeroom in operation are presented under Storeskeeping Control. Special topics such as centralized and decentralized storeskeeping, location marking, accumulation stalls, drawing and issuing material, and stores records, are given detailed treatment.

4. **Development and engineering.** This chapter deals particularly with the steps preparatory to manufacturing. It describes the work of the staff specialists in the engineering department in preparing drawings for use in manufacturing. Each of the following is given particular attention: the records that must be kept relative to drawings, the use of a parts index, new and changed parts notices, changing or renewing drawings, a system for numbering parts so that they may be readily identified, and manufacturing instructions.
5. **Planning procedures.** When the work preparatory to manufacturing is finished, it becomes necessary to plan production procedures as contrasted with carrying them out. The relation of estimating to manufacturing and particularly the four types of manufacturing processes are discussed. This is followed by treatment of the "how" of preparing production estimates so as to make manufacturing profitable. In addition, particular attention is given to the type of control as a determining factor in the work of the planning department. This is followed by a discussion of the use of the master routing card and the job of the planning department in planning a new venture.
6. **Type 1 control.** This chapter is an illustrated presentation of the detailed control procedures best suited to jobbing or special-order production. Each of the steps incident to controlling this type of plant is given detailed treatment and backed up with illustrations and forms required to carry out the control procedures.
7. **Type 2 control.** The control procedures requisite for the rate or mass-production type of industry are handled in the chapter on Type 2 Production Control. Here again, the treatment is complete as to sequence of procedures and the forms and organizations necessary to implement the control of operations.
8. **Type 3 control.** In organizations where manufacturing orders must be scheduled to particular machinery, and where control procedures are necessary to assign the use of the available time of these machines, the type 3 control is needed. The detailed mechanics of operating this kind of procedure is the subject of the chapter on Type 3 Control.
9. **Type 4 control.** Where manufacturing or other types of undertakings are such that they are not likely to be repeated and still require control the *timing of specific undertakings* is essential. The problems encountered and procedures to be followed in controlling nonrepetitive work are the subject of discussion in the chapter on Type 4 Control.

CHAPTER XXIII

INTRODUCTION TO PRODUCTION CONTROL

The Productive Process

When a production man begins to think about a plan for the systematic control of production in his plant, he is bewildered by the great maze of schemes which have been tried elsewhere with varying degrees of satisfaction. He finds himself overwhelmed with doubts and uncertainties as to whether or not he dares to stake his time, the company's money, and perhaps his reputation, on the idea he has had in mind. It may or may not prove sufficiently valuable and rugged to withstand the doubts and uncertainties of other people in the organization whose affairs must inevitably be affected by any program of production control.

One should not undertake to propose any plan for production control until he has acquired a substantial knowledge of the proper functions of the several departments involved in the production cycle. The purchasing, receiving, stores, planning or methods, engineering, cost, pattern storage, tool, and all production-shop departments are regularly involved in the production cycle of the machinery industry in which are found the most complicated, and at the same time most valuable, aspects of production control. All are interrelated in the common current of activity. What is done in one department determines what must be done in another department. Coordination is of fundamental importance in any program of production control that is to be satisfactory and economical. Probably more failures in production-control ventures have resulted from insufficient knowledge of departmental relations than from any other cause. To know what contribution each department should and must make is of paramount importance at the beginning.

All of the departments concerned with production fall into three groups:

1. Those departments, or functions, whose responsibility it is to prepare the product and the clerical records for straightforward production.
2. Those whose responsibility it is to execute the production.
3. Those whose responsibility it is to record, for improvement purposes, the results of the coordinated efforts of the first two groups.

In the machinery industry, which is the most complicated case, those functions which fall in the first group are development, engineering, toolmaking, pattern making, and planning or methods. Those which fall in the second group are the purchasing, receiving, stores, engineering, planning, tool-crib, and pattern-storage departments and the various foundries and production shops. Those which fall in the third group are the cost, accounting, statistical, and management activities.

Probably 85 per cent of the confusion, and therefore, the needless expense, encountered in production-control systems results from undue haste in the initial preparation of a product and its clerical records for production. Those departments whose responsibility it is completely to define a product, to put it into shop language, and to set up the most helpful records, often take a short view of the production cycle. Frequently, at the behest of the management or the budget officer, the engineering department, for example, undertakes to reduce its own expense by abridging its normal functions and passing part of its responsibility down the line to some point beyond which it cannot be passed. That point is usually the assembly department, which is the last link in the chain between the order department and the customer — the place where things have to go together and beyond which there is no one to whom responsibility can be passed.

In the chapter on Type 1 Control, which relates to the machinery industry, there will be explained the relations between the several departments. These relations will then be recorded graphically so that an over-all view of the whole range of production activities can be had.

First attention, therefore, should be given to those departments or functions which are concerned with preparing the product for straightforward production. Four sections, which are made to precede the chapters on control, will be devoted expressly to those preparation departments. In the present chapter there will be explored the various types of productive processes, for it is the nature of the productive process itself that determines the kind of control.

Individual, Elementary Control

The most fundamental, the most primitive, form of productive enterprise is the personal activity of an individual engaged in handling his own affairs. He may be engaged in maintaining his home, in getting a hobby under way, in setting up a business of his own, or in improving his job or his shop surroundings. The usual manner of going at such undertakings, which may require attention over considerable periods of time, is simply to let the spirit move one, doing what occurs at the moment or doing what has to be done as a necessity — the last minute

jobs or the jobs which, having escaped any advance planning, intrude abruptly as emergencies.

It is astonishing what a change is effected in one's state of mind — in one's emotional equilibrium — by resorting to the most rudimentary form of production control in any of these personal situations. Merely to make a list of the things which need to be done will greatly increase one's accomplishments with less expenditure of nerve energy. If the list were arranged according to a definite sequence, bringing together the tasks which are related in any reasonable way, efficiency would increase, and if estimated times were placed opposite the listed tasks one's time could be budgeted most effectively, and without special effort. A busy person, with many things to do, can cover a surprising amount of ground without fatigue by thus resorting to elementary production control. A card, or a number of cards, should be ruled, carried in the pocket, and the jobs to be done noted on them as they come to one's attention. For example:

New light of glass in skylight	20 minutes
Cut down old cherry tree	30 minutes
New hinge and paint bulkhead	30 minutes
Paint garage door	25 minutes
Repair picket fence	2 hours

As they are completed the jobs are checked off and new ones added as they come up; rational pace should be set and the results will be astonishing.

Group Control

From such a rudimentary case of individual performance normal development leads to group performance involving the coordinated endeavors of several persons in a common venture. Immediately the problem of control becomes complicated. Results depend not only on how systematically each member of the group keeps his own tools or equipment and supplies, but also upon his capacity to time his accomplishments in relation to those of others in the group and, most important of all, on the proficiency with which each member of the group so performs his part of the work as to make easier, rather than to impede, the work of the next person in the line. In large organizations where the sense of individual personal responsibility tends to become diluted, this conscious regard for the conditions of cooperative, forward urge — this getting the wind on the back — is reduced. More will be said concerning this situation in a later chapter on the triangle diagram.

Two features of group endeavor require consideration: the size of the group and the nature, or character, of the productive process. If these two features are thoughtfully considered much can be done to

clarify the confusion which has settled into the applications of the fundamental types of production control in industry.

Among the manufacturing establishments in the United States the size of the group varies from 1 or 2 employees to more than 100,000. There are multitudes of establishments with less than 50 employees; very few with more than 2500 employees. The average size establishment at the last census was around 42 wage earners. (It was about 33 at the preceding census.) Where does production control begin to be profitable? Would the same type of control be profitable for both a small and a large organization?

If the principles of the various types of production control are mastered there need be little difficulty in answering such questions and in first designing a control plan for a small group of 10 employees, then designing control plans for groups as large as 10,000 employees. The four fundamental types of control will be taken up in ensuing chapters with illustrative applications from practice.

The Small Producer

There is concern at present over the fate of the small producer in industry. Questions arise as to whether or not he can survive this period of emergency defense production. It is not altogether easy to get a satisfactory picture of just what the small producer is, for it is quite as important to know which type of production he is engaged in as it is to know his size. It depends not only on his number of employees and his volume of output, but also upon whether his productive process falls under Type 1, Jobbing, or Type 2, Mass Production.

Over all industry the number of wage earners averages 42 regardless of the type of manufacturing process. There are more than six times as many establishments below this average as above it. All together they have about one-quarter of the total number of wage earners and they do around one-fifteenth of the total business. Figure 208, plotted from United States Census of Manufactures data, shows how the somewhat more than 200,000 manufacturing establishments in the United States are distributed according to the number of wage earners. Of all the groups the greatest mortality occurs in the first, with its 1 to 5 wage earners, and within this group the greatest difficulties fall to those establishments whose productive process falls under Type 1.

An important reason for the higher mortality in this group is the factor of overhead expense or burden. An individual may start a manufacturing enterprise and build it up to some $5000 a year singlehanded. With the help of two other producers he may increase the business to some $12,000 to $15,000 per year, where his difficulties will begin. He will find that he can no longer be his own telephone operator, book-

keeper, purchasing agent, cost man, biller, and designer as well as development man, maintenance man, and promoter. He is confronted with a choice between two alternatives in order to remain solvent: either he must raise his prices to provide for the addition of overhead expense which, in the beginning, he may not have anticipated, or he must select especially talented and versatile helpers who can rise to the challenge of trying to build a successful business; and he must, through

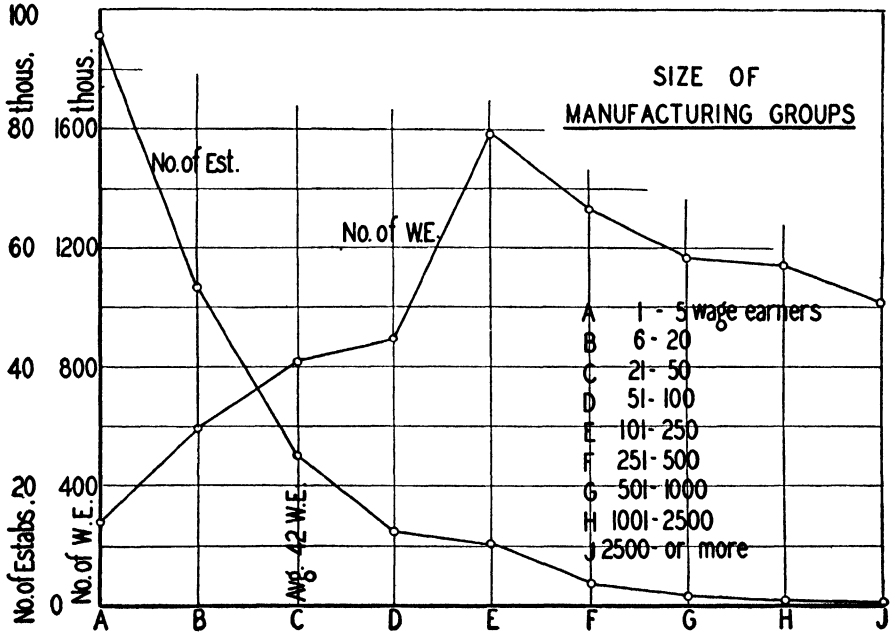


FIGURE 208. SIZE OF MANUFACTURING ESTABLISHMENTS

reputable leadership and skillful planning of jobs, make their efforts intelligent and efficient. This applies more particularly to those producers whose productive process falls under Type 1, or specific order production. Of the establishments in this group which do survive, those which attain a business of some $30,000 a year will have become well enough known to enjoy a local recognition, or acceptance, which, with proper handling, will "get the wind on their backs" and make their difficulties somewhat less. Their difficulties will persist, however, until they attain a size of some 50 employees.

Figure 209, which indicates the distribution of size groups according to sales, has somewhat the same characteristic as the curve of distribution according to number of wage earners. There are some eight times as many establishments below the average value of output as above it, and these are the small producers who have an uphill road in trying to

make a profit which is encouraging in its relation to the profit made by the larger units. Among these small establishments those whose productive process falls under Type 1 have the hardest time, since the jobbing character of their production requires a higher grade of talent than is required under Type 2 production. They also require more employees for a given volume of business because of the inability inherent in the specific-order type of production to take fuller advantage of

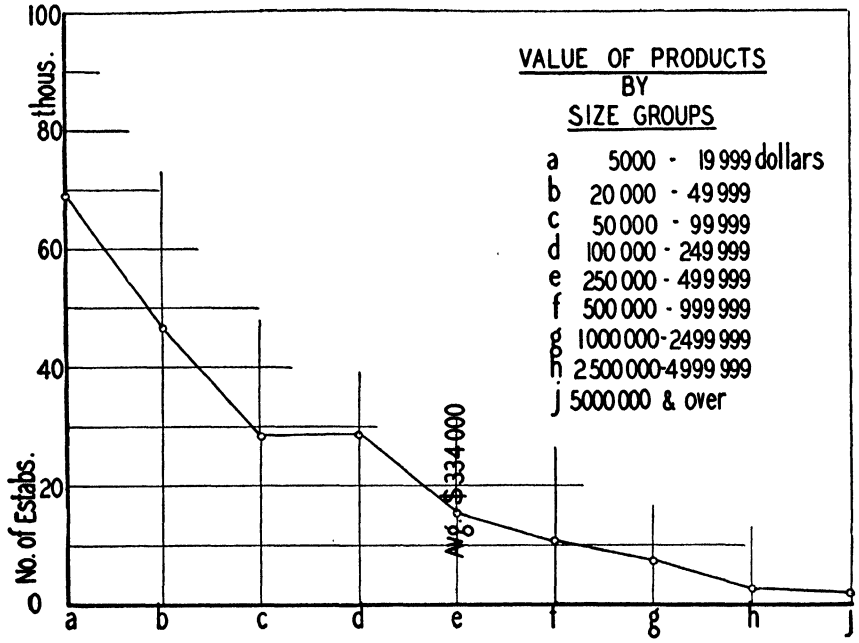


FIGURE 209. NUMBER OF ESTABLISHMENTS IN VARIOUS SALES GROUPS

repetitive and mechanized operations. Operations are of relatively short duration and of great variety, without opportunity for making use of automatic machines or of continuous standard activity.

The small jobbing, or specific-order, producers may find consolation, however, in knowing that except in their smaller number of employees, they are quite as well off as similar very large producers in that large producers, under Type 1 production, will also average somewhere around $4500 sales per wage earner. That is, in specific-order production, a concern doing a business of $1,000,000 per year is little better off than one doing business of $150,000 a year as far as the income per employee is concerned. The only advantages the larger concern might have are in obtaining purchase discounts as a large buyer and in a possible opportunity to group or combine some of its operations so that they may be brought under Type 2, or mass production, thereby gain-

ing the advantage of repetition and of mechanized operation. In a large establishment where this grouping is executed — putting all punch presses together in one department, for example — the production supervisor should be Type-2-minded, keeping in mind that one of the chief advantages of the grouping which provides him with his responsibility is the possible opportunity of combining orders in such a manner as to make as many jobs as possible approximate continuous

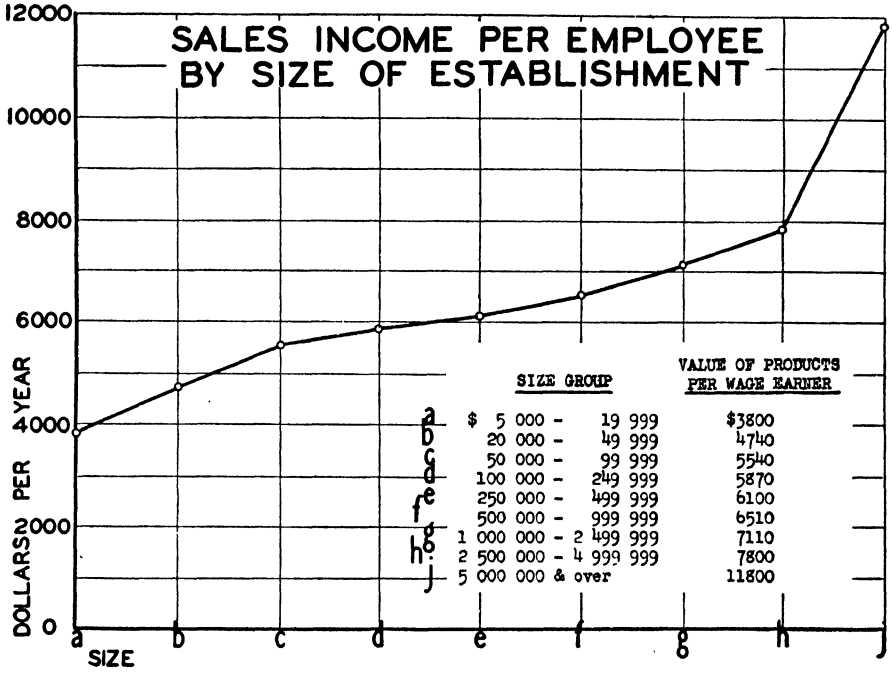


FIGURE 210. THE DOLLAR VALUE OF A WAGE EARNER TO VARIOUS SIZE GROUPS

runs, such as are common under Type 2 production. In so doing he is not merely saving some setup time, or gaining the advantage of operator proficiency; he is doing the more important job of raising the department's income per employee, which is the consideration that tends most to elevate his company into the next higher group.

Figure 210 carries the analysis of the census figures a little farther and shows the average value of production in relation to the number of wage earners involved.

For all the more than 200,000 manufacturing establishments in the United States the average output value is around $7970 per year per wage earner. This figure is high because of the great American drive to find products and conditions which encourage mass production. If all of the manufacturing concerns were devoted to Type 1 production,

then this figure would be considerably lower — somewhere around $4500 to $5000. Processes such as the production of oil, flour, needles, corn flakes, steel, and all other standardized products, raise the average and have a much easier existence.

In the small establishments, whose sales average around $5000 to $20,000 per year, the average sales income per wage earner is around $3800 per year. In the largest units, doing an annual business of $5,000,000 and over, the average sales income per wage earner runs up to some $11,800 per year. Their margin of safety is therefore about three times that of the smallest group.

The change in the inflection of the curve occurs at the *e* group, that is, the establishments doing a business of between $250,000 and $500,000 per year. Establishments below this point have an uphill road; those above it an increasingly easy road.

The average output value below this point is around $5600 per year per wage earner and above it something over $8900 per wage earner. A striking advantage falls to those some 1800 establishments whose business runs to $5,000,000 and over since their average income per wage earner jumps up to around $11,800. These large units, having this natural advantage of size, do not experience so great a need for systematic production control since their operation is much more profitable and, therefore, they do not suffer so seriously from the costliness of inefficient production.

If an establishment is doing a business of, say, $150,000 per year and has 25 employees, it will be in line with the average of all other establishments of this size. Should it have 20 employees instead of 25 then it is one of the "big producers" in its group and is either exceptionally efficient or, which is more likely the case, is engaged mainly in Type 2 production or has a patented specialty which commands a high price through its freedom from competition. If this establishment should have 30 employees instead of 25 then it is a "small producer" in its group, which in itself is a small producer group, and is either exceptionally inefficient or more likely engaged in Type 1 production.

A jobbing, or specific-order establishment — that is, one operating under Type 1 production — which is doing a business of around $80,000 per year and has 14 employees, is well off as far as its position in its size group is concerned. This favorable position is probably not possible unless one or more of its products falls under Type 2 production.

Three manufacturing establishments whose products are related to each other, and each of which is doing a business of around $150,000 per year, would, by merging together, be able to raise their output value per wage earner by about $1000 per year through the advantage

of standardization and mechanization alone. It would be instructive to review such mergers of the past 20 years from this standpoint. Here, however, we are concerned only with trying to get a picture of this thing we call the "small producer."

Those establishments which have attained a business of $250,000 to $500,000 per year, shown as group *e* in Fig. 210, have attained a position in which existence begins to be more comfortable. They will average roughly between 40 and 80 wage earners and also around $6100 per year per wage earner.

In his publication on "Small Business Enterprises in New England; A Problem or Resource?" Mr. Eldon C. Shoup, Regional Consultant, Department of Commerce, Boston, presents some thought-provoking analyses of the relation of the New England territory to the war effort. In it he says

> Small business in New England accounts for about 92% of all firms, for about 30% of the business volume and employs about 40% of the personnel. The proportion varies with the type of business. Of 16,136 manufacturers in New England in 1939, 14,121 or 87.5% employed less than one hundred workers. This group accounted for 26.7% of the manufacturing business and employed 23.6% of the personnel.

He explains that

> Classification of small business in New England is identical with that used by the Bureau of Foreign and Domestic Commerce in its statement covering the entire country, presented by the Special Committee to study Problems of Small Business, United States Senate, December 18, 1941. Businesses of the following sizes were classified as small:
>
> Manufacturers with one hundred or fewer employees;
> Wholesale establishments with $200,000 or less in annual sales;
> Retail stores, service establishments, hotels, construction firms, and places of amusement with sales or receipts of $50,000 or less.
> All figures cover 1939.

In this text we are concerned only with manufacturing. If we consider a producer with 100 employees as small, that would place him in group *f* of Fig. 210, with an annual business of somewhere between $500,000 and $1,000,000. Being on the up side of the curve, beyond the point at which the inflection changes, he finds his enterprise in a position to get some comfort out of its size, receiving some $640, or 11 per cent, more per worker than his neighbor in group *d* who has perhaps 40 workers doing a business somewhere between $100,000 and $250,000 per year. One hundred workers seems a little too high to be considered small, from the standpoint of the struggle involved and the income rate attained.

To get an impression of the importance, in any such analysis, of the type of production involved, one has merely to ask himself whether he would feel more like a small producer if he had some 100 workers engaged in such an occupation as bottling Coca Cola than if this number of workers were engaged in producing special tools, jigs, and fixtures, or in producing paper carton stock rather than in building special machinery.

It seems reasonable to consider that any manufacturing establishment which is in group *d*, or below, doing a business of less than $250,000 per year, or having less than 40 wage earners, is the small producer, particularly if its productive process falls under Type 1. The Type 1 producers in this class must strive to obtain high-grade employees, to increase their efficiency through skillful planning of jobs, and to develop a greater number of products with common parts. The Type 2 producers in this class have principally to seek wider markets for their standardized products. If all such courses are closed, and if these producers seek to lessen their struggle, then the only remaining road left open is to consider a merger.

A small producer would not find it at all impossible to attain an income of $7500 per year per wage earner, if he is engaged in Type 2 production. On the other hand, if he is engaged in Type 1 production, he has a long and difficult battle in trying to lift his enterprise above $2500 per year per wage earner. In one case he may enjoy an income rate of more than $8.00 per dollar of direct wages while in the other he has to try and struggle up from less than $2.00 per dollar of direct wages which, of course, represents a loss.

Such levies as the social security tax hit both cases alike, though the income tax differentiates them. Compensation and liability insurance lays far more heavily on the Type 1 producer. Thus the Type 1 producer, besides requiring a higher grade of workers, has to bear preponderant burdens which fall to his kind of productive process. Exhausting toil for him knows no end. Much constructive thought could well be devoted to making a far clearer distinction between the small producers of the Type 1 class and the Type 2 class than exists at the present time.

It is the Type 2 producer, whether large or small, who enjoys prosperity from wide acceptance and who therefore gains most because of his freedom in our social order. For him there is little if any exhausting toil. President Roosevelt was the first public leader to invite attention to this advantage. Had those who were charged with the administration of the New Deal given a little more thought to the distinction between the large and small producers and the Type 2 and Type 1

producers there might have been avoided much of the accusation concerning the "crucifixion of business." What is comfortable for the Type 2 producer may be unbearable for the Type 1 producer, and, for want of more painstaking thought, our general tendency is to make easier the already easy path and to make discouragingly harder the already difficult path. Morale depends largely upon the intelligence and the justice with which we approach our problems and difficulties.

These two classes of small producers should be especially interested in production control. In view of the fact that the small Type 1 producer has the hardest time to attain a comfortable existence and has to depend upon a higher grade of employees, more intelligence and higher efficiency, the forthcoming chapter on Type 1 Control has been prepared in particular detail.

Type of Control Depends on Type of Process

While there are numerous variations in the methods of handling the details of production there are a very few fundamentals which are common to all productive groups. The multitude of variations arises principally from endeavors to handle production difficulties locally, that is, from the viewpoint of a single department. The engineering department may undertake to set up some form of control board, various groups in the several shop departments may also seek to get a convenient mechanism which will help their control, and the production or planning offices may be seeking the same sort of aid. All of these well-meant ventures will vary in different manufacturing plants because they arise from individual viewpoints wrestling with local difficulties. That may not be bad since, after all, any control plan, if it is carried on with the hope and the faith of the individual who conceived it, will very likely be helpful in stimulating morale and a desire to get results. "All plus is good, only put it in the right place."

The safest way to approach a production-control problem is to consider first how many fundamental types of productive processes there are. These will be found few. It matters little whether the product is buttons, incandescent lamps, or airplanes. The product is not the important thing in production control, but rather the process under which the product is turned out — whether it is on a tailor-made basis or a mass-production basis. If buttons and airplanes are both produced on a mass-production basis, then the fundamental form of control is the same, the difference being only one of degree.

All manufacturing enterprises, whether they be small unit plants or individual departments within a large plant, fall under only four types of productive process.

Four Types of Productive Process

Each type of productive process has its individual type of production control. In a small group of, say, five people there is usually only one type of productive process. For example, a productive group of five people — even one hundred people — may be engaged in the making of tailored clothing, or in making Venetian blinds, or sheet-metal specialties, or special machinery, or in doing jobbing-machine work. Other small groups may be engaged in the mass production of a popular chemical, or of spark plugs, or matches, or rivets, or radios, or shoestrings. Other small groups may be engaged in commercial printing, or in making roll roofing, or special textiles, or paper, or screw-machine products, or punchings. Still other groups may be engaged in the construction of buildings, or battleships, or the making of custom-built boats requiring special skill, or in equipping newly constructed factory buildings, or in moving departments or plants from one location to another, or in planning a military campaign.

In large organizations of 2500 employees or more, all of these processes may be going on simultaneously among several departments. If the processes in small or large groups are the same, the production-control plans by which they would be governed are the same. The only difference between the large and small groups in any one of these classes is one of degree. It is not feasible to govern all of the above types of productive process by a single type of production control. Similarly it is not feasible to have a single type of production control govern all departments of a large company unless all of the departments are engaged in the same type of productive process. Before venturing to set up a plan of control it is necessary to determine under which of the four fundamental types of productive process the work comes.

These four fundamental types of productive process are as follows:

1. The jobbing type, or the specific-order type, in which jobs, as they are received, have to be assigned to individuals or to production centers. The jobs are usually of relatively short duration and they entail a wide variety of operations. High intelligence, skill, and high caliber people are required.
2. The rate type, or mass-production type, in which one or more standardized products are regularly in production and in which it is desirable to maintain a uniform production rate that will keep up with the sales rate and yet not lead to an excessive inventory when sales decline. Once the product has been established, only average intelligence, skill, and personnel are required in the productive end of the business.
3. The load type, or available-equipment type, in which inflexible amounts of equipment are involved and which necessitates a knowledge of when

the present job will be completed before equipment availability, and therefore the starting time of a new job, can be determined.

4. The time-schedule type, or coordinated-effort type, in which the execution of a specific project depends on the timed contributions of a number of individuals, groups, or departments. Average intelligence and skill, but high character, are required since success is in proportion to the will of the constituents to be responsible and dependable.

Type 1 process. Illustrations of the jobbing, or specific-order type of production are any made-to-order products: turbines, special crates, electric controllers for elevators, cranes, pumps for commercial purposes, sails, truck covers, custom-made clothing, Venetian blinds, machine tools, colonial furniture, fraternity or lodge jewelry, and any other product which either has a limited market or is produced according to special specifications.

Characteristic of this type of process is the fact that in large measure no work can be started in the shops until a sales order has been received and interpreted. The productive shops are constantly at work on specific sales orders and do not often handle stock orders. There are many instances, however, in which small quantities of standard products can be built for stock. If ten or one hundred may be expected to sell over the period of a year it is more profitable to issue a production order for such a quantity and to carry them in stock rather than undertake to produce one unit in the spring, and a few in the fall, according to the way in which the sales orders come in.

Equipment is usually tied up for relatively short times and the problem involved in this type of process is that of assigning specific jobs systematically to individuals, machines, or production centers. The efficiency with which the work is executed depends in great measure on the expertness with which the initial planning of the jobs is carried out. Specially designed forms on which to record the job specifications are of great assistance in that. Of the four fundamental types of production this jobbing type, because of the variety of products and activities, requires the most complex scheme of production control and the highest grade of personnel.

One of the tragedies commonly encountered in Type 1 processes results from the struggle to make the process profitable. Instead of perfecting the planning and production-control scheme the course most often taken is that of trying to cut down on the pay roll by getting cheaper help and by trying to introduce time studies where they do not properly apply. One manager of a large enterprise remarked "I would rather have one hundred cheap employees than ten highly paid ones." That sort of thing may be appropriate under Type 2 production, but is hopeless under Type 1 production.

In Type 1 processes, as Henry Ford shrewdly observed, "the best method of wage payment is day work under capable management." More will be said of this in the later chapter on the triangle diagram. In Type 1 processes incentive is derived from the natural instinct of right-minded people to want to be busy. This spring of incentive is tapped by first avoiding confusion — a highly important factor — and by maintaining a smooth flowing stream of jobs, adequately planned in advance.

In the chapter on Type 1 Control an illustration will be taken from the machine industry, which is the most complex, and carried through the whole program of control.

Type 2 process. Just the opposite of Type 1 is that of mass production of standardized products. Incandescent lamps, oil, storage batteries, regular output of automobiles, standard windows and other mill products, matches, cigarettes, flour, corn flakes, standard textile fabrics, drink mixers, tooth paste, ammunition, standard electric motors, refrigerators, typewriters — all such standardized items which can be produced regularly without regard for individual sales orders — all come under Type 2 process. The productive shops are constantly at work on stock orders and do not often handle sales orders.

Characteristic of this process is the relatively long periods of time during which equipment is tied up on continuous runs. Also characteristic is the flow nature of production, everything being constantly on the move. Materials flow into the plant in accordance with rate schedules and flow through the productive departments and assemblies into shipping stock, usually in standard packages, where they pause temporarily and then flow out into the market. Because of mechanization and the rapid rate of turnover, this type of process can be profitable. A company making roll roofing was, at the time production control was installed, turning out some 20 carloads of finished product daily and was receiving in about 20 carloads of raw materials, thus practically doing business on wheels. That is typical of the Type 2 process.[1]

In the chapter on Type 2 Control an illustration will be taken from the electric-wiring devices industry (the same mechanical device taken to illustrate Type 1 control, assuming that it had begun to move popularly, could be used since when a new device is first started in production it will usually move slowly and will be produced in small quantities).

[1] The roofing process would make an interesting study for the student. Estimating the probable future demand for each type of roofing produced and the setting up of the production schedules would come under Type 2 control. The roofing mills are large, not easily added to, and expensive when idle, thus introducing considerations of equipment availability. This, in the actual execution of the production schedules, introduces Type 3 control also.

As the demand for a product increases because of public acceptance, the tempo of production must be stepped up and the product switched over from Type 1 control to Type 2 control. A similar situation arises in the automobile industry. When a radically new model is adopted, production runs at a reduced tempo under Types 1 and 4 control. If the model proves popular, and shows signs of moving successfully, production is switched over to Type 2 control. Thus it is the nature of the process, and not the product, which determines the type of production control. A given type of control is the same for all products manufactured under the process into which its production falls.

Type 3 process. In contrast with the jobbing process, with its variety and relatively short operations, and the mass-production process with its relatively continuous runs of standard items, the load process involves a distinct problem of equipment capacity and availability. The initial investment per productive unit is greater and the cost of changing the setup is considerably greater. In the jobbing process a sales order may call for the turning out of 10 special radio knobs. In the mass-production process a rate sheet may call for the production of standard radio knobs at the rate of 10,000 per week. In the load process a sales order, or a contract, may call for 100,000 special radio knobs which have to be turned out by a hydraulic press; or 500,000 Lucky Strike wrappers which have to be turned out by a large and costly printing press. The load-type process thus has a characteristic of the jobbing-type process in the matter of producing in accordance with specific orders, and also a characteristic of the mass-production type in the matter of long runs, but it differs from mass production in not continuously producing a standardized product that can be handled through inventory. No finished inventory is involved in the load-type process.

Under this type of process come such classes of work as commercial printing, forming presses, automatic-screw machines, looms, paper mills, forging hammers, roofing machines, and any other work which has to depend upon the availability of special, not easily expandable, equipment. The problem involved is that of loading against the available equipment the amount of time required for each job assigned to it so that some means may be provided of ascertaining when any new order may be promised or when work must be sublet because of orders exceeding productive capacity.

The type of control which governs this process does not stand alone necessarily. Frequently it is very helpful when used in conjunction with Type 2 processes particularly, and sometimes in conjunction with Type 1 processes when a peak of work of one particular character may impose a preponderant load on one piece of equipment, thus introducing a bottleneck.

In the chapter on Type 3 Control, an illustration from the printing industry and a molded product, turned out by hydraulic presses, will be used for explaining the operation of the control scheme.

Type 4 process. All of the foregoing three types of process imply the use of equipment and of such groups of people as assemblers, who come under the supervision of the department head who has authority over them. The remaining situation, or process, is that in which a project, or specific undertaking, involves not only individuals or groups under the authority of the department head within the organization, but also widely separated groups who bear no other relation to the individual or company in charge of the general project than that of being a party to the contract. For example, it may be planned to remodel a building into which a manufacturing plant is to transfer its facilities. A contract is let, or the general project is assigned. The one in charge has to call upon the services of a mason, carpenter, interior finisher, millwright, painter, electrician, mover, floor finisher, and plasterer, and has to confer with a number of suppliers of a variety of materials which will be required.

The problem is to coordinate the efforts and services of all concerned in such a manner as to make the execution of the project efficient and as economical as possible. Any form of systematic control is rarely used in situations of this type, except by the most progressive and successful concerns, partly because of the haste with which projects are pounced upon, and partly because of the difficulty of assembling for any common project a group of individuals whose attentions can all be focused in a common direction. Yet there is probably no one type of process which offers a greater opportunity for the cultivation of a successful attitude toward American enterprise than this Type 4 process.

The most elementary situation in which this type of cooperative endeavor exists is a manufacturing group, small or large, in which it should be the common purpose to turn out a product which, because of its quality, and the dependability of service with which it is handled, makes such an impression as to ensure the success of the company and therefore of the individual. It requires expert management and expert selection to build such a group. More difficult and more tedious is the task of getting acquainted with a list of subcontractors whose business characteristics are such as to make it feasible to carry out, with some measure of success at least, an important project like the construction of a building in accordance with the type of control which applies to that type of process. There is always a good deal of the Venezuela story in every such undertaking. Of three workers seated on the curb chipping stones for a Venezuela construction job, who were asked the question, "What are you doing?" one replied, "I'm chipping

stones," the second replied, "I'm making 30 cents an hour," and the third replied, "Me? I'm helping to build that cathedral." Because of the differences in personal backgrounds, it is difficult, if not impossible, to reconcile divergent viewpoints.

Type 4 undertakings call for a high degree of character since the will to be responsible and dependable is of first importance. An illustration of the importance of this central characteristic of successful coordinated-effort undertakings is had in the motion picture starring Gary Cooper in *Sergeant York.* The first platoon was to go over the top at 6:10, other platoons to follow at regular intervals. The way was to be prepared by an artillery barrage starting at 6:00 o'clock. Watches were synchronized, the approach of the zero hour was watched intently; it got to be 6:09:59 — but where was the barrage?

In the execution of a military campaign this Type 4 control is carried out under very rigid discipline and, as the Nazis have demonstrated, can be highly successful. In civilian life, however, it is difficult, if not impossible, to make it generally successful because of the shortage in the type of character required both on the stimulating end and on the execution end.

The timing type of process applies to such undertakings as construction work, setting up a circus, moving a plant or department, starting a new business, writing a book, planning a sales campaign, taking an inventory, remodeling a building, and all other ventures which require effort from a number of different individuals or groups. For an illustration to be used in the chapter on Type 4 Control the construction of a dwelling will be taken.

Analyzing the Situation

It is highly desirable to obtain a clear understanding of the differences between these four types of process and particularly of the four fundamental types of production control used to govern them. This is important because of the complication which arises when the manufacturing group is large. With small groups of perhaps 5 to 50 employees there is not likely to be much about production control which is complicated, but in a corporation of 2500 employees it may be necessary, in order to obtain satisfactory management knowledge of affairs, to make use of all four types of control in varying degrees, sometimes as a permanent part of management work and sometimes only temporarily to get affairs rolling smoothly, after which the control may be boiled down to normal essentials.

Two considerations should be borne in mind throughout this study of production processes and control. One is that even in a single department manufacturing a number of products, some of the products may

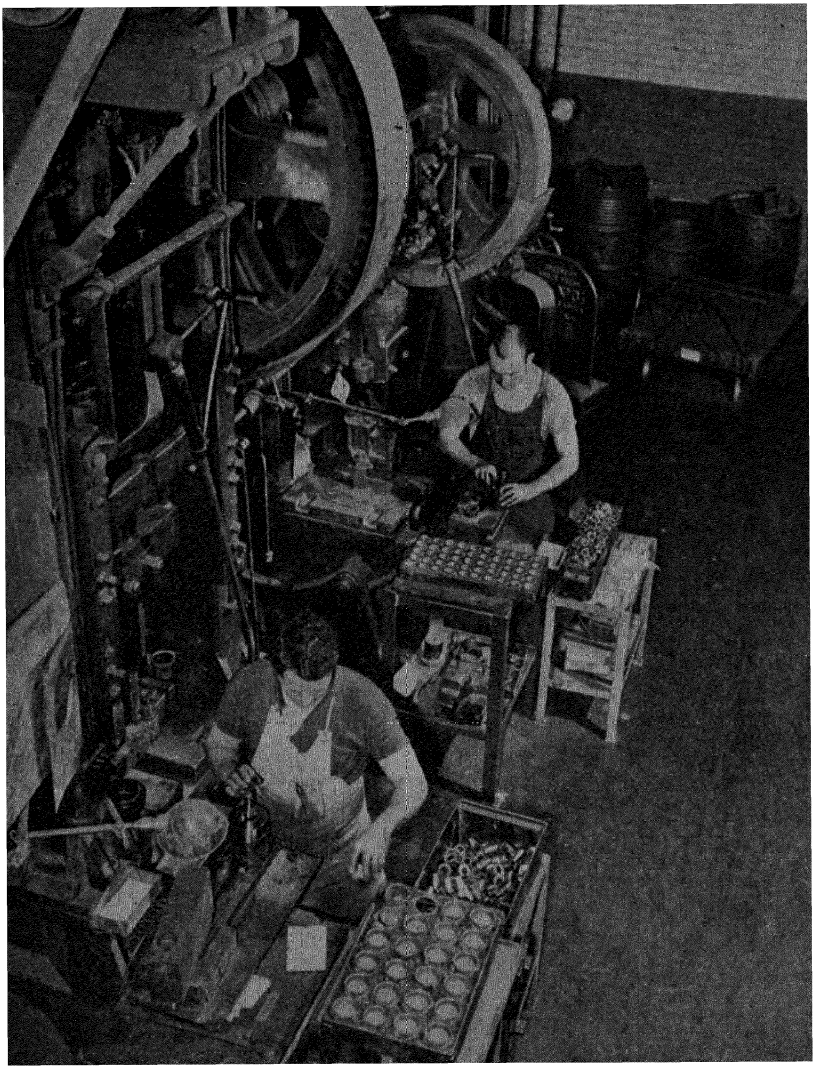
move abundantly by popular demand while others may move only in small quantities. This is nearly always the case. All such products should not be included under a single type of control. Apply each type of control to the products which come under the particular process to which that form of control applies. An automatic screw-machine department, in which some orders are large while others are small, is a good illustration. The other consideration is that we have constantly to ask the practical question, "Should we undertake to control every detail, every move, or should we rely upon the exception principle, applying the control generally and trusting to 95 per cent of the work coming out satisfactorily once it has been started off under control?" That is, should one undertake to control 100 per cent of the details in order to catch the 5 per cent which go wrong? Here it is assumed that we shall rely upon the exception principle.

The departments affected by any plan of production control will depend on the character of the process. A mill producing chip board from which corrugated containers are made, and turning out only one or two standard grades of board in quantity, would come under Type 2 process. The production-control problem would be that of maintaining a steady rate of production based on a forecast of future sales. The operation of the control plan would involve the purchasing, sales, and production departments. Such a case would not be at all difficult.

A plant manufacturing machine tools — lathes, boring mills, planers, shapers, millers, gear cutters, automatic machines, or a plant manufacturing looms, or any other type of machinery — will nearly always fall under Type 1 process. The departments affected by a proper production-control plan will be purchasing, receiving, stores, pattern vault, tool crib, engineering, planning, cost, foundries, machine shops, and assembly. Such a case involves the most complicated form of production control and affords the best opportunity for instruction in the procedure of establishing a control plan. In the following procedure of thinking through given cases the student should look upon them as exercises in concentration. It will be of great advantage if the student has had enough practical contact with industry to have acquired a background of knowledge of shop conditions and activities. However, the cases will be developed as simply as is consistent with brevity.

In any industry certain fundamental forms, records, and data are necessary before production control can be attempted. The character of these fundamental tools will have an important bearing on the quality and the economy of the control. One should think through the successive steps which go to make up the productive process. A chart should be drawn and filled in showing the functions which each step should include. Then a comparison with what is being done at present

should be made to see if some of the functions can be done more economically and more logically at some other point or in some other department. One should try to see the picture as a whole. The analysis should be divided into two parts: (1) the successive steps required to create, define, record, and tool up for a new product (see page 552), and (2) the successive steps required to put through the shops a production

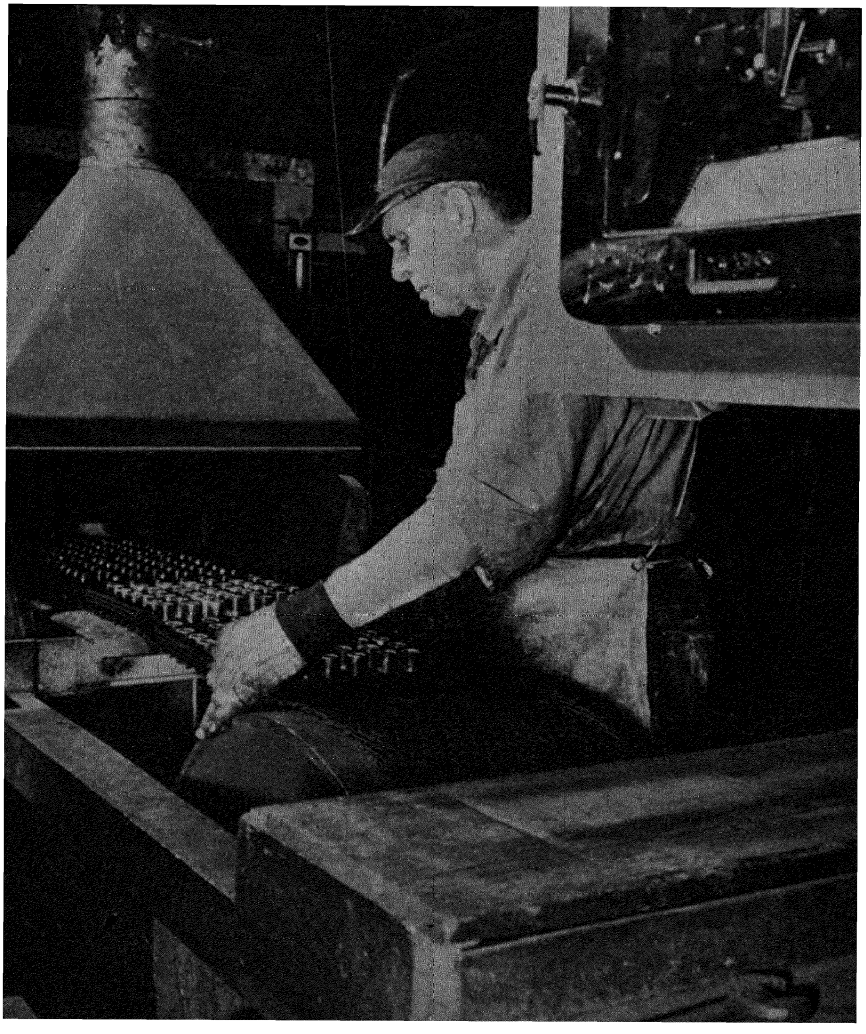


Courtesy of General Motors Corporation

FIGURE 211. ILLUSTRATING THE MOLDING OPERATION

order for a given quantity. Nothing is more valuable than the painstaking effort involved in such a study.

As an illustration, this analysis may be applied to the productive process of a department or of a small company. It is producing plastics — molded products such as radio knobs, wiring insulating blocks, flatiron connectors, attachment plugs, and the like. The operations are



Courtesy of General Motors Corporation

FIGURE 212. ILLUSTRATING THE CURING OPERATION

press, cure in oven, then a series of finishing operations such as burr, grind, groove, polish. In Fig. 211 is shown a similar pressing operation, using mechanical presses.

From the pressing operation the parts go to an oven department for curing. This operation is illustrated in Fig. 212.

This illustrated process is identical with the molding of the radio knobs and flat-iron connectors, for which two analysis charts are here presented.

The container of compound goes to the press. If the production run is a long one, this material may have to be drawn out in convenient quantities over a number of days or weeks. The requisition form which is convenient in such cases is shown in Fig. 223 on page 546. The course of the work itself should be traced from beginning to end by a heavy line. Around this heavy line, and each at its customary place, is drawn in to scale and in color each of the forms involved in the clerical, or control, part of the process. All copies of each form should be accounted for, each one traced through its various operations until the form either is destroyed or lands in a file. At each point where some operation is performed on the form, a circle is drawn with an operation number within it; then notes may be typewritten with these operation numbers as a key between notes and chart. All of the exhibits should be lettered and indexed so that as an appendix to the typewritten notes there will be a complete record of all forms used in putting through the productive work itself.

The chart should be reviewed to make sure everything is accounted for or disposed of. The result will be something like the chart shown in Fig. 213, and the summary will show that it requires something like 252 pieces of paper and the operation of 18 files to process an average order.

Then the general situation should be studied after the principles of the four fundamental types of production control have been mastered and a new chart built up to show the activities as they might more profitably be arranged. The result will be something like the chart shown in Fig. 214 and the summary will be that it now requires around 39 pieces of paper and the operation of 5 files to process an average order. The comparison is reviewed to make sure it is as sound and as complete as possible, then presented to those concerned as a possible means of making their responsibilities easier, and especially of helping to step the company up into the next higher group in which the income, or volume of output, per employee comes nearer to making existence more comfortable. When the new arrangement is applied, and it will take several weeks to apply it, out of the cumbersomeness of old ways will issue a saving of thousands of dollars per year. The control board

shown as Exhibit I in Fig. 214 is Type 3 — or load board, often referred to as the "Gantt chart." These charts should be studied until the technique becomes clear, then improved upon in any way apparent or put in such other form as best suits one's own type of imagination. The typewritten notes will include, as an appendix, all of the exhibits.

In the machine industry those departments, or functions, which are responsible for creating, defining, recording, and tooling up for a new product are the development, engineering, and planning, or methods. These warrant study at the outset because of the importance of so setting up the fundamental records as to facilitate the production which follows. A chapter will be devoted to these departments, or functions, but it will be deferred until after the chapter on Storeskeeping in order to bring the preparation forms and details closer to those of the production-control chapters with which they are so closely associated.

Stores Problems

Affected also by the character of the productive process is the procedure of storeskeeping. Under Type 1 process, in which the jobbing nature of production covers a wide variety of more or less special products moving in relatively small quantities, it is necessary to carry an inventory of many different items. In machine-building companies of around 100 employees the inventory may include few or no finished products but may include 15,000 different parts and raw materials; in companies of 2500 employees the inventory may include 60,000 parts and materials. Try as you will to obtain a four-times inventory turnover per year you will do well to attain a turnover of two and a half times. That situation presents one type of stores problem.

On the other hand, under Type 2 process, in which relatively few products are processed more or less continuously under established weekly rates, there may be a considerable inventory of finished goods and a relatively small inventory of parts and materials. Were it possible to operate such a process with perfection, then materials would be flowing into the plant at precisely the same rate at which the finished standardized products were being shipped out, so that there would be no inventory other than the work in process. That situation presents another type of stores problem.

These two stores problems call for two distinct types of stores records, which should be clearly differentiated to remove the ambiguity concerning the application of the two already well-known forms. In the chapter on storeskeeping these two forms will be described and they will be taken up again, each in its own field, in the chapters on the different types of production control to which they apply.

Other Considerations

One other subject — that of the numbering and classifying of various parts and materials which are carried in stores — should be treated before considering the procedure of controlling production. The engineering department is best qualified to handle this function. The subject might best, therefore, be taken up in the chapter which relates to the work of the engineering department. However, it is desirable to separate it from that chapter in order to make it possible to emphasize those activities in the engineering department which contribute directly to production control. The subject will therefore be considered in the following chapter.

CHAPTER XXIV

NOMENCLATURE

The Numbering and Classifying of Items

Experience in any manufacturing plant, operating under Type 1 process, with numerous small-quantity orders flowing through the shops each calling for many items, both parts and materials, would quickly reveal the importance of some arrangement for identifying the items in telegraphic form both for facility and accuracy. If there were only a few employees, in a small plant, handling relatively few orders, it would not be too inconvenient to rely entirely on the description of the items. For example, on each order requiring it there could be called for "one ½-inch 6:32 round-head steel machine screw, nickel plated." In a larger plant through which may be flowing 100 orders a day, requiring 2000 parts and material items each day in relatively small quantities, the task of designating all of these by such long descriptions would not only be costly, but it would also conduce to numerous errors because of the mental effort required in reading and checking the descriptions. Some telegraphic language is required.

Frequently the position has been taken that "if numbers, or telegraphic designations, are going to be applied to all of the parts and materials used in production, then these numbers, or designations, should be so designed as also to classify the items." That raises the question as to whether it is more helpful to use brief designations to both identify and classify items, or to use brief designations merely to identify items and then maintain a classification list to bring related items together. That is, the question might be raised as to whether it is best to try and assign telephone numbers in such a way as to both identify parties and at the same time classify them as doctors, lawyers, or paper hangers, or to use the numbers merely to identify the parties and then to rely on yellow pages at the back of telephone directories to bring together the numbers of all parties falling into various classification groups.

A well-known example of the use of brief classification numbers is the Melvil Dewey decimal system used by libraries. "Its purpose is to make books more available." This numbering system classifies only in order that "Books can be arranged so that all encyclopedias of music

will be together; all handbooks on engineering; all histories of France." [1] Individual books have to be identified by their titles and authors. There are ten main classes:

000	General works	500	Pure science
100	Philosophy	600	Useful arts
200	Religion	700	Fine arts
300	Social science	800	Literature
400	Philology	900	History, biography

Each of these is subdivided. For example:

500	General science	550	Geology
510	Mathematics	560	Paleontology
520	Astronomy	570	Biology
530	Physics	580	Botany
540	Chemistry	590	Zoology

And again, under mathematics:

510	General mathematics
511	Arithmetic
512	Algebra
513	Geometry

And still further, divisions indicating the form in which the literature appears:

01	Theory	05	Periodicals
02	Outlines, compends	06	Societies, congresses, conferences
03	Dictionaries	07	Study and teaching
04	Essays, addresses	08	Polygraphy

An illustration: under 600, "Useful arts," would come 20, "Engineering," and under that would come 1, "Mechanical." Thus 621 indicates literature on mechanical engineering, and if the form in which it appeared is a pamphlet, the classification number would be 621.5. Obviously it would require study, attention, and aptitude to handle such classification work intelligently. That is true of every system devised for putting into telegraphic language either identifications or classifications or both for the convenience of other people.

Sometimes used in industry to classify and to identify parts and materials is the mnemonic system, "a device for aiding the memory." If it is true that the memory is like a measure and that by putting some things into the memory other things are crowded out, then one must consider whether helping the memory retain classifications of items used in the factory is of greater importance than remembering other things such as where to find needed information. If remembering clas-

[1] Susan Grey Akers, *Simple Library Cataloging*, 2nd Edition, 1933, page 10, American Library Association, Chicago.

sifications is of first importance then the mnemonic system of designation is helpful.

This system, as applied to industry, originated with Frederick Taylor. A good picture of how it is applied may be obtained from C. B. Thompson's *Scientific Management*, from which the following is quoted.[1]

> The classification of worked materials, however, is not quite so simple as that of stores, for it must be based upon a strictly logical analysis of the product being made and this analysis can be made only by one thoroughly familiar with the product and the details of its design and construction. Inasmuch as the classification should be made only of those parts which at any stage of the process may be treated as units, it is necessary for the classifier to know what these units are. Since, further, the classification must be so made that it automatically reduces down to the finished product as the parts become assembled, the relation of one part to another and to the whole must be clearly understood.
>
> The information should be gathered from drawings and bills of materials for the product. The bill of materials shows the entire list of raw materials and partly finished parts going into the machine, together with the dimensions and quantity of each. The drawing shows the shape and dimensions of each part of the finished product and the method of bringing these parts together.
>
> A very complex product, such as a machine, consists first of several large groups of parts. Take, for example, a molding machine, such as is found in up-to-date foundries. This machine consists of 4 groups, any one of which may be assembled independently and put into worked materials stores if necessary.
>
> These are the base group, the hose group, the yoke group and the miscellaneous group, the latter consisting mainly of those parts which are necessary for the assembling of the other three groups into the completed machine. Again, each of these groups is made up of divisions which may be made independently: the base group, for example, consists of a strain bar division, a cylinder division, a platen division, and again, a miscellaneous division. These divisions likewise consist of sections, elements, and so on, until you get down to the separate pieces which go into the machine.
>
> In the original base sheet which ties together all classifications into the cost classification, the letters F to W, with the exceptions of S and T, were reserved for products. Suppose that you take M for molding machines. Molding machines are of several varieties of which the following are a few examples:

MA Automatic Stripping Plate Machines	MF
MB	MG
MC Core Ramming Machines	MH Hinged Vibrator Machines Hand Ramming, Hand Draft
MD	
ME	MK

[1] Clarence Bertrand Thompson, *Scientific Management*, 1914, page 503, Harvard University Press, Cambridge.

ML
MM
MN
MP Power Ramming, Power Draft Machines
MR Plain Power Ramming Machines
MS Shockless Jarring Machines
MT
MU
MV
MW
MX
MY
MZ

We are dealing with a plain power ramming machine, MR. Classifying the groups composing this machine we get:

MRA
MRB Base group
MRC
MRD
MRE
MRF
MRG
MRH Hose group
MRJ
MRK
MRL
MRM Miscellaneous group
MRN
MRP
MRR
MRS
MRT
MRU
MRV
MRW
MRX
MRY Yoke group
MRZ

The base group divides into:

MRBA
MRBB Strain bar division
MRBC Cylinder division
MRBD
MRBE
MRBF
MRBG
MRBJ
MRBK
MRBL
MRBM Miscellaneous division
MRBN
MRBP Platen division
MRBR
MRBS
MRBT
MRBU
MRBV
MRBW
MRBX
MRBY
MRBZ

And the strain bar division again resolves itself into the final units or elements as follows:

MRB1B Right hand strain bars
MRB2B Left hand strain bars
MRB3G Trunions
MRB4B Trunion shafts

It frequently happens, as in the case of these molding machines, that several different sizes of the same design are manufactured. The symbols for all these sizes and their parts are exactly alike, except that some significant dimension peculiar to each size is selected and inserted after the first letter of the symbol.

The particular right hand strain bar we have in mind may be for a machine with a platen 10 × 32 inches; and our symbol for that piece of metal then will be

M 10 32 RB1B.

If this strain bar were for a machine with a platen 16 × 48 inches, its symbol would be M 16 48 RB1B.

Notice how these symbols develop into the symbol for the complete machine. We start manufacturing on M 10 32 RB1B, the right hand strain bar; M 10 32 RB2B the left hand strain bar. When these are made and assembled into the strain bar division, they become M 10 32 RBB. In the meantime the cylinder division, M 10 32 RBC, and the platen division, 10 32 RBP, have been made in another part of the shop. These, together with the miscellaneous division M 10 32 RBM, are brought together to be assembled into the base group of the machine. When this is done, B for strain bar division, C for cylinder division, M for miscellaneous division and P for platen division, drop out of the symbol and we have the symbol

M 10 32 RB

as the symbol for the base group. While this is going on, the hose group, M 10 32 RH, and the yoke group, M 10 32 RY, have been made up and assembled and these, together with the miscellaneous group, go to the final assembling, from which emerges the complete machine, M 10 32 R, which means a plain power ramming machine with a platen 10 × 32 inches.

Obviously the same set of drawings, route cards, progress sheets, and so forth, may be used for this machine over and over again. It is important, however, that we keep track of different lots going through. It happens that this particular machine is sent through in lots of 50 and each lot is numbered serially. The last lot is, perhaps, No. 68. This is indicated by adding the lot number to the end of each symbol.

If we want to symbolize all operations on this machine all we have to do is to prefix a number to the symbol of the piece, division or group on which the work is done. Thus the first operation on the right hand strain bar may be to lay out, the second to drill. We indicate this simply as

1M 10 32 RB1B 68,
2M 10 32 RB1B 68, and so on.

The foregoing is a good exposition of how the mnemonic system is expected to function. Here again, it would require study, attention, and aptitude to handle such classification work intelligently. The value of this system may be questioned, inasmuch as it presupposes the existence of a complete set of drawings which always come before anything else. The drawings are all numbered, so that the parts they picture are briefly and clearly identified. It becomes a matter of decision whether it is more useful to keep the drawing numbers for identifying the parts and then grouping all parts for any machine on a material list and to classify all groups of parts by means of an index, or to set up such a mnemonic classification in addition to the drawings and material lists. The answer would have to be obtained by setting against the cost of preparing and maintaining such a mnemonic classification whatever would be saved by setting it up, in addition to the drawings and material lists which must exist anyhow.

On page 526 is described a parts-and-materials numbering system which is very simple and whose application does not require a great

amount of special aptitude. It is based on the following fundamental premises:

1. To facilitate the clerical and stores activities where numerous parts and materials are constantly being specified, handled, and costed, long names or descriptions should be coded by some designating numbers.
2. The purpose of these code numbers should be merely to identify the items.
3. If parts are designated by drawings, then the drawing numbers become the identifying code numbers. No other numbers should be assigned to such items.
4. The code numbers to be explained in later paragraphs should be applied only to purchased commercial items which are carried in stock.
5. Any classifying of items should be accomplished by means of classifying lists. It should not be attempted to make the identifying number also do the classifying. These classification lists are here called the "Parts Index," or "Parts Catalogue," which will be described in the chapter on Engineering Department.

Three elements enter into the designation of any part: the name or kind of part, the material of which it is made, and the size. For parts which a company itself manufactures there exist appropriate drawings which completely define these elements. What we are concerned with at this point is the assigning of code numbers to those multitudes of items which are purchased from other manufacturers and carried in stock.

Whether or not numbers should be assigned at all depends upon what service the numbers are expected to perform. In a pattern shop, where the patterns are made for the company's own use — that is, the patterns are not made for sale — a considerable number of wood screws, nails, and brads which move in relatively small quantities will be required. Usually it is not worth while to attempt to cost a few such items as "direct material," and therefore there is little or no advantage in assigning numbers to them. Merely let the patternmaker use what he requires and treat them as supplies or else add an estimated cost for them.

Again, in the commercial production of such items as Venetian blinds, a definite number of screws of definite sizes go with each type of blind. These may be costed as a group and a supply may be kept in the assembly department, no special designation being required since they do not vary from one job to another. No code numbers need to be assigned in such a case.

However in the case of machine companies whose commercial items vary between jobs and must be quickly specified, handled, and costed without allowing opportunities for errors in interpretation or reading, resulting from mental fatigue and distractions, code numbers are useful. An illustration of the advantage of code numbers may be had in

considering the work of the stores record clerk whose duty it is to deduct from the stores record all items called for by production orders. If it were necessary to read individual requisitions such as "200 ½-inch 6:32 round-head steel machine screws" and then to find the corresponding stores record sheet or card, the operation would be both exhausting and costly. The mnemonic system of numbering might help the memory some by specifying this item as "200 ½-inch 6:32 RHSMS" but that admits of errors in interpretation. It would be vastly better to specify the item as "200 7359–45," which is the designation used in this text.

Since there are three elements involved in the designation of a part, namely (1) kind of part, (2) material of which it is made, and (3) size, the designating code number must comprise three parts. A number such as 0000.000 accomplishes this, the first two digits being reserved for specifying the kind of part, the second two digits the material, and the digits following the decimal point being reserved for the size. In a very few cases four digits may be required after the point. Then if there is to be a finish, such as nickel plate, the finish letter should follow the number, as 0000.000N.

Each different manufacturing plant will have to make up its own numbering chart since conditions vary so widely. For example, one company may manufacture pipe fittings. The fittings will all be designated by drawing numbers, and that is sufficient. If that company wishes to classify the items, bringing together all regular elbows, for example, then classification lists will be prepared, one sheet being devoted to elbows. On that sheet will be listed the sizes and the drawing numbers of all the regular elbows manufactured. Another company may manufacture pipe clothes racks, with or without wood shelves, for shops and stores. It may carry in stock quantities of various pipe fittings which it purchases according to description — regular ½-inch elbows, ¾-inch by ½-inch reducing tees, and so on. This company, if it is a busy one, would find it profitable to assign code numbers for such stock items and any classification would be accomplished by lists which show the part, the sizes stocked, other sizes available commercially, and the code numbers of the stocked items.

Thus some thought must be exercised in applying code numbers lest one go too far and try to assign numbers to items which, because of already existing drawing numbers or because of isolated or infrequent use in specifications, will not return a profit in proportion to the cost of making the assignments.

The case assumed here, for illustrative purposes, is the most complicated one — that of a machine-tool company. Such a company ordinarily falls under Type 1 process; that is, jobbing. Orders come in for one of this type of machine, ten of that, a replacement subassembly

unit, and so on. There may be as many as a thousand items required for one machine.

Again, each different machine-tool company may have its own chart from which to assign the code numbers. It would be quite feasible, however, to have a standard numbering chart for the whole machine-tool industry, or the whole pump industry, and so on. The illustrative chart which is shown in Fig. 215 on page 528 should therefore be taken merely as a guide to the numbering scheme. Effort should be directed solely to grasping the principle and this should then be applied to the specific case in hand.

Referring to page 528, the first column is the code base for the first two digits of the numbers and these two digits refer only to the kind of part. The designations will vary according to the plant concerned. For example, number 63 is assigned for solid rivets. For one general class of rivets there may be, say, 5 different diameters and 37 different lengths. Then there may be 14 different head shapes such as

Flat head	Wagon-box head
Cone head	Belt head
Rose head	Button head
Globe head	Machine head
Round head	Steeple head
Wheel head	Flat countersunk head
Oval head	Oval countersunk head

It is not likely that any one plant would have occasion to purchase all of these styles and sizes for stock. However, for illustration, assume that it does. There may be required, for this particular class of rivets, some 2590 designating numbers. Three alternatives are open in assigning the numbers:

1. Make use of several of the key numbers, such as 63, 64, 65, 66, to group selected divisions of kind or type of rivet, *or*
2. Make use of only one key number, for example, 63, and then accomplish all of the group dividing by assigning blocks of numbers following the decimal point. For example, .0001 to .0185 would indicate flat-head rivets of all diameters and lengths; .0186 to .0370 all cone-head rivet diameters and lengths; and so on to .2590, *or*
3. Make use of a combination of the above two plans as best suits the case in hand.

If the principle of assigning the numbers from the code sheet on page 528 is understood, little difficulty need be experienced in handling the details.

In the second column of the numbering chart are shown the various materials which may be used in a particular plant. Here again scarcely any two plants will have the same list. If a particular rivet is of $\frac{1}{2}$ inch

NUMBERING CHART FOR STOCKED COMMERCIAL ITEMS

1st 2 Digits: Class of Item	*2nd 2 Digits: Class of Material*	*1st 2 Digits: Class of Item*	*2nd 2 Digits: Class of Material*
00 Unclassified	00 Unclassified	50 Pins: Straight	50 Rayolite
01 Bars: Square, Rect., Hex.	01 Aluminum	51 Cotter	51 Cyclops Extra Refined
02	02 Babbitt Metal	52 Escutcheon	52 Sanderson Extra Knife
03	03 Brass		
04	04 Bronze: Commercial	53 Tapered	53 Firth Sterling Special
05 Bolts: Carriage	05 Government		
06 Eye	06 Anti-Acid	54	54 Firth Sterling Best
07 Machine	07 Phosphor	55 Nuts (Subdivide if desired)	55 Cyclops B–6
08 U-Bolts	08 Tobin		
09 Castings	09 Carbon	56 Pipe	56 Rex AA
10	10 Composition: Bakelite, etc.	57 Plates	57 Bethlehem
		58 Punchings: Pressed Parts	58 Drill Rod
11	11 Allegheny Metal		
12 Clamps	12 Duralumin	59	59 Screw Stock
13 Cocks	13 Copper	60 Rings	60
14 Mechanical Couplings	14 Felt	61	61
		62	62
15 Cups: Oil	15 Fibre	63 Rivets: FH, RH, OH, Ctrsk. H.	63
16 Grease	16 Paper		
17 Plunger	17	64 Tubular	64
18 Discs	18	65	65
19	19	66 Rods, Rounds	66
20	20 Iron: Grey	67	67
21 Forgings	21 Semi-Steel	68	68
22 Hose: All Kinds	22 Close Grain	69	69
23	23 Nickel Cast Iron	70 Screen Wire: Wire Cloth	70 Lead
24	24 Malleable		
25 Keys: Square, Rect.	25 Wrought	71 Screws: Cap	71 Monel Metal
26 Gib	26 Norway; Swedish	72 Lag	72 Rubber
27 Adapter	27	73 Machine	73 Leather
28 Woodruff	28	74 Set; with head	74 Tin
29	29	75 Set; headless	75 Zinc
30 Pipe Fittings: Adapters	30 Steel: Cast	76 Wood screws	76
		77 Studs	77 Graphite
31 Angles	31 Cold Finished; Rolled	78	78 Wood
		79 Sheets	79 Wool
32 Connectors	32 Hot Drawn; Rolled	80 Spacers	80
		81	81
33 Couplings	33	82	82
34 Els, Tees	34	83	83
35 Nipples	35	84 Strips; Straps	84
36 Flanges	36 Key Stock	85	85
37 Plugs	37 SAE 1020, X1020	86 Structural Angles	86
38 Straight Reducers	38 SAE 2315	87 Channels	87
39 Reducer Angles	39 SAE 6135	88 I-Beams	88
40 Reducer Els, Tees	40 SAE 1040, 1045	89 T-Bars: Z-Bars	89
41 Reducer Unions	41 SAE 3140	90	90
42	42 SAE 1360	91	91
43	43 Simplex Forging	92 Tube; Tubing	92
44 Regular Unions	44 Carpenter "Solar"	93	93
45 Railroad Unions	45 Hi-Ten B–3 Temper	94 Washers: Plain	94
		95 Lock	95
46	46 Hi-Ten B–5	96 Burrs	96
47	47 Hi-Ten M	97 Wire: Ordinary, Soft	97
48	48 Alpha #4	98 Spring, Piano, Music	98
49	49 Columbia		
		99 Flat	99

The make-up of any number would be 0000–000, the digits following the dash indicating the size. Finish letters follow the number: —

G	Galvanized	C	Copper Plated
J	Japanned	P	Polished, Buffed
N	Nickeled	Ch	Chromium Plated
B	Brass Plated	Etc.	

Thus 1″ Galvanized Iron Pipe would be 5625–5G and Tubular, Flat Head, Brass Rivets, Nickel Plated, would be 6403–21N, the 21 indicating the particular size, say $\frac{1}{8}'' \times \frac{3}{4}''$

FIGURE 215. BASIS FOR NUMBERING

diameter, $1\frac{3}{4}$ inch long, with flat head and made of Swedish iron, its complete designating number, when put into stock, might be 6326.0004. All sizes of flat-head rivets would be listed on a classification sheet for convenient reference, but stock numbers, or code numbers, would be indicated for only those items carried in stock. To illustrate, take round-head rivets as shown on page 410 of *Machinery's Handbook*.[1] All of the sizes would be listed on the classification sheet of the plant which uses such rivets commonly. The listing, if the rivets are made of Swedish iron, would be as follows:

ROUND-HEAD RIVETS

D	*Grip*	*Length*	*Stock No.*
$\frac{1}{2}$ in.	$\frac{1}{2}$ in.	$1\frac{1}{2}$ in.	
	$\frac{5}{8}$	$1\frac{5}{8}$	
	$\frac{3}{4}$	$1\frac{3}{4}$	6326.0742
	$\frac{7}{8}$	$1\frac{7}{8}$	
	1 in.	2 in.	6326.0744
	$1\frac{1}{8}$	$2\frac{1}{8}$	
	Etc. to		
	5 in.	$6\frac{3}{8}$	
$\frac{5}{8}$ in.	$\frac{1}{2}$ in.	$1\frac{3}{4}$	6326.0778
	$\frac{5}{8}$	$1\frac{7}{8}$	
	$\frac{3}{4}$	2	
	$\frac{7}{8}$	$2\frac{1}{8}$	

The whole list would appear on the classification sheet, that is, the parts index, or parts catalogue sheet, which would be the principal reference of the engineers in putting new designs into shop language, but there would be shown stock numbers for only those sizes carried in stock. In the chapter which explains the work of the engineering department a more complete illustration will be given for commercial drill rod.

It is important that a good understanding of this numbering plan be had at this point. It comes into the chapter dealing with the engineering department where reference is made to the parts index in selecting existing items and in recording them on the all-important material list taken up in that chapter.

[1] Eighth Edition, 1931, The Industrial Press, New York.

CHAPTER XXV

STORESKEEPING CONTROL

The stores department is the connecting link between the planning, or production department, and the shops. Parts and materials move through it much as money moves into and out of the commercial department of a bank. Rough castings, when used for more than one finished part, move into stores; raw materials, finished parts, and supplies in great variety move into stores. The primary object of the whole stores department is to contribute economy and facility to production, and the administration of the department should be based on these two factors.

In the organization plan the stores department may come under the purchasing department, or under the planning department, or under the manufacturing department, or directly under the management. Its place depends partly on the type of productive process — whether the jobbing or specific-order type, or the rate or mass-production type, and partly on the personalities involved. It is best placed when it is under the jurisdiction of that department in a position to make the most of the economy and facility which it should contribute.

One of the greatest advances made in the management of manufacturing enterprises resulted from the separation of the planning function from the physical execution of production. There are still many plants in which orders are entered and then transmitted directly to the shops where the foremen interpret them, requisition necessary materials, and then plan and execute the work. Even in a small organization of 10 wage earners, however, it is much more profitable to have the orders planned in advance and not transmitted to the shop until everything is ready for them or is near enough in sight to ensure that the job may proceed to completion without interruption.

Generally the most satisfactory place for the stores department is under the planning department, with provision for the purchasing department to feel free to take advantage of favorable market conditions and make commitments for such items as pig iron or any other staple without too strict a relation to current production programs. In this text it is assumed that the stores organization functions under the planning department.

The functions of the stores department are:

1. To check in and put away all incoming materials which are stock items.
2. To systematically house the items and be responsible for their safekeeping.
3. To prepare raw materials for production in accordance with the cutting instructions shown on the route tag issued with the production order.
4. To issue parts and materials on the authority of whatever form of requisition is presented.

These functions will be illustrated in the separate chapters on the various types of control.

It will be necessary to clarify these functions because, in large manufacturing concerns particularly, one storeskeeper may have charge of the finished-parts storeroom while another has charge of the raw-materials storeroom where cutting operations are required. Further, stores issues, as explained later, are made on the authority of material lists and route tags instead of the usual form of requisitions.

Finished stock, that is, the finished products which are ready for shipment, sometimes comes under the shipping department and is called "shipping stock." This arrangement is appropriate under Type 2 process wherein the products are standard and are produced under rate schedules based on estimates of future sales and wherein the planning department is not concerned with individual sales orders. Under Type 1 process, however, wherein the only items carried in finished stock are the relatively few products which are standard, it is more satisfactory to have the finished stock come under the planning department where attention has to be given to individual sales orders.

In the raw-materials storeroom of a machine-building plant the storeskeeper should have access to various kinds of cutting machines. He will work almost entirely from route tags, which will be explained more in detail in the chapter on the Planning Department. These route tags will read something like " Draw 106 inches of 6658–143 from location 7C9." In this case the storeskeeper would go to aisle 7, tier C, bin 9 and take out 106 inches of the $\frac{5}{8}$-inch drill rod, cutting one of the pieces if necessary, then attach the route tag (which is the third copy of the production order) and forward the stock and tag to the department designated for the first operation.

In the finished-parts storeroom of such a plant the storeskeeper would not often handle route tags in the issuing of stores. He would work almost entirely from material lists, these lists serving as blanket requisitions for all of the stocked finished parts required for the corresponding erecting or assembly orders. There might be, in a simple case, 25 items on a material list such as illustrated in Fig. 239 on page 570. Of these items there may be 9 which are stocked items and these 9 parts are all

that concern the finished parts storeskeeper. For each of these stocked items the material list would indicate such instructions as "From location 63–9F8 draw 25 Z–1146 and put them in accumulation stall 16." In this case the part would be in storeroom 63 and the storeskeeper would go to aisle 9, tier F, bin 8, check to see that the drawing number shown on the bin label corresponds with what is called for, then draw out the 25 hexagon lock nuts and put them in a tote box. After doing this for all the stocked items shown on the material list he would transfer them to stall 16. Here the material list would be placed in its clip to await the arrival of purchased and manufactured parts which will be flowing in from various sources until the day when the job is scheduled to go to the assembly floor. The steps in this operation will be explained more fully in the chapter on Type 1 Control.

In neither the raw-materials storeroom nor the finished-parts storeroom where the above operations constitute the bulk of the work, is any clerical work required by the normal flow of production orders to the shop.

There will be occasions when, because of spoilage in the shop, more material will be required than was called for on the route tags or material lists. In these few cases a customary form of requisition has to be presented, but these also call for no clerical work on the part of the storeskeeper. The only times when clerical work is required of him are when he has to record the receipt of material, when he prepares occasional bin check tickets such as explained on page 543, when he posts the assembly schedule blackboard at the accumulation stall as explained on page 614, and when he takes physical inventory under Type 2 control.

Centralized and Decentralized Stores

It is not feasible to lay down any general rule governing the choice between centralized and decentralized stores. The great advances made in the technique of handling materials have introduced changes in the manner of locating and arranging stores. Policy in the matter depends on the size of the manufacturing establishment and on the type of its productive process. Certain fundamentals, however, should be observed, the most important of which is that, insofar as possible, it is best to centralize the control but to decentralize the activity.

In small companies it is desirable to centralize the stores so they may be brought under the jurisdiction of one storeskeeper, and the location of the storeroom should be in the vicinity of the department using the stores. If there are several manufacturing departments, then the storeroom is most convenient when it is near the center of gravity of these departments in order to minimize travel. In larger companies, however,

where there are several departments, each using a different class of materials and parts, it becomes advantageous to separate, or decentralize, the stores, locating near the forge shop the materials required there, near the radio assembly department the parts which are used there, and near the automatic screw-machine department the materials which are used there. The circumstances, or the characteristics of each individual case, would determine what arrangement is most economical. Type 1 production presents one picture, Type 2 presents a different picture It will make the differences in procedure and in the choice of stores locations clearer if these factors are considered in connection with specific cases to which the stores function applies. Storeskeeping and location will therefore be mentioned more specifically in the later chapters on Type 1 and Type 2 Control.

In large manufacturing establishments some stores which are common to several or all departments are best centralized. An illustration is supplies — brooms, printed forms, soaps, stationery. While the main quantities are centralized, sub stores of small quantities set up in the various departments are convenient and economical. This arrangement makes it possible for the cost department to make allocations of expense more economically by charging out the items in quantity rather than n numerous small transactions.

Location Marking

Whether the materials storage place is a yard, an open floor, or a section of wood, steel, or pipe frame compartments or bins, it will be of great advantage in the production plans described in later chapters if the numbering or designating of these places is made to conform to a few very simple principles. While constant contact with storerooms necessarily gives the storeskeeper considerable familiarity with the locations of many items, it is not wise consciously to overload the memory by trying to memorize locations. The important things for the storeskeeper are to be orderly, accurate, and forever mindful of his executive responsibility in keeping things on the move and on schedule. To clutter the memory with elementary things such as the locations of various items tends to reduce his executive value and his ability to rise to greater responsibility. All papers coming to him from the planning department, and relating to stocked items, should have the stock locations noted on them. For all items called for on requisitions received from the shop departments he should have a locations index. This would be a copy of the parts index, explained in the chapter on Engineering.

If a new item is set up in stores, the storeskeeper selects a location for it and the location number is entered in the storeskeeper's copy of the parts index. The location number is forwarded to the planning de-

partment where it is entered on the stores record as illustrated in Fig. 224, page 548. Thereafter the storeskeeper does not need to remember it. The convenient manner in which the planning department communicates these location numbers back to the storeskeeper is explained in the chapter on Type 1 Control.

In general, for want of more careful attention to the value of the storeskeeper, the arrangement and numbering of locations is still quite primitive, considerable reliance being still placed on memory. In small companies that may not be a disadvantage. However, when there may be 2000 items in stores the memory becomes unreliable, and when there are more than 50,000 items in stores, as is common among the larger companies, the memory has to give way to appropriate records.

In order to pick up some item for a production order the storeskeeper has to approach its location from his headquarters at the front of the storeroom. He is directed to the location by the route tag or the material list which was received from the planning department. He first has to find the location. This step is simple and quick if the location number is stated in the natural manner by which it would be approached — first the area, then the aisle, then the tier or row, and then the bin — as, for example, 29–18F32. Here the location is in storeroom 29, aisle 18, tier F, and bin 32. While walking toward the location the storeskeeper's eye will have traveled as far as the F so that when he gets to the eighteenth aisle he has only to spot bin 32. If the aisles are numbered from the storeskeeper's desk, or from the front of the storeroom, and if the tiers are lettered upward from the floor, and if the bins are numbered in from the main aisle, then the numbering arrangement will conform to the natural approach and is therefore most advantageous.

The principles, then, to keep in mind when numbering locations are:

1. First designate the general stores area by number. If it is an inside storeroom this will be the department number. If it is an outside yard area, adjacent to a particular building, then it would be designated by the building number followed by Y, as 4Y. This area number would be followed by a dash.
2. Cross aisles, or sections of bins, should be designated by numbers beginning at the point from which they would normally be approached, that is from the front of the storeroom or from the main approach to the yard area.
3. The tiers should be designated by letters beginning at the floor level. Thus the letter A would always indicate the floor, or first tier.
4. Bins or compartments should be numbered, starting from the aisle and not from the wall.

5. The location numbers should be as permanent as the locations themselves and should be clearly marked on the locations.
6. Each location should have a bin label holder if possible. This holder should have in it a removable label, or card, bearing the drawing number or stock number of the item in that location. When the item or material is transferred to some other location this bin label should go along with it to the new holder.
7. Since it is not always feasible, nor desirable, to carry all available material in the service-bin location some provision should be made for indicating the other location where the balance of the material may be found. This is done by having a narrow strip of colored card which can be inserted at the right-hand end of the holder and on which can be marked the surplus stores location.
8. The stock number or specifications of the material should never be marked on the location itself but rather on a removable tag, preferably inserted in some convenient card holder.
9. All stores areas throughout the establishment should be numbered in conformity with this central plan regardless of the type of construction of the bins or compartments.
10. All of the numbering of locations should be done in such a way that the numbers are visible from the path of approach.
11. The storeskeeper should have a copy of the parts index (see page 560) and he should note the location numbers opposite the stock numbers of those items which are in his storeroom.

Accumulation Stalls

In the finished-parts storeroom of a Type 1 plant — that is, a plant engaged in jobbing, or specific order, production — provision should be made for accumulation stalls or depots in which to accumulate gradually all of the parts required for specific assemblies. If the plant produces heavy machine tools, such as planers, lathes, milling machines, or boring mills, there will be some parts such as the base or frame which are not likely to become lost or robbed for some other order than the one for which they were intended. These heavy parts should always be routed directly to the floor on which they will be machined. There are many smaller parts, however, which have to be strictly guarded or, when the time to assemble them arrives, it will be found that some of them have been taken in order to complete some other job ahead of its scheduled date. Costly confusion results from this common weakness in the control mechanism.

Furthermore, to keep the assembly floors free from the clutter of numerous accumulations of parts on various erecting or assembly orders, it is advisable to provide systematic accumulation stalls out of the assembly departments where the parts may be kept safely until the material requirements for each order are ready for erection. When

the planning department first issues an assembly order, the material list which accompanies it may indicate that some of the required items are in stock and therefore immediately available. Other parts, or materials, have to be procured either from outside through the purchasing department or from the various shops. By first assigning an accumulation stall to this order a systematic place is established to which all the parts may be routed from their several sources. These parts may be flowing in for several days, or weeks, and during all of this time there can be absolute confidence that the job is intact. A glance at the material list will reveal just what parts have not yet been received, the production order numbers, if they are M parts, or the purchase requisition numbers, if they are P parts, shown opposite these parts are all that is required to trace them through the planning department. This can all be done in one or two minutes without any stock chasers. This situation is characteristic of Type 1 production in which the plant is working largely on individual sales orders.

The arrangement of a finished-parts storeroom with provision for these accumulation stalls is shown in Fig. 216.

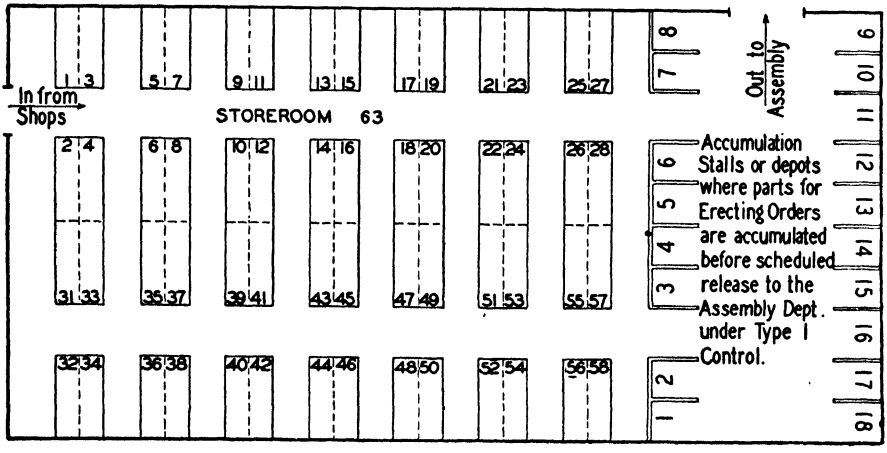


FIGURE 216. STORES LOCATION NUMBERING

In numbering the cross aisles the odd numbers are on one side, the even numbers on the other, and these numbers should be prominent. The tier, or row, numbers and the bin numbers are of less prominence since they are read from closer range.

Figure 217 illustrates two accumulation stalls with the parts for two assembly orders gradually accumulating. The material list for each order is hung at its place, and as the parts flow in from various sources the storeskeeper checks them off on the material list until all of the parts have been received, or near enough in sight, so that the job may

be released to the assembly floor. The blackboard which hangs near the accumulation stalls will show the wanted date which is the guide for releasing the job to the assembly.

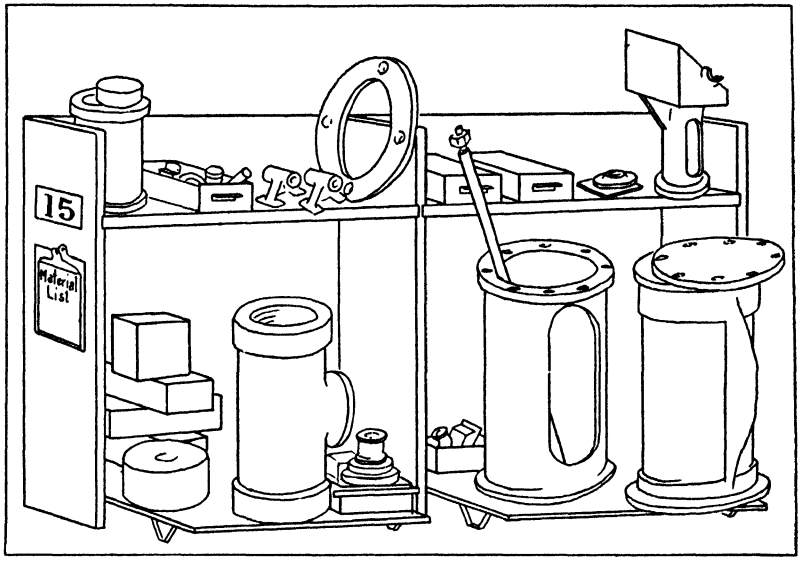


FIGURE 217. ACCUMULATION STALLS

The numbering of tiers and bins is illustrated in Fig. 218 which shows aisle 2 in a small company engaged in Type 1 production of such items as awnings, terrace covers, and Venetian blinds. The company carries in stores something like 1000 items of wide variety. Each bin has a card holder with a ticket showing the stock number of the item. At A in the top tier there is shown the colored tab inserted in the card holder and bearing the separate location number of the surplus stores from which the bin can be replenished. There are 18 such tabs shown in the illustration. From time to time there may be more or less, as the situation shifts.

When the service stores in any of these bins is replenished from the separate location in which the bulk stores are kept, the time may come when the bulk stores become exhausted. In that case there arrives a choice from three alternatives:

1. When the bulk stores are exhausted, a requisition for more may be sent immediately to the office for a replenishing order.
2. The colored tab may be removed from the service-bin label holder and placed in a clip on the inside of the service bin. The absence of the tab indicates that the bin holds all of the stores on hand and, therefore, when that supply gets low a requisition must be sent to the office.

FIGURE 218. TYPICAL NUMBERING OF BIN LOCATIONS

3. The storeskeeper may know that a perpetual-stores inventory record is maintained in the office, and that it is the responsibility of this stores record keeper automatically to replenish stores in accordance with the rate of use indicated on the record. In this case the storeskeeper merely removes the tab. When the replenishment stores come in, routed to the service-bin location, the storeskeeper may find the bin full. He looks inside to see if the tab is in its clip. If so, he replaces it in the holder and then puts the new supply of stores away in the surplus location indicated on the tab. If there is no tab, then he prepares one for whatever surplus location is available.

Examination of the illustration will reveal the letters marking the tiers, on the left-hand edge, and the numbers of the bins along the edges

of the shelves. For example, in location 2G5 will be found #4, $\frac{3}{4}$-inch awning elbows and in location 2F3 will be found $2\frac{1}{4}$-inch thimbles.

This particular illustration, in which a sample part is attached to the front of each box, serves excellently in a small company. In large companies, however, in which there may be more than 50,000 parts, it would not be practicable to attach samples in this manner, although every bin should have its card holder and card showing the drawing or

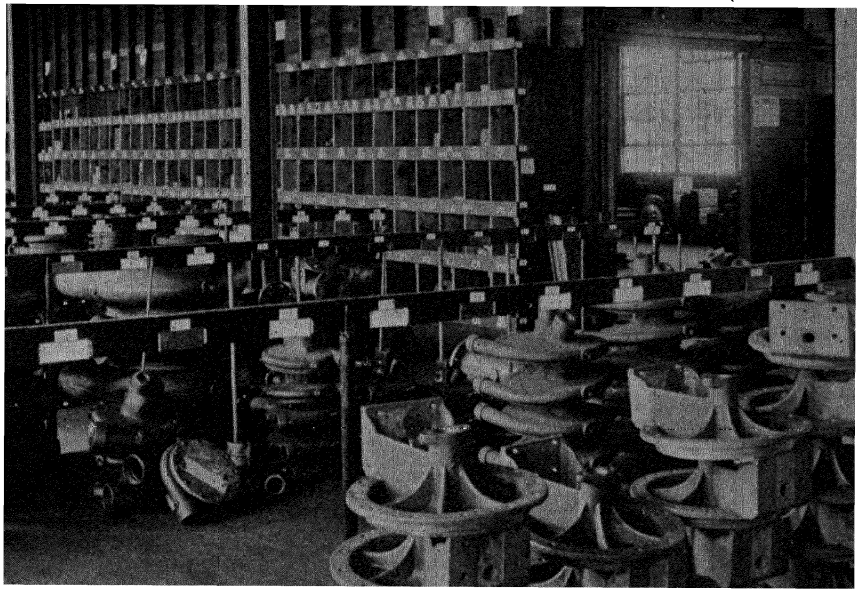


FIGURE 219. TYPICAL NUMBERING OF FLOOR LOCATIONS

stock number. This identifying stock number should never be marked on the location itself. If parts are transferred to another location the label, or card, should go along with them.

Frequently parts are of such a nature that they cannot be conveniently stored in bins but have to be stacked on the floor, just as there are many parts such as castings and forge blanks or billets which have to be stacked in open yards. The same marking principle should be carried out in all such areas, cross aisles being fitted with rails on which to mount the location card holders. This is illustrated in Fig. 219, which shows a section of a floor in a company engaged mainly in Type 1 production of pumping equipment, and which stocks something like 20,000 items. The control of all parts and materials carried in stores centers in the stores record which is maintained in the planning department. On the stores record is shown the location number, so

that when the record clerk turns to it to make the advance deduction of the quantity called for on an assembly material list he picks up the location number for the convenience of the storeskeeper. The finished-material list, with these locations noted on it, will be illustrated in the chapter on Type 1 Control.

In the raw storeroom where pipe racks are constructed for carrying bar and rod stock, it is not quite so easy to provide for card holders. These holders should be put on, however, wherever possible. Where it is not possible to do so a chart, or diagram, should be mounted at the end of the aisle to show the numbering of the compartments and to indicate their contents.

The specifications of such materials as steels cannot readily be placed on the bin label if there is no way of attaching a bin label to the location. Furthermore it is not practicable for the planning department to write out the specifications on each production order. If steel of the SAE 2315 specification, and $\frac{5}{8}$ inch round, is to be specified, the planning department would show it on the production order as "90 inches of 6638–4" and the location would be shown as perhaps 29–6C25. When the storeskeeper goes to his location there would be no way in which he could tell, by looking at the steel in this bin, that it was SAE 2315. He could look at the chart at the end of the aisle but unless there were some way in which to identify the particular steel itself he would still be uncertain. It is for just such situations as this that the steel color code is resorted to, and the identifying color is painted on the steel itself. Such a color code may be found in the catalogue of the Joseph T. Ryerson & Son Company from which the following colors are listed:

Green	SAE 1020; general forging and case hardening
Yellow	SAE 1040, 1045
Blue	SAE 1035, auto parts
Red and Blue	SAE 1040, auto parts
Black	SAE 1120, free cutting
Red	SAE 1112, accuracy stock
White	SAE 1112, Bessemer steel
Orange	Bessemer high-speed steel
Gold	SAE X1314 Open hearth, Rycase X1314
Aluminum	Ry-Ax heat treated axle steel
Red and Yellow	SAE 1095, spring steel
Red and Green	Lewis iron; chains, hooks, U-bolts, mine car parts
Red and White	Lewis special iron, locomotive parts, ground shaft stock, key stock
Red and Purple	Chrome nickel, hot rolled, heat treated, SAE 3135
Red and Aluminum	Ry-Arm heat-treated armature steel
Pink and White	SAE 9255

Green and White	Inland Hi-Steel structurals, hot rolled strips, flats, sheets, plates
Green and Aluminum	Nichrome M heat treated, hot rolled alloy steel
Green and Pink	3½ % Nickel steels, hot rolled, SAE 2340
Black and Green	3½ % Nickel steels, hot rolled, SAE 2315, 2320
Aluminum and Blue	3½ % Nickel steels, hot rolled, SAE 2330, 2335
Yellow and Blue	3½ % Nickel steels, hot rolled, SAE 2345, 2350
Black and Brown	SAE 1335 Cumsco ground and polished shafting; accuracy stock
Black and Yellow	Hot rolled chrome nickel SAE 3115, 3120
Black and Red	Hot rolled, not annealed, SAE 3135, 3140, X3140
Black and Pink	Hot rolled chrome nickel SAE 3150
Black and White	Chrome molybdenum, heat treated SAE 4140, Rychrome heat treated alloy
Black and Gold	Rytense AA machinery steel, hot rolled
Black and Aluminum	Ryco heat treated machinery steel
White and Gold	Cold finished hi-carbon, hi-manganese, SAE X1335
White and Brown	Hot rolled, annealed, SAE 3150
Aluminum and Pink	Chrome nickel, hot rolled, annealed SAE 3250
Blue and Gold	Chrome molybdenum, hot rolled, not annealed SAE 4140
Yellow and Aluminum	Chrome molybdenum, hot rolled, annealed, SAE 4150
Yellow and White	Nickel-molybdenum, hot rolled, not annealed, SAE 4615, 4620
Yellow and Pink	Chrome vanadium, hot rolled, SAE 6145
Orange and Purple	HTM alloy steel
Red, White, Blue	Chrome bearing steel, hot rolled, SAE 6145
Red, Yellow, White	Octagon steel poker bars, hot rolled forging quality

With so many specifications, each in a number of sizes, it becomes imperative to have a systematic index and arrangement for location marking.

Drawing vs. Issuing Materials

In many plants engaged in Type 1 production there are one or more stock chasers whose job it is to run down shortages of parts or materials that are required for assembly orders in process. Their existence is substantial evidence of control difficulties which are costly. Not only are assembly jobs interrupted and confusion introduced, but these stock chasers are usually charged to overhead expense. The result of their efforts is usually to throw current jobs in the shops out of line by putting pressure behind those orders which are entered on the shortage list. This is an indication of either inadequate production control arrangements or of the existence of the "draw" method of obtaining parts.

Under the draw method, jobs are usually planned out in the shops and the foremen of assembly departments have to requisition the needed materials. After the requisitions are filled in the storeroom they go to the planning department where they are deducted from the stores record. This means that when a shortage is created it may be hours or even days before the shortage is reflected on the stores record from which the replenishing order is issued. The stores card thus becomes an historical record of past transactions and exercises no control function. In situations of this kind the first thought is for the easiest course, and stock chasers are added.

Under the draw method the relation between the stores record, the bin, and the requisitions is illustrated in Fig. 220.

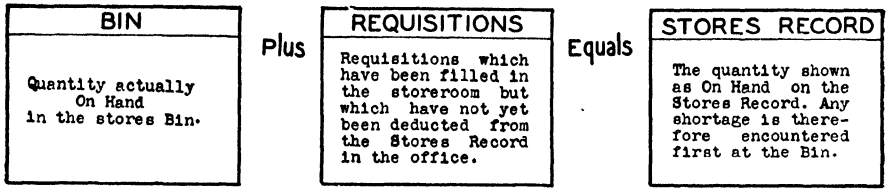


FIGURE 220. INADEQUATE POSITION OF STORES RECORD

It will be observed that the first knowledge of a shortage is obtained by going to the bin and finding it empty. This experience, and the cost of resulting stock chasers, has led to the criticism that no stores recard should be maintained but that in its place there should be an in-and-out bin tag on which the storeskeeper can do his own bookkeeping. Such criticism is not without reason.

Properly, the stores record should be put ahead of the storeroom and stores should be handled on the issue basis. Here the clerical deduction is made before the storeskeeper issues the material. The benefit of this method is that in taking advantage of the load of work going through the shops an impending shortage may be detected days, even weeks, ahead of the actual shortage. This usually gives ample time for replenishing the depleted stores without interrupting operations in the shops or assembly department. The arrangement is illustrated in Fig. 221, which shows the stores record as coming first.

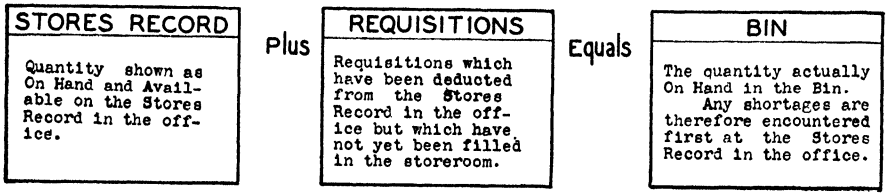


FIGURE 221. THE CONTROL POSITION OF STORES RECORD

With this arrangement no stock chasers should be necessary and the shops should rarely have occasion to know that a shortage exists. Any follow-up of jobs is handled as one of the regular duties of the planning department and the simplicity of the procedure is explained in the chapter on Type 1 Control.

By putting the stores record ahead of events the issue method makes it an important control tool, and as such it cannot profitably be replaced by any manner of bin tag. There will, of course, be a few requisitions which come to the storeroom directly from the shops as in the case of spoilage. These will have to be filled first and deducted from the stores record some time later. They will be in the minority and will not cause any serious dislocation of the stores record.

In this text the issue method is assumed and its workings will become clear in later chapters.

Form 94

BIN CHECK

DATE _____

DRG.OR STK.NO. X-531 PART Shaft MATL Steel

STOCKROOM 63 LOCATION 16 F 4

A	QUANTITY IN STOCKROOM BIN OR LOCATION	20
B	QUANTITY ON UNFILLED REQNS. & M.L S. IN STOCKROOM	4
C	QUANTITY ON UNFILLED REQNS. & M.L'S.IN OFFIGE ALREADY POSTED	3
D	QUANTITY THAT SHOULD APPEAR ON STORES RECORD A-B-C	13✓

C.H. _____ a m. _____

STORES RECORD BIN COUNT BY

FIGURE 222. TICKET FOR PERIODIC BIN CHECK

Bin Check

It is desirable to keep the actual count in the bin and the quantity shown on the stores record as on hand, in agreement. Usually any adjustment is made at the close of the year when the physical inventory is taken or, as happens often, when trouble is encountered and an immediate check is made. Both the trouble and the cost of taking an inventory can be avoided by keeping the bin and the stores record in agreement through the year. This can be accomplished by making systematic use of bin-check tickets such as illustrated in Fig. 222.

There will be times when the storeskeeper is not busy. In anticipation of these times he can prove his worth by preparing a few bin-check tickets. He could start with the first aisle, insert the blank

tickets in perhaps 25 bin label holders, like flags, and then from time to time count the stock in the bins and fill in the tickets. Having flagged the last bin checked he can start again from where he left off. In the course of the year every bin can thus have been checked. The tickets go to the planning department where they are checked against any material lists or route tags which have already been deducted from the stores record, but which have not been forwarded to the storeroom. They are then checked against the stores record and destroyed. If this work is done intelligently the stores record should always be reliable.

It is important to note that this checking procedure applies only to Type 1 production in which the stock in the bins may be static for days at a time. It would not be practicable to try it with Type 2 production since the stock is never static but always on the move, flowing continuously. In Type 2 it is necessary to stop production when an inventory is taken.

Requisitions

What should be the form of the requisition? In some plants, where a great many requisitions are involved, typewriters are set up with continuous strip forms and as many as 2000 requisitions typed in a day. There may be three copies to each, one of which may go to the statistical or cost department and two may go to the storeroom. When the storeskeeper undertakes to fill the requisition he may destroy the second copy if there is no stock shortage. If there is a shortage, however, he may turn the second copy of the requisition over to the shortage section where it is entered on the shortage list and the stock chasers put on the trail. This is all expensive and unnecessary.

The functions normally to be expected of a requisition are:

1. To serve as authority for the issuing of material.
2. To provide a medium from which the planning department can make a deduction from the stores record.
3. To provide a medium from which the cost department can make a transfer of value from inventory to work in process or to a specific order, or, in case of spoilage, to an expense account.

If the requisition is made a separate form, then it is necessary to copy all of the information which defines the material. The material list already completely defines the material or, in the case of raw stock, the route tag completely defines it. It should not be necessary to do 100 per cent copying merely to obtain a traditional form of requisition. If the material list covers as few as 25 items, of which 9 are stocked parts, then it would be necessary to copy the descriptions of 9 items merely to obtain the traditional form of requisitions. Let the

material list serve as a blanket requisition, pass it over the stores record, and let the storeskeeper pick up the stock items directly from it. The parts for each job will all be kept together, clerical expense will be avoided, and a more intelligent atmosphere will prevail since the picture of preparing materials for specific jobs will not be lost.

It may be argued that some items will appear two or more times among the material lists going through in a day and it will be worth while to write out requisitions for all items in order to make it possible to sort them, combine all that call for a particular item, and then make one grand deduction from the stores record for each of these repeat parts. An analysis of such a case for a few days will indicate whether parts repeat often enough to warrant the expense of copying all the items. Usually the number of parts which repeat within any day is negligibly small.

There are some cases in which large amounts of material are called for on jobs which may run for a number of days or weeks. For example, in an automatic screw-machine department an order may call for 2000 pounds of steel in bar form. It may not be convenient to place the whole quantity at the machine; better practice being to issue perhaps 100 or 200 pounds at a time. That would mean that there might be 10 to 20 issuances, each one of which would ordinarily call for a requisition. Similarly, in a plastics department a job may call for 1000 pounds of the molding compound which is best issued in lots of 50 pounds as required, thus ordinarily necessitating 20 or more requisitions each of which has to be priced, extended, and put through the cost procedure. This should be avoided.

The most profitable manner of handling such cases is to have the planning department prepare a blanket requisition for the full quantity of material called for by a job, and then to let the operator draw against this requisition in any way that suits his convenience. The form of this blank requisition would be as illustrated in Fig. 223, and it should be printed in various denominations according to the department to which it is issued. The total quantity of material is figured and is marked off on the requisition as shown at 420 pounds. The requisition goes to the shop with the production order and ends up in a file in the storeroom which will issue the material as it is called for. Each issue is punched out on the card until the stop mark is reached. That represents the full amount of material charged against the order in advance. Should more material be required, it must be ascertained what it is to be charged to so the storeskeeper has to call the planning department where the quantity allowed is checked. If the requisition was figured correctly, then the additional material must be charged to the appropriate expense account and a supplementary requisition of the tradi-

tional form has to be presented for it, showing the expense-account number instead of the original order number. Frequently there are numerous small items, the value of which scarcely warrants writing a special requisition. An idea of the origin of the difficulties which usually generate debates between the cost and production departments

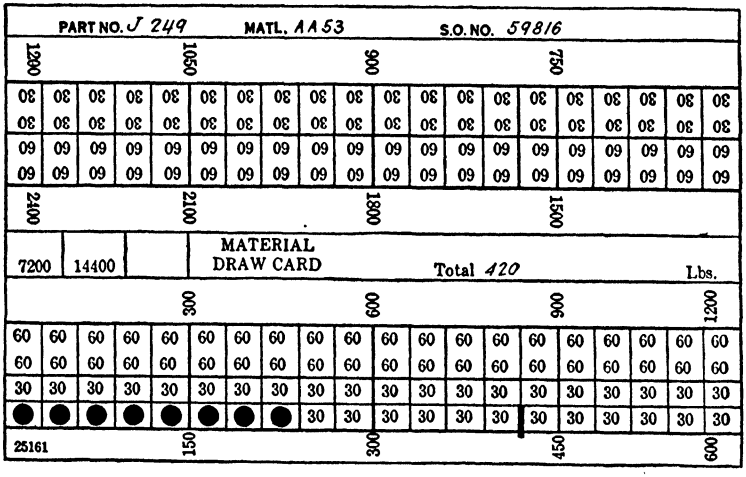


FIGURE 223. STANDING OR "MEAL TICKET" REQUISITION

over the handling of requisitions may be had from the following illustration. Among the material lists going through each day in a large company some particular items may appear over and over again but in different quantities. On one job only 1 of such an item may be called for, on another 2 may be required, on still another 4, or even 12, may be required. If such a small item were, for example, a 6:32 hex steel nut, the costs of the various quantities in which it appears may range from say 0.00356 for 1 to 0.04272 for 12. But the finished products in which this part is used may be going through production in quantities varying from one to several thousand. These products may be handled by different shop departments.

The situation may be summarized as follows: On the various material lists for jobs going to several departments,

An Item May Appear	*Among*	*And Cost*	*Out of a Total of*	*And Travel in Lots of*	*Valued at*
once	21 items	$0.00356	$11.14	2	$ 0.00712
4 times	237 items	0.01424	87.83	12	0.04272
once	27 items	0.00356	1.20	1750	6.23
once	10 items	0.04272	0.256	50000	178.00

It may cost 4 cents for a requisition, to write it, price it, extend it, and post it. Thus it would not be profitable to write requisitions for the first two of the above cases. Usually more than 70 per cent of the traditional form requisitions in a Type 1 concern are for such little items whose values are small. The question would arise as to how they should be handled in order to minimize overhead expense. There are only a limited number of ways in which they can be handled:

1. They may be ignored as far as the job cost is concerned. That is, a small quantity may be given out by the storeskeeper without any record, and the parts may be used as required. This is loose practice.
2. Although the parts are productive material, they may be classed as expense material and treated as supplies, a quantity being requisitioned into the assembly department, charged to the supplies expense account number, and used as required without further record.
3. For each assembly requiring these small quantity items of small value there could be established a standard cost percentage. A quantity could be requisitioned into the assembly department, charged against a departmental inventory account, and the value of this inventory liquidated by transferring this standard percentage to the cost of each assembly order going through the department.
4. For each assembly job these small parts could be lumped together as "fastening parts" or "small parts," put up in a package which would be given a stock number and stocked, a cost set up for the package, and then handled like the cost of any of the more important items.

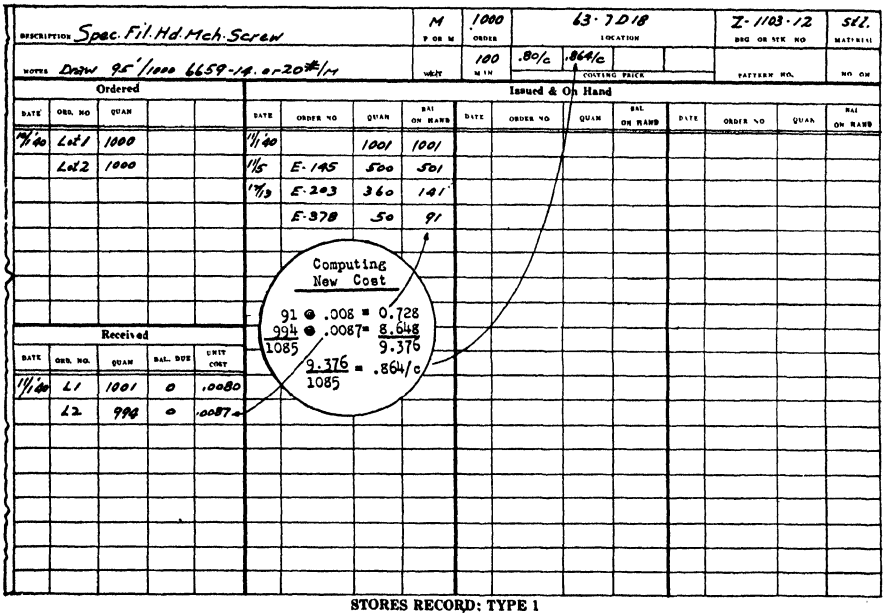
If assemblies are sufficiently standardized so that repeat orders come in for them, the last method would be most satisfactory. If, however, the assemblies are such that no repeat orders may be expected then, in the original estimates for the jobs, these small parts may also be estimated and handled informally by one of the other methods, preferably method 3.

The Stores Record

There are two fundamental forms of stores record, one applying to Type 1 production, the other to Type 2 production.

In Type 1 production the problem is to make advance deductions, usually in relatively small quantities, of a wide variety of items. First, in the case of finished parts, all which are carried in stock are indicated on the material list as S items. The parts are completely defined on the material list. Before the list is sent from the planning department to the storeroom for picking up the parts, it should be passed over the stores record and deductions made from the balance on hand. That is all that is necessary as far as the stores problem is concerned. In the case of raw materials, all of the requirements for parts which have to

be made as needed are indicated as M items on the material list. For these items the list will read, for example, "9½ feet/C of 6659-14," and this has to be deducted from the stores record. This information gets from the material list onto the production order, which is written in three copies. The third copy is the route tag, the function of which is to provide the medium for this posting, to serve as the requisition, and to pilot the material through the shops, picking up a history of all that happens to it.



STORES RECORD: TYPE 1

FIGURE 224. SIMPLE STORES RECORD FOR TYPE 1 PRODUCTION

The form of the stores record which applies to this situation is illustrated in Fig. 224. It applies to Type 1 production.

No provision is made for advance commitments or reservations. The time which elapses between the posting of the stores record and the actual issuance of the material in the storeroom is usually a matter of but a few days, but this depends on the volume of work that is ahead of the shops. This means that the stores record will lead by that many days, thus providing time to get a replenishing order under way in case a shortage is encountered in the posting.

When replenishing orders, that is, stock orders, are issued it is convenient to make the order number include the part number, as in the case illustrated on the above stores record, Z–1103–12 Lot 1, Z–1103–12 Lot 2, and so on. These order numbers will soon come to be written

Z–1103–12L1, and that distinguishes these stock orders from the special orders which are written for M parts and which are numbered in an arbitrary series. At the top of the record is shown the stores location, the cost, whether the part is replenished through a purchase order or a production order, and a minimum point from which to reorder. There is also shown the weight of the part. This is of value chiefly to machine tool manufacturing plants in which the weight figures prominently in the process of estimating new jobs. Opposite the pattern number is shown "No. on." That means the number of patterns on a match plate. There may be 10 patterns on the plate so that the order quantity should be a multiple of that.

The stores record should be arranged in colors for the different classes of stores as follows:

White	for all finished parts
Blue	for all rough castings
Pink	for all raw materials such as bars
Yellow	for all supplies or expense materials

Should it be desired to tabulate the inventory at the close of the year all that is necessary is to break down the stores record, sort out the colors, tabulate the inventory, and then restore the records to their files.

Visible index cards are too voluminous for convenience in Type 1 production. It is better to have the stores record printed on thin, good quality paper and have the sheets put into easily handled post binders of about 1000 sheets each, these binders to be numbered on the end and kept in pigeonholes in front of the record clerk.

For Type 2 production the problem is quite different. Here, in preparing for an advance production schedule which may run over a quarter, half year, or full year, it is necessary to make reservations or commitments of materials considerably in advance. These reservations have to be made as a safeguard so that the materials will be available when needed. This differs from the Type 1 situation in which no reservations are necessary, since the materials will move out of stores in the full quantity specified and within a few days after the stores record is posted. Thus to the Type 2 stores record there has to be added a column for "Assigned and Available." Otherwise the two forms are about the same.

In Fig. 225 representative entries are shown and a study of these will reveal how the record is kept. The question sometimes arises as to what should be considered as "available." On the one hand it is wise to consider as available only such material as has actually been received and is not reserved for any particular order. It is both on hand and free to be used. If so considered, then it may become neces-

sary to show some balances as negative, since reservations have to be made in advance of the receipt of the material, thus making the "balance available" negative. On the other hand, it is probably safer to consider material as available as soon as it is ordered. This is not strictly true and may lead to allowing orders to get into the shop before the material

DESCRIPTION Spec. F.I. Hd. Mch. Screw — M — 63-7D18 — Z-1103-12 — Stl.

NOTES Draw 95'/M 6659-10 or 20#/M — .71/c

Ordered

DATE	ORD. NO	QUAN
9/24	Sched 440	50M

Received

DATE	ORD. NO.	QUAN.	BAL. DUE	UNIT COST
9/25	Sch 440	5000	45000	
10/2	"	10M	35000	
10/9	"	10M	25000	
10/16	"	10M	15000	
11/7	"	15010	0	.0071

Assigned & Available

DATE	ORD NO	QUAN	BAL AVAIL	DATE	ORD. NO.	QUAN	BAL. AVAIL.
9/24		50000	50000				
9/24	Sch 440	48000	2000				

Issued & On Hand

DATE	ORD NO	QUAN	BAL. ON	DATE	ORD. NO.	QUAN	BAL. ON
9/25		5000	5000				
10/2		10000	15000				
10/8	E.480	7000	8000				
10/9		10000	18000				
10/16		10000	28000				
11/5		5000	23000				
11/7		15010	38010				

STORES RECORD: TYPE 2

FIGURE 225. STORES RECORD FOR TYPE 2 PRODUCTION

required for them has been received. However, it has the advantage of avoiding negative balances with the clerical errors which that invites.

In the illustration the postings indicate the latter plan. They show that 50,000 became available when ordered on 9/24. Then immediately 48,000 parts were reserved for the forthcoming production schedule number 440, which will run through the fourth quarter of 1940. Thus the record shows that there are 38,010 parts on hand but only 2010 of them are available for jobs outside the planned schedule.

Some intelligence will be required in keeping this record or it will get badly out of gear. For example, suppose 50,000 parts are ordered from outside. The vendor, in cleaning up the job, may actually ship in 50,500. Or if 50,000 are ordered through the shops on a production order, something may happen so that only 49,500 reach the storeroom. Unless the quantity available, which was posted at the time the order was issued, is corrected accordingly the record will soon be badly in error. To make this sort of correction easy, a Balance Due column is

added under "Received." When the last delivery comes in and is posted to the stores record, a comparison of it with the former entry in the balance due column will show any needed correction at a glance. In Fig. 225 it will be noticed that 15,000 were due in the last shipment but 15,010 actually arrived. Hence this additional 10 have to be added to the balance available and the balance on hand columns, as has been done.

It will be observed that an error was made in the posting of this sheet. In the Issued and On Hand column, under date of 11/5 there were issued 5000 parts, but the order number does not appear as it should. Order E–480 is the erecting order which has been issued for the particular assembly on which the part is required for schedule 440, and this order number should have been posted to the order number column as was previously done on 10/18 when the first quantity was issued.

If the differences between these two fundamental forms are understood at this point, it will not be difficult to follow their use in the later chapters on Type 1 and Type 2 Control.

CHAPTER XXVI

DEVELOPMENT AND ENGINEERING

Many plants, notably machine-tool establishments, do not distinguish between the development and engineering functions, the two merging almost imperceptibly into the general work of engineering. However, in growing concerns the distinction is made clear.

The primary responsibilities of the development function are

1. The creation of new devices
2. The improvement of existing devices
3. Simplification and standardization

DV-140 Order No.	Account No.	Engg. Issued to Dept	Pattern Planning Tool Copies to Depts.	6/10'40 Date
Necessary engineering, planning, tool, pattern and experimental work to add new Model 7 Mechanical Transmitter to line.				
ESTIMATED COST. $5000	Material	Labor	Burden	Patterns / Total
WORK ORDER Green—Development White—Maintenance Yellow—Investment Pink—Disposal Salmon—Other		Date Completed / Per	A. B. C. Approved by	
WHEN COMPLETED RETURN TO COST DEPT				

FIGURE 226. DEVELOPMENT ORDER

Where progressive conditions warrant it, a development committee is appointed to meet regularly at a specified time. On this committee are representatives of the sales, manufacturing, tool, engineering and planning, or methods, departments. Ideas which are encountered in the field are submitted by the sales department, competitive devices are purchased and analyzed, the patent office gazette is reviewed, and models of new devices may be constructed, analyzed, and tested until, at length, a new device is created and approved. All of this costs money. Large establishments spend fortunes on development work and it is hoped, of course, that ensuing sales will return this development cost within a period which is predetermined by policy.

The cost of development-committee meetings may be charged to a standing overhead expense account. When a specific undertaking is launched, let us say for the mechanical transmitter which we will use for the Type 1 example, then a development order such as illustrated in Fig. 226 is requested of the cost department. Copies of this order are issued to the departments concerned and they remain in their live files until completed or called in for closing out. Time and materials are charged against them.

When a development order is issued the cost department also prepares for itself a development liquidation card such as is illustrated in Fig. 227, as a convenient medium for getting the cost back.

Description: New Model 7 Mechanical Transmitter							Drawing No.: X-150			
Est. Quan. for Base: 5000			Est. Per Unit				Unliq. Dev. Acct. No.: 244			
DEBIT					CREDIT					
Item	Date	Ord. No.	Amount	Total	Date	Ord. No.	Units	Dev. Liq.	Unliq. Dev.	J.E.V. No.

DEVELOPMENT LIQUIDATION RECORD

FIGURE 227. DEVELOPMENT LIQUIDATION CARD

As charges are made against this order the cost department tabulates the costs on a summary sheet until the order is completed, then resummarizes the cost items on the liquidation card and, at the suggestion of the development committee or supervisor, enters at the top of the card the estimated number of units over which the development is to be spread or liquidated — in this case 5000. That will give the liquidation charge per unit which is entered at the top of the card.

When a production order is later issued for, say, 25 transmitters, it will be assessed in the costing process with its pro rata development liquidation cost and so on until the development cost has been absorbed and the sales price may be reduced. Should it so happen that the design is changed, or the product is dropped, before the development is all liquidated, then the loss is written off by charging it to the unliquidated development account which appears later in the profit-and-loss statement. The charge is accomplished by preparing a journal entry voucher whose number is recorded in the last column of the liquidation card.

While this transmitter will be used as an illustration right through the whole process of setting up records and processing a production order, it should be noted that for obvious reasons the specifications, drawings, and forms are not those of the manufacturer, but have been prepared especially for purposes of instruction.

All being well, the development function has succeeded in creating a new device. It might appear about as illustrated in Fig. 228.

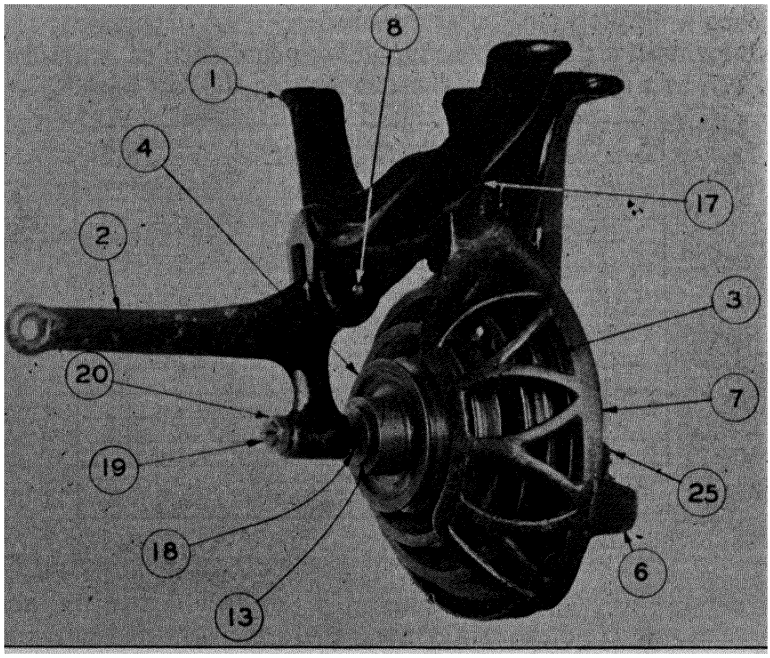


FIGURE 228. THE NEW DEVICE *Courtesy of Singer Mfg. Co.*

Having approved its design, the development function is through with it, and it is turned over to the engineering department for working drawings, material list, and setting up the drawing-room records. With the device there will be a rough draft of the material requirements, the material of which each part should be made, and a notation of those parts which, for repair or replacement service, should be carried in stock. The drawings will reflect the methods of manufacture that were thrashed out in the development committee meetings.

Engineering

A draftsman will first prepare an assembly drawing such as is illustrated in Fig. 229, each part shown being assigned a reference number to key the reference to the material list. Considerable care will be

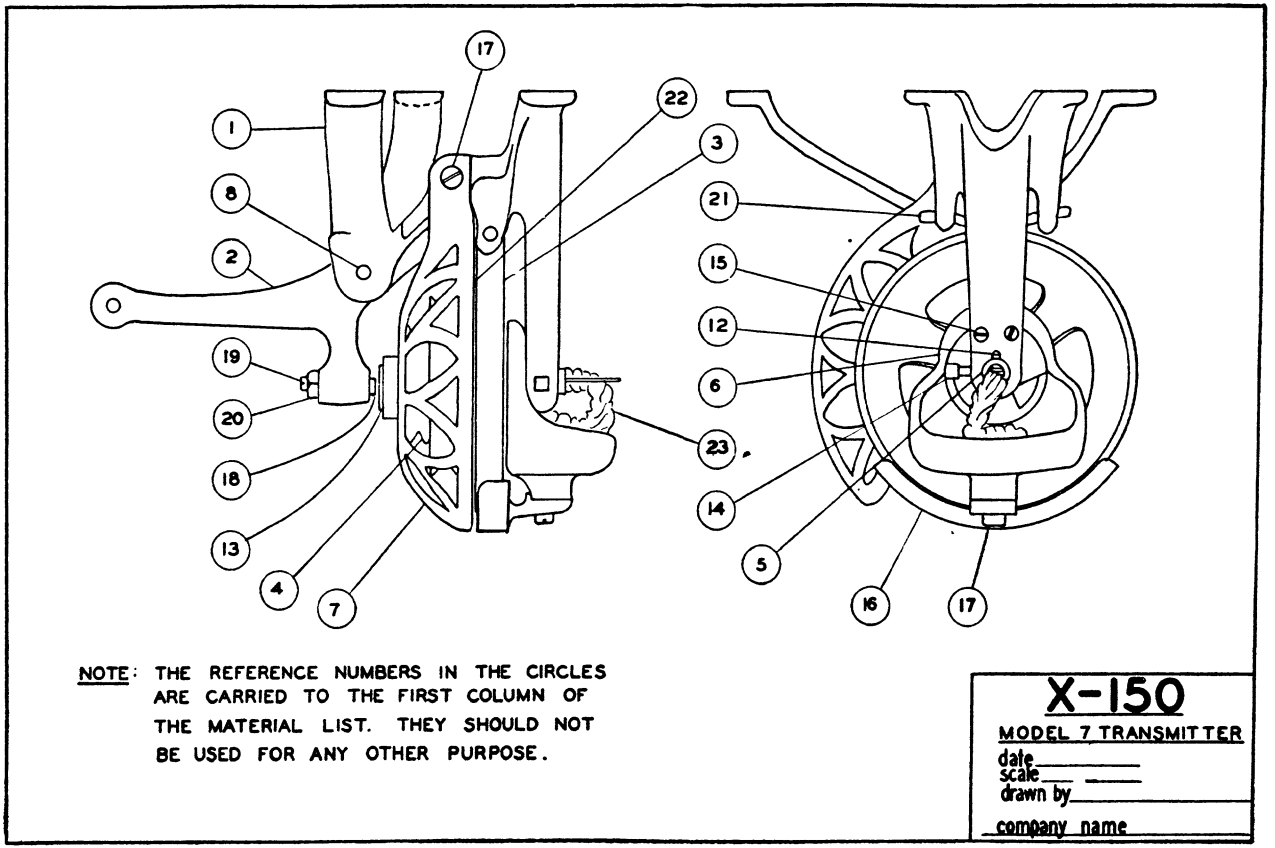


FIGURE 229. THE ASSEMBLY TRACING

required in selecting these reference numbers since it will be convenient to bring together on the material list those parts which may be put together as a sub or unit assembly. In order to obtain the drawing number, the draftsman has to go to the record clerk who assigns the number according to the size of the drawing. This may be done considerably in advance.

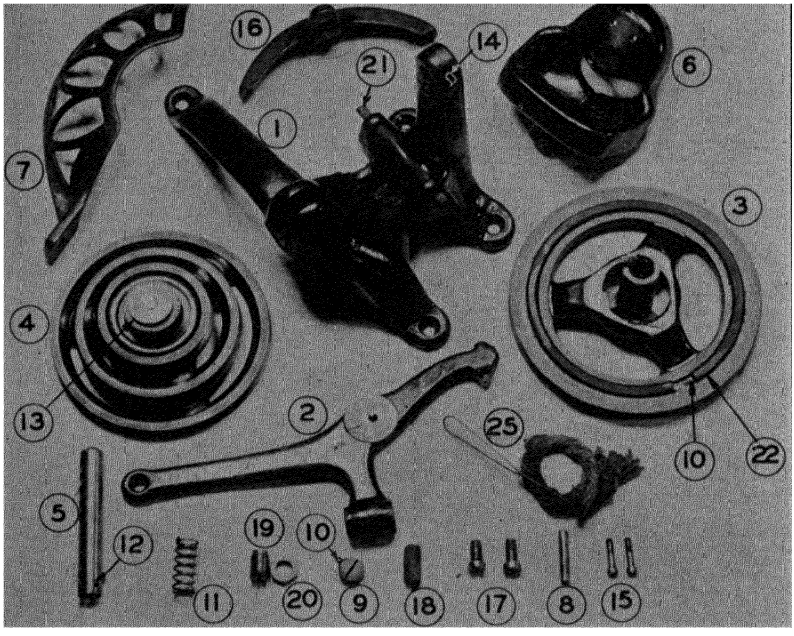


FIGURE 230. THE DEVICE DISASSEMBLED

The draftsman will then proceed to disassemble the device, with considerable regard for the way in which it will be most practicable to reassemble it, making his notes accordingly. The exploded view of the device is shown in Fig. 230.

In this case there will be required 22 drawings of parts, a very simple case. An army tank may require some 1500 drawings, a bomber may require more than 30,000, and a battleship may require many thousands. In such complicated cases the material list may comprise several, or many, pages, each page being for a subassembly.

Drawing Numbers

Drawings may be of a number of sizes. Some provision should be made for assigning numbers in such a way as to differentiate the sizes for convenience in filing. Two series of sizes are common, the 9 × 12

series and the $8\frac{1}{2} \times 11$ series. Here we will make use of the latter. Starting with the smallest size of sheet such as is used for all small parts, the successive sizes are prefixed by letters as follows:

Z	$5\frac{1}{2} \times 8\frac{1}{2}$
Y	$8\frac{1}{2} \times 11$
X	11×17
W	17×22
V	22×34

Then under each size letter the numbers are assigned consecutively, beginning always with 1. Here again the question arises as to whether or not an attempt should be made to assign all numbers for any given device in sequence. If that is attempted in the beginning, it will soon get out of gear as parts are added, removed, or improved. It is best to make no attempt to group or arrange the drawing numbers artificially; merely assign them as the drawings come along, and do all the grouping on the material lists and parts-index sheets.

There are three general types of parts drawings:

1. Individual part drawings
2. Group drawings on which are shown the whole range of sizes of a given part
3. Simple unit assemblies for those cases in which nothing is gained by further breakdown

Illustrations of these three types are shown in Fig. 231. Parts shown on group drawings such as Z–1103 are designated by their subnumbers. For example, the screw of diameter 0.180 would be identified by drawing number Z–1103–12. Referring to drawing Z–1147, the wick material is specified as "12 inches of No. 2 wool rove." When such a wick, or part, is all that is made of any particular material, nothing is gained by assigning a stock number to the material. If, however, this wool rove were used for numerous other things, and for wicks of various dimensions, then it would be advantageous to set it up with a stock number such as 9379–1 and then to specify the requirement here as "12 inches 9379–1."

Drawings like Z–1147 should be limited to simple assemblies which require but a few parts. They require special handling in the planning department. Their routine differs from regular assemblies as follows:

1. Assemblies which have a separate material list, as is usually the case, call for a regular assembly order. The material list is passed over the stores record for deducting the S-items.
2. Simple assemblies which have their material lists shown on the assembly drawing itself, call for a regular production order. The material requirements are written in at the top of the production order, each S part being indicated by the writing in of the letter S in the space marked "From."

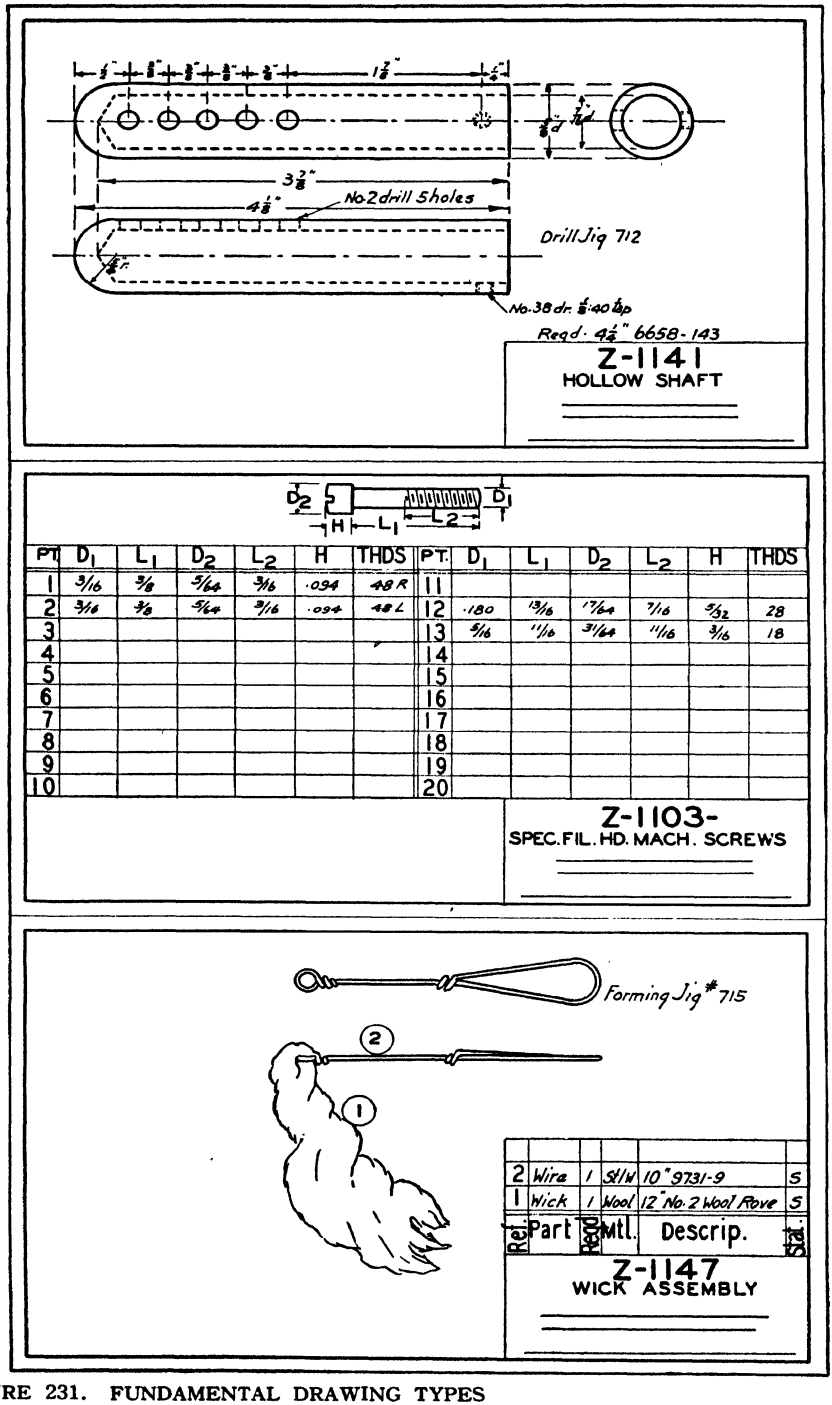


FIGURE 231. FUNDAMENTAL DRAWING TYPES

Then the route tags (which are the triplicate copies of the orders) are passed over the stores record. If these simple assembly drawings call for an M part, then the planner has to be alert enough to catch that and issue another production order for that part, copying the material requirements from the drawing. Similarly, if a P part is indicated he has to issue a purchase requisition, charging the part to the particular production order number and then send the route tag to the receiving department to conduct the part to the shop where it should meet up with the production order.

A situation arises commonly in which formal drawings should be avoided. Frequently customers call for an existing product "except" for certain changes. When the sales order comes to the engineering department for clarification and interpretation, it has to be decided whether the requested changes are such as may come up again. If so, then it is good practice to make the drawings in the regular form and have them recorded in the various files and indexes. If, however, as is often the case, the changes are quite special and are expected never to come up again, they should be considered as a part of the particular sales order and therefore kept out of the permanent company records. For such special cases a series of drawing numbers are set up in an SK series, and pencil sketches are made freehand (if neatly done) on tracing paper. These are blueprinted as required, but the SK numbers are not recorded on the drawing record cards nor are they entered on any index or other record. This omission in the records saves in the cost of drawing and record maintenance.

Drawing Record

All drawing numbers are assigned by the drawing-record clerk who maintains a permanent record of all drawings, drawing references, and material lists on which drawing numbers are entered. This record is in card form, and the file is divided into sections according to drawing size. Such a form is illustrated in Fig. 232. A card is prepared for each new drawing, and the drawing number is entered in the upper right-hand corner. In a separate section of the file there must be a card for each stocked commercial part which has no drawing number but which is identified by its stock number, as, for example, 6658–143. This stock number goes in the upper left-hand corner. There should be no cards which have both a stock number of this kind and also a drawing number; only one number for any part should exist.

This is the most important record in the drafting room. The illustration shows the card for Operating Plug Z–1148 which, since it is identified by a drawing number, is manufactured. This part appears on six material lists and four other drawings. Should it be changed at

any time, all of these material lists and drawings have to be changed accordingly.

Often there exists one assembly drawing for a whole line of different sizes of a device. Each different size has to have its own material list. Therefore, there may be more material lists shown on a drawing-record card than drawings, as is the case in this illustration.

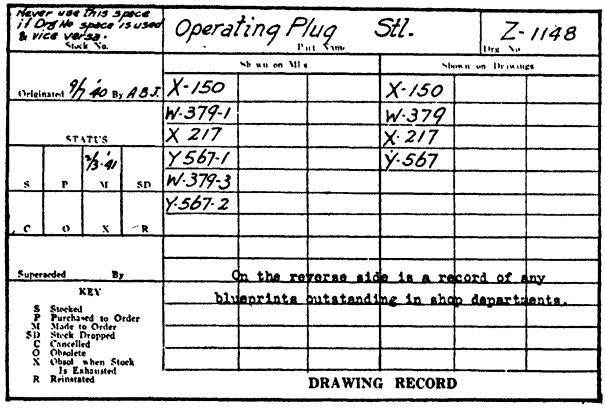


FIGURE 232. DRAWING RECORD CARD

Under "Status" there are a number of conditions:

- S indicates that the item is stocked.
- P that it is purchased as required.
- M that it is manufactured as required.
- SD that it is dropped as a stocked item and set up as a manufactured or purchased item.
- C that it has been canceled and cannot thereafter be reinstated.
- O that it has been obsoleted and superseded by some other part but that the records must still be maintained for repair orders.
- X that it is to be obsoleted when present stock is exhausted.
- R that it has been reinstated, after once having been obsoleted.

Parts Index

The parts catalogue, or index, can, if intelligently maintained, be one of the most valuable instruments in the scheme of production control, particularly in Type 1 production. In machine-tool plants, or plants making any other kind of machinery, this index is practically indispensable. It is virtually the private handbook of the organization and is of particular value to the engineering, stores, planning, and development departments.

On the first page of this parts-index volume there should appear a copy of the numbering chart shown in Fig. 215 on page 528. If there should come up some stock number such as 3620–5 and one wanted to

find out what it was, and on what page of the parts index it appeared, he would refer to this chart and ascertain that it is a cast-iron pipe flange. Then by referring to the alphabetical index which should follow this front page the parts index listing of all such flanges could be located by page number.

Another type of case may come up. A clerk, in making out a production order, or other record, may refer to drawing number Z–1273 and neglect to include the name of the part. To obtain this, reference could be made to the file of tracings in the drafting department, but it is more direct to call the drawing-record clerk who can consult the drawing-record file and know immediately that this number is a group drawing showing lever discs. By referring to the alphabetized index in the front of the parts index, the list of all such discs can be traced to the page of the parts index, where its dimensions and status are given.

An impression may be had of how this parts index may best be set up by assuming that one is in the engineering department and receives a sales order. The sales order may call for a Model 7 Transmitter except that the customer wants an oil cup (part 6 in Figs. 228 and 230) which measures about 4 × 5. The questions arise if such a cup exists, or if there is one anywhere near that size, or if there is one which can be readily changed, or if it will be necessary to design a new one. All these questions can be answered in less than 5 minutes by referring to the parts index. The degree of practical imagination with which the index is arranged, and the neatness of its composition, will have much to do with the facility with which it can be used. The listings which should appear in the index are:

1. Tables of all commercial items from which selections have to be made in preparing designs.
2. Lists of like parts for which drawings exist, flanges, special screws, shafts. For special screws the parts-index page would be practically a copy of such drawings as illustrated by Z–1103 in Fig. 231 on page 784.
3. Mere listings of such parts as special bases and frames which do not call for frequent reference.

To illustrate the listing of commercial items there are shown in Fig. 233 the various sizes of commercial drill rod. Only one of the sizes is indicated as carried in stock. All of the other items — since they are not stocked — have to be purchased as needed. To illustrate the listing of manufactured parts there are shown in Fig. 234 the various sizes of lever discs. Two sizes are indicated as stocked. All of the others have to be made as needed or purchased to drawing as needed.

As an exercise in the use of the parts index assume that you are in the engineering department and are to design a hollow shaft $\frac{5}{8}$ inch in

diameter and $4\frac{1}{8}$ inches long. You would first consult the parts index to see if such a shaft already exists or if there is one near enough to it to permit some slight change in over-all design to accommodate it. Suppose that there are no such choices. Then you proceed to design the new shaft and you prepare your drawing as shown in Z–1141 in Fig. 231

Standard 3' lengths — DRILL ROD — Page 142

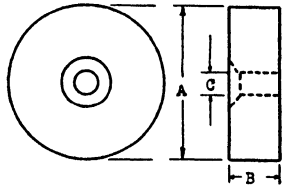
Finest crucible steel suitable for Twist Drills, Taps, Punches, Dental Tools, Reamers, Watch Parts, Etc.

Size	Dec.	Stk.No.	Size	Dec.	Stk.No.	Size	Dec.	Stk.No.	Size	Dec.	Stk.No.
80	.013		40	.097		2	.219		9/16	.5625	
79	.014		39	.099		1	.227		37/64	.5781	
78	.015		38	.101		A	.234		19/32	.5937	
1/64	.0156		37	.103		5/64	.2343		39/64	.6093	
77	.016		36	.106		B	.238		5/8	.625	6658-145
76	.018		35	.108		C	.242		41/64	.6406	
75	.020		7/64	.1093		D	.246		21/32	.6562	
74	.022		34	.110		1/4	.250		43/64	.6718	
73	.023		33	.112		E	.250		11/16	.6875	
72	.024		32	.116		F	.257		45/64	.7031	
71	.026		31	.120		G	.261		23/32	.7187	
70	.027		1/8	.125		17/64	.2656		47/64	.7343	
69	.029		30	.127		H	.266		3/4	.750	
68	.030		29	.134		I	.272		49/64	.7656	
67	.031		28	.139		J	.277		25/32	.7812	
1/32	.0312		9/64	.1406		K	.281		51/64	.7968	
66	.032		27	.143		19/64	.2968		13/16	.8125	
65	.033		26	.146		N	.302		53/64	.8281	
64	.035		25	.148		5/16	.3125		27/32	.8437	
63	.036		24	.151		O	.316		55/64	.8593	
62	.037		23	.153		P	.323		7/8	.875	
61	.038		22	.155		21/64	.3281		57/64	.8906	
60	.039		5/32	.1562		Q	.332		29/32	.9062	
59	.040		21	.157		R	.339		59/64	.9218	
58	.041		20	.161		11/32	.3437		15/16	.9375	
57	.042		19	.164		S	.348		61/64	.9531	
56	.045		18	.168		T	.358		31/32	.9687	
3/64	.0468		11/64	.1718		23/64	.3593		63/64	.9843	
55	.050		17	.172		U	.368		1"	1.000	
54	.055		16	.175		3/8	.375		1 1/32	1.0312	
53	.058		15	.178		V	.377		1 1/16	1.0625	
1/16	.0625		14	.180		W	.386		1 3/32	1.0937	
52	.063		13	.182		25/64	.3906		1 1/8	1.125	
51	.066		12	.185		X	.397		1 5/32	1.1562	
50	.069		3/16	.1875		Y	.404		1 3/16	1.1875	
49	.072		11	.188		13/32	.4062		1 7/32	1.2187	
48	.075		10	.191		Z	.413		1 1/4	1.250	
47	.077		9	.194		27/64	.4218		1 9/32	1.2812	
5/64	.0781		8	.197		7/16	.4375		1 5/16	1.3125	
46	.079		7	.199		29/64	.4531		1 11/32	1.3437	
45	.081		6	.201		15/32	.4687		1 3/8	1.375	
44	.085		13/64	.2031		31/64	.4843		1 13/32	1.4062	
43	.088		5	.204		1/2	.500		1 7/16	1.4375	
42	.092		4	.207		33/64	.5156		1 15/32	1.4687	
3/32	.0937		3	.212		17/32	.5312		1 1/2	1.500	
41	.095		7/32	.2187		35/64	.5468				

FIGURE 233. PARTS INDEX PAGE SHOWING COMMERCIAL ITEM

on page 558. You want to make it of ground drill rod, for hardening, and, if such a size exists, you would like to use rod of $\frac{5}{8}$-inch diameter to avoid turning and grinding operations. Consulting the alphabetical index, drill rod is located on page 142 which is shown in Fig. 233. You notice that $\frac{5}{8}$-inch rod is a standard size and that it had already been set up as a stock item. So you specify on the drawing that the shaft requires $4\frac{1}{4}$ inches of 6658–143. It may be well to check the steps in-

LEVER DISCS Page 271



	A	B	C	Drawing Number	Status
	1"	5/16	1/4	Z-1273-3	
	1 1/8	5/16	1/4	Z-1273-1	S
x	1 1/8	3/8	1/4	Z-1273-5	
x	1 3/16	3/8	1/4	Z-1273-2	S
	1 1/4	3/8	1/4	Z-1273-6	
	2"	5/8	3/8	Z-1273-4	

FIGURE 234. PARTS INDEX PAGE SHOWING MANUFACTURED ITEM

volved: turn to the numbering chart in Fig. 215, page 528, and see if the root number 6658 is correct; then count down on Fig. 233, page 562, and see if the size number 143 is correct; then examine drawing Z–1141 in Fig. 231 on page 558 and see what allowance has been made for cutoff.

To the development department, which, among other things, is charged with the responsibility of simplifying and standardizing existing items and designs, the parts index is of considerable value. The development engineer may assign a junior engineer to the task of checking for possible simplifications, rather than engage the time of a development man. By examining each page of the index possibilities will be quite evident. For example, refer to Fig. 234. Two items are marked with a cross. These two can be eliminated since they are so nearly duplicates of others.

The first cross marks an item which is not stocked. All that is necessary, therefore, is to decide which of the other items will replace that

one. Then go to the drawing-record clerk and obtain the drawing-record card for this Z–1273–5 item. The card will show a list of every drawing and every material list on which that part is referred to. All of these will have to show the change. The drawing itself, or the master routing card (which will be described in the chapter on the Planning Department), will indicate any special jigs or tools or patterns affected. The drawings can then all be changed, and a decision made on the disposition of any special tools or patterns.

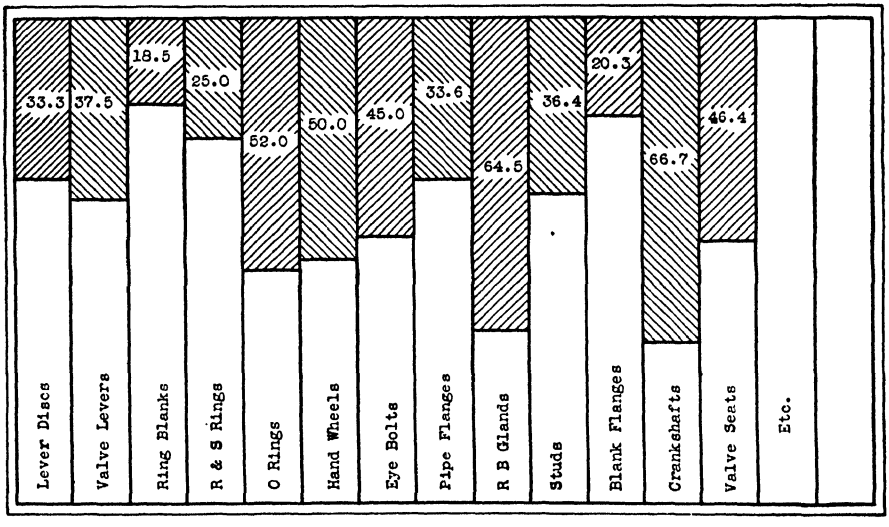


FIGURE 235. SIMPLIFICATION FROM PARTS INDEX RECORD

The second cross marks an item which is stocked. The procedure is the same in this case, with the exception that there may exist a quantity of stock whose disposition has to be decided. It may be decided to postpone the change until this stock is used up.

There is quite a little detail to the routine, which may be proceeding in considerable volume, particularly if the parts index is a new development in the company. At the same time there are numerous details involved in the normal flow of activity in the engineering department. It is highly essential, therefore, that all such work proceed systematically, without confusion. In order to accomplish it, while also efficiently setting up records of new parts, there must be provided a formal "new part notice" and a formal "changed part notice."

Upon going through the parts index with this simplification procedure in mind, there will be many reductions in the existing variations of parts and materials. For example, by eliminating the two items marked in Fig. 234, the number of variations in lever discs is reduced

by 33.3 per cent. In Fig. 235 there are shown a few such actual reductions which represent only a beginning in one progressive company. To conduct the simplification work in this manner makes it most economical and almost effortless.

New and Changed Part Notices

Any newly created part and any changed part may affect a number of records and existing items. Changes and additions must be made

NEW PART NOTICE

✓ PLANNING DEPT. ✓ PATTERN DEPT.
COST DEPT. ✓ TOOL DEPT.
✓ ENGG. DEPT.

Y-173 PART NO.	C.I MATERIAL	Lever PART NAME		
FIRST MADE FOR	X-150 Model 7 Mech'l. Transmitter			
NEW PATTERNS?	✓ YES	NO	REMARKS	5 on match plate
NEW TOOLS?	✓ YES	NO	REMARKS	Drill Jig & Tapping Fixture Drg. T-797
NEW RAW MATERIAL?	YES	✓ NO	REMARKS	
STATUS RECOMMENDED	S	P	✓ M	IF STOCKED, INITIAL QUANTITY RECOMMENDED
NOTES	Chg. to Development Ord. DV-140			
DATE 2/24			APPROVED	E.H.J.

FIGURE 236. NEW PART NOTICE

with a knowledge of what will result to existing drawings, the drawing-record file, the master operation card in the planning department, parts index, storeroom locations, jobs in process, existing tools, jigs and patterns, and to any stock which may be on hand, on order, or in process. Any change should not be authorized until it has been determined what should be done with the tools, patterns, and stock affected, because there has to be weighed against the saving resulting from the change, the cost or the loss occasioned by it. The changed part notice is designed to provide for this situation.

In Fig. 236 is shown an illustration of the new part notice covering the lever for the new Model 7 Transmitter which is being used as an example. When approved, copies are sent to the departments indicated at the top of the form. Since no stock is recommended, the planning department has only to set up a master operation card and file it by drawing number. The engineering, or drawing-record, clerk has to see that the new part is recorded on the drawing-record card (which is done from the original tracing) and that it is entered in the parts-index copies in all departments. Rather than make a special trip to the various departments which have copies of the index, it may be satisfactory to bring all index copies up to date once a month. The pattern

and tool departments, upon receiving their copies of the notice together with a blueprint, issue their orders for the necessary patterns and tools. Should an initial quantity of stock be recommended, then the planning department has to set up a stores-record card and issue a production order, if the part is manufactured, or a purchase requisition, if the part is purchased, having first obtained from the storeskeeper an assigned location to which the parts can be directly routed. The maintenance of stock on hand is thereafter the responsibility of the stores-record clerk, who enters the minimum and order quantities on the stores record and revises these as conditions require.

CHANGED PART NOTICE

✓ PLANNING DEPT. ____ TOOL DEPT.
✓ COST DEPT. ____ INSPECTION DEPT.
____ ENGG. DEPT. ____ STORES DEPT.
✓ PATTERN DEPT. ____

W-881-3 P. I. NO.	C.I. MATERIAL	Piston PART NAME			
STOCK DISPOSED	✓ CANCELLED	OBSOLETED	W-881-9 SUPERSEDED BY	ORD. WHEN STOCK EXHAUSTED	REINSTATED

DIMENSIONS CHANGED FROM ____ TO ____

MATERIAL CHANGED FROM ____ TO ____

FINISH CHANGED FROM ____ TO ____

PATTERNS AFFECTED W-881-3

RECOMMENDATION Add core box to make hollow per drg change 7/18

TOOLS, JIGS, GAUGES AFFECTED ____

RECOMMENDATION ____

UNLIQUIDATED DEVELOPMENT $17.00 RECOMMENDATION Transfer to W-881-9

STOCK ON HAND 3 LOCATION 42-3A12 RECOMMENDATION Use up first

PARTS IN PROCESS 25 ON ORDER NO Lot 2 RECOMMENDATION Let come through & use up first.

COST OF CHANGE CHARGED TO Development Order DV-98

DATE 7/18 APPROVED E.H.S.

FIGURE 237. CHANGED PART NOTICE

In Fig. 237 there is shown the changed part notice, which has to cover more ground.

For better illustration, the notice has been prepared for a piston which is to be lightened by making it hollow. The pattern has to be changed. In the stores department there are three finished pistons that will be used up before the change is made effective, and in the shop there are 25 coming through and, since the castings are all made, these will be finished up and used. Thus this profitable change is put through in such a way as to cause no disturbance anywhere.

These notices are issued from the engineering department, but recommendations for changes may originate anywhere for the consideration of the development engineer. When properly handled they forestall costly confusion.

Changing or Renewing Drawings

Most tracings are expensive to produce. The custom used to be to make them quite artistic, with parts shaded and carefully inked in. That practice has become obsolete. Now tracings are made on bond paper and in pencil, the pencil being carefully selected to produce a clean and uniform line. From this paper tracing a copy is made on tracing cloth by the photolitho process.

Furthermore, some tracings become tattered with age and these are reproduced into fresh form by the photolitho process. Also, having once set up a complicated tracing, the engineering department sometimes can save the cost of another tracing for a new job by taking the tracing which comes nearest to what is wanted, blocking off the unwanted parts, and inserting the new desired arrangement. This is done quite inexpensively and quickly by the photolitho process. In this case the new tracing has to be assigned a number, of course, although 98 per cent of it may be a duplication of some other tracing. If any change is made in an item then that item is no longer the same and it cannot any longer be identified by the same number. It must be assigned a new number.

To illustrate the photolitho process assume that the transmitter shown in Fig. 229 on page 555 is ordered by a customer who wants a lever (part 2) with a triangular, instead of a round, end and a bottom guard (part 16) which has a round eye at the bottom of it. Ordinarily these changes could be effected without making a new assembly tracing, but suppose that the customer has requested blueprints of the finished device, for which he offers to pay. Three tracings will then have to be changed — X–150 assembly drawing, Y–173 lever drawing, and Z–1149 bottom guard drawing. Again, it would not be necessary to make finished tracings. Such changes, which may never be called for again, would ordinarily be set up in the sketch series, indicated on pencil drawings, which could well be freehand, and filed away ultimately with the particular sales order to which they apply. However, suppose finished tracings were required. Then the original tracings are printed, preferably in a vacuum printing frame — not on blueprint paper, but on photolitho paper, which is developed in a photographic darkroom. This will be in the form of a paper negative, with heavy brown background and white lines. When dry, this negative is placed on a transparent table top, illuminated from below, and with photo opaque the parts to be removed are painted out, and the drawing number is painted out, all the painting being done on the back of the negative. Then the negative is contact printed, preferably in a vacuum frame, on a sheet of sensitized tracing cloth which, also, is developed in the darkroom.

When the new tracing is dry the new arrangement and drawing number are inked in, just as on ordinary tracing cloth.

In up-to-date drafting rooms all tracings of new devices are originally made in pencil on bond paper from which crisp cloth tracings are obtained by this photolitho process, developed through the cooperation of the General Electric Company and the Eastman Kodak Company. It is quite profitable.

FIGURE 238. A MODERN DRAFTING DEPARTMENT *Courtesy of General Motors Corp.*

An up-to-date engineering and drafting department is shown in Fig. 238, where Buick engineers are shown preparing preliminary sketches and drawings incident to the manufacture of Pratt and Whitney aviation engines.

S, P, and M Parts

Just before explaining the material list, attention should be given to one of the most important considerations in the whole production-control scheme. Regardless of the endless variety of materials and part shapes, there are only three fundamental kinds of parts and materials with which the production process is concerned. In putting

together any assembly all parts have to be obtained from somewhere. Either the parts and materials are Stocked or they are not stocked. If they are not stocked, then it is necessary to either Make them as they are needed or to Purchase them as needed. That is to say, there are only

S parts,
P parts, and
M parts

and it is highly important, as will be seen when the work of the planning department is considered, to indicate this on the material list. Column 7 of Fig. 239 is therefore provided.

The Material List

Having completed the assembly tracing, Fig. 229, page 555, and all of the parts drawings, Fig. 231, page 558, for the transmitter which is being used as the example throughout this chapter, the draftsman has only to prepare the material list.

The material list takes the same number as the assembly tracing, in this case X–150. In those cases wherein one assembly drawing is used for a whole series of assemblies differing mainly in size, the series of material lists bear the same number but with subnumbers added, as X–150–1, X–150–2, and so on, respectively.

In listing the parts on the material list the principal consideration requiring care is to group together those parts which can be put together as parts or subassemblies. The subassembly has to be set up on a separate assembly drawing, and its number is entered on the material list and indicated as an assembly in the fifth column. The parts going into this subassembly are indented as is illustrated in items 23, 24, and 25 in Fig. 239.

In the first column on the material list appear the reference numbers which key the list to the assembly drawing, Fig. 229, page 555. In the fourth column appear the drawing or stock numbers. In this case the only stock number appearing is for item 14 which is a standard square-head set screw which, as a purchased item, is carried in stock. One of the most important columns on the list is column 7 which indicates whether the part is stocked, made to order, or purchased to order.

Then, for the convenience of the planning department, there are provided a series of columns which will show in white on the blueprints so information may be written in. These columns are not used until the work of the planning department is executed and they will be explained in the chapter on Type 1 Control.

At the top of the material-list tracing spaces are provided for the sales-order number, for the serial number if any, for the erecting, or assembly-order number, for the quantity to make, and for the number

Page 1 of 1 — **MATERIAL LIST** — Asm. Drg. No. X-150

MODEL 7 TRANSMITTER

Accum. Stall No. [redacted] — Make — Sales Ord. No. — Asm. Ord No. — Serial No.

Ref.	Part	Matl.	Stock or Drg. No.	Reqd. As	Reqd. Pt	SPM	Ord	Order No.	✓	Date Wtd	Pattern No. or Material	SPM	Ord	Fdry Ord. or Pur. Reqn	✓	Date Wtd
1	Frame	CI	X-240		1	M					X-240	M				
2	Lever	CI	Y-173		1	M					Y-173	M				
3	Driven Pulley	CI	X-241		1	M					X-241	M				
4	Driving Pulley (3 step)	CI	X-242		1	M					X-242	M				
5	Hollow Shaft	Stl	Z-1141		1	M					35 3/8 "/c 6658-143	S				
6	Oil Cup	CI	Z-1142		1	M					Z-1142	S				
7	Side Guard	CI	Y-174		1	M					Y-174	M				
8	Pin for #2	Stl	Z-1101-10		1	S					12 "/c 6659-13	S				
9	Screw Plug for #3	Stl.	Z-1143		1	M					3 5/8 "/c 6658-147	S				
10	Stop Pin for #3 & 9	Stl	Z-1101-1		2	S					25 "/c 6659-5	S				
11	Spring	PW	Z-1144-5		1	P					-	-				
12	Screw Pin for #5	Stl	Z-1101-2		1	S					25 "/c 6659-9	S				
13	Operating Plug for #4	Stl	Z-1148		1	M					31 1/2 "/c 6658-171	S				
14	Sq. Hd. Set Screw	Stl.	7458-16		1	S					5/16-18 x 3/4	P				
15	Fil. Hd Mch Scr. for #6	Stl.	Z-1103-12		2	S					9 1/2 "/c 6659-14	S				
16	Bottom Guard	CI	Z-1149		1	M					Z-1149	M				
17	Fil. Hd. Mch. Scr. for #7 & 16	Stl	Z-1103-13		2	S					8 3/8 "/c 6659-28	S				
18	Operating Plug	Wd	Z-1104-2		1	S					11 1/2 "/c 6678-6	S				
19	Adjusting Screw	Stl.	Z-1145		1	S					93 3/8 "/c 6659-29	S				
20	Hex. Lock Nut for #19	Stl	Z-1146		1	S					37 1/2 "/c 0131-13	S				
21	Peripheral Brake	Lea	Z-1105-1		1	M					33 1/3 "/c 6673-3	S				
22	Clutch Ring	Lea	Z-1105-11		1	M					137 1/2 "/c 6673-3	S				
23	Wick Assembly	-	Z-1147	1		M					-	-				
~~24~~	Wick	Wool	"		1	-										
~~25~~	Wire	Stl	"		1	-										
6																
7																
8																
9																
0																
1																
2																
3																
4																
5																
6																
7																
8																
9																
0																

FIGURE 239. THE MATERIAL LIST TRACING

of the accumulation stall (Figs. 216 and 217, pages 536 and 537) in the finished-parts storeroom to which all easily handled parts are to be routed before release of the job to the assembly floor.

When the material-list tracing is finished it goes to the drawing-record clerk who, in this case, has to take out of the file 23 cards and enter the number X–150 in their material-list columns. Reference to Fig. 232, page 560, will reveal that this has been done. The material list then goes to file.

In machinery-building establishments the material lists may become somewhat more complicated. As an illustration, take the plain power ramming molding machine described on page 522. There are four groups, or subassemblies — the base group, hose group, yoke group, and miscellaneous group. In making up the material list for such cases, it is most flexible and convenient to list the parts for each group on a separate page. Thus for this molding machine the material list would have five pages, the first of which, or complete assembly, would be numbered page 1 of 5, as is provided for in the upper left-hand corner of Fig. 239.

In more complicated cases, such as locomotives, large automatic screw machines, battleships, hotel elevator controllers, army tanks, automobiles, the material lists may comprise numerous pages. If the principle explained in the above illustration is adhered to, then the production-control problem will be made extremely simple. When the material list is prepared in this manner it becomes possible for even a new worker, who has had some mechanical experience but who may never have seen the device covered by the list, to go into the assembly department, take the list, the assembly drawing, and the parts and put the device together without supervision.

It is important that on the material list there should appear no information whatever except that which pertains to the material specifications. Any routing information such as descriptions of operations, or of machines, or of departments working on the parts, should be put on the master routing card and not on the material list. It should be kept in mind that what the material list is to the material, the master routing card is to the labor. Properly designed, these two fundamental records constitute the whole foundation of production control.

Manufacturing Instructions

The planning department will find frequent occasions when it will be necessary to issue to the shop certain manufacturing instructions concerning the setting up of fixtures, the use of the tools issued for the job, and the proper speeds and feeds. Since these instructions may have to be issued each time a production order for the kind of parts

concerned is issued, it will be most convenient to have the instructions in the form of tracings so they can be blueprinted. The file of tracings would be kept in the engineering department, along with all the other tracings, and the instructions number would be recorded on the master routing card which is kept in the planning department. See column 5 on Fig. 248, page 588.

CHAPTER XXVII

PLANNING PROCEDURE

Production is concerned with only two elements — materials and direct labor; that is, with materials and the operations on them. In Type 1 and Type 3 production the work of the planning department is directed to those activities which effect and make more efficient the preparation of material requirements for individual jobs, and which determine what to do, where best to do it, and when it should be done. Type 2 and Type 4 production have to go a little farther, since considerations are introduced which make it necessary to relate individual jobs to other things. For example, in Type 2 production a work schedule has to be geared to forecasts of future sales and to the rate of incoming orders, and in Type 4, a specific project involves the necessity of lining up a special group of workers whose separate efforts have to be coordinated.

The forms and mechanisms which enable the planning department to function efficiently will depend on the type of production and the kind of product. Some form of material list and master operation list are common to all types of production control, and the appropriateness with which these fundamental forms are designed will have much to do with the efficiency and the effectiveness of the control.

There are still numerous manufacturing establishments, particularly small ones, which adhere to the principle of having work planned in the shop by the foreman. This is satisfactory only when there are but a few orders being received weekly and when the foreman, besides being essentially a practical man, has sufficient knowledge of office contacts, prices, supply sources, and design techniques to be also a good designer. A profitable foreman would not want to be responsible for keeping informed on the maintenance of stocked items and on paper procedures; his specialty is to direct the application of labor and equipment to specific jobs, and he is thankful to have the jobs clearly and completely defined before they are transmitted to him.

The whole principle of profitable production control is lost if planning and execution are intermixed in the processing of work. It would not be a very large manufacturing plant which received 200 orders per week. If these orders were planned in the shops, the situation

would be as illustrated in Fig. 240, there being about four weeks of work ahead, the probability being that promises are given for "three weeks delivery." Rarely does such an arrangement work satisfactorily. Too much is expected of the foreman and no provision exists for anticipating requirements. Stock chasers have continually to encourage makeshifts in order to help complete overdue orders, introducing a confusion which is costly and disruptive.

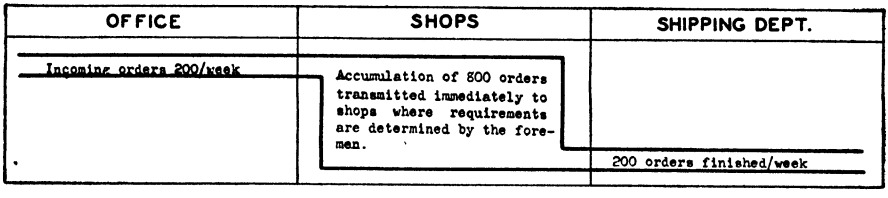


FIGURE 240. PLANNING IN SHOPS NOT ECONOMICAL

In processing each of the accumulated 800 orders there are only three classes of materials to be provided for. There are S parts, P parts, and M parts. The S parts have to be checked against any available stock on hand, and any required replenishing orders started off. The P parts call for the writing of purchase requisitions and the following up of deliveries. The M parts will require blueprints, material requisitions of some form, and production orders. All of this preliminary activity is of a character which does not readily appeal to a foreman whose thoughts have to center around the manner of doing the work, the qualifications of available operators, and getting things done. The usual result is to provide the foreman with an assistant who is good at the planning part of the work but who, by being located in the shop, is greatly handicapped in being detached from the office departments.

Even in sheet-metal work, which is one of the difficult cases because of the amount of special layout work incident to each job, advance planning is indispensable to profitable performance. As much planning as possible should be done in advance before the shop ever receives the orders, and it is the responsibility of the industrial engineer, or the planning officer, to devise means of making this planning expeditious and efficient in order to accomplish the desired results with a minimum of overhead expense. To keep the orders in the office until they are ready for straightforward production would bring about the situation illustrated in Fig. 241. This is the arrangement assumed in this text.

Among the accumulation of orders in the office there will be numerous stocked items which will have to be reserved for their respective orders, there will be numerous required purchase requisitions which will have to specify where the materials should be delivered when they arrive

at the receiving department, and there will be numerous production orders, and possible foundry orders, which will have to specify where the parts must be routed in order to meet up with the other classes of parts which are to flow together from several sources. This is the common picture in all cases involving the preparation of parts for assembly operations. All of these activities, which have to move swiftly and accurately, are provided for primarily in a suitably designed mate-

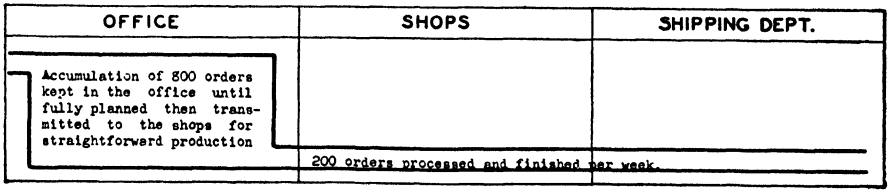


FIGURE 241. ADVANCE PLANNING IS PROFITABLE

rial list, which is by far the most important element in any production-control plan, and which will be illustrated clearly particularly in the chapters on Type 1 and Type 2 Control.

Estimating

An estimate is a price based on a computed probable cost of a new job or project. Its consideration immediately entails division of the four types of producers and of plants of different sizes. Type 2 producers, engaged in mass production of standard items, are not greatly concerned with estimating problems. Their task, as far as new products are concerned, is just the reverse of customary estimating procedure in that, as first explained by Henry Ford, they must first ascertain what a contemplated product will sell for and then determine the scale on which it must be manufactured and the production method necessary to yield a profit. Large companies, less concerned with competitive pressure, can be rather independent in the matter of estimating. With them an estimate is often a relatively offhand suggestion of what they would be willing to undertake a new project for, on an incentive basis, and it is often a price arrived at readily by comparison with some previous job of somewhat similar nature.

Type 4 producers, engaged in construction projects, find estimating a matter of very considerable importance and of research proportions. Reputable contractors, in compiling their own specifications, or analyzing architect specifications, have to handle specification sheets which make up books of sizable scope. They have to assemble bids from subcontractors, key them, and index them, to make up their estimate for the completed project. It is one of the serious tragedies which have

crept into our way of doing things that less reputable contractors seek their main profit from the destruction of subcontractors. Properly, in preparing estimates under Type 4 production, the prime contractor should be of sufficient integrity to want everyone associated with a project to profit by it. The purchaser should get as fine a job as possible at a price which can guarantee improved character among all who are called upon to contribute to the common venture. Workmanship and materials must be strictly according to specifications, and prices must be based on carefully planned performance and honest conclusions. There seems no other way to safeguard our democratic way of life from the mounting forces which threaten it in this field of estimating.

A small Type 1 producer, operating a jobbing plant which he has built to a successful standing from scratch, needs a new building. He scrutinizes the specifications with ambitious care and makes sure that his wants are made clear — copper flashings, five-ply roof, and all other details. The contract is let for an undisputed price. The contractor signs the contract and is given his copy. Presently the owner is apprised of the fact that the roof is practically finished and has galvanized steel flashings and is of only one ply. The job has to be done over and the owner has to hire, at his own expense, a full-time inspector for the sole purpose of ensuring honesty in the execution of the job. This is but a very small illustration of the principle, or lack of principle, which tends to overburden productive enterprise with nonproductive expense and to destroy the whole framework of intelligent estimating. One type of mind argues that in giving an estimate one should "charge all that the traffic will stand" or that one should "put in something for the chisel," all of which tends to bring about the destruction of the free enterprise system, to discourage productive effort, and to substitute a regime of chiseling, piracy, and decay.

Type 1 producers and Type 3 producers, engaged largely in nonrepeat work of wide variety — jobs of much smaller scope than those occupying the attention of Type 4 producers — are the ones who are called upon to devote more time to estimating. They come more intimately into contact with competition, particularly if they are small producers. Having no advantage of size, and relatively small advantage of prestige, they find it necessary to stand out from the crowd either by superior character and by sales strategy or by superior values in their products, depending on the class of trade served by them — whether it be other manufacturing companies, public institutions, or the public itself.

For such small producers it is important to prepare estimates with some care, not only to avoid losses they cannot afford, but also to build up a reputation for dependability. Not long ago the existence

of contributing enterprises that were engaged in the production of parts for the automotive industry was threatened and destroyed by heedlessness in estimating. They were invited to bid on, say, 50,000 pairs of head lamps for a new model automobile. They might arrive at a price of $7.50 per pair. The buyer's agent would say, "You're high; we got a price from one of your competitors of $6.50 per pair," whereupon the producer would say, "Is that so? Well, if our competitor can do it we can do it — put us down for $6.50 per pair." In such a case had the estimate been prepared intelligently it would not have been difficult to decide whether a competitor was actually superior or whether the buyer's agent was dishonest.

In preparing the estimate, shrewdness dictates that the estimate sheet be so designed that if the job is obtained at the quoted price some provision is immediately available to ensure that the various items involved be not exceeded. A detailed list of materials and a carefully prepared list of operations are all that is required. These should become the strict specifications for the shop, with an understanding that if, in the process of production, prospects are that some item will be exceeded, the supervisor must decide what should be done before it is too late. It is of no avail to hold conferences, after the job is finished, on why there was a loss. That merely introduces more loss.

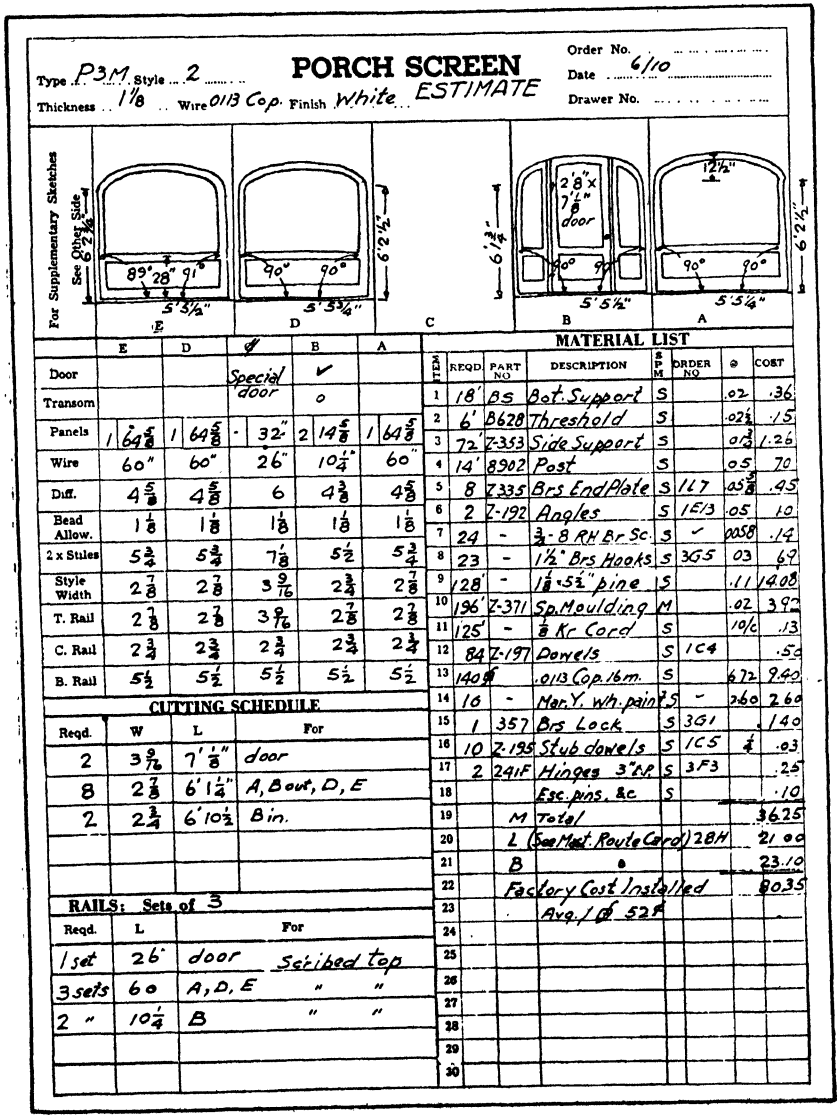
To illustrate an effective estimate sheet from the records of a successful small producer who is in a position to nearly monopolize a field in his territory, take the job of estimating the construction of a screened-in breezeway for a new home. The first step is to measure the openings. In doing this a freehand sketch is made and the construction thus designed quickly, before any figuring is done. This becomes a part of the final instructions to the shop. Obviously a qualified estimator is required, since he has to design the structure mentally before he can compute the cost. The design is then analyzed, item by item, until the estimate is arrived at and, as a by-product, there is made available the complete cutting schedule, ready for immediate production without further figuring or planning. Such a sheet is shown in Fig. 242.

The time required for measuring, making the rough sketch, and determining the design should not exceed 30 minutes, in this case. To complete the estimate sheet required $\frac{3}{4}$ hour and that completed all of the necessary planning work as well as providing the estimate. The labor operations are prepared on a separate list, which becomes the guide for the shop supervisor.

The finished job in this case looked like Fig. 243, which may be compared with the rough sketch on the estimate sheet. This relatively simple case was selected for an illustration because it should fall within the experience of the student reader and be easy to follow through. It

should be worth the effort to check through the estimate sheet to make sure each step is clear and to reveal the straightforward simplicity of such analyses. There is little excuse for crude estimates or for failure to meet the estimates which are carefully prepared.

In the machine-tool industry the task of estimating has been reduced to the estimating of weights. If a large planer is to be figured, the estimating department makes up a schedule of the probable weights of



Type P3M Style 2 — **PORCH SCREEN ESTIMATE** — Order No. — Date 6/10 — Drawer No.

Thickness 1⅛ Wire 0113 Cop. Finish White

For Supplementary Sketches See Other Side

E: 89° 28" 91°, 5'5½"; D: 90° 90°, 5'5¾"; C: 6'2¼", 6'1¾"; B: 2'8"x 7'1" door, 90° 90°, 5'5½"; A: 12½", 90° 90°, 5'5¾", 6'2¼"

	E	D	C	B	A
Door			Special door	✓	
Transom				0	
Panels	1 64 5/8	1 64 5/8	- 32"	2 14 6/8	1 64 5/8
Wire	60"	60"	26"	10 1/4"	60"
Diff.	4 5/8	4 5/8	6	4 3/8	4 5/8
Bead Allow.	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8
2 x Stiles	5 3/4	5 3/4	7 1/8	5 1/2	5 3/4
Style Width	2 7/8	2 7/8	3 9/16	2 3/4	2 7/8
T. Rail	2 7/8	2 7/8	3 9/16	2 7/8	2 7/8
C. Rail	2 3/4	2 3/4	2 3/4	2 3/4	2 3/4
B. Rail	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2

CUTTING SCHEDULE

Reqd.	W	L	For
2	3 9/16	7'1 1/8"	door
8	2 7/8	6'1 1/4"	A, Bout, D, E
2	2 3/4	6'10½	Bin.

RAILS: Sets of 3

Reqd.	L	For
1 set	26'	door Scribed top
3 sets	60	A, D, E " "
2 "	10 1/4	B " "

MATERIAL LIST

ITEM	REQD	PART NO	DESCRIPTION	S P M	ORDER NO	ø	COST
1	18'	BS	Bot. Support	S		.02	.36
2	6'	B628	Threshold	S		.02½	.15
3	72	Z-353	Side Support	S		.01¾	1.26
4	14'	8902	Post	S		.05	.70
5	8	Z335	Brs End Plate	S	117	.05⅝	.45
6	2	Z-192	Angles	S	1E13	.05	.10
7	24	-	¾-8 RH Br Sc.	S	✓	.0058	.14
8	23	-	1½" Brs Hooks	S	3G5	.03	.69
9	128'	-	⅛ x 5½" pine	S		.11	14.08
10	196'	Z-371	Sp. Moulding	M		.02	3.92
11	125'	-	⅜ Kr Cord	S		10/c	.13
12	84	Z-197	Dowels	S	1C4		.56
13	1400		.0113 Cop. 16 m.	S		.672	9.40
14	16	-	Mar. Y. Wh. paint	S	-	.360	2.60
15	1	357	Brs Lock	S	3G1		1.40
16	10	Z-195	Stub dowels	S	1C5	4	.03
17	2	241F	Hinges 3" NP	S	3F3		.25
18			Esc. pins, &c	S			.10
19		M	Total				36.25
20		L	(See Mat. Route Card)		28H		21.00
21		B	"				23.10
22			Factory Cost Installed				80.35
23			Avg. / @ 52¢				
24							
25							
26							
27							
28							
29							
30							

FIGURE 242. DETAILED ESTIMATE AND PLANNING SHEET

cast iron, cast steel, forgings, machine steel, bronze, and brass, basing the figures on weights of previously made parts which have been tabulated on engineering data sheets for convenient reference. It is to assist in this that the part weights of stocked items are shown at the top of the stores-record cards as indicated in Fig. 224, page 548. Estimates prepared in this way have no value for the shop; they serve nothing but the estimators. If a job comes through at a loss, it is almost im-

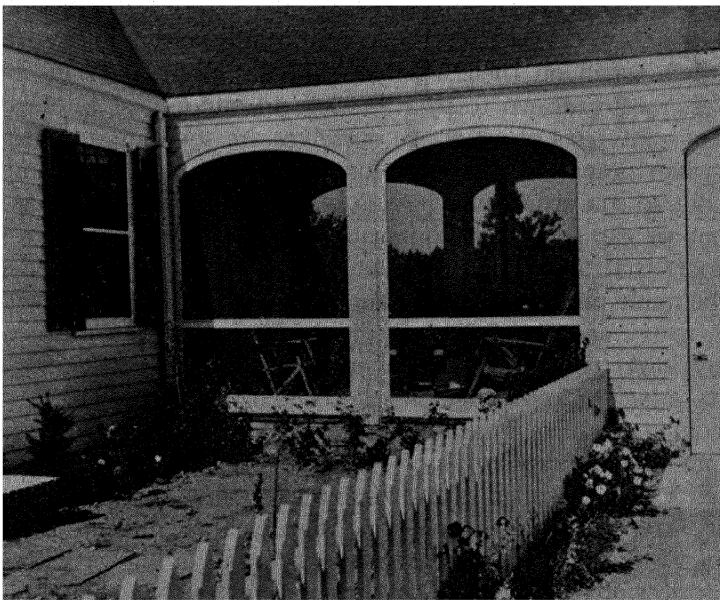


FIGURE 243. THE COMPLETED JOB

possible to determine the source of the difficulty, without considerable research. What often happens is that the engineering department is criticized for having taken too much time on the job, or the shop is criticized for excessive labor charges, and so on, all without intelligent foundation. If such criticisms are permitted to arise, without first having enough facts to substantiate them, the cost of the ensuing demoralization will more than outweigh the original cost of preparing the estimate on a sound engineering basis.

In presenting an estimate to an average consumer it will be important for the salesman to understand one or two fundamentals of behaviorism. The average consumer is likely to be dominated by certain sentimental considerations and, though standing detached, exhibit the same reactions as a person in a crowd. It is well to understand that "things must be laid before the crowd as a whole, and their genesis

must never be indicated." If the estimate is put into tabular form, showing a number of combinations and prices, the job will almost certainly be lost. If a customer's wish is acceded to and the price stated for material and for labor, the job will almost certainly be lost. The estimate must make all the decisions and present only the final result. Any sales appeal must be made on the sentimental side as, in the case of the porch-screen illustration, "this is virtually the price of a new living room out of doors" or "which gives the baby a healthful out-of-doors nursery." "Above all else, people give their attention to themselves and to their own affairs: to their own wants and problems; to the things that touch on their own experience. Irresistibly, in spite of ourselves, we are drawn to what is close to our inmost interests and impulses — interests of which we ourselves are sometimes unaware." [1]

But when preparing estimates for other manufacturing companies we are not so concerned over buying motives. The estimate has to be such that we can refer back to it with certainty. A prospective buyer may report that the estimated price is too high, whereupon a decision has to be made promptly on whether to execute a new design with less quality, to try and find less costly methods of execution, to recognize that any lower competitive price may indicate a competitor's superiority or a lack of knowledge of true costs, or to let the job go. Some larger companies have what amounts to a prepricing department that makes an advance appraisal of probable prices on purchased jobs. The vendor may be called upon to submit as many as five copies of his invoice. After these copies have gone through their routines the buyer has some assurance that the prices are not far out of line with previous, similar, prices or with what an astute mind judges they should be. All of this nonproductive endeavor has to be paid for by those who do the productive work of the world. All should be largely unnecessary if there prevailed a condition of confidence based on established, dependable reputations.

The importance of taking adequate time in the preparation of estimates has been forcefully brought home to those small producers who have been badly hurt in their attempts to bid hastily on defense contracts in the current war program. Invitations for bids are issued with the stipulation that the bids must be in within, perhaps, four days of the time the producers learn of the defense requirements. To obtain the necessary specifications it may be necessary to write to another state, perhaps three days being required for that. In the case of sleeping bags, for example, made from canvas, the specifications go as far as prescribing the length of cotton fiber to be used in spinning the yarn

[1] Strategy in Handling People, page 27. Ewing T. Webb and John J. B. Morgan, Chicago, Boulton, Pierce and Company.

to be used in weaving the duck of which the bags shall be made. None of this is of concern to the bagmaker. He wants to know what duck to use, where to get it, and what it will cost him. But there is only a day left in which to do all of his analyzing and for getting his bid back to headquarters in another state. The only safe thing is to pass up the bidding. A large producer can bid "cost plus some percentage" and get a contract. That is the only safe procedure for the small producer in cases such as cited. It is imperative that he prepare a definite material list and a sound operation list before venturing any other kind of a bid and that, with the time limit imposed, is not possible in many cases. Thus a host of small producers are prevented from putting their shoulders to the wheel.

The only safe rule for estimating procedure is first to obtain, or make up, a clear picture of just what is to be done, analyze it carefully for both material and labor cost, base the quoted price on a scrupulous and intelligent regard for what is right, and then stand one's ground. If the order is received, as in most cases it will be when thus prepared for, one should see that the component prices which make up the estimate become the pattern for performance.

Another situation which has to be given attention is that estimates should clear through the order department, or in smaller companies, through the person likely to see the order if it is obtained. An inquiry comes in: "Please quote us your very best price on 500,000 and 1,000,000 pieces like sample enclosed." (That means Type 3 production.) The estimator prepares an itemized cost and submits the quotation. In perhaps two weeks the order is received, but the order calls for 10,000 and has the 1,000,000 price typed on it. It will be worth the student's time to take a piece of paper, lay out all of the elements which go into any cost, put down some definite figures for material, labor, burden, selling, and administrative expense and profit. Then assuming that labor is paid by piecework he should figure out just where quantity discounts come from and how much they may be in a case wherein a prospect proposes to double the size of his contemplated order.

Which Type of Control?

The work in the planning department is largely determined by the type of production control involved. It is necessary for the planner to decide quickly and correctly which type of control to establish. One of the most unfortunate and costly errors made by industrial engineers during the production rush of the First World War, when the dominant urge was to get more production out of a given shop capacity, was setting up wrong types of control. The war rush, just as with the Second World War, made it necessary for Type 1 plants to take on

Type 2 ways. The Type 2 control was so different from what they had been used to that their organizations were afraid of it. The attempts to "tune up" the old Type 1 control, and to centralize it, were almost invariably failures.

As preparation for a better understanding of the various types of control, to be explained in detail in the following chapters, take the cases illustrated in Fig. 244.

What types of control should be used for these various machines? Obviously such a question cannot be answered until it is first decided under which of the four types of productive process they are made. Then the question decides itself.

First take the Cameron machine. It is a Camachine No. 6 for accurately slitting any fabric from cotton bagging to uncured rubber — binding tapes, gimp, artificial leather, felt, burlap, cheesecloth, paper, or coated fabrics. On ordering the machine one is required to specify the width of fabric to be slit, and whether it will be slit from a roll or a bolt. Thus, the machine is one that is made up of standard parts which may be put together in different combinations. The machines would not be produced for stock in accordance with forecasts of future popular sales. Therefore it must be classed as a favorable case of Type 1 production, for which see page 509.

The Saranac machine, shown to the right of this Camachine, is an automatic paper-box machine for one size of box such as cartons for eggs, crackers, fancy bakery goods, and hardware. The particular case illustrated is for 2 inch $\times$ 6 inch folding egg cartons. The machines are made to order and the making of them is the regular speciality of the Saranac Company. That means Type 1 process (see page 509) and, since the whole machine is apt to be specially designed, it is a less favorable case than that of the Camachine.

In the center is shown a new, popular model, of the South Bend lathe, size 9 $\times$ 3. It was designed to sell at a popular price for home workshops, schools, and small production shops, and operated from any light socket. A feeler lot would be produced first to see if it were to meet with popular approval. That would mean Type 4 control to start with; see page 512 for Type 4 process. It did prove very popular, being a most excellent piece of equipment. That would put the machine in regular production, close out the Type 4 control, and introduce some other type of control. Being in the form of capital goods, rather than consumer goods, the product would not be consumed, thus providing a continual stream of new orders. Consequently, though a very successful product, it would not be apt to come under the Type 2 process of continual mass production. It would therefore be a very favorable case of Type 1 process in which it would be produced in

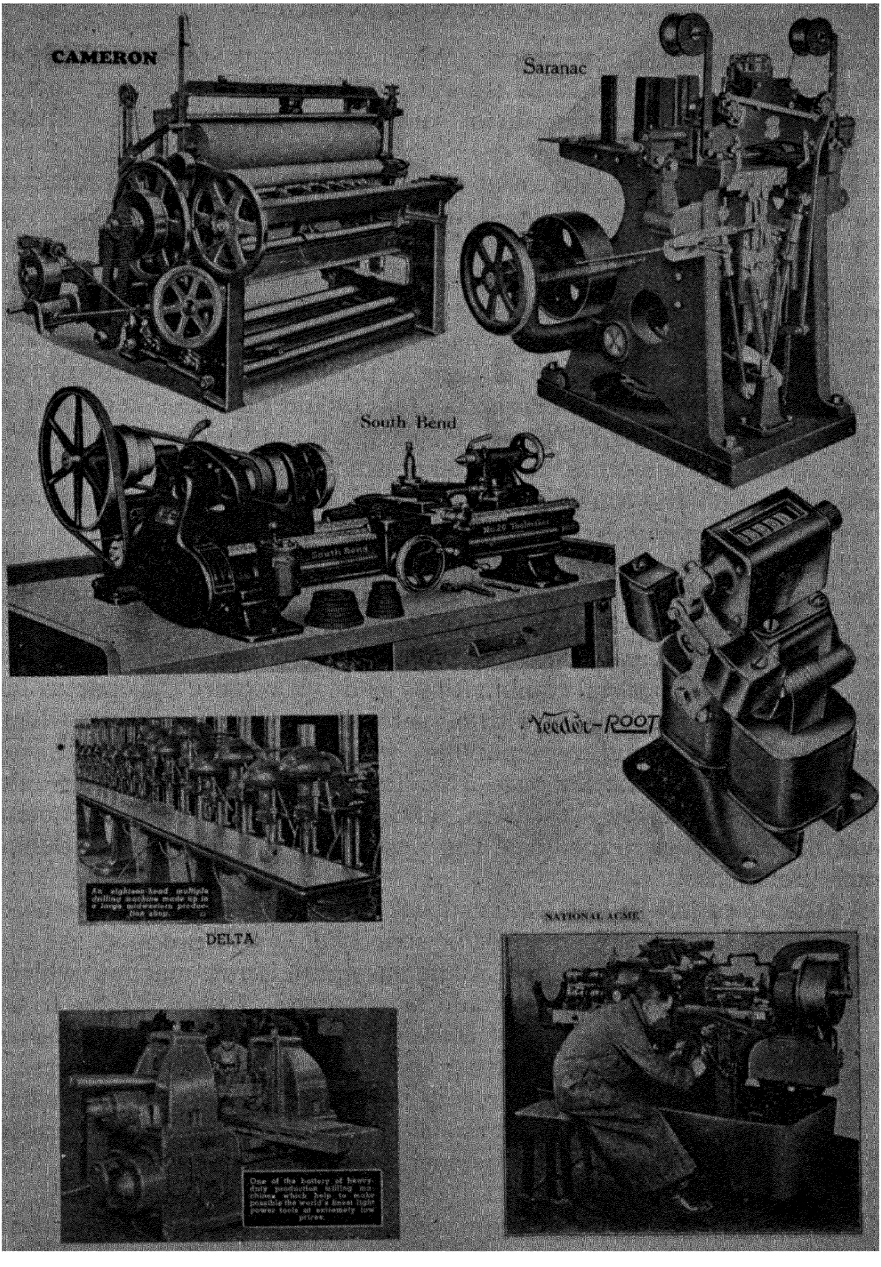


FIGURE 244. ILLUSTRATING VARIOUS PRODUCTION CONDITIONS

occasional quantities for stock. When that stock became depleted another stock order would be issued for a somewhat larger or smaller quantity according to the run of sales, and so on until the demand subsided.

The Veeder counter, shown at the right, would be a case similar to the Camachine, lesser only in degree, and produced in a different type of shop. It is a magnetic counter to be placed at a distance from the machine on which a count is desired, such as elevators or printing presses, etc. In ordering it is necessary to specify the voltage, which must be of direct current but may range from 6 volts to 220 volts. Thus the coils are special, but otherwise the parts are standard, just as in the Camachine case. These counters would therefore represent a favorable case of Type 1 process. However, in the Veeder-Root factory there would be numerous other fully standard counters which would be produced on the continuous basis, just like Waltham watches, and which would come under Type 2 process; see page 510.

Then there is shown a special multispindle Delta drill with 18 heads. The heads are standard; the table and mounting are special. The parts for the head would be listed on one page of the material list as explained on page 571. That page could be put together with other material-list pages for as many special combinations as might require that particular head. Thus the head, along with numerous other Delta products which are relatively new and very popular, would, for a time at least, fall under Type 2 process; see page 510. Being capital goods there would presently come market saturation, fall in demand, and the consequent shift of the product to the Type 1 process, thus being identical with the South Bend case.

At the lower left in Fig. 244 is shown a special milling machine used in the Delta factory. This would be strictly a Type 1 product. At the lower right is shown a National Acme automatic screw machine which, except in the cam equipment, would be standard. It would have to be ordered for a particular kind of work and would therefore be another case like the Camachine — a rather favorable case of Type 1 process.

Now suppose you were visiting the Stimpson factory and saw what is illustrated in Fig. 245 — numerous types of machines for inserting different kinds of grommets, fasteners, and eyelets, hand, foot, and power operated.

Numerous types of machines are shown. All move into a market that consists of manufacturing plants, large and small, and the volume of sales would depend upon expansion in existing plants, the origin of new plants, or the replacing of competing types of machine. There is nothing in this which would suggest the possibility of continuous, popular demand. The products are capital goods. They could not be

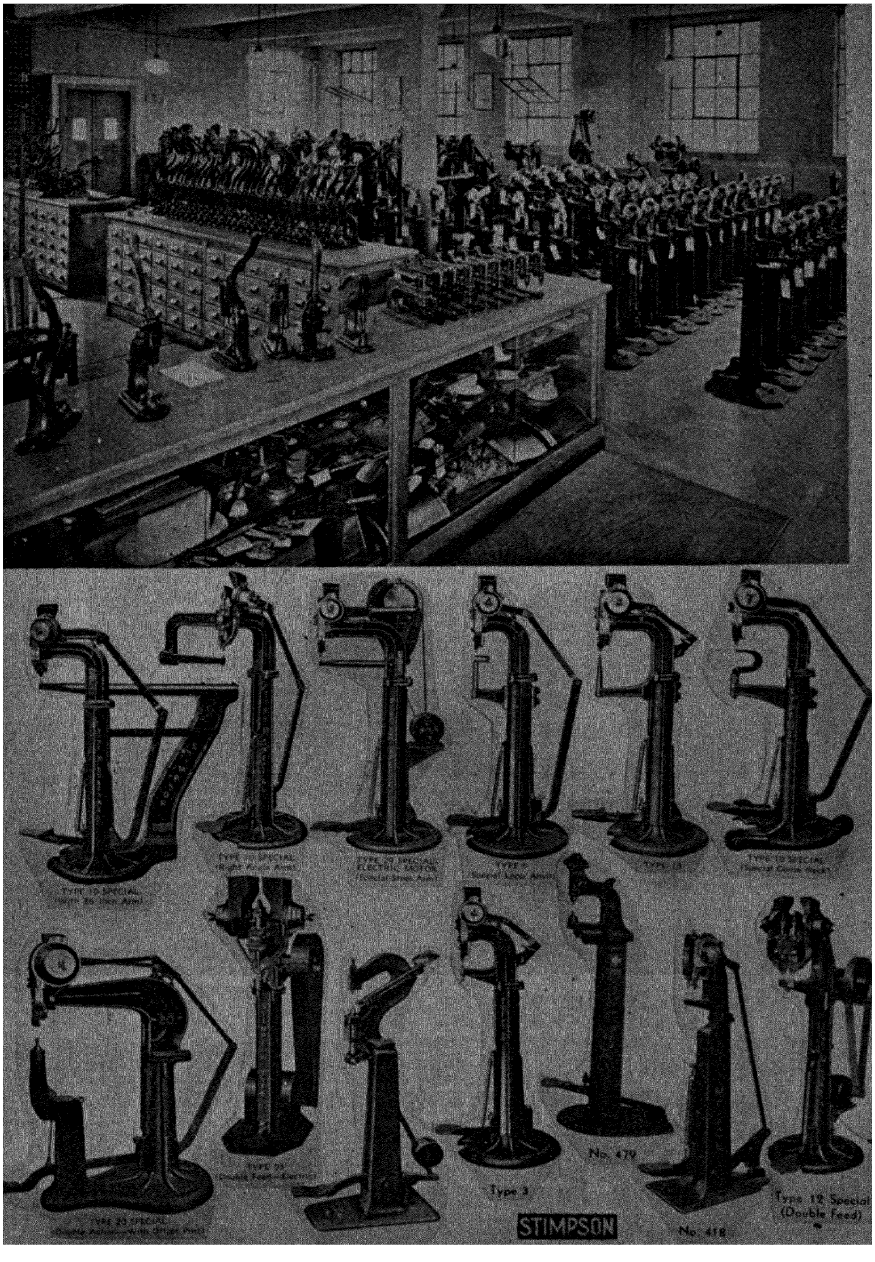


FIGURE 245. ILLUSTRATING PRODUCTION CONDITIONS

handled under Type 2 control, especially after the initial stage of introduction to the market, and should be handled under Type 1 control in which they represent a very favorable case. The standard motors which operate the power machines are, however, quite different. The market for the motors is so broad, and their construction is so standard, that they could and should be handled under Type 2 control, with the production schedules based on forecasts of probable future sales.

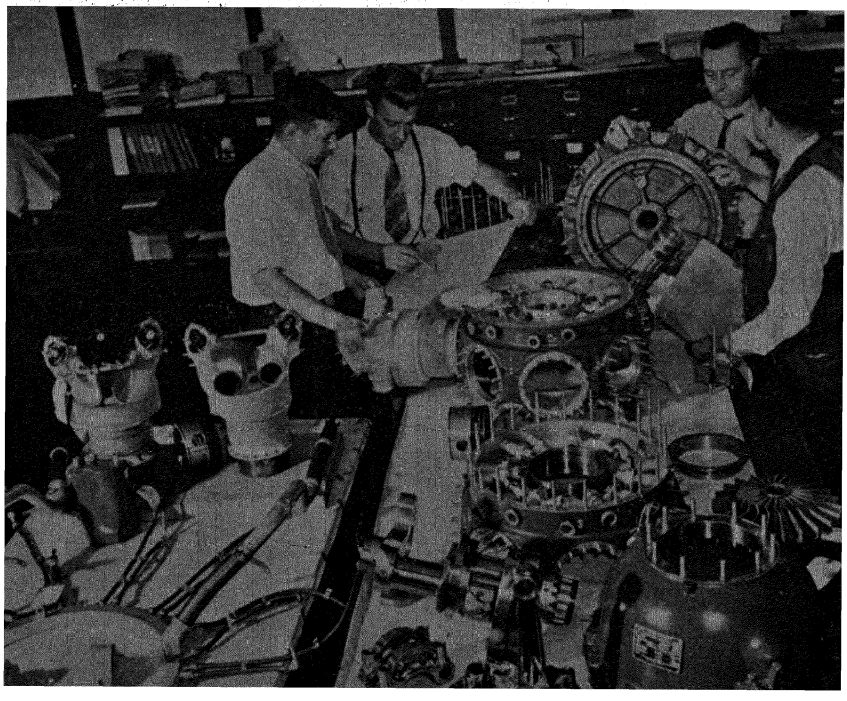


FIGURE 246. AIRPLANE MOTOR PARTS

Courtesy of General Motors Corporation

In Fig. 246 are shown the parts of a Pratt & Whitney aviation engine which has been torn down for inspection. Ordinarily this engine would be produced under the Type 1 process, orders being put through the shops for a definite number and handled under Type 1 control. With the urgency of the war program, however, it becomes necessary to produce much larger quantities and on a rate basis. The fact that it is desired to increase the rate as much as possible means that equipment and facilities will be expanding and the many parts involved will be coming through at widely different rates. Unless a systematic program of production control is in operation great confusion can result. Obviously the control plan would change from Type 1 to

Type 2. Provision has to be made for spare parts in addition to the parts needed directly for the scheduled quantity of engines. This is all covered in the chapter on Type 2 control.

In this illustration it will be evident that the production-control problem is no different from that involved in the illustrations shown in Fig. 244. The precision required is greater and therefore the inspection responsibility is greater. That means multitudes of special

FIGURE 247. TYPE 2 PRODUCTION

jigs, fixtures, gauges, and special tools. The cost of all these is a part of the initial development expense which has to be handled as explained on page 553.

It should be borne in mind that Type 2 production depends upon standardization. A product should never be started under Type 2 production until its complete design has been set for the duration of the initial schedule period. That is, if a production schedule has been prepared for the next quarterly period, then no changes should be permitted for that period. All changes should be lined up so that they may be incorporated in the preparation of the next succeeding schedule.

In Fig. 247 there is shown a somewhat typical illustration of Type 2 production. Skilled machinists are grinding in the threads and per-

forming other operations according to the Allison aircraft engine-propeller hub specifications. The parts may move along in convenient small-lot quantities or may be passed along one at a time from one operation to the next without any special identification as to order number or lot number. Conveyors may be used and chutes may be provided between machines if the parts move to lower levels. All this is typical of Type 2 production and at some point one would expect to find a Type 2 control chart either in the form of a large control board

MASTER ROUTING CARD PART Hollow Shaft DRG. NO. Z-1141 MATL. Stl

DEPT.	OPER. NO.	OPERATION	MACHINE NO.	MFG. INSTNS	JIGS, FIXTURES	SMALL TOOLS	STD. TIME.	RATE BASE	RATE PIECE
7	1	Set up lathe	L-101				.25		-
	2	Drill & Cut off	"			7/16 dr.	4.17/65	65	2.71
	3	Form end	"				.83	65	.54
	4	Set up drill (2 spindle)	D-76		J-263		.25		
	5	Drill oil & pin holes & tap	"		"	#2, 8, $\frac{1}{8}$-40	1.67	50	.84
	6	Set up miller	M-9		F-332		.33		
	7	Mill slot	"		"		.83	75	.62
	8	Harden (Engg. Data 167)		✓			.50	75	.38
	9	Grind (centerless grinder)	G-13				1.00	75	.75

FIGURE 248. MASTER ROUTING CARD

or a small chart kept at the desk of the planner. The control board used by the General Motors planning department is shown in Fig. 289 on page 658. It has been inserted in the chapter on Type 2 control so that it may be more readily compared with the typical form of board appropriate to that form of control.

Master Routing Card

The master routing card, or master operation card, is to the direct labor what the material list is to the direct materials. The material list was explained on page 569, the illustration being for a power transmitter. This material list would be the same in form for all of the other illustrations shown. The only other fundamental production record required by the planning department is the master routing card. Figure 248 shows a representative and satisfactory form for this important record, the illustration being for the part shown in Fig. 231 on

page 558. In none of these illustrations are the data shown the actual figures of the company through whose courtesy the cuts are exhibited; they are inserted purely to illustrate a principle.

This form must be made out for every part and for every assembly which is processed on any basis other than day work. When new jobs are estimated it is necessary to prepare this form to arrive at the labor cost and to govern the performance whenever the order may be received.

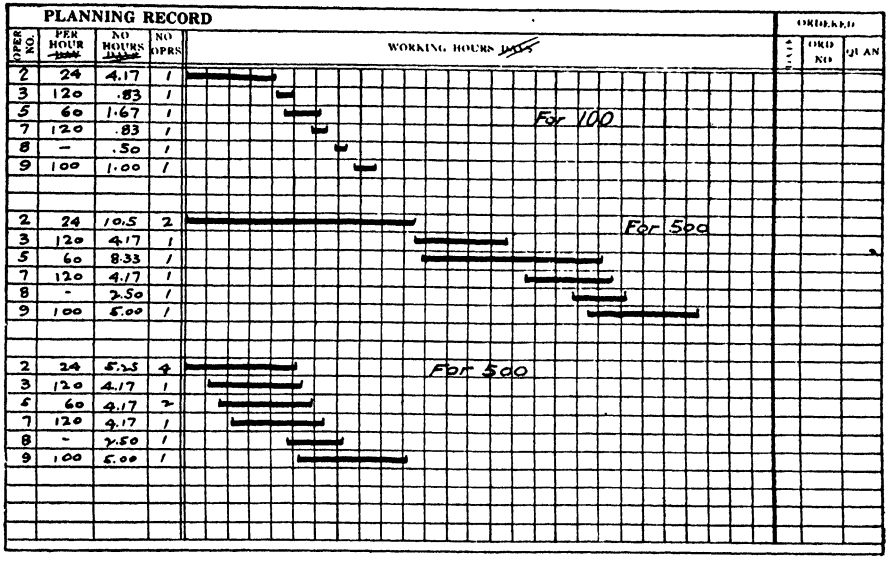


FIGURE 249. GRAPHIC PLANNING RECORD

For Type 1 and Type 2 production this is all the information that is required on this record. Under Type 3 and Type 4 production, however, it is desirable to go somewhat farther and show how the operations may be scheduled for maximum turnover or minimum processing time. On the back of the card may be shown a graphic record as in Fig. 249. In the first section is the arrangement of the operations, in terms of working hours, for a lot of 100. The operations are of such short duration that turnover difficulties are not very apparent. In order to magnify the difficulties inherent in such a job, the chart for a lot of 500 has been drawn in the second section with one correction — the putting of 2 operators on the first operation to remove this one bottleneck. This shows that the best that can be done, with that setup, is to process 500 in about 23.6 hours. Other bottlenecks now become apparent. Operation 3 was planned to run on the same lathe with operation 2, with the same operator. That means that operation

3 cannot start until all of the parts have been finished on operation 2. By transferring operation 3 to another machine it can start some 3 hours earlier. Similarly, by putting 2 operators on operation 5 another 4 hours can be saved. Incorporating these changes the chart becomes as shown in the third section of the graphic plan. Thus a lot of 500 can be processed under this arrangement in nearly the same time that was required for a lot of 100 under the arrangement shown in the first graph. This is of considerable importance in busy manufacturing establishments handling many orders since it greatly reduces the amount of money tied up in work in process.

This graphic record is the basis of the so-called Gantt chart. It is the basis on which the control board shown in the chapter on Type 3 Control is constructed, and it is the basis for the more eloquent chart shown for a construction job in the chapter on Type 4 Control.

The rule to apply in preparing such a graphic planning record is

1. When the next operation is slower, it can be started as soon after the start of the preceding operation as is practicable and
2. When the next operation is faster, it has to be charted backwards from the finishing end with the plan that it shall finish as soon after the finish of the preceding operation as is practicable.

Unless this simple rule is observed the chart cannot be properly constructed since a fast operation, fed by a slow operation, will be constantly running out of work if it is started too soon. The fast operation cannot be started until enough work has accumulated from the slow operation to permit the fast operation to be completed without interruption. The simplest way to provide for it is to plot all fast operations backward when they follow slower operations.

This form of graphic planning record is of considerable importance in Type 4 projects but is of very limited value to the other three types of process. It is occasionally useful to Type 1 producers in ascertaining the fastest practicable time for processing an individual order, but such an order has to have the right of way without regard for any other orders that may be in process. To get a clearer understanding of why this is so, assume that a job whose graph looks like the second section in Fig. 249 is to be followed by a different job whose graph might look like section 3 of Fig. 249. Try and piece these two graphs together in such a way as to show continuity of production on each of the operations. During the First World War some tragic mistakes were made by industrial engineers in their attempts to do just that in a centralized control department of large plants. The costs of such errors ran as high as $50,000 in one large plant. This form of graph is of chief value to Type 4 control and will be discussed again in that chapter.

In order to make it possible to approximate a flow of work on specific orders of any considerable size, arrangement should be made to split the order up into lots. For example, the 500 order referred to could be suitably split into 5 lots of 100 each. As soon as one lot is finished it may be forwarded to the next operation. This splitting into lots is accomplished by merely manifolding the route tags, which are the third copies of the production orders. This will be explained more fully in the chapters on Type 1 and Type 3 control where splitting is important. Type 2 control does not call for any splitting since the whole productive process is reduced to a flow, with conveyors and chutes, regardless of any lot quantities.

When production orders are issued for replenishing the supply of parts which are carried in stock, there will be a record of these orders on the stores-record card. When production orders are issued for M parts shown on the material lists there is no central record of them and therefore no convenient way of knowing when, because of frequent use, it may become desirable to issue a changed part notice to change the status of a part from M to S. Such a central record should be provided in the planning department and it is most convenient when placed on the master route card as shown in Fig. 249. When this card is drawn from the file to type the routing on M production orders, the ordered quantity is jotted down together with the date. If an M part is frequently ordered, change its status to S; if an S part is ordered very infrequently, as indicated by the legend on the stores-record card, change its status to M, using the regular changed part notice.

Planning a New Venture

The planning department may be called upon to evolve plans for a whole new department for some Type 2 product. For example, it may be required to set up a department for the weekly production of, say, 2000 percussion fuse bodies for artillery shells. If approached systematically, the whole setup can be determined in a very short time, when a graphic approach is adopted. First the problem must be made clear. The skeleton operations may be ascertained from the ordnance officer or from a manufacturing analysis of one of the fuse bodies. This should be put into graphic form as shown in Fig. 250. Then the operations should be mentally weighed to see if they can advantageously be broken down into two or more simpler, or more closely balanced, operations, taking into consideration such operations as drilling and tapping so as not to have one operator drill or tap two sizes of holes which are of such widely different dimensions as to call for a conspicuously different "feel." If one hole calls for a No. 50 drill and another hole for a No. 2 drill it would be proper to separate them rather

than have the same operator try to drill first one and then the other. Going through the operations in this manner will make Fig. 250 look more like Fig. 251. That is, after recording the skeleton arrangement of operations, the chart is expanded vertically.

Then the chart is expanded horizontally. Having decided upon the manner in which the successive operations should be performed and the equipment required for them, it is only necessary to divide the production rate of each operation into the required weekly production rate for the product to arrive at the number of machines and operators that will be needed. This having been done, the chart becomes something like Fig. 252, and this chart is the basis for procuring the equipment and for laying out the floor space.

Since the product will be turned out under Type 2 production the drilling and tapping operations can be arranged with chutes between them or such a machine as is shown in the Delta illustration in Fig. 244 on page 583 may be used.

The Order Forms

After planning a job for production the planning department communicates the requirements to the shops by means of production orders. The manner in which these orders are prepared is determined by the type of process. Type 4 process, dealing mostly with large undertakings of specific projects, is usually governed by contracts and letters, which serve as orders. Type 2 process, dealing with continuous production rates which may run over a number of months, may have to have the production orders split up for the convenience of the cost department in "closing the books" once a month. However, the same form of production order may be used for Type 2 processes as for Type 1 and Type 3 processes.

In all the work of transmitting requirements to the shops the planning department has only to deal with S parts, P parts, and M parts (see page 568). The S parts are carried in stock and do not need any additional form since they are all drawn out of stock on the authority of the material list, as will be more fully explained in the chapter on Type 1 Control. The P parts have to be purchased only as needed and in the quantity needed. That calls for a purchase requisition which is sent to the purchasing department. Any simple form will suffice, but it is important for the planning department to inform the purchasing department where the material should be sent when it arrives at the receiving department. This information is copied onto the receiving department's copy of the purchase order. The purchase requisition, bearing a serial number for reference, need be written in only two copies, the duplicate remaining in the planning department. Usually

these requisitions are printed in book form so that only the originals are torn out.

The production order has to be written in three copies in all cases. The original goes to the shop, the duplicate is the cost and planning copy which remains in the office, and the triplicate is the route tag which first goes to the department where it will pick up the raw material for the order and then remains with that material clear through the whole productive process. It serves to identify the job and also to pick up the whole story of the material — who performed the operations, any rejections and record of inspections, finally serving as the receiving ticket at the end of the process. As will be mentioned in the chapter on Type 1 Control the policy will have to be established as to whether the one original copy should serve more than one department, moving from department to department as the work is forwarded, or a separate copy made for each department. There is no important advantage in making more than one copy of the original, although some concerns prefer to do so. In this text it is assumed that only one copy is made. The form of the production order will be shown in the chapter on Type 1 Control.

The foundry order might be expected to be similar to the production order, with only three copies, but there are other considerations which enter into foundry procedure, and these make it desirable for the foundry order to have five copies. It is well to have the iron-foundry orders of one color, steel-foundry orders a different color, and still different colors for the brass- and alloy-foundry orders. Each different color would be consecutively numbered, beginning with No. 1, but the different colors should have their number series prefixed with a letter, I, S, B, A, and so on, to make reference to them clear and quick.

The original of the foundry order goes to the foundry, just as the original of the production order goes to the shop performing the first operation. The second copy of the foundry order goes to the checking, or receiving, room of the foundry where the castings are checked and weighed. It serves as a tally sheet on which the checker records the castings received day by day until the order is finished, and the copy turned in at the foundry office. The third copy goes to the pattern-storage department to pick up the pattern and conduct it to the foundry, where it must be kept and attached to the pattern when returned to storage, it being the identification ticket. This is important in view of the fact that many patterns are so made that there are removable and loose pieces which may be added to the pattern or taken off in order to make one basic pattern serve for several different castings. Each different setup of the pattern has to be given a different identify-

ing number, usually arranged as a subnumber following a dash after the basic pattern number as X–279–1, X–279–2, and so forth.

The fourth copy of the foundry order is similar to the third copy except that it is attached to the core boxes which go with the pattern. Both of these copies go to the pattern-storage department and return to it when the patterns and core boxes return. The fifth copy of the order is the planning and cost copy and remains in the office. This form also will be illustrated in the chapter on Type 1 Control.

The desk of the planner in the planning department will have on it, then, a book of purchase requisitions, a pad of triplicate production orders, a quantity of separate route tags for those cases in which the quantity of work has to be split into lots for convenience in processing, and a quantity of the five-copy foundry orders. These foundry orders can be conveniently handled from rolls in autographic register machines or they may be typed, to get five clear copies. On the planner's desk it will be convenient to have two telephones, one being the connecting link with the several shop departments where local production control is handled by a local representative of the planning department, and the other to handle incoming calls. The use of all of these will be explained in the chapters on control.

CHAPTER XXVIII

TYPE 1 CONTROL

JOBBING, OR SPECIFIC-ORDER, PRODUCTION

Although the great American ambition in manufacturing is to get some Type 2 product which can be continuously processed under methods of mass production, nevertheless there are many more cases of Type 1 production in which jobs have to be processed individually. These Type 1 plants have certain natural handicaps, such as higher burden, or overhead, and the need for higher grade employees. Type 1 employees have to have alert minds, to use them continually, to be resourceful in catching up short cuts, and to think ahead constantly. In performing one operation the mind must be on what comes next so that it becomes almost automatic to "get the wind on your back" by doing each operation in such a way as to prepare for what comes next. It is not easy to train employees to do this skilfully. This chapter will therefore go into more detail than the succeeding chapters. Type 1 control is far more complicated than any of the other types of control, and it is more difficult to get a clear over-all picture of its myriad details.

In Type 1 control one would expect to find individual job costs. Standard costs are of little value here. The cost department has to be so closely associated with what goes on in the planning department that it is of advantage to have the two departments in the same or adjacent offices. If the planning records are built up to serve the productive process best, then the costs are practically all assembled and the jobs should be ready for billing on the day they are completed.

Furthermore, since Type 1 producers generally have little or no advantage of repetition, it becomes paramount that overhead expense be cut to a minimum in the routine work of processing orders through the shops. The overhead incident to development, or research, and engineering is necessarily high. That cannot be helped greatly, but it is quite possible to design a production-control system which will minimize the cost of processing orders. Its study is the purpose of this chapter.

The three fundamental, and highly important, records upon which the whole control scheme is based have already been presented. They

are the stores record (Type 1), Fig. 224, page 548, the material list, Fig. 239, page 570, and the master routing card, Fig. 248, page 588. The proper design of these records has much to do with the economy and efficiency of processing numerous orders each day.

In the industrial engineering work of transforming the production of a Type 1 plant from a loss to a profit it will be necessary to give attention to these fundamental forms. It would not be practicable to attempt to make an expensive change-over suddenly. This has to be done gradually and in such a manner as to avoid confusion. It is best to provide the forms and then have each new order issued with the new forms. In the shops there will be many of both the new forms and the old forms until, in due course, the old forms disappear. In this way the advantages accruing from the new control will more than pay for the cost of the change.

In a Type 1 plant engaged in making machinery, there will be 11 departments affected by the control plan. It is desirable to be familiar with what should normally go on in these various departments and to know whether or not present practices should be done elsewhere for better advantage. These departments are the engineering and drafting, estimating, planning, cost, purchasing, receiving, foundry, machine shops, raw stores, finished parts stores, and assemblies. To get a clear picture of all of the forms involved in the control scheme and the operations on them, it will be helpful to prepare a graphic chart that not only shows the relations between the departments, but also the whole course of each form along with that of the work itself. Reference has already been made to such charts and an illustrative case was shown in Figs. 213 and 214 between pages 516 and 517.

There are some very favorable cases of Type 1 production, such as were cited in connection with Figs. 244 and 245 on pages 583 and 585. These cases form the border territory between Type 1 and Type 2 production. Instead of every order being something different, there will be numerous stock orders for 25 of one type of machine and 50 of another, the finished machines to be put into stock, shipped out one or two at a time, and then another stock order issued. These cases do not change the form of production control. If, however, the demand were broader, or more continuous, then the products should be switched over to Type 2 control.

The graphic chart for Type 1 control is shown in Fig. 253. A copy of it should be kept visible in some convenient place until the control is fully operative and thoroughly familiar. The encircled numbers are the operation numbers, explained in the following paragraphs, and the letters at the top right corners of the forms are the exhibit numbers, as follows:

A	Development order	Fig. 226, page 552
B	Development liquidation card	Fig. 227, page 553
C	Assembly tracing	Fig. 228, page 554
D	Parts tracings	Fig. 231, page 558
E	Material-list tracing	Fig. 239, page 570
F	New part notice	Fig. 236, page 565
G	Changed part notice	Fig. 237, page 566
H	Drawing-record card	Fig. 232, page 560
I	Parts-index book	Figs. 233, 234, pages 562, 563
J	Type 1 stores record	Fig. 224, page 548
K	Master route card	Fig. 248, page 588
L	Material-list blueprint	Fig. 260, following page 608
M	Purchase requisition	Fig. 254, page 600
N	Production order	Fig. 257, page 605
O	Foundry order	Fig. 259, page 607
P	Purchase record	Fig. 261, page 609
Q	Receiving record	No special form shown here
R	Bin check ticket	Fig. 222, page 543
S	Type 1 control board	Fig. 264, page 613
T	Job-time card	Fig. 263, page 612
U	Blackboard in stockroom	Fig. 266, page 615
V	Blackboard in assembly	Fig. 267, page 615

The illustrative case which is to be used in illustrating this Type 1 control is the power transmitter shown in Figs. 228 and 230, pages 554 and 556.

Preliminary to Issuing Production Orders

Just before starting the production-control procedure it will be helpful to review, in connection with the graphic chart, the routine of setting up a new product (the operation numbers key to Fig. 253):

1. In originating a new device the development department (or the engineering department if development is not a separate function) requests of the cost department a development order, Fig. 226, page 552. Cost department issues the order with copies to such designated departments as pattern, tool, testing, planning, and cost. At the same time the cost department sets up a development liquidation record, Fig. 227, page 553, on which to keep track of the amount of development expense liquidated into ensuing production orders, and of any unliquidated development cost that remains after the product has been changed or abandoned. This unliquidated cost or the overliquidated cost is usually shown in the profit-and-loss statement at the end of the year.

2. In making the tracings (see page 567 for the photolitho process) drawing numbers are assigned, according to the size of the sheet, by the drawing-office clerk. A drawing record card, Fig. 234, page 563, is kept for every new tracing and for every part which appears on material lists. The purpose of this record is to make easy the task of

drawing maintenance. When any part is changed this record shows at once every other drawing and every material list which is affected by that change. Sketches, which are made for parts which it is not expected will be repeated, are numbered in an SK series and are not recorded on the drawing-record card since they will not need to be maintained. These informal sketches are considered to be a part of the specific sales order and are filed away with the sales order and correspondence.

3. The material list, which takes the same number as the assembly drawing with which it is associated, is completely extended by the engineer, or draftsman, as illustrated in Fig. 239, page 570. Nothing short of this will completely define the job and it is far more economical to have the engineer thus record his mental design than to pass the responsibility on down the line to someone else. The work has to be done at some point and it is best done in the engineering department, using junior engineers if necessary. In preparing the M.L., reference is made to the parts index, Figs. 233, 234, pages 562 and 563, for selecting the most suitable parts and materials for the design.

4. Every part and material shown on the M.L. has to appear on a drawing-record card. This is done by the clerk.

5. If no suitable part or material is found in the parts index, then a new item is created and a new part notice, Fig. 236, page 565, is issued, as previously explained. From this notice the clerk in charge of the parts index sees that the new part or material is recorded in the index and its recommended status recorded.

6. The engineering work is then completed, except for any changes which may come up. When any part is changed, or any material status is changed, an investigation has to be made to ascertain what else may be affected. This is the purpose of the drawing record. A changed part notice, Fig. 237, is then issued as explained on page 566.

7. When a copy of the new part notice is sent to the planning, or methods, department it should have a blueprint attached, if it is an M part. The planning department analyzes the part and prepares a master route card, Fig. 248, page 588. If the new part is recommended for stock, then the planning department has to set up a stores-record card, Fig. 224, page 548, and issue an initial production order. If it is a P part, purchased only as needed, then the planning department has nothing to do at the moment.

The records are now all established, ready for production. Generally, in Type 1 plants, production cannot proceed until a sales order is received. In many cases, however, in anticipation of sales orders for standard products, a small quantity may be produced for stock, as already explained.

Issuing Production Orders

8. A copy of the sales order is received in the planning department from the order department. In larger companies this sales order is copied from the customer's order onto the company form so as to obtain the required number of copies. The number of copies may run as high as a dozen. In the case illustrated in Fig. 213, following page 516, there are 11 copies as follows: cost and statistical, an initial copy for statistics department which uses automatic tabulating machines to tabulate orders and later shipments, accounting copy, shipping copy, 2 copies for the district office from which the order arrived, 3 invoice copies, an acknowledgment, and a job ticket. The job ticket is the copy which goes to the planning department and is all that concerns us here.

If the sales order requires engineering interpretation or clarification, it is recorded on a tracer memorandum and sent to the engineering department. It is sometimes remarked that the order copy should always go directly to the engineering department first. That depends on the proportion of incoming orders that require engineering attention and can be decided in each individual case.

When the order comes back from the engineering department it should have attached to it:

2 blueprints of the material list
1 blueprint of the assembly drawing
1 blueprint for each M part shown on the M.L.
1 blueprint for each P part which has to be purchased according to drawing as indicated by a drawing number for that part on the M.L.

If the sales order does not require engineering attention then it is necessary for the planning department to requisition these blueprints, calling, in the case of the mechanical transmitter, for "blueprints of Assembly X–150, M.L. X–150 and for each M part thereon and each P part purchased to drawing." See operation 10.

9. The planning department makes out an erecting order, or assembly order, in duplicate, seeing that the E-order number is entered on the sales order and that both the E-order number and sales-order number appear on the material list. The original assembly order and the assembly blueprint are sent immediately to the assembly department for advance scheduling; see operation 24. The duplicate assembly order is filed numerically in the file shown in the cost department on Fig. 253. The sales-order copy is filed numerically in a book binder until completed. Then see operation 49.

10. The planner then calls on the finished-parts storeskeeper for the number of a vacant accumulation stall to which all parts requiring

safekeeping may be routed prior to their issuance to the assembly. Assume that he is given stall number 16. This number is entered at the top of both copies of the material-list blueprint, and all purchase requisitions, stores requisitions, and production orders must route their respective items thereto.

With a carbon paper between the two copies the material list is then extended. Here we will assume that we are processing a stock order, E–378, for 25 of the mechanical transmitters. This quantity is placed at the top of the material list directly over the column which has to be multiplied by it. Multiply columns 5 and 6 by this quantity and enter the extension in column 8, which is the quantity to be ordered.

PURCHASE REQUISITION

DATE 3/1 P-1103

QUAN	DESCRIPTION	WTD
45	Springs Z-1194-5 BP attached	3/15

CHARGE TO E-378

DELIVER TO 63 Stall 16 FOR E-378 E C Ross
SIGNED

FIGURE 254. THE PURCHASE REQUISITION

An inspection of column 7 on the material list, Fig. 260, following page 608, will show that to process this assembly order there will be required 1 purchase requisition for a part purchased to drawing, 9 S-items, which are carried in stores, and 13 production orders.

The most important thing is to get the purchase requisitions under way first. The requisition is written as illustrated in Fig. 254 and conveys to the purchasing department that the receiver should be informed to send the parts to accumulation stall 16 when they arrive. If any special inspection is required before the parts are accepted by the company, a notation to this effect should be put on the purchase requisition. It will help the cost department if a checkmark is entered in column 14 of the duplicate material list as illustrated in Fig. 253 for item 11.

11. The planner then takes a triplicate pad of production orders, serially numbered, and fills in the top portion longhand, then enters at the bottom of the form the information that the parts are to be delivered to storeroom 63, accumulation stall 16, for assembly order

E-378. The carbon over the triplicate copy should be short, covering only up to the heavy vertical line. On the triplicate copy the planner should mark the order number in heavy crayon to make it readable from a distance. This is important since in the shops, with parts for many orders around the floor, the order number should be conspicuous.

Wanted dates are entered on all orders and in their proper places on the material-list copies. In most cases the dates will all be the same — one day before the assembly should start, but judgment has to be used here to allow for processing time for those purchased parts which have to be worked on in the shops before they are ready for the assembly.

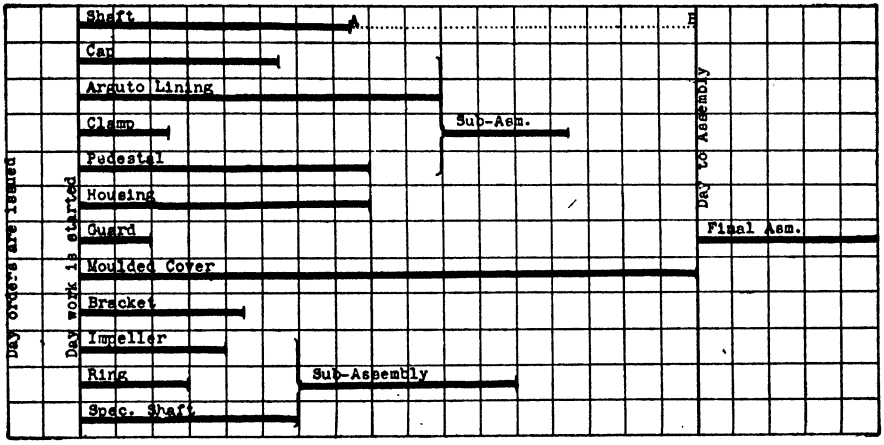


FIGURE 255. PROCUREMENT WITHOUT PLANNING

In the absence of wanted dates, the procurement of P and M parts for assemblies will look somewhat as illustrated in Fig. 255. All orders go out together and are pounced upon. Some parts will arrive very quickly and will lie around until it is time to start assembly. That starting time is determined largely by the part which requires the longest procurement time, in this case, the molded cover. The length of the heavy line represents the procurement time.

The dotted line *A-B*, for each of the parts, represents the time that part will have to lie around. If each vertical division represents 1 day, then the guard, in this illustration, will have to wait for 15 days before it can be sent, with all the other parts, to the assembly. This condition represents the situation in the average plant today. There is invariably much confusion, wasted effort, disorganized production, and needless overhead expense. Some of the parts will become mislaid or "robbed" for other orders which are subjected to pressure. The clerical work incident to the switching of parts from one order to another is almost invariably neglected because we place first premium on "men of action."

To predicate action on mindful planning would make the above diagram look like Fig. 256. Wanted dates, thoughtfully arrived at, not only tend to bring materials and parts to their work stations at the appropriate time, but they also accomplish a number of other things of considerable importance. First, and most important from the over-all good management standpoint, they provide proper planning times. In Fig. 256 the line *C-D* for each part represents this planning time. Very few new recruits in modern purchasing departments get any instruction in trying to obtain intelligent wanted dates on the purchase requisitions coming to them from other departments. "It goes without

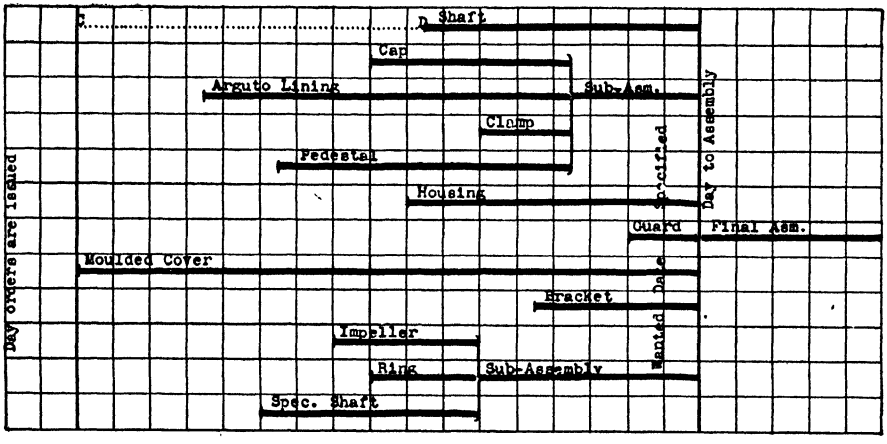


FIGURE 256. PROCUREMENT WITH PLANNED WANTED DATES

saying that we want everything as quickly as possible," yet in production planning the whole principle of quick results lies in the exercise of our brains rather than our nerves; in concentration rather than distraction.

A Type 1 producer in one of our large industrial cities received an order from the purchasing department of a large corporation. It called for shipment "at once," which in that case was quite impossible. The manager had previous orders from this corporation looked up. In every case it was stipulated that shipment was wanted "at once," "immediately" or "soon as possible." Furthermore the purchase order stipulated the price of an earlier, similar order of some two years previous, before the start of the ascending spiral of wartime material prices. Obviously the producer could not handle such an order, so, with a brief report on this corporation's previous purchase orders, this one was returned to the purchaser. The order presently came back to the producer, with a simple request for shipping date and with an able letter from the chief purchasing agent indicating that, for the moment at least, his attention had been directed to a common characteristic in

our social drift wherein nerves tend to gain the ascendency over brains. Or, as one of this country's prominent industrial leaders put it, "the trouble in large corporations, which results from injurious impressions being gained by the public, is that executives do not know what is going on down the line."

Take the time to calculate proper wanted dates and production will become more orderly and the turnover of work in process will be quickened.

12. For each M part the planner has to ascertain what material is required. That information is shown in column 12 of the material list. If a casting is required he prepares a foundry order in five copies. If raw material is required he computes the quantity and enters it at the top of the production order.

The triplicate production orders, with carbons still interleaved, go to a typist who pulls their respective master route cards from file, places them with the orders, and then proceeds to type the routing on the orders. The master route cards are returned to file as promptly as possible and the order copies are disposed of as follows:

12*a*. Original, with blueprint attached, goes directly to the shop department responsible for the first operation. If it is desired that each shop department concerned have a copy of the order then the additional copies must be prepared.

Duplicate, with the route tag triplicate, is turned over to the raw-stores record clerk who deducts required material from the stores record. In doing this the price of the material is copied from the stores record to the duplicate order copy in the space provided for it, and the material location number is copied onto the route tag, in the space provided for it. This operation is identical with the deducting, pricing, and locating of finished parts shown on the material list.

Triplicate, or route tag, has to remain with the work and is disposed of in accordance with these conditions:

a) In the case of purchased parts or materials which have to be worked on in the shops before they are ready for the assembly, the tags are sent to the receiving department. When the parts or materials arrive the tag is attached and accompanies the specified item to the department responsible for the first operation, where it meets the original production order copy. See operation 30.

b) In the case of castings made in the plant foundries the tag is sent to the specified foundry receiving room where it will be filed by production-order number to await the appearance of the castings. Then it accompanies the castings to the department designated for the first operation.

c) In the case of raw material which is carried in stock the tag goes to the raw-material storeroom where the required amount of material, as specified on the tag, is cut or prepared, and forwarded, with tag attached, to the department designated for the first operation.

Now examine the material-list blueprint, following page 608 and survey what has been done.

There are 9 S items of finished parts which require no attention on the part of the planner other than deduction from the stores record, as already explained. These are items 8, 10, 12, 14, 15, 17, 18, 19, and 20. There is one S casting, item 6, for which the planner has to fill in the top of production order 2176 so that it reads "Draw 1 Z–1142 casting from S." The material list informs him that this casting is drawn from stock but the stock location cannot be specified until the deduction is made on the stores record. There is one P part, item 11, which calls for a purchase requisition. The requisition indicates that the item should be routed to accumulation stall 16 when it arrives in the receiving department. Then there are 13 M parts which require production orders and these production orders call for 6 foundry orders; items 1, 2, 3, 4, 7, and 16. Of the 13 production orders their route tag copies will go as follows:

6 to the foundry to pick up the castings from the 6 foundry orders,
6 to raw stores to pick up raw stock
1 (item 6 stock casting) to the stores-record clerk for deduction, pricing, and locating. The stores location is entered at the top of this tag which then goes to the stores department, where it acts as a requisition, thence to the designated shop department with its casting.

Thus all paper work is finished as far as getting into the various shops the required parts for this order for 25 Model 7 mechanical transmitters is concerned.

If it is profitable to split up the total quantity called for on a production order, as explained on page 591, the planning department has to prepare additional copies of the triplicate, or tag copy. This can be conveniently done on any hectograph machine with copying ink.

The completely written production order, with its three copies, is illustrated in Fig. 257. A convenient size for the order is 5 inches × 8 inches.

To illustrate the handling of rejections in the shop the route tag shown in Fig. 257 has been filled in as it would be marked in the shop. It is assumed that at the tapping operation one of the castings was dropped and broken. The inspector prepares a defective-work ticket such as shown in Fig. 258 and sends it to the planning department, where it finally ends up filed back of the designated production order.

Judgment has to be exercised in preparing these tickets. It is evident that to process an order for a single small casting, when there may be five or more patterns on a match plate, would be costly. On the other hand not to do so would leave all the remaining parts for the

25 QUANTITY	Y-173 DRAWING NO.	Lever C.I PART NAME		2172 ORDER NO.	–
25 QU./TAG	25 Castings	Patt. Y-173 C.I.	Fdry. Ord. # A-949	DATE ISSUED	DATE WANTED
1 NO. OF TAGS	DRAW	OF PATT. OR STOCK NO.	FROM	PRICE	

DEPT	OP NO	OPERATION	S.U.	WORK STA.	STAND. TIME	TOOLS
17	1	Enamel & Bake	–		Over night	
18	2	Straddle Mill	.33	M 72	.38	F-188
	3	Drill for Adj.Scr.& Lever Pin	.25	D 91	.63	J-216
	4	Tap	.25	T-8	.30	F-189
20	5	Inspect				
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					

This copy goes to the control board in Dept. 18 with blueprint Y-173 attached. When the castings arrive the board operator posts the date (see paragraph(31)here.

PRODUCTION ORDER — SHOP COPY

DELIVER TO 63-16 FOR E-378

25 QUANTITY	Y-173 DRAWING NO.	Lever C.I PART NAME		2172 ORDER NO.	–
25 QU./TAG	25 Castings	Patt. Y-173 C.I.	Fdry. Ord. #A-949	DATE ISSUED	DATE WANTED
1 NO. OF TAGS	DRAW	OF PATT. OR STOCK NO.	FROM	PRICE	

DEPT	OP NO	OPERATION	S.U.	WORK STA.	STAND. TIME	TOOLS
17	1	Enamel & Bake	–		Over night	
18	2	Straddle Mill	.33	M 72	.38	F-188
	3	Drill for Adj.Scr.& Lever Pin	.25	D 91	.63	J-216
	4	Tap	.25	T-8	.30	F-189
20	5	Inspect				
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					

Cost Records on reverse side.

This copy remains in the office. Back of it are filed the time tickets and any other cost papers.

PRODUCTION ORDER—PLANNING & COST COPY

DELIVER TO 63-16 FOR E-378

25 QUANTITY	Y-173 DRAWING NO.	Lever C.I. PART NAME		2172 ORDER NO.	TAG NO.
25 QU./TAG	25 Castings	Patt. Y-173 C.I.	Fdry Ord # A-949		
1 NO. OF TAGS	DRAW	OF PATT. OR STOCK NO.	FROM		

DEPT	OP NO	OPERATION	S.U.	WORK STA.	STAND. TIME	QUAN. O K	QUAN. REJ.	EMPL. NO	INSP
17	1	Enamel & Bake	–		Over n				
18	2	Straddle Mill	.33	M 72	.38			131	
	3	Drill for Adj.Scr.& Lever Pin	.25	D 91	.63			203	
	4	Tap	.25	T-8	.30	24	1	99	G
20	5	Inspect							
	6								
	7								
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
	17								
	18								
	19								
	20								

This copy goes first to pick up the designated material and then remains with it to the end.

Short carbons clears this space. The above entries are made in the shop departments.

When finally delivered to Stkrm.63, Storeskeeper signs here and returns to Planning Dept.

ROUTE TAG - KEEP WITH WORK

DELIVER TO 63-16 FOR E-378 RECD. 7-4 DATE ✓ BY J.B.

FIGURE 257. THE PRODUCTION ORDER COPIES

whole assembly standing in the assembly department or storeroom. The finished-parts storeskeeper would be the first to note the shortage since, upon checking in his receipt and posting it to the material list at the accumulation stall, he would note that only 24 of the ordered 25 parts had arrived. He would have no way of telling whether or not a replacement part had been ordered and might release the order to the assembly department on the scheduled date where difficulty would be encountered.

DEFECTIVE WORK TICKET

Date	Quantity	Drawing No.	Matl.
3/2	1	Y-173	C.I.

Description: Lever

Dept.	Weight	Order No	Tag No.
18	3¼	2172	—

Operations Completed: 1, 2, 3.

Defect: Dropped & broke

Charge to Dept.	Acct. No	Replacement wanted?
18	186	Yes

Signed: C. R. M. Approved: J. Smith

LOSS ACCOUNT NOS.

Defective Development ..... 178 — Defective Casting 187
Defect. Engg. & Drafting 183 — Defect. Workmanship 185
Defect. Purch. Material .. 104 — Damaged in Handling 186
Other 190

COST	
Material	
Labor	
Total	

FIGURE 258. SPOILAGE TICKET

Should the assembly put together the 24 units, then the incomplete set of parts for the remaining unit should be returned to stores, a location assigned, and a credit slip prepared for the planning department so that the parts may be recorded as on hand to be used up on the next assembly order. The planner would have to order an extra casting at that time, which would cause a reaction in the foundry since, in this particular case, there are five patterns on the match plate and in order to obtain one extra casting a mold has to be prepared and all but one of the impressions stopped off in the flask.

Sometimes it is quite possible for the inspector to call for the one additional part and have it come through promptly enough to catch up with its lot before the machine setups are torn down, but not always.

In the case illustrated it is assumed that the inspector has weighed the factors involved and has decided to call for a replacement part as the more economical of his two alternative courses. The cost department should credit this job with operations 1, 2, and 3 and charge these operations on the replacement order to the expense account. Often such replacement parts are processed with red "rush" tags attached so as to give them the right of way in catching up with their lot. However, it also often happens that so many red tags begin to appear in all departments that their designed effect is largely lost.

This illustrative situation is explained to show the incessant need for understanding, concentration, and attention on the part of those closest to the task of controlling production. A very large portion of

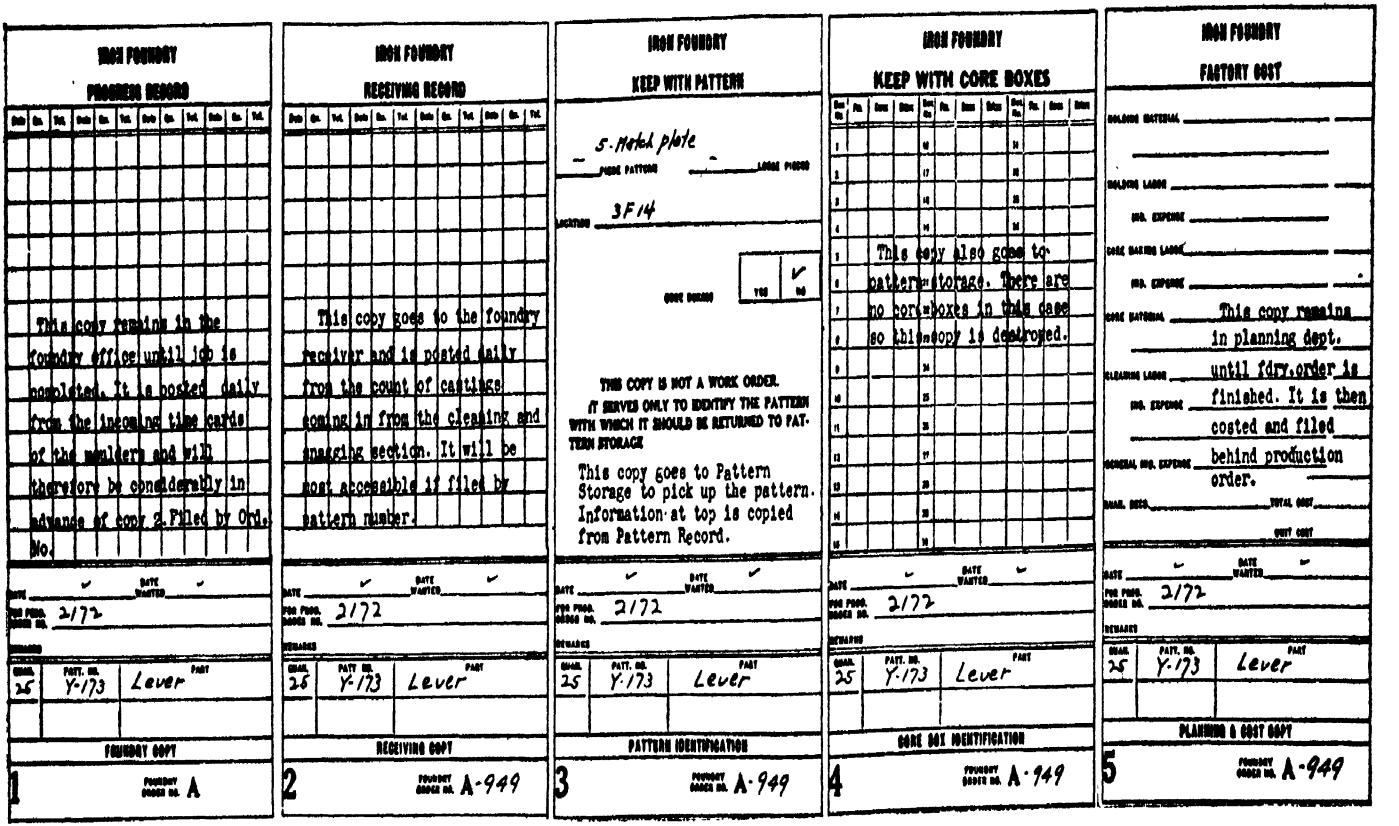


FIGURE 259. THE FOUNDRY ORDER COPIES

all difficulty experienced in production control arises from the endless confusions resulting from failure to follow through to their later consequences the acts we perform day by day.

This type of difficulty has been considered so costly in some progressive plants that separate departments, under skilled leadership, have been set up with suitable equipment just for handling repair and replacement part work to keep such work out of the main production line in which interruptions are expensive.

In the case of the foundry orders, all of the castings required for the illustrative power transmitter are relatively simple and do not fully show the value of copies 3 and 4. However, this value may be imagined from a study of the pattern record in Fig. 262 and visualizing a foundry order calling for pattern P–735–1C.

The fully written foundry order is illustrated in Fig. 259. The pattern and core-box data on copies 3 and 4 are copied by the pattern-storage department from the pattern record filed there. This information serves to identify the complete pattern combination and also as a charge to the foundry to ensure the safe return of the complete pattern.

When the pattern and core boxes return to storage, with their identification copies attached, reference has to be made to the pattern-record card to record the date of return. In so doing the location of the storage place is ascertained and the pattern checked and put away. The identification copies may then be destroyed. The pattern-record card is important since it records the movements of the pattern and its location at any time. It is illustrated in Fig. 262.

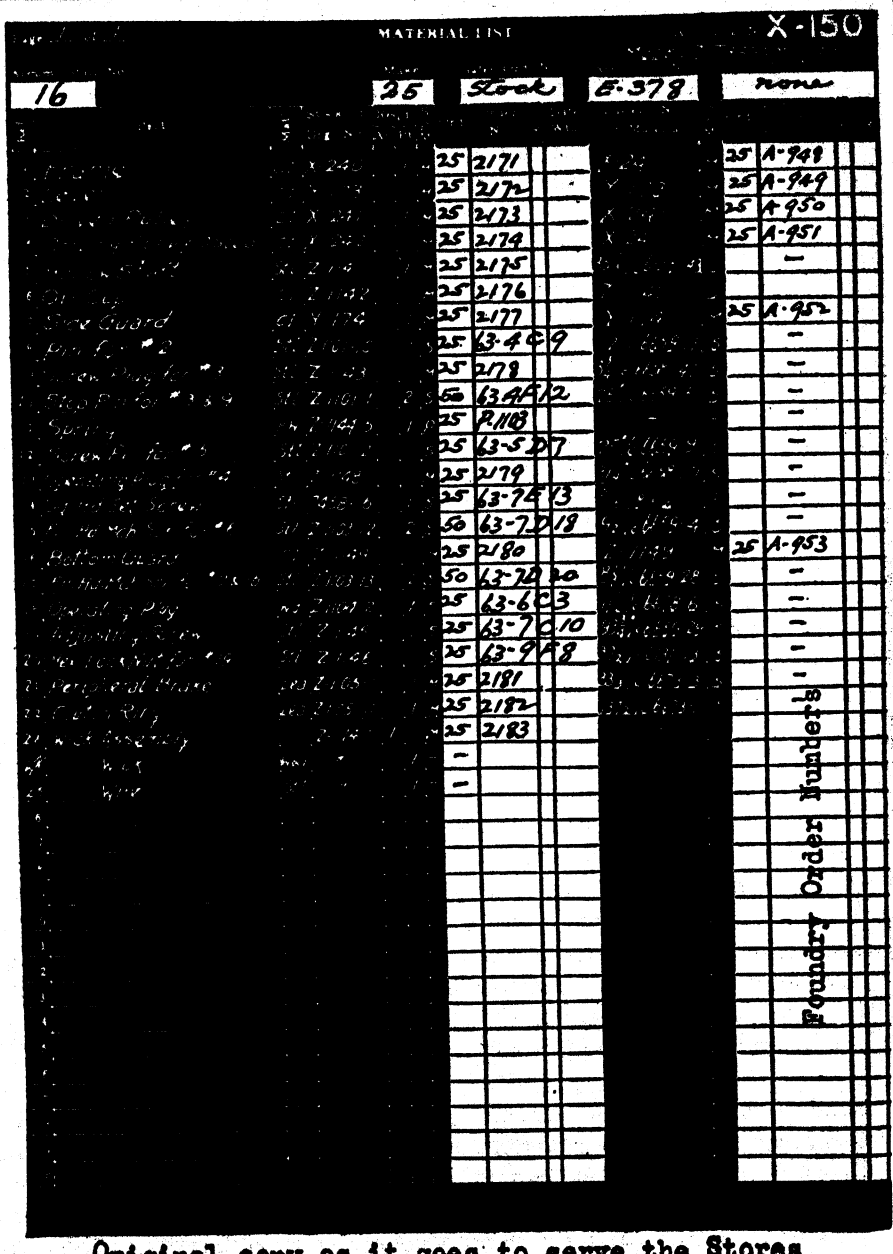
The two copies of the material list, with carbon removed, are then turned over to the finished-parts stores-record clerk by the planner for deducting the S items. The first copy is folded back, or offset, so as to expose the last four columns on the second copy. As a deduction is made on the stores record the stores location of the item is copied onto the first copy of the material list in column 9. At the same time the unit cost is copied to column 14 of the second copy of the material list for the later convenience of the cost department.

The fully prepared material list will then appear as illustrated in Fig. 260.

This figure is printed so as to simulate the blueprint after it has been filled in with pencil. Actually the information shown in columns 8, 9, 14, and 15 should appear as pencil figures on the blueprint.

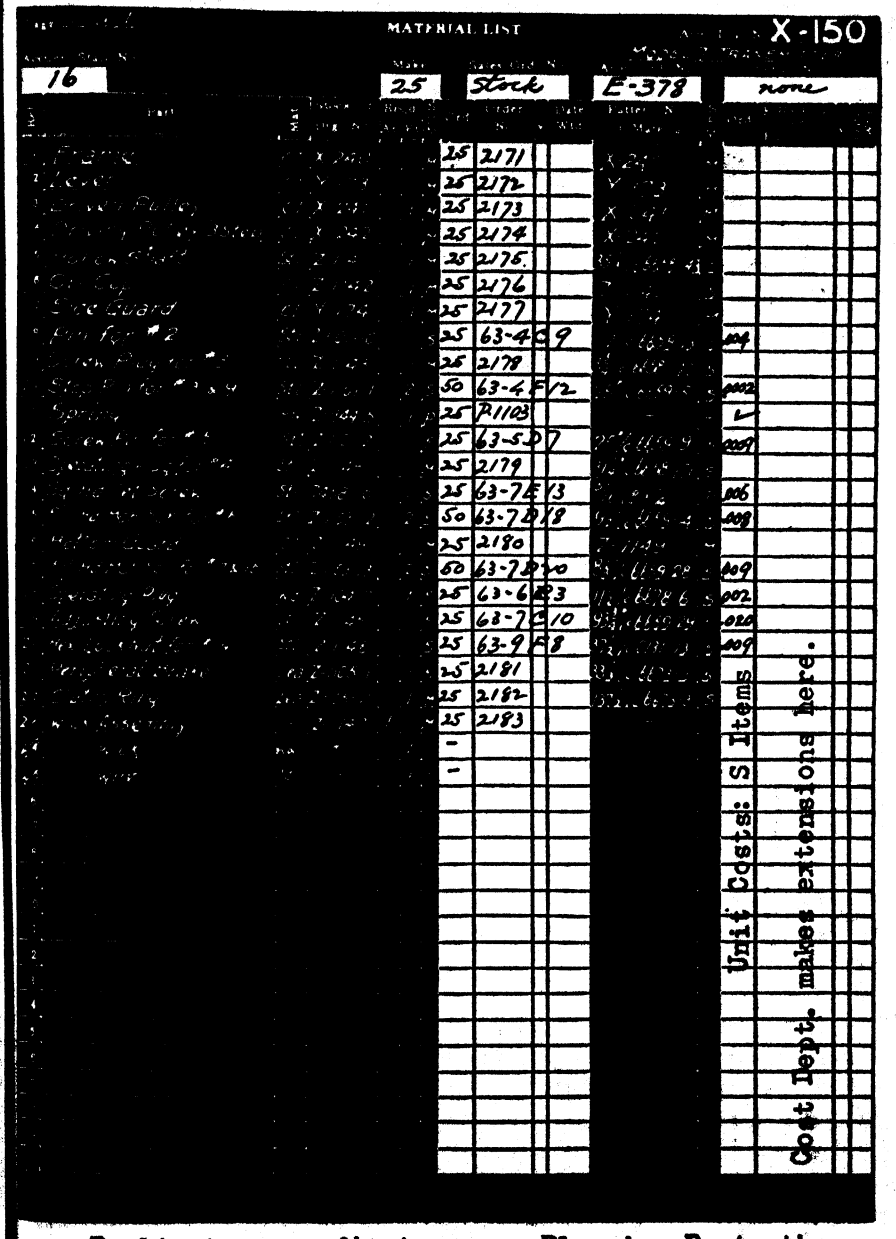
It is not necessary to show the foundry-order numbers on the second copy of the material list since, as they are individually costed, they are filed back of their corresponding production orders without any reference to the material list as explained in operation 44.

The original copy of the material list is then sent to the finished-parts



Original copy as it goes to serve the Stores Dept. first and then the Assembly Dept.

All S items have their locations shown for the convenience of the Storeskeeper.



Duplicate copy first serves Planning Dept. then the Cost Dept. Costs of all S items are shown as indicated at the right.

FIGURE 260. THE TWO MATERIAL LIST BLUEPRINT COPIES

storeroom for operation 20, and the second copy is filed by assembly-order number in a binder in the planning department for reference until the job is finished. It is then disposed of as explained in operation 49.

The work of the planning department, as far as issuing all orders required for a job is concerned, is then completed. In experienced hands all of this routine incident to issuing orders for a relatively simple assembly, and all of its requirements, is executed in a matter of minutes. For a more complicated assembly such as a locomotive, the amount of work in the planning department is proportionately greater. In the case of a battleship the work is greater still. It is all of precisely the same kind of detail and is only a matter of degree, one case requiring only 13 production orders, another requiring hundreds, another thousands.

The Activities of Production

13. When a purchase requisition is received in the purchasing department from the planning department it may be for material which

#1 GROMMET & WASHER — 5/16 Description — Specif. Wgt. — 2303-3 Stock No — BRASS — GROSS Standard Unit

Date	Ord No	Quan	Source	Date	Quan	Invoice	Terms	Transportation	Disct.	Net	Unit Cost
7/27	79	5 Gr.	1	7/30	5 Gr	.73	2/10	.14	-	.87	.174
7/6	143	2 "	2	7/6	2 "	.52	2/10	.15	-	.67	.330
12/10	159	10 "	3	12/13	10 "	3.50	2/10	.25	-	3.75	.368
12/19	167	25 "	3	12/22	25 "	6.75	2/10	.30	-	7.05	.277
1/7	293	50 "	4	2/1	50 "	9.00	2/10	.35	-	9.35	.183

PURCHASE RECORD

FIGURE 261. RECORD OF PAST PURCHASES

has been purchased before, possibly from more than one source. To ascertain which source is most satisfactory, reference may be made to a purchase record which shows terms and prices and from which can be learned the times required for delivery. An illustrative form of this record is shown in Fig. 261. On the front of the card the source is indicated by a key number and these numbers are translated on the back of the card. Thus, if a salesman called, it would be safe to show him this record without revealing the names of his competitors.

For materials not purchased before, the purchasing department has a file of catalogs, skillfully indexed for quick reference. There should

also be available such a reference volume as the huge Thomas's *Commercial Register* which lists all important producers according to product and according to trade names. The purchase order is usually written in three copies. In small plants, or in banks, where the purchasing and the stores and receiving functions are merged into the same office, two copies suffice.

14. The original is mailed to the vendor, bearing wanted date. The duplicate, with purchase requisition attached, is filed numerically to await invoice and receiving ticket (47), and the triplicate is put back in the typewriter for notation of inspection instructions and of where the receiver should send the material — to storeroom 63, accumulation stall 16, to department L for shop work on production order 2473, or to location 27–6C14 for stock, as the case may be. When the material is to be sent to a shop department for work to be performed on it, the planning department will have already sent to the receiving department the route tag which bears the production-order number, as explained in paragraph *a*, under operation 12*a* on page 603.

15. It is the responsibility of the purchasing department to try and meet the wanted dates specified by the planning department. To assist in this it is desirable for the purchasing department to maintain a tickler file by putting in a date file, a day or two in advance, a slip bearing the purchase-order number. It is common practice to add a fourth copy to the purchase order to serve as an acknowledgment. This is also sent to the vendor, with the notation "if you cannot meet this delivery data please specify best promise." Then the tickler file is set on that date. If the planning department does not hear from the purchasing department to the contrary, it may be assumed that all wanted dates will be met. That is the exception principle. It should never be arranged to have the purchasing department send communications to the planning department on all purchase requisitions; merely on the few that may be out of line.

16. It need not be repeated here, but reference should be made to what is said on pages 533 to 535 on stores-location numbering because the storeskeeper is now confronted with the task of quickly picking up all S parts from various locations with only a copy of the material list for his guide. If the locations are logically and clearly marked, this task will be simple. The storeskeeper's only responsibility is to be accurate; he is not called upon to make any clerical entries in this process.

17. Two copies of the foundry order are received in the pattern-storage department — the pattern identification copy and the core-box identification copy. This department maintains a record of all patterns, when they go out, when they come back, their stores location,

and any changes which may have to be made in a basic pattern in order to adapt it to other castings which may also be made from it. For more satisfactory illustration the case of a complicated centrifugal pump volute is taken for Fig. 262. All of the information needed to fully describe the pattern is copied from this record to copies 3 and 4 of the foundry order.

PATT NO. P-735-1C USED FOR W-7134

MATL. Wood

LOCATION 43-7A5

NAME 5" 5-Stage Volute Bottom- S&D Opposite

OUT	TO	QUAN	IN	OUT	TO	QUAN	IN
1/2	I	1	1/6				
2/7	O	2	2/21				
4/6	I	3	4/15				
4/17	B	1	4/25				

PATTERN RECORD

FIGURE 262. FRONT

2 PIECE PATT 3 REMOVABLE PIECES 2 LOOSE PIECES

NOTES Patt P-735-1 with removable pieces DE&F put in.

Use P 735-1 Core boxes where specified below.

* Core box 1 of P 735-1 with removable pieces 1B & 1C put in.

CORE BOXES

BOX NO.	PCS	CORES	DRIERS	BOX NO.	PCS	CORES	DRIERS
P735-1 *1	1	1	0				
2"	2	1	0				
3"	1	1	1				
4"	1	1	1				
5"	1	4	0				
6"	1	4	4	P-735-1 18	1	1	1
				19	1	1	1
				20	2	1	0
9"	1	1	0	21	1	1	1
10"	1	1	5				
12"	2	1	0				

FIGURE 262. BACK

The pattern and core-box specifications are of importance to the coremaker and molder. They also charge the foundry with responsibility for the complete pattern as thus described. The "out" date is recorded on the pattern record, the identification copies attached to their respective items, and the patterns sent at once to the foundry where they meet up with the corresponding foundry order. Upon their return to storage, with identification tickets still attached, the "in"

date is posted to the pattern record at which time the storage location is noted, and the pattern and core boxes put away.

18. For any purchased item which has to be worked on in the shops, the planning department sends to the receiving department the production-order route tag. This is filed by production-order number to await arrival of the item. It is then disposed of as explained in operation 26.

19. In the foundry, when the foundry order is received from the planning department, the wanted date is noted. In order to meet that date the starting time is noted on it and a time card is placed in a tickler file a day in advance of the starting time to await the arrival of the pattern. A convenient form for the time card is illustrated in Fig. 263, but its layout will depend on what type of time clock is in use. If cores are required the core time card is dated in advance of the molding time card according to the core work involved. Across the top of the job time card is printed a heavy line so that it will be an easy matter to detect any gaps resulting from lack of assigned work.

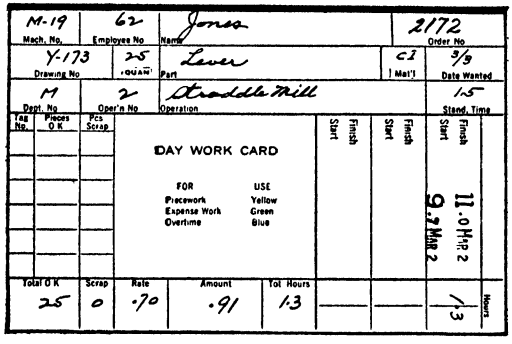


FIGURE 263. JOB TIME CARD

As soon as the pattern arrives in the foundry it is important to notify the control-board operator either by having the trucker post the order number to a memorandum, as explained in operation 30, or by having the foundry clerk check in the patterns himself. A check mark is placed on the order to indicate that the pattern is on hand. A molding-floor number is assigned and the job is then ready to schedule by placing the time card on the control board under "Jobs Ready." All information required by the coremaker is on the identification ticket attached to the core boxes.

The control board for Type 1 production should have four pockets for each operator or work station marked "This Job," "Next Job," "Jobs Ready," and "Jobs Waiting." The time card goes first to the fourth pocket. Each day the time cards representing about a day's work should be moved over into the third pocket and, if all goes well, these jobs will be completed on that day. When the molder punches in on his first job the time-stamped time card is transferred to the first pocket as "This Job," and the control-board operator puts into the second pocket the time card for the next job, and so on.

A representative control board is illustrated in Fig. 264, which is in the iron foundry of a Type 1 plant. The same form of board is used in the machine shops where the blueprints are filed in the table drawer and the tool requisitions are kept on the table back of the clock. The particular time clock shown in the illustration is the Periodograph, an exceptionally clever clock but no longer on the market. The particular board shown covers 54 work stations.

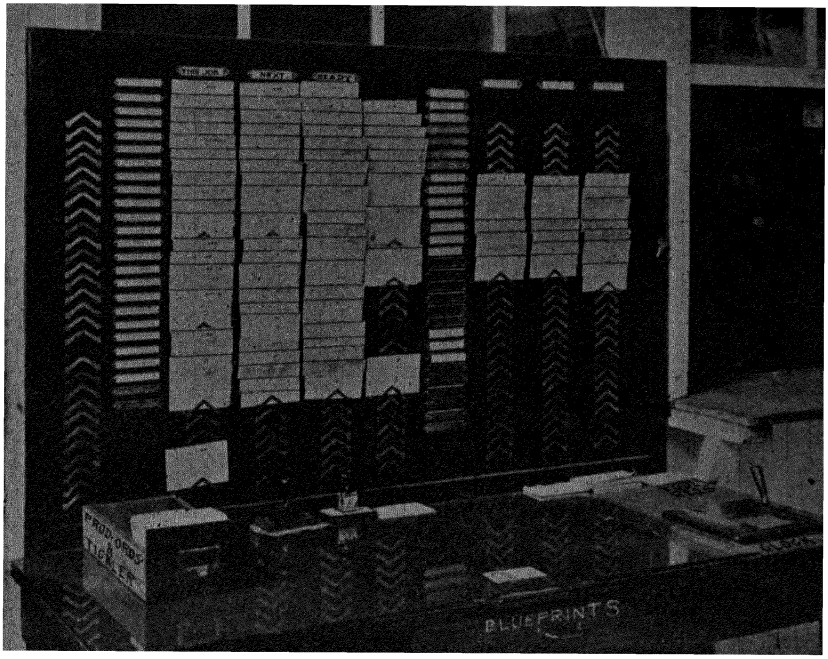


FIGURE 264. THE TYPE 1 CONTROL BOARD

This is the simplest control board and accomplishes nothing more than to provide a systematic, graphic means of arranging a continuous series of jobs ahead of each work station. That, alone, provides considerable incentive of the most efficient kind.

The location of such a control board in a machine shop is illustrated in Fig. 265. It is near the center of gravity of the operations and has floor space near it for the receiving of materials which come into the department. Note that every job visible on the floor has its route tag attached. This tag shows where the material came from, what has already been done on it, what has yet to be done, the date on which it should be finished, and where it should be delivered when finished. Jobs to be moved are placed adjacent to the main aisle so that the

trucker can immediately see them by merely glancing down the length of the floor.

20. While these activities have been going on in the foundry the finished-parts storeskeeper will be performing his duties. He will have received from the planning department the original copy of the material-list blueprint. He posts a record of the job to a blackboard near the accumulation stalls, or to a memorandum sheet on his desk, as illustrated in Fig. 266.

FIGURE 265. SHOWING LOCATION OF CONTROL BOARD IN MACHINE SHOP

On the material list there are shown the locations of all the S items. He takes any necessary tote boxes, goes to these locations, checks to see that the bin label corresponds with what is called for, counts out the correct number of parts, and when finished sends the parts to the designated accumulation stall, hangs the material list there to await the arrival of any P parts that will presently arrive, and M parts which will begin to move in from the various shop departments — all routed to this stall. On the material list the storeskeeper places a check mark in the tenth column for each item which he picks up or receives into the accumulation stall. When all of the items are checked the job is ready for operation 34.

21. Occasionally because of spoilage, it will be necessary for the storeskeeper to issue more stock than was called for on the material

list. The same will be true in the raw-stores department when more stock is required than was specified on the route tag. In such cases the storeskeeper has to ascertain what this additional stock is to be charged to. It may be to the defective-workmanship account number, or some other account number. Then an individual stores requisition is written, the stock given out, and the requisition sent to the planning department for deducting from the stores record and pricing, thence to the cost department for extension and charging to the specified expense account. Similarly there would be credit tickets for stock returned as excess.

Order No.	Want Date	Accum Stall	In	Out	Notes
E-318	3/20	16	3/1	3/10	To Asm.

FIGURE 266. TRACER RECORD IN FINISHED-PARTS STOREROOM

22. In his spare time the storeskeeper should prepare a few bin-check tickets to make sure that the counts in his bins and locations are kept in agreement with the counts shown on the stores record in the planning department. This procedure was explained on page 543.

23. While all of this is going on in the stores departments, the machine shops which perform the first operation will have received from the planning department the originals of production orders with blueprints attached. The blueprints are filed by drawing number in the drawer of the control-board table, and the order is handled just as was the foundry order in operation 19. The starting time is noted on the order, the first operation time card is prepared and put in the tickler file a day ahead of the starting date, and the order is filed by order number, there to await operation 30.

Order No.	Want Date	Floor	Matl In	Job Out	Notes
E-378	3/20	12	3/10		

FIGURE 267. TRACER RECORD IN ASSEMBLY DEPARTMENT

24. Similarly in the assembly department there will have been received from the planning department the original assembly order and assembly blueprint. In the graphic chart, Fig. 253, the material list is shown dotted because that does not arrive until some time later. The starting date is determined, noted on the order, posted to a blackboard or a memorandum sheet such as illustrated in Fig. 267.

It is convenient also to have control boards in the assembly departments. These would be precisely the same type of boards and handled in the same manner as already explained.

25. While all of this has been going on, the raw-stores department will have received various route tags from operation 12*a*, specifying the quantities of raw material to be cut for their respective production orders, such as "100 inches 6658–143 from location 42–7C4." The stock is accurately cut as specified, the tag is attached, and it is sent to the department indicated for the first operation, the department control man being informed of its arrival as explained in operation 30. No clerical work is involved in the stores department.

26. All preliminaries are now under way and parts and materials will begin to move in from the receiving department, foundry, various shop departments, and various stores departments.

Purchased items come from various vendors to the receiving department. The shipper's name is noted and the purchase order is located in the alphabetical file by the receiver. The material is checked against the order, specially inspected if that is called for, and if all is well, a receiving ticket is written in three copies. According to the instructions typed on the receiver's copy of the purchase order, the material will be disposed of in one of three ways:

a) If the purchase order were for replenishing stock, the stores location would be shown on the order. A transportation tag has to be written, attached to the material, and set out for the transportation department.

b) If the purchase order were for a finished part required for an assembly order, this would be stated on the purchase order. A transportation tag is written, directing the material to the designated accumulation stall. The exception would be large castings or heavy parts such as purchased engines, which need not be handled through an accumulation stall. These would go directly to the shop where they are to be used. The proper instructions should always appear on the purchase order copy in the receiving department.

c) (Which is the case illustrated at operation 27.)
If the purchase order were for a part which has to be worked on in the shop before it is ready for use, then there would be on file in the receiving department a route tag, from operation 12*a*, filed by production-order number. The purchase order would show the production-order number. The route tag is attached and the part sent to the department designated for the first operation on it, there to await operation 31.

The papers are then disposed of as follows:

One receiving ticket is filed in the receiving department for a limited time, together with any delivery ticket left by the shipper's delivery agent.

Purchase order copy and two receiving tickets are sent to the purchasing department for operation 47.

28. In that section of the foundry which is set aside as a receiving area, where the newly made castings are checked and weighed after being cleaned, there will have been received copy 2 of the foundry order. The castings will have to be identified and recorded on the order. This operation often encounters difficulty. One of three conditions will always exist:

a) The foundry-order number is marked on one of the castings by the molder. The castings are usually "shaken out" during the night and are cool enough to forward in the morning. However, there may be a central pouring floor to which all flasks are moved for the pouring operation. All may be shaken out at that point so that it becomes difficult to identify each different casting with its order number.

b) The pattern number is practically always marked on an embossed plate attached to the pattern. This pattern number will usually be legible on the castings.

c) The pattern number may not be legible on the castings and the order number may not appear on any of them, thus introducing an extra operation to identify them.

The safest rule on which to rely is that the pattern number must show on the castings. Then the checker will file his copy of the foundry order by pattern number. The original copy of the foundry order will be filed by order number at the control board in the foundry office. In the event that a pattern number is not legible on any casting it will be necessary for the checker to go to the foundry office or get the foreman to help identify it.

The number of castings and their weight are recorded on the second copy of the foundry order. If the order is completed, or if the quantity called for is to be split into lots, this copy will indicate it. A route tag will be on file by production order number, having been previously received from operation 12*a*. The tag is attached, castings are forwarded to the department indicated for the first operation on them, there to await operation 31, and the order copy, if completed, is turned in at the foundry office.

29. In the foundry office, the two copies of the completed foundry order are clipped together and sent to the planning department for operation 43.

30. When truckers move to the various machining departments the castings from the foundry, raw stock from the raw-stores department, or purchased items from the receiving department, it is important that the production-control operators in those departments be promptly informed. The operators are very busy, however, with many details

requiring concentration, and should not be interrupted needlessly. A memorandum sheet, or blackboard, is therefore provided and truckers instructed to jot down on this merely the production-order number shown in bold print on the route tag attached to the material they have brought in. If the truckers cannot be relied upon to do this, then a designated floor area has to be marked off and deliveries always placed within this area.

31. Periodically, when he can conveniently do so, the control operator goes to this memorandum, or this incoming area, and makes note of the production-order numbers for which the materials have arrived. He posts the date to the top portion of the production order under "Material Received," takes note of the starting date which he had written on the order in operation 19, withdraws the starting-time card from the tickler file, and places it in the "Jobs Waiting" pocket of the control board opposite the operator or work station to which the starting operation had been assigned.

This is the appropriate time to prepare time cards for each of the other operations which are performed on the job in this same department and to place them on the control board opposite their assigned work stations and in the "Waiting" pocket.

Each day, as soon as he can, the control-board operator should refer to the tickler file and see what jobs are scheduled to start. The starting time cards, which were placed in this file at operation 19, were filed a day ahead of the starting date. If the material for a job has not already arrived then the time card will still be in the file, and the control operator should phone the planning department. The planning department should refer to its copy of the production order, note the source of the material as shown at the top, and then do whatever is necessary to get the material dispatched at once to the shop department.

Each day, also, the control operator provides for laying out a day's work for each work station. This is done by taking from the "waiting" pocket, according to wanted dates, enough time cards to represent the day's load. This can be done very quickly by adding up the "standard times" shown on the time cards. In this it is desirable to schedule something less than the full 8 hours, unless the shop is efficient. Better to schedule 7 or 7½ hours in this way until production becomes efficient enough, and the control functions smoothly enough, to make it possible to schedule the full 8 hours or even more.

If work is flowing through the department in heavy volume, some work stations will become overloaded, as indicated by an excess number of time cards on the control board. The foreman should then be requested to transfer some of the work to other equipment, other departments, or to some outside concern. It is this provision which obviates

the need of attempting to set up a centralized load chart in the planning department, a venture which usually does not work out well.

Of the jobs ready, the time card for the first one to be worked on is transferred over to the "Next Job" pocket on the control board, at which time a tool requisition is written for the tools that are required for that particular operation. This requisition may be sent to the tool crib by an attendant, and the tools brought to the shop and placed with the material, or the workman may be expected to go to the tool crib himself, according to the size of the shop and the policy of the management.

When a workman finishes the operation he has been working on he goes to the control board, punches out on "This Job" and in on the "Next Job," dropping the finished time card in the box provided for finished-job time tickets and placing the "Next Job" time card in the pocket marked "This Job."

As the time card for each operation is thus punched out, the control operator refers to the corresponding production order and checks off that operation as completed.

If the work of that particular shop department is finished, as evidenced by the checking off of the last operation, the production order and blueprint are sent immediately to the next department for the scheduling of its operations.

32. The completed time cards are sent to the planning department where the timekeeper first uses them for posting the pay roll. They are then handled as explained in operation 39.

In the case of production orders calling for quantities which have been split into lots for economy in processing, each lot is represented by a time card and is forwarded as soon as that time card is punched out as finished. All work is forwarded according to the instructions shown at the bottom of the order and route tag.

33. In the finished-parts storeroom there will be parts arriving from the several shop departments, each with route tag attached. If the delivery instructions at the bottom of the tag indicate that the parts are to be delivered to accumulation stall 16 they are placed there and the storeskeeper checks off that item on the material-list blueprint which lodges there, making sure that the order numbers correspond. It will be convenient in helping the assembler to identify the parts later if the route tags are left with the parts. Otherwise they may be destroyed.

If a route tag indicates that the parts are for stock, and are to be delivered to such a location as 63–2F7, then the storeskeeper counts the parts, puts them in their location, and then signs the tag in the lower right-hand corner, as a receiving ticket, and sends it to the plan-

ning department for posting to the stores record, after which the tag may be destroyed.

34. When the last item has been checked onto the material list at the accumulation stall the job is ready for the assembly department. The job, together with its material-list blueprint, is sent to the assembly department for operation 35 after the storeskeeper has posted the date to the blackboard tracer record which he maintains at the accumulation-stall section of his storeroom.

It is not necessary for the storeskeeper to hold the job until all of the parts have been received into the accumulation stall, so long as he can retain a control over his work. There are times when the assembly work may be started in advance and then the late parts forwarded directly to the assembly floor by the storeskeeper. It would be necessary for the storeskeeper either to remember what had happened, or to go to the accumulation stall with the late parts to ascertain if the job on that production order were still there, or to refer to the record on the blackboard tracer to see if the job had been forwarded to assembly. After a day or so the storeskeeper may erase the record on the blackboard since its purpose is to serve merely as a tracer record during the time the job is passing through his department.

35. When the parts for an assembly order are received in the assembly department from the storeskeeper, the order number on the material list is noted, the date is posted to the "material received" column of the blackboard in the assembly department, the assembly-floor number, to which the job had been assigned, is noted, the assembly blueprint is pulled from its file and sent with the material and the material list to the designated floor.

With the material list designed as previously explained and with the assembly drawing keyed to it by the reference numbers, it would be possible for a relatively inexperienced assembler to get the job together properly. The assembler's time cards are punched in and out in the same manner as was explained in operation 31. A control board of precisely the same type as used in the shops will be of advantage in the assembly department, since it provides a systematic and semi-automatic means of assigning jobs in rotation and of keeping a visual record of work ahead of each assembly floor. It is not necessary to have a full-time operator in charge of the control board unless the volume of work warrants it. The foreman or any department clerk can give the board such attention as it requires.

36. Completed time cards are sent to the planning department for operation 39.

37. As soon as the shop department that performed the first operations on a part has finished its work, it disposes of the order and the

blueprint. If work is to be done in another department, these papers are dispatched there and the work will automatically follow, being guided by the routing shown on the route tag attached to it. If, however, the production order has been completed, then the order and blueprint are dispatched to the planning department for operation 45, and the work will find its way to the location designated on the route tag attached to it.

It is evident that a shop department which has to continue from where a preceding department left off will not have much time for planning the work. It is very probable that on all jobs coming in from other departments the control operator will not need to make use of the tickler file or the "Jobs Waiting" pockets of the control board. Such jobs will be ready as soon as they arrive, and a time card should be prepared and put directly into the "Jobs Ready" pocket of the control board, being sorted in among any other cards already there according to wanted date.

38. Similarly in the assembly department, when an assembly, or E order, is finished, it is drawn from its file, attached to the assembly and material-list blueprints, and sent to the planning department for operation 49, after the "date out" has been entered on the assembly blackboard as a temporary tracer record. After a day or two this record may be erased.

39. Completed time cards are received in the planning department once a day and go directly to the timekeeper. The hours on the cards are totaled for each employee and time and earnings entered on the pay-roll record where, at the end of the week, the hours are checked against the in-and-out clock card. The time cards are then turned over to the clerk in charge of the order file for operation 40 or 42.

40. Time cards from the shops are sorted by production-order number, checked off on the file copies of the production orders, and then filed back of their orders to await operation 46.

41. Similarly there will come to the planning department any individual stores requisitions from operation 21. These have first to be deducted from the stores record, at which time they are priced. They are then turned over to the clerk in charge of the order file for operation 42.

42. The time cards and individual requisitions coming to the clerk in charge of the order file are sorted by order number. The time cards are checked off on the file copies of the production orders, thus indicating the progress of the jobs, and then all of the cards and requisitions are filed back of their respective orders to await the costing-out procedure of operation 46. Assembly-time cards are filed back of the E orders. Thus in this order file there gradually accumulates the whole story of

each order. The original material requirements were all specified on the material list, in the case of assembly orders, and on the order itself in the case of individual production orders. Then in this order file there accumulate the time cards for the various labor charges, defective work tickets, credit tickets, and the individual requisitions for any additional material that may have been required.

43. From the foundry office there will have been received in the planning department the original copy of the completed foundry order with the foundry receiver's record attached as explained in operation 29. The file copy of the foundry order is drawn from its file, attached to the other copies, and turned over to the clerk in charge of the order file for operation 44.

44. The original copy of the foundry order is of no further value and may be destroyed. The second copy shows the number of castings which were received on the order and their weight. The fifth copy is the cost copy. Both of these copies are sorted by production-order number, rather than foundry-order number, which shows on the copies, and both copies are filed back of these production orders to await the costing out, operation 46.

45. Next the completed production orders will begin to come to the planning department, with their blueprints attached, as explained in operation 37. The blueprints may be disposed of according to company policy. They may be returned to the engineering department for file or they may be destroyed so that new blueprints have to be issued for each new order. The latter is the safer policy, generally, since changes may have been made in a tracing while prints are outstanding in the shops. However, in smaller plants the cost of new blueprints may be quite an item and the regular change notice, Fig. 237, page 566, can be relied upon, if properly handled, to catch all outstanding prints.

At the bottom of the production order will be shown the E-order number for which it was issued. The material-list copy filed in the planning department is turned to and a check mark placed in the column provided for it, opposite the production-order number, thus indicating that this item is finished. The production order is then turned over to the clerk in charge of the file for operation 46.

46. The file clerk will know that by the time these finished production orders come in the file will contain all of the time cards and individual requisitions pertaining to the orders. Accordingly the file copies of the orders, with all of the papers filed back of them, are taken from the file, attached to the original copies which have come back from the shop, and turned over to the cost clerk for figuring the costs.

On the reverse side of the file copy of the order there are columns for entering the details of the cost. The costs are figured on the individual

job cost basis and all of the information required for figuring these production orders will be on the papers which have been taken from the order file. The material cost is figured and entered, then the labor cost is figured and entered. Any extra requisitions which may have got into the file have to be examined to see if they are rightly chargeable to the job. Usually they represent some expense charge such as defective material, defective workmanship, damaged in handling, lost between departments, and so on, and the appropriate expense account number should be shown on the requisition. Thus these requisitions would be set aside to be charged to expense and not to the production order.

After the material and labor costs are recorded on the job cost sheet the overhead expense, or burden, has to be added. The commonest method of applying this is to charge in the expense as a percentage of the direct labor, although it may be applied on the basis of productive hours, machine-hour rate, or whatever basis is appropriate in the particular plant. This expense is then entered on the cost record. Then the development liquidation card, Fig. 227, page 553, has to be referred to, if there is one, and the proper development charge added to the cost record. The total of these items gives the factory cost of the production order.

If there is a foundry order among the papers attached to the production order, this will have already been costed. The production order shows the foundry-order number and the foundry order shows the production-order number.

In the case of a part which was purchased and had to have work done on it in the shops, there will have been received from the purchasing department a copy of the priced receiving ticket showing the production-order number to which it should be charged. This comes to the planning department from operation 47 and is filed back of the production order.

Thus the costs of production orders flow together gradually until at the costing operation the work is minimized. The planning and cost copy of the costed production order is then filed back of the assembly order to which it applies to await operation 50. The other papers relating to the costed order may be filed for a limited period and then destroyed.

47. In the purchasing department there will have been received from the receiving department the receiver's copy of the purchase order with two copies of the receiving ticket attached. The purchasing department draws its copy of the order from file and should find the invoice attached. The invoice may have arrived before the receiving ticket, in which case the order is removed from file and held in a special

file to await the receiving ticket. If the invoice is not on hand, the papers have to be held. The papers are checked, any irregularities corrected, the invoice is approved for payment and sent to the accounting department for payment, the purchase order with one copy of the receiving ticket and any correspondence is filed, and one copy of the receiving ticket, which is priced by the purchasing department, is sent to the cost department for operation 48.

48. The receiving ticket arriving in the cost department shows the number of the production or assembly order to which it is to be charged. At the time of its arrival there is nothing to do, other than to make any required extension, but to file it back of the order to which it applies, there to await the costing of the job in operation 50.

49. The last thing which happens in the planning department is the receiving of the completed assembly, or E order, from operation 38. When that arrives, the assembly and material-list blueprints, which are attached, are disposed of. The E-order number is noted, the file copy of the corresponding material list is drawn from its file, attached to the order, the sales order is drawn from its file and the completion date written on it, the sales order is attached, and the papers are turned over to the order-file clerk for operation 50.

50. The order-file clerk recognizes these papers as the final step in the processing of the assembly order. By this time all of the foundry orders will have been costed and attached to their respective production orders, all of the production orders will have been costed and transferred back of the assembly orders to which they apply. Now when the shop copy of the completed assembly order arrives, with material list and sales order attached, the file copy of the order is taken from the file with all of the papers pertaining to it. All are clipped together and turned over to the cost clerk. The costing will now be very simple, if all of the papers are in good order.

The costs of the individual production orders are copied onto the material list in the right-hand white column. This completes the cost tabulation of all M parts. Any P parts will have been indicated by check marks in the right-hand column, as explained in operation 10 on page 599, thus warning the cost clerk that he should look for a priced receiving ticket in the file.

If it is there, the cost of the P part is posted to the material list. All that remains are the S parts. These were all priced from the stores record in operation 12*a* on page 603. The cost clerk merely has to make any extensions, multiplying the quantity called for by the unit price, and post these costs to the material list.

The cost column on the material list is then totaled. This gives the total material cost of the assembly order. To this is added the assembly-

labor cost, as shown on the time cards, and the assembly-department expense, or overhead, thus arriving at the factory cost of the product. This cost is entered on the sales order in the column provided for it.

When the sales order was originally received by the order department it would be convenient for any statistical work desired by the management if the order were stamped as indicated in Fig. 268.

Product Group	Trade Class	Territory	Sales Agent	Discount Base	Factory Cost	Sales Price
13	9	10	68	3	470.13	578.50

FIGURE 268. CODING OF SALES ORDERS

The order is coded by territory, product class, agent or salesman, trade class, and discount base. The code numbers are entered in this stamped table along with the sales price. When the cost clerk enters the factory cost the order will be ready for statistical analysis, the value of which will be explained in the chapter on The Triangle Diagram.

Stock orders, in such cases as cited in Figs. 244 and 245 on pages 583 and 585, are handled in precisely the same manner as sales orders. Such stock orders merely represent particularly favorable instances of Type 1 production. An authorization, or stock order, comes to the planning department from the sales department, or the planning department might be authorized to maintain finished stock in accordance with the "minimum-maximum" provisions of the stores-record card, having any contemplated stock order first approved by the sales department.

When an assembly order is in process, if an inquiry should come to the planning department as to how the order stands, the planner refers first to his file copy of the material list. On this each completed item will have been checked off so that he can see at a glance what is still incomplete. If one production order has not been checked off on the list, then he can refer to the production order file and ascertain what operations on this order have not yet been completed. If he has not thus arrived at a suitable answer, he can call the shop control board and ask for the latest information on the order and thus arrive at a conclusion as to when he may expect to make shipment. All of this can be done quite quickly while the inquirer holds the phone.

On the stores record there will be the unit cost of each stocked part. On the purchase record there will be the price of each P part or material. There will be no place where the costs of M parts may be had unless there are kept on file the costed copies of completed production orders. Once the production orders have been costed and the costs posted to the material list, the orders are of no further value to the cost depart-

ment. They may then be filed away by part number for the future convenience of the estimating department. The costed copy of the material list should be retained as a part of the permanent file of sales orders.

If an industrial engineer were to go into a Type 1 plant to make a survey on why the operations are not more profitable, he would find it of first importance to ascertain whether or not anything is out of order internally. If he were to go first to the assembly departments, he would get the first part of that picture. In the assembly departments things have to go together quickly and properly. If there is anything wrong with the engineering, the materials, the planning or the specifications of parts, or with deliveries, it will show up in the assembly operations. Whatever is wrong with the mechanics of production control will show up there.

Then he would find it profitable to go to the cost department where the costs of assembly jobs should flow together as smoothly as the jobs themselves flowed together in the assembly departments. If there is anything wrong with the handling of the paper work associated with the processing of orders, it will show up in the costing operation. It should not take more than a very short time to survey these two departments and to thus ascertain whether or not the troubles are internal. If there are troubles, and if there are a number of stock chasers required to run down shortages, then it should be possible in comparatively little time to make striking, even spectacular, improvements in the financial condition of the company.

CHAPTER XXIX

TYPE 2 CONTROL

RATE, OR MASS, PRODUCTION

In Type 2 control we have a very different situation. Individual sales orders do not affect the shop departments. They come in, are tabulated in the order department, coded for statistical purposes, and are then forwarded directly to the shipping department for shipment from finished stock. It is essential that the products be thoroughly standardized and approved before they are released for production under Type 2 control.

Here one would expect to find standard costs, or process costs in which all costs are rolled up into a monthly total for each class of products and divided by the monthly output of those products to arrive at the unit costs. It is not so essential that the cost department be located in the same office as the planning department because their respective records are independent of each other.

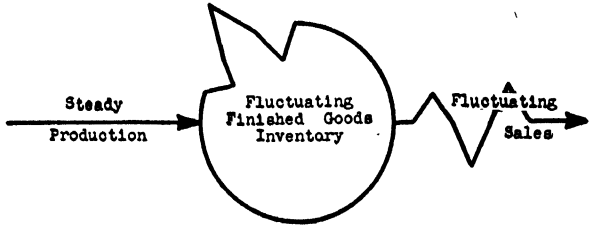


FIGURE 269. CUSHIONING PRODUCTION

The function of the planning department is to establish definite production, or schedule, periods, to compute from the material lists the total material requirements for those periods, to determine from sales statistics what quantities to produce, and then to maintain a steady rate of production which will meet the sales requirements and at the same time minimize the average inventory of finished goods, parts, and raw materials. The inventory of finished goods acts like a bellows in cushioning the established production rate from the shocks of widely fluctuating sales. The situation may be illustrated as in Fig. 269.

The control starts with setting up "authorized stock" for each product. This enables the planner to make corrections readily for the usual discrepancies between estimated and actual sales, any over- or under-

production in one period being compensated for in the preparation of the "want" sheets for some succeeding schedule period. Then the incoming sales have to be tabulated and a moving average computed. From this moving average the future sales forecast is estimated.

The Sales Forecast

In order to forecast sales conveniently it is very desirable to have properly designed tabulation sheets. Mail may be received once or twice daily. The quantities of each product called for on the orders are simply jotted down on a tally sheet which is totaled for each day. The daily totals have to be copied to a daily summary sheet and thence to a weekly summary sheet in order to bring the data to an appropriate degree of concentration for making future estimates. The data should be kept in terms of units and not in terms of values.

The case of a drink-mixer motor such as is seen on soda fountains may be assumed. The sales curve has been charted and it is apparent that this product experiences two sales peaks within the year, one in the spring and the other just before Christmas. By examining the characteristics of this sales curve it must be decided whether it is more advantageous to plan an annual production schedule, or a semiannual schedule, or a quarterly schedule. The process of making that decision will be explained in a later paragraph. For this illustration a quarterly period is decided upon. Then the data shown on the weekly incoming order summary, from which the forecasting is done, will be as shown in the following table.

In Fig. 270 there are plotted the sales curve and the average-week moving-average curve from which the forecasting is done. Around the first of December the planning department would prepare the production schedule for the first quarter of the new year. The sales estimate for that quarter was set at 2330 units, and the schedule prepared accordingly. It will be observed that this advance estimate turned out to be very close, so close that the authorized stock would very easily take care of the slight underestimate. Then, at the beginning of March, the estimate would be made for the second quarter. That estimate was for 2740 units per week. The estimate is spotted on the curve as shown and as the quarter proceeds the curve creeps on toward this point, thus providing ample notice of any serious discrepancy in the forecast.

The curve indicates that the time is the first of June, the orders for the last week in May having just been charted. It is time, therefore, for making the estimate for the third quarter. After examining the curve and giving consideration to any anticipated changes in the general business situation, the forecast is made for 2650 units per week during that quarter. This estimate is spotted on the chart as illustrated.

MODEL C DRINK MIXER

Week Ending	Unit Sales	13-week Total	Average Week
Jan 8	1030		
15	900		
22	1285		
29	1265		
Feb 5	1100		
12	1645		
19	1790		
26	1130		
Mar 5	2825		
12	2700		
19	2490		
26	1940		
Apr 2	2300	22400	1723
9	2200	23570	1813
16	2510	25180	1937
23	3325	27220	2094
30	2985	28940	2225
May 7	2895	30735	2363
14	1990	31080	2390
21	2590	31880	2450
28	2490	33240	2556
Jun 4	1775	32190	2475
11	1400	30890	2375
18	1760	30160	2320
25	1890	30110	2316
Jul 2	1620	29430	2263
9	1720	28950	2226
16	1815	28255	2173
23	3720	28650	2204
30	1565	27230	2093
Aug 6	1280	25615	1970
13	2750	26375	2028
20	1140	24925	1917
27	1585	24020	1847
Sep 3	1375	23620	1817
10	2850	25070	1928
17	1745	25055	1927
24	1950	25115	1932
Oct 1	2050	25545	1963
8	2810	26635	2048
15	2550	27370	2105
22	2350	26000	2000
29	3390	27825	2140
Nov 5	2020	28565	2196
12	2350 *	28165	2196
19	3565 5435	30590 32460	2351 2490
26	1675 3545	30680 34420	2359 2646
Dec 3	2400 4170	31705 37315	2439 2875
10	(7480) 1870	36335 36335	2439 2870
17	1985	36575	2813
24	1110	35735	2747
31	1355	35040	2694
Jan 7	1350	33580	2585
14	1255	32385	2483
21	2140	32075	2466
28	2480	31165	2396
Feb 4	1885	31030	2386
11	2570	31250	2403
18	1475	27290	2098
25	4055	27800	2138
Mar 4	4670	28200	2169
11	2090	28420	2186
18	2785	29220	2247
25	2045	30155	2319
Apr 1	2085	30885	2375
8	3330	32865	2527
15	2100	33710	2594
22	3710	35280	2714
29	2680	35480	2730
May 6	3260	36855	2835
13	5711	39996	3075
20	4245	42766	3289
27	2730	41441	3187
Etc.			

* Any pronounced peak, such as that at Christmas, may be prevented from too greatly distorting the curve from which the forecasting is done by spreading it back over a number of the preceding weeks and then revising the figures in the "average week" column. This is illustrated here by spreading back over three weeks the peak of (7480) for Dec. 10. This not only removes the sharp peak from the curve but also builds up the curve in advance of the peak, thus tending to make the forecasting anticipate this seasonal demand in the following year.

Thus Fig. 270 indicates the picture, for this one item, which the planner has before him at the beginning of June.

There may be numerous products in such a Type 2 plant, and it might be considered too arduous to maintain such charts for all of them. The data must be kept, however, and a planner who is sufficiently familiar with the business and with the trade situation in general can do the sales forecasting directly from the figures if he wishes. By draw-

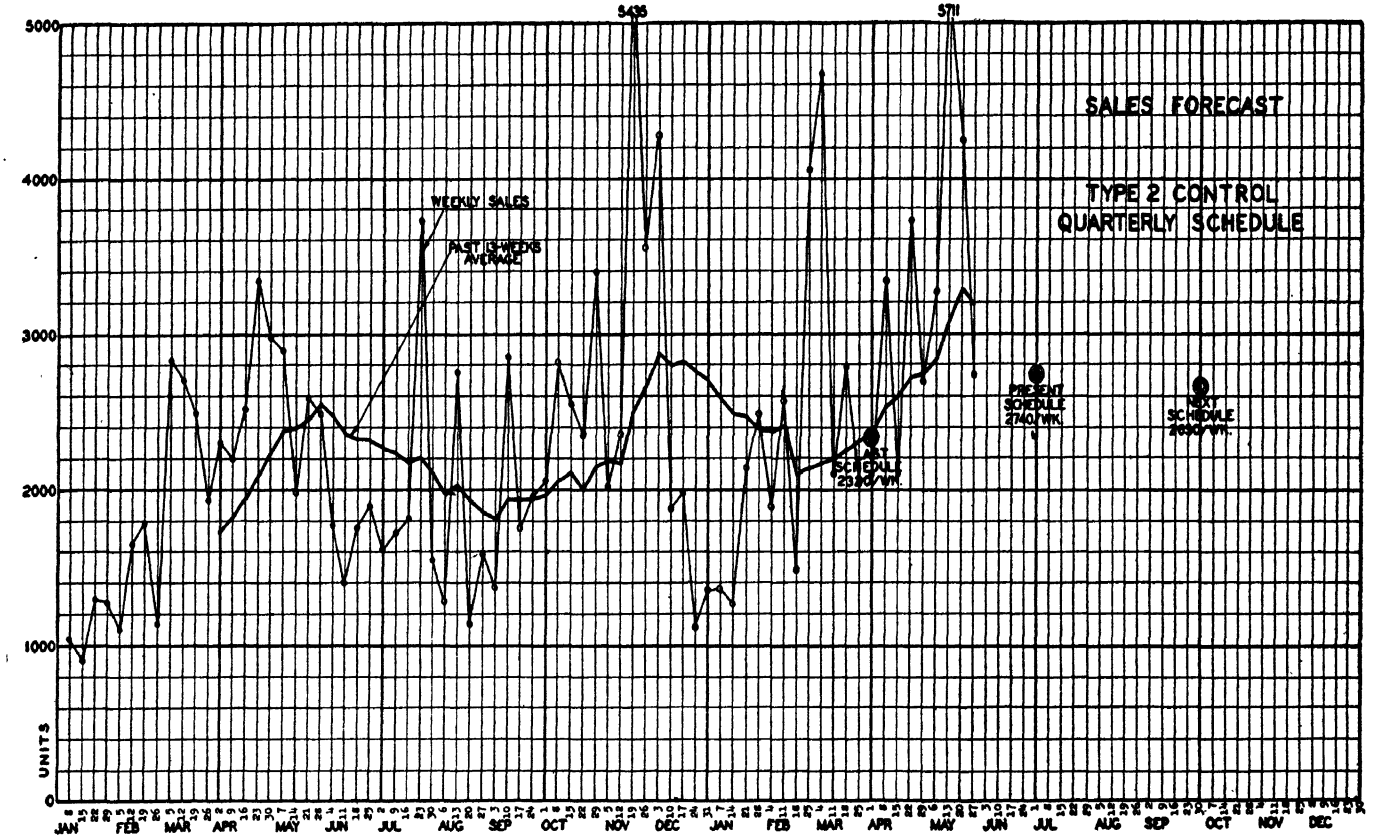


FIGURE 270. FORECASTING FUTURE SALES OF DRINK MIXERS

ing all of the charts to the same scale, giving them page numbers, and showing those page numbers on the summary sheet from which the data are plotted, the preparation of the charts can be made quick and easy and the charts are very helpful.

Determining the Best Schedule Period

The choice of whether to make the schedule period a full year or a half or quarter year is a matter of balancing values between the magnitude of movements into and out of inventory and the difficulties of increasing and decreasing the size of the productive force. A long-schedule period will permit a uniform production rate throughout, but it will mean adding to the finished-goods inventory for weeks at a time. This may make it necessary to plan for special financing. In time, of course, the sales will exceed the production rate, and then the accumulated inventory will again be depleted.

For an illustration there may be taken a typical case of a company manufacturing sanitary enamelware. In such a plant there will be both Type 1 products, which move in relatively small quantities and not particularly regularly, and also Type 2 products which move in appreciable volume. For the purpose of production control the sales curve should be plotted in terms of units so that the forecasting of sales will be done in terms of units. To illustrate the movements into and out of inventory, however, it will be more enlightening here to plot the sales curve for all Type 2 products in terms of value, care being taken to correct for any price changes which may have been made during the year.

Month of	*Total Net Sales Type 2 Products*			
Jan.	$258,500			
Feb.	296,100			
Mar.	357,200			
1st Qtr. Avg.		303,930		
Apr.	460,600			
May	425,300			
June	418,300			
2nd Qtr. Avg.		434,730		
1st Semiann. Avg.			369,330	
July	437,100			
Aug.	413,600			
Sept.	426,400			
3rd Qtr. Avg.		425,700		
Oct.	476,900			
Nov.	341,900			
Dec.	253,700			
4th Qtr. Avg.		357,500		
2nd Semiann. Avg.			391,600	
Annual Average				380,467

The shape of the sales curve is shown in Fig. 271. It illustrates the difficulty of a sustained summer volume followed by a low winter volume. A choice has to be made in such a case between financing long production runs or sustaining the costs of repeated labor turnovers. If financing is something of a problem it will be desirable to try to set the schedule periods to minimize the exchanges into and out of inventory while, at the same time, making the changes in production rates as small as practicable.

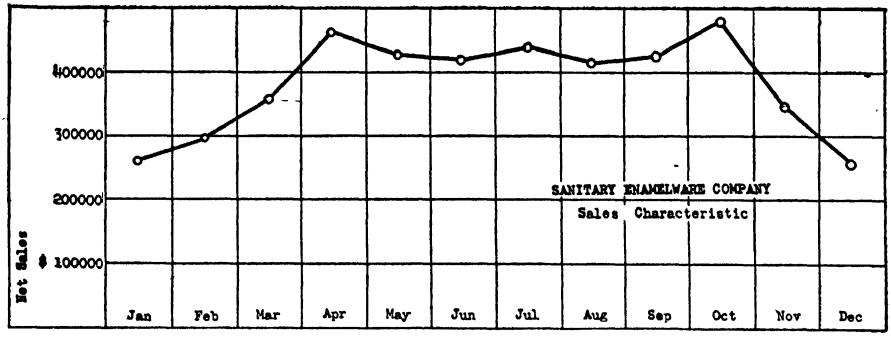


FIGURE 271. SANITARY ENAMELWARE SALES CHARACTERISTIC

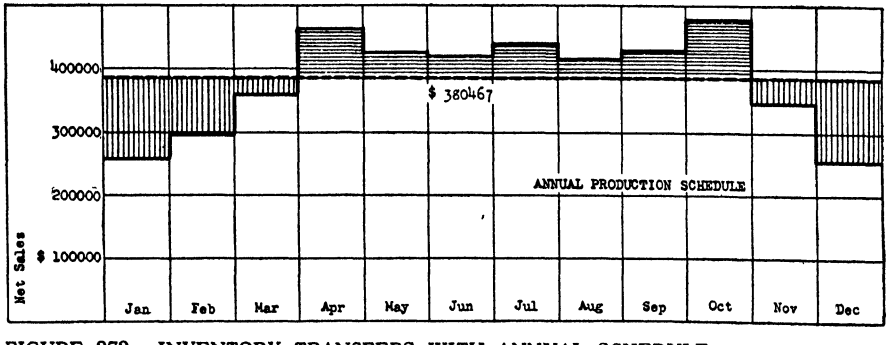


FIGURE 272. INVENTORY TRANSFERS WITH ANNUAL SCHEDULE

Try first the annual schedule period. By replotting the sales curve and then drawing a line through the annual average of $380,467, as illustrated in Fig. 272, the exchanges into and out of inventory will become apparent. The vertical shading indicates movement into inventory since the production rate of $380,467 per month exceeds the sales. The horizontal shading, where sales exceed production, represents movement out of inventory. By analyzing the data it will be evident that during the first three months of the year, in this particular case, $229,601 worth of production will have moved into inventory, the production for those three months being that much in excess of the

corresponding sales. During the following seven months the sales continually exceed production and in that period there will have moved out of inventory some $394,931 worth of production. That exceeds the first three months' accumulation by some $165,330. To meet that temporarily excess demand it is necessary to either carry some authorized stock or to have it understood that deliveries of these standardized units can be made in three weeks from receipt of orders. Following these seven months there are the last two months in which production again exceeds the sales, so that by the end of the year conditions should have averaged out.

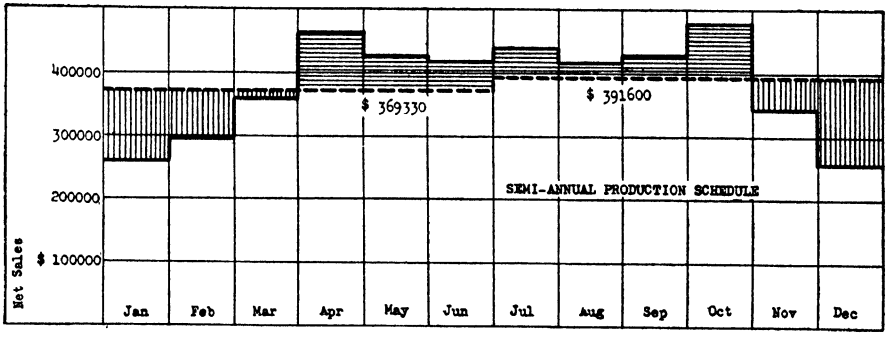


FIGURE 273. INVENTORY TRANSFERS WITH SEMI-ANNUAL SCHEDULES

Considering the production cycle as starting with October, there will be five consecutive months in which production, at the average rate of $380,467 per month, will exceed the sales demand. In those five months there will have moved into inventory, in excess of shipments, some $394,931 worth of production, and this amount will not have moved out of inventory until after the following seven months have passed. That calls for financing, the cost of which will be amply repaid by the economy of having production running on an even keel throughout the year. This will be illustrated more clearly in a later problem on a stove company.

This situation would be improved somewhat, but not greatly in this case, by considering a semiannual production schedule, running production at an average rate of $369,330 during the first six months and $391,600 during the last six months. This would mean a fluctuation in production from one schedule period to another of about 6 per cent, which is not excessive. This is illustrated in Fig. 273. It would mean that during the five months in which production exceeds sales there will have moved into inventory, in excess of shipments, some $383,700 worth of production instead of the $394,931 worth under the annual schedule. This is not sufficiently advantageous to be a deciding factor.

Trying finally the quarterly schedule period, the situation would be as illustrated in Fig. 274, production being run during the respective quarters at $303,930, $434,730, $425,700, and $357,500.

Here the largest movement into inventory would be from November through February, and in this period some $172,660 worth of production, in excess of shipments, would move into inventory. From the financing standpoint this is advantageous, but against this gain has to be set the disadvantage of fluctuating production with its consequent

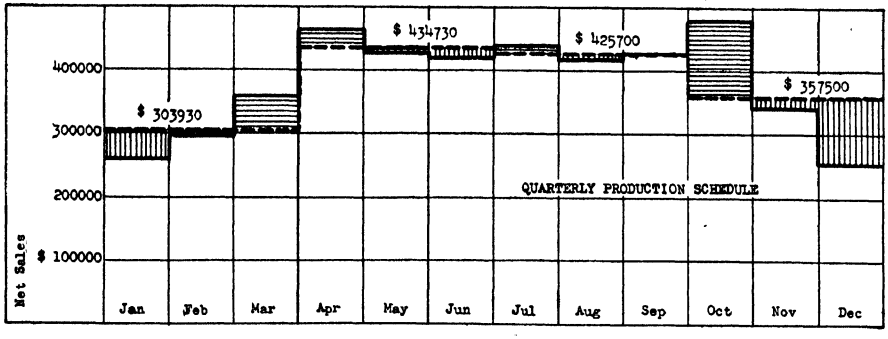


FIGURE 274. INVENTORY TRANSFERS WITH QUARTERLY SCHEDULES

cost and confusion in labor turnover. Upon moving into the first quarter, production would have to fall 15 per cent; on moving to the second quarter it would have to be stepped up 14.3 per cent; on moving to the third quarter it would have to fall 2.1 per cent; and on moving to the fourth quarter it would have to drop 16 per cent. This is not desirable.

Thus in a case of this kind it would be best practice to consider semiannual schedules and to make such arrangements as may be necessary to finance the accumulating inventory.

Typical Case for Annual Scheduling

Stove companies, for example, present a more striking problem than either of the two foregoing illustrations. A pronounced peak of sales occurs in the fall of the year with very low sales during the other three seasons. Unless production is intelligently planned, after the models of stoves to be produced have been agreed upon, the cost per unit will be excessively high.

In Fig. 275 there are shown a typical sales curve, production curve, and labor-cost-per-unit curve for a company manufacturing stoves. The situation illustrated existed before scientific production scheduling was installed. To arrange either semiannual or quarterly schedules would entail conspicuous fluctuations in production rates between the

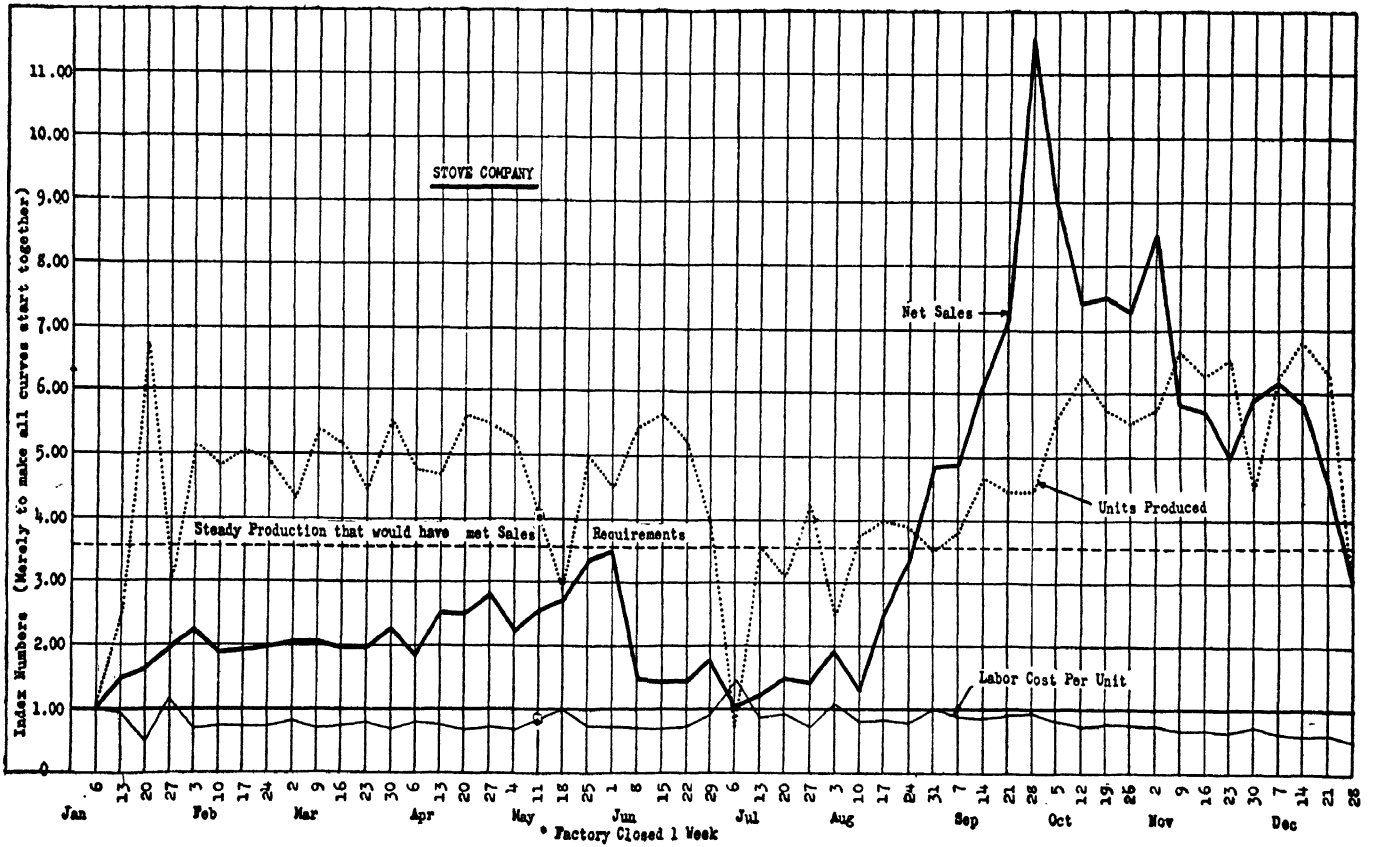


FIGURE 275. TYPICAL CASE FOR ANNUAL SCHEDULING

succeeding schedule periods. The annual schedule is essential here, and it involves the necessity of financing and providing sufficient storage space to house the large inventory which will have been built up during the first eight months of the year.

Two common features will be evident from an examination of the chart. First, when production is not adequately planned, there always exists the tendency for production to respond to fluctuations in sales, after a consistent time lag, and to outswing the sales fluctuations. The inertia of the production system will be evidenced by the amount of time which elapses between an upswing, or downswing, in the sales curve and the corresponding swing in the production curve. In this case the time lag is about two weeks, and that is not at all uncommon. The responsiveness of the production curve is quite evident in this chart, and it is a common characteristic of Type 2 production that it is the function of Type 2 control to avoid. Some of the sharp fluctuations in the production curve are explained by the fact that this is the total curve and in some weeks there are quantities of certain simple models put through, while in other weeks there are quantities of more difficult models turned out.

Then in the second place the cost curve will be sensitive to the production curve. An increase in production is almost invariably accompanied by a decrease in the unit labor cost, and vice versa. This situation is also evident in this chart.

It is quite a simple matter for an industrial engineer, in making a survey of plants which exhibit this situation, to make a fairly reliable estimate of possible savings which will result from introducing Type 2 control; savings which can be obtained from the reduction of confusion, stock chasing, and inefficiency inherent in methods which have merely grown up with the business. A problem will be presented on this case.

The Case Illustrating Type 2 Control

The mechanical transmitter used to illustrate Type 1 control could be used also for illustrating the details of Type 2 control. The transmitter turned out to be one of the best in the field and sold in very considerable volume. However, in order to broaden the student's experience in analyzing products, repetition will be avoided and the case of an electrical attachment plug will be taken.

The attachment plug is one of numerous products turned out by plants engaged in the manufacture of electrical devices. Some of the devices, as is invariably the case, will move in relatively small volume and therefore would be handled under Type 1 control, an occasional stock order being issued for such a quantity as will replenish a depleted

stock. The majority of the products, however, will move fairly regularly and in sufficient volume to call for Type 2 control.

In Fig. 276 is shown the operation chart of the attachment plug. There are 39 operations on 12 items which involve 10 different materials. All of these have to be so planned that they will flow through production at synchronized rates which will keep the finished product moving without interruption. At the same time there will be flowing through production numerous other parts for many other products, some of the parts being common to more than one product. The control problem is that of keeping production moving at a uniform rate that will satisfy the sales demand while maintaining a practical limitation on the finished-goods inventory, all with a minimum amount of expense effort.

It should not be attempted to set up in a central planning department a general control over all of the details. Such a policy has caused more failures among production-control ventures than any other one defect. Centralize the over-all control but decentralize the details. This is accomplished through the schedule, or rate, sheets and the production-control board. The planning-department control would then be exercised at the point marked *C* in the chart and a weekly production report would be required from that point.

Preliminary Statistical Forms

There are required a few forms on which to record the data which have to be assembled before a production schedule can be established. If a government war contract is received, or any other definite order which will substantially load up the capacity of the plant, then the production schedule is thus set directly and no preliminary statistical forms are necessary. Under normal conditions, however, it is important to make some systematic effort to forecast future sales in order to arrive at a production schedule adequate to meet the anticipated demand with minimum inventory. It is for this purpose that these preliminary forms are helpful. These forms are the daily incoming order tally, daily incoming order summary, weekly incoming order summary and the manufacturing authorization.

Since mail and telephone orders come in at various times during the day it is essential to record them so that weekly totals may be quickly drawn off. The orders may be written up on a company form to obtain any desired number of copies. One copy of each order may be dropped in a basket until the end of the day and then all copies sorted and totaled for the day. This arrangement works satisfactorily when the majority of the orders call for only one item, and when the company produces only a limited number of products. In other cases, however,

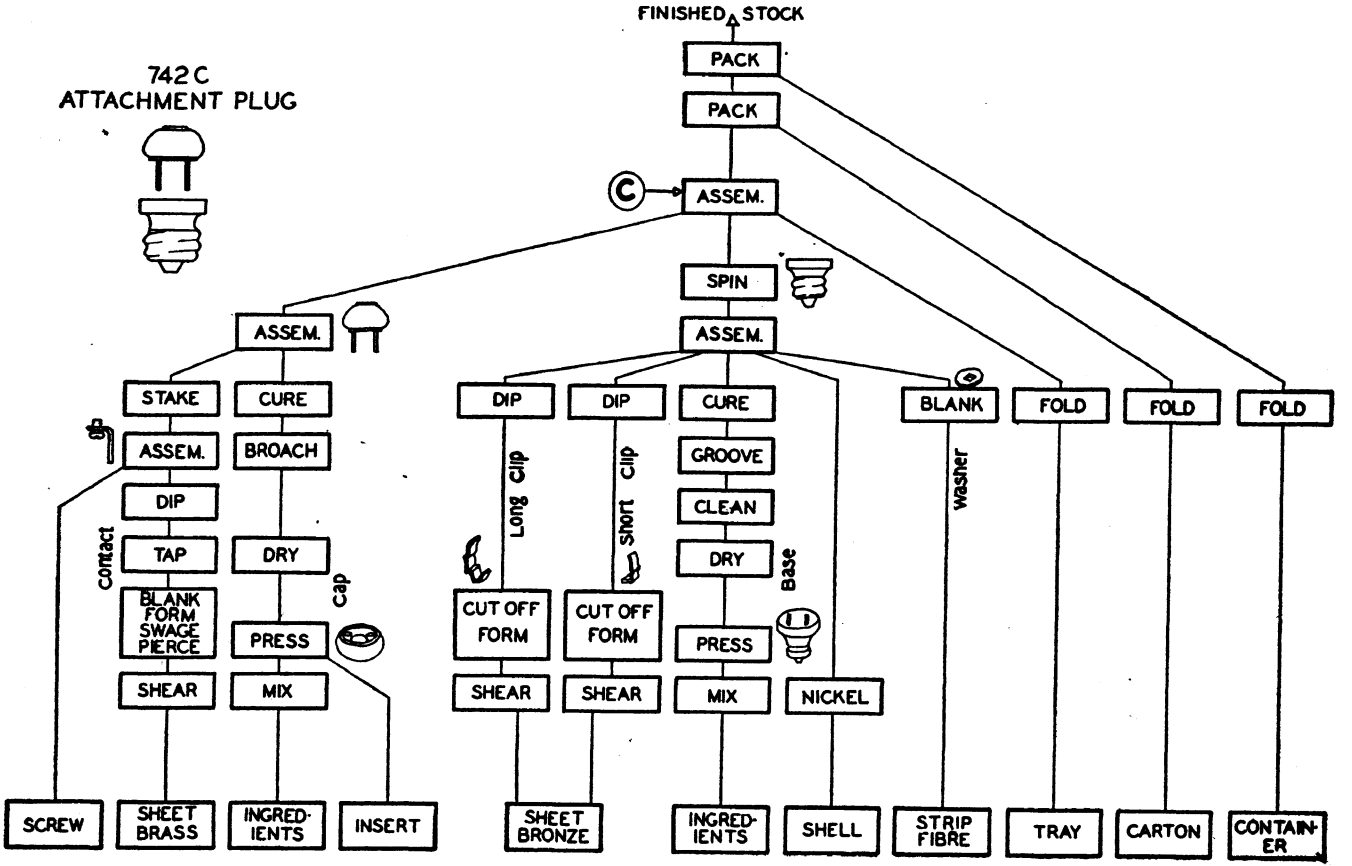


FIGURE 276. THE MAKING OF AN ATTACHMENT PLUG

it is more convenient to jot down the items, as the orders are written up, on a tally sheet such as illustrated in Fig. 277.

As soon as the orders are jotted down on this tally they may be turned over to the finished-stock record clerk for deduction from the stock record and then sent to the shipping department, or they may be sent at once to the shipping department and the stock-record clerk

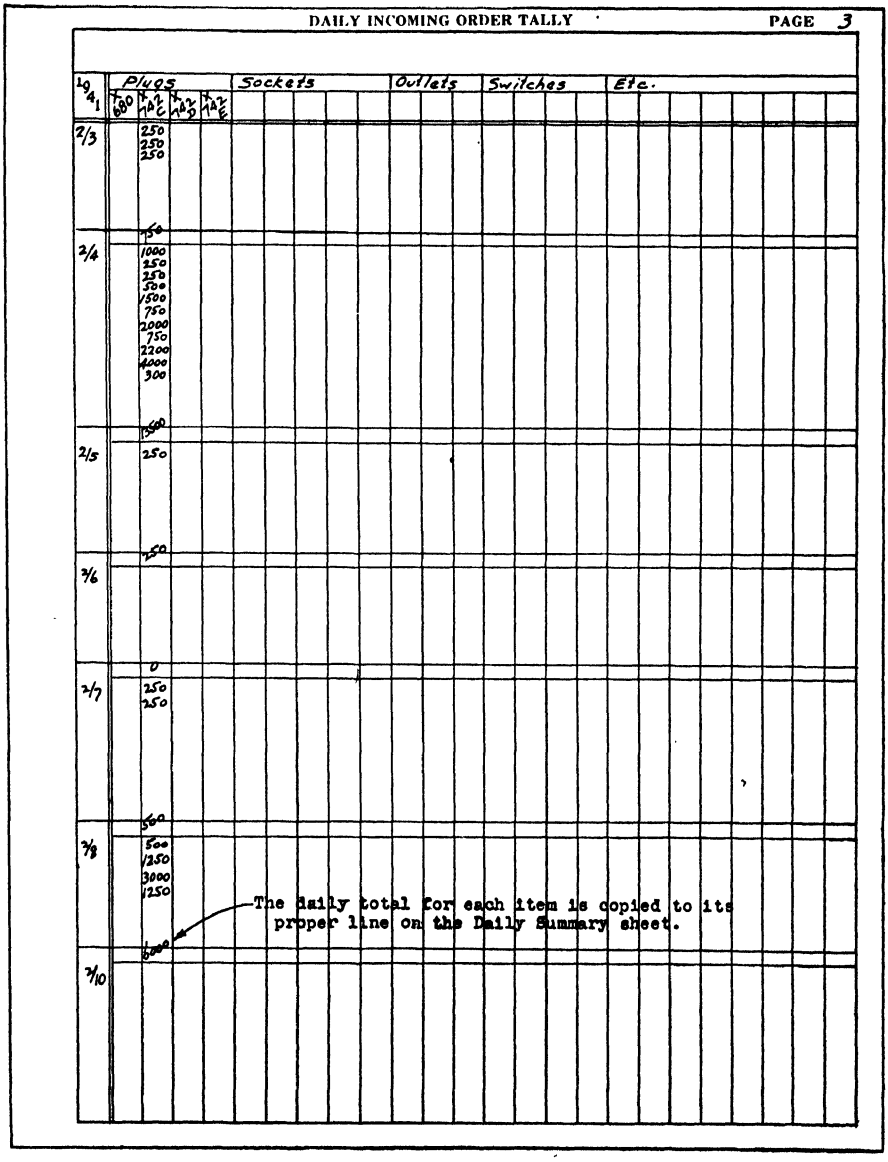


FIGURE 277. THE ORDER TALLY

allowed to make a blanket deduction from the stock record once a day from the daily incoming-order summary, or once a week from the weekly incoming-order summary. Individual plants vary so greatly in the nature of their products and manufacturing arrangements that what is best in this matter of stock-record deductions may be decided in each specific case.

The planning department does not need to see the sales orders at all unless the tally sheet is kept there. The order department is a convenient place to post the tally sheet; however, the sales department may prefer to do it as a means of keeping more closely in touch with daily sales, especially during campaigns. It is best to have the tally sheet kept where it will avoid duplication and where it will be carefully kept up.

At the close of each day a line is drawn across the tally sheet, the columns added, and the totals, by products, transferred to their corresponding lines on the daily incoming order summary, as indicated in Fig. 278. It will be observed that the sales data begins to get more concentrated on this form. One more degree of concentration is required before the data reaches a form in which it is of value to the production planner. At the end of each week this summary is added by products so as to give the total orders for the week and the total orders to date from the start of the schedule period. The weekly totals are transferred to the weekly summary as illustrated in Fig. 279. This ends the preliminary statistical work which is required as a basis for the quarterly sales forecast.

The sales data, thus concentrated, may be charted if desired, as illustrated in Fig. 270. If the production schedule is to be on an annual basis, instead of a quarterly basis, then this degree of detail is not necessary. The sales forecast for the coming year would be made from a record of the sales in preceding years. Similarly, production schedules set on the semiannual basis would not require this degree of detail, the sales forecast being made from a monthly record of sales. In either the annual or the semiannual case the foregoing preliminary forms should be redesigned.

Ordinarily this preliminary statistical work moves with considerable rapidity. If the data are charted, it is desirable to choose uniform scales so as to minimize confusion and liability of errors. Furthermore, it is well to keep in mind that this statistical work is not an end in itself. It should not be coveted as a job but merely as a means to an important end. Obtaining an intelligent forecast of future sales is the goal to keep in mind. In the case of the attachment plug used here for illustration, it may be assumed that as a result of this statistical work the estimated sales for the ensuing quarter are 260,000 units. The remainder

of the task of preparing the advance production schedule is straight clerical work.

The basis of Type 2 control is the authorized stock which is established as a cushion to shield the steady production rate from the temperamental demands of fluctuating sales. One of the objects of this type of control is to prevent the actual stock from becoming excessively

DAILY INCOMING ORDER SUMMARY PAGE 4

1941	Plugs				Sockets					Outlets		
Day	X-680	X-742C	X-742D	X-742E	Etc.							
30 M		8750										
31 T		6000										
1/1 W	Holiday	–	–	–	–	–	–	–	–	–	–	–
2 T		4750										
3 F		1250										
4 S		250										
WEEK		21000										
TO DATE		21000										
6 M		0										
7 T		3000										
8 W		1500										
9 T		7000										
10 F		2000										
11 S		500										
WEEK		14000										
TO DATE		35000										
13 M		12000										
14 T		250										
15 W		0										
16 T		7500										
17 F		2250										
18 S		1000										
WEEK		23000										
TO DATE		58000										
20 M												
21 T												
22 W												
23 T		Etc.										
24 F												
25 S												
WEEK		17000										
TO DATE		75000										
26 M												
28 T												
29 W												
30 T												
31 F												
2/1 S												
WEEK		20000										
TO DATE		95000										
3 M		750										
4 T		13500										
5 W		250										
6 T		0										
7 F		500										
8 S		6000										
WEEK		21000										
TO DATE		116000										
10 M												
11 T												
12 W												
13 T												
14 F												
15 S												
WEEK												
TO DATE												

The weekly total for each item is copied to its proper line on the Weekly Summary sheet.

The total to date is used for extending the production control chart.

FIGURE 278. THE DAILY SUMMARY

high in consequence of overoptimistic sales forecasts, while at the same time shielding the authorized stock from exhaustion in consequence of overconservative sales forecasts. Were it possible to know the actual stock at the time of preparing the new production schedule, then the difference between this and the authorized stock would show either an excess of actual stock on hand or a deficiency of stock on hand. The

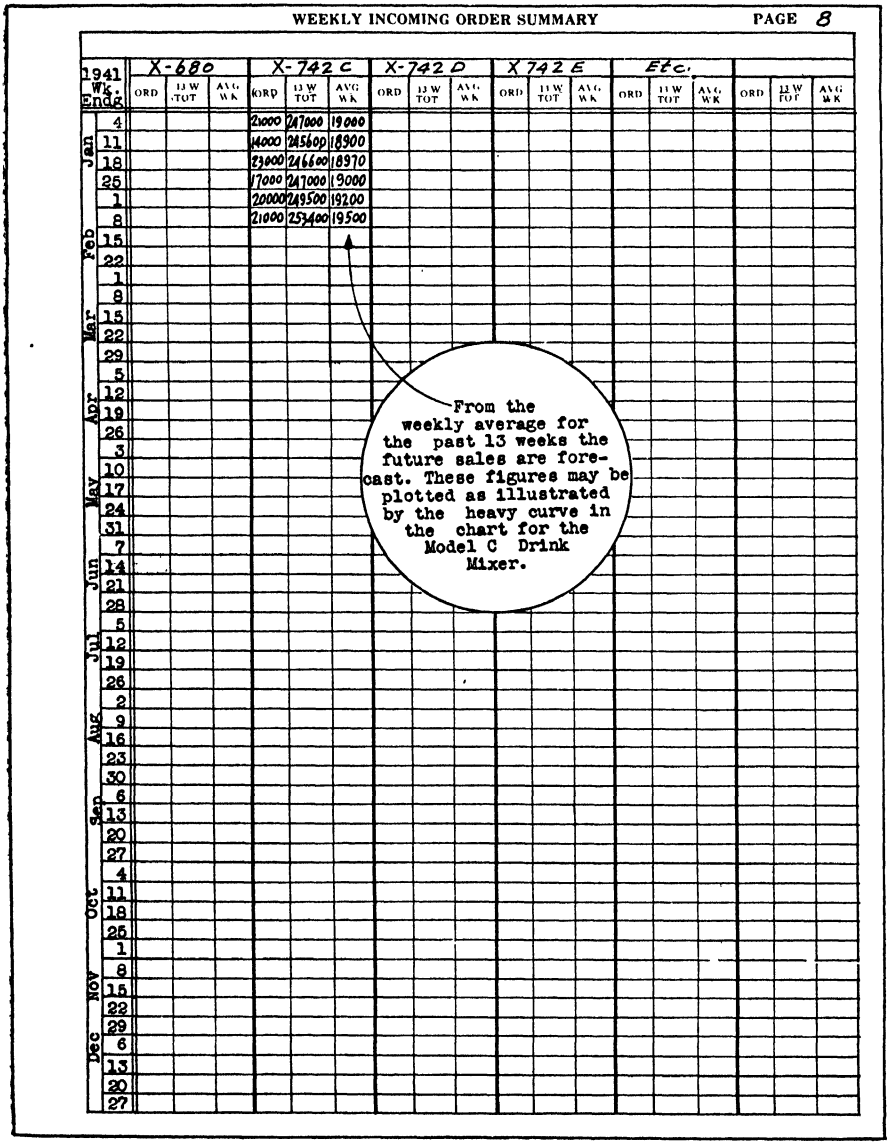


FIGURE 279. THE WEEKLY SUMMARY

planner would therefore have to subtract something, or add something, so that the planned production would include an appropriate allowance which with the estimated sales might bring the results out correctly at the end of the new schedule period. That is, to the sales forecast must be added the deficit-for-stock or from the sales forecast must be subtracted the excess-of-stock, in order to obtain the "want" [1] for the next production period. For convenience in arriving at the want quantity, the clerical work is executed on the manufacturing authorization form, Fig. 280, which, when approved, becomes the blanket manufacturing order for the new schedule period.

The only difficulty encountered here is in ascertaining the actual stock at the time the schedule is prepared. Usually the time for preparing quarterly schedules is about a month in advance of the closing of the current period so that the new production rates may be known a little in advance of the start of the new period. That permits enough time for making any necessary adjustments in the number of employees. But it is characteristic of Type 2 production that everything is constantly on the move: there is no way of taking an inventory at the time it is needed. Two courses are open to the planner at the time he prepares the advance schedule:

1. He may assume that by the time the current schedule period closes there will probably have been produced the precise quantities which were ordered for the current period and, from an examination of the most recent sales figures shown on the weekly order summary, he may estimate that the sales will actually have been higher or lower than anticipated by some percentage. Accordingly he may figure that the close of the current period will have resulted in an overproduction or an underproduction which will leave either more or less stock on hand which he should consider as the surplus or deficit for the current period. That is not at all easy nor is it satisfactory.
2. He may recognize that the most recent reliable inventory figure will be that which will appear on the stock-record card some days after the close of the last preceding schedule period — that is, some two months ago. This figure would be dependable and is easy to obtain. This is the alternative which is assumed in this text.

The manufacturing authorization is thus completely filled in and shows, for each of the standard, stocked items, the quantity required for the next quarter. It is not necessary to issue assembly orders; a

[1] In computing the "want" for the particular item illustrated the calculations would be 260,000 estimated sales plus 15,500 to correct the stock deficit, making a total want of 275,500. It had been decided to discontinue this design by dropping sales effort and by reducing future production schedules by whatever was necessary gradually to exhaust the authorized and actual stocks. Hence this schedule was set for 250,000 units instead of the normally required 275,500 units.

copy of the authorization sheet for each department concerned is sufficient. On the authorization sheet there is a column showing the average weekly production rate which, if maintained throughout the schedule period, should come very close to meeting the anticipated sales demand while also readjusting the actual stock on hand into conformance with the authorized stock.

DEPT. WD — MANUFACTURING AUTHORIZATION

DATE ISSUED 12/1,'40. — FOR 1st Q '41.

CAT. OR DRG NO	PRODUCT	AUTH STOCK	10/1 ACTUAL STOCK	SURPLUS OR DEFICIT	EST SALES	WANT 13-WEEKS	WKLY AVG.
X-680	Attachment Plugs	5000					
X-742C		30000	14500	-15500	260000	250000	19200
X-742D		10000					
X-742E		8000					
Z-6273	Sockets	3000					
Z-7241		1000					
Z-7257		1500					
Z-7314		2500					
Z-7319		500					
Y-4777	Outlets						
Y-5310							
Y-5444							
Etc.	Switches						

Established as a cushion. A convenient figure is roughly a two weeks supply.

Taken from the stores record at the beginning of the current schedule period.

FIGURE 280. THE MANUFACTURING AUTHORIZATION

The assembly departments are not necessarily bound to produce the indicated weekly rate regularly and without fail. They may exceed the average rate in one week and fall below it in another week, according to work conditions in the departments at the moment. It is essential, however, that the weekly average rate be maintained rather closely, because the planner will have set in motion a whole series of related production orders that will establish flow rates for all of the various parts involved in the assembly operations, and these flow rates are geared to the assembly flow rates shown on the authorization sheet. Any one item which is allowed to get seriously out of line will throw the whole chain of production out of gear. That is a common occurrence, the result of which is to upset the whole control arrangement with consequent reversion to hit-or-miss production.

It will not be difficult for the assembly departments to maintain the weekly average-production rates if they are assured an uninterrupted flow of parts. In large manufacturing plants operating Type 2 departments it is very common to experience numerous shipment difficulties because of the one difficulty of unsynchronized flow rates of the parts required for the assembly operations. It is to make easy the planning of the parts and materials requirements that the parts and materials schedule is given the form illustrated in Fig. 281.

The Planning Procedure

For each item shown on the manufacturing authorization there should be on file a tracing such as this illustration. It is adapted from the fundamental material-list form shown in Fig. 239 on page 570 solely as a convenience in Type 2 planning. In columns 7 and 16 there is provision for a factor by which to multiply the normally required production in order to make allowance for usual losses, rejections, and repair or replacement parts.

The planner takes the tracings from file and attaches a transparent fly sheet on which to enter all his figures. The two tracing sheets are blueprinted together, after which the fly sheet may be destroyed and the tracing returned to file until the next schedule period. Each horizontal line is filled in until the spaces become blocked off for one reason or another, as may be noticed in the illustration. Item No. 3, for example, is an assembly. That line is filled in as far as the assembly-order number, which is all that is required. Item No. 4 is filled in as far as column 17 where the extension stops because the material is common to other products in the schedule, and the requirements are therefore posted to common raw materials, sheet 7, line 2, where it comes together with similar postings from other parts schedule sheets to yield the total of all requirements for this particular common material for

the whole schedule period. Similarly, item 12 is a common carton, the requirements of which are posted to common parts, sheet 14, line 3, there to become a part of the total requirements involved in the whole schedule.

When this parts-and-material schedule sheet is filled in and blueprinted, it will appear as illustrated in Fig. 282.

PARTS & MATERIAL SCHEDULE

X-742-C

Sched 141 — Make 250,000 — ATTACHMENT PLUG — Page 1 of 1

Ref	Org No.	Part	Rqd Ea	S or M	Reqd Tot.	Factor	Avail.	Want	Rqn or Ord No.	Patt. or Stock No.	Material	Rqd. Ea.	S or M	Reqd Tot.	Factor	Avail	Want	Rqn. Ord. No.
1	Z-145	Cap	1	M	250000		0	250,000	141-13	15A	Compound	271/lb	S	9-25#	-			
2	Z-731-4	Insert	2	P	500000	105	2000	523,000	P.1150									
3	Z-146	Plate Asm	2	M	500000		0	500,000	141 A5									
4	Z-147	Plate	2	M	500000		3000	497,000	141-14	7903-9	.057x10" Brs	792/lb	P	6270#	-	CR7.2		
5	Z 605 3	Screw	2	P	500000	105	0	500,000	P.1151									
6	Z-148	Base	1	M	250000		0	250,000	141-15	15A	Compound	169/lb.	S	1480#	-			
7	Z-151	Fib Washr.	1	M	250000	101	4500	745,500	141-16	7915-14	3/64 x 2 3/4 Fib	28.6/Lt	P	8750'	0	1700'	7550'	P.1158
8	Z-152	Scr Shell	1	M	250000		0	250,000	141-17		Brs. to Drg.	1	P	250000	0	0	250000	P.1155
9	Z-155	Short Clip	1	M	250000		100	250,000	141-18	7907-4	.016x4" Brz.	667/lb	P	375#	-	CR7.9		
10	Z-156	Long Clip	1	M	250000		0	250,000	141-19	7907-4	.016x4" Brz.	512/lb	P	490#	-	CR7.10		
11	Z-93	Tray	1/25	P	10000		0	10,000	P.1152	-								
12	Z-88	Carton	1/25	P	10000	-	CR14.3	-	-	-								
13	Z-74	Container	1/250	P	1000		0	1000	P.1153	-								
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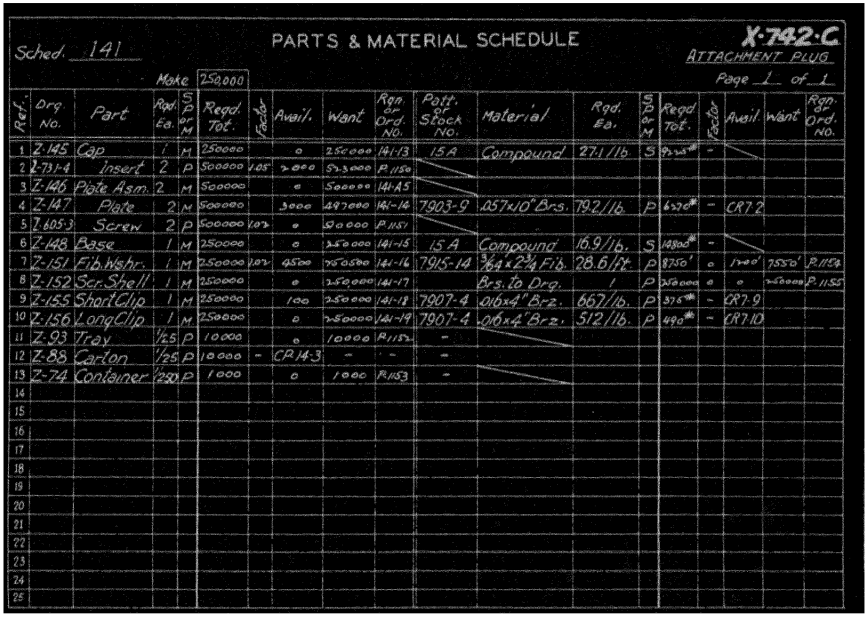
FIGURE 281. THE MATERIAL LIST TRACING ADAPTED TO TYPE 2 CONTROL

All of the parts-and-materials requirements, with the exception of common parts and common raw materials, are thus provided for. The production orders and purchase requisitions are written and their numbers are shown on this schedule sheet. Common parts-and-materials requirements are posted to appropriate sheets such as illustrated in Fig. 283, thus bringing together all corresponding requirements for all of the finished products covered by the manufacturing authorization for the schedule period. The common parts sheet would be identical in form. The references shown in the first and third columns may be printed in permanently since they will stand as long as the product itself is in standard production. All that will have to be written in, for each advance schedule, will be column 4 and beyond. The available quantity is taken from the stores record just after the

close of the preceding schedule period, as was the case also with the finished product itself. In the last column, for the guidance of the purchasing or shop departments, the average rate per week is entered. Were it practicable to maintain this exact rate for the incoming materials then the financial requirements would be minimized, since the materials would be flowing in at just the rate they are required for the



Sched. 141 — PARTS & MATERIAL SCHEDULE — X-742-C — ATTACHMENT PLUG — Page 1 of 1 — Make 250,000

Ref.	Drg. No.	Part	Rqd. Ea.	S or M	Reqd. Tot.	Factor	Avail.	Want	Rqn. or Ord. No.	Patt. or Stock No.	Material	Rqd. Ea.	S or M	Reqd Tot.	Factor	Avail	Want	Rqn. Ord. No.
1	Z-145	Cap	1	M	250000		0	250000	141-13	15A	Compound	27.1/lb.	S	9.2#	-			
2	Z-731-4	Insert	2	P	500000	105	2000	513000	P.1150									
3	Z-146	Plate Asm.	2	M	500000		0	500000	141-A5									
4	Z-147	Plate	2	M	500000		3000	497000	141-14	7903-9	.057x40" Brs.	792/lb.	P	6270#	-	CR7.2		
5	Z-605-3	Screw	2	P	500000	107	0	500000	P.1151									
6	Z-148	Base	1	M	250000		0	250000	141-15	15A	Compound	16.9/lb.	S	1480#	-			
7	Z-151	Fib. Washr.	1	M	250000	107	4500	745500	141-16	7915-14	3/64 x 2¼ Fib	28.6/ft.	P	8750'	0	1400'	7350'	P.1154
8	Z-152	Scr. Shell	1	M	250000		0	250000	141-17		Brs. to Drg.	1	P	250000	0	0	250000	P.1155
9	Z-155	Short Clip	1	M	250000		100	249900	141-18	7907-4	.016x4" Brz.	667/lb.	P	375#	-	CR7.9		
10	Z-156	Long Clip	1	M	250000		0	250000	141-19	7907-4	.016x4" Brz.	512/lb.	P	490#	-	CR7.10		
11	Z-93	Tray	1/25	P	10000		0	10000	P.1152		-							
12	Z-88	Carton	1/25	P	10000	-	CR.14-3	-	-		-							
13	Z-74	Container	1/20	P	1000		0	1000	P.1153		-							
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FIGURE 282. BLUEPRINT OF THE MASTER SCHEDULE

production orders and the payments of invoices for these materials could be made progressive, at a rate which would be covered by the rate of billings for the finished products being shipped out. However, purchasers often issue the order for the full requirements and that means that when full shipment is made, and the invoice paid within the 10-day discount period, the money involved is tied up for the duration of the schedule period, being liquidated gradually as the materials are used.

Difficulties are encountered in this precise control of material requirements and flow rates when a portion of the production cycle does not lie within the control of the subject company. For example, in the production of established models of automobiles, the material requirements are controlled largely by this Type 2 mechanism. A purchase

order may be received from the automobile manufacturer and call for 50,000 pairs of Type 432 head lamps for the 1942 sedan. The lamp manufacturer has to set up his Type 2 control to register with the automobile manufacturer's control and maintain the required weekly rate. However, on the purchase order there may be a clause "to be shipped in accordance with our releases" and that means not only that

COMMON RAW MATERIALS

SCHED. NO. 141 SHEET 7

ITEM	Line	FROM	QUAN	TOT	Fact.	REQD	AVAIL	WANT	REQN. NO.	RATE
.057 x 10" Soft Brass	1	X-080 pl 14	780#	9566	102	9757	140	9600	P.2113	750 #/wk. Beg. 12/23
	2	X-742C pl 14	6270#							
	3	X-742D pl 14	1060#							
	4	X-742E pl 14	935#							
	5	Z-7421 l 8	207#							
	6	Z-7314 l 10	314#							
	7									
.016 x 4" Ph. Bronze	8									
	9	X-742C pl 19	375#							
	10	" l 10	490#							
	11									
	12									
	13									
	14									
	15									
	16									
	17									
	18									
	19									
	20									
	21									
	22									
	23									
	24									
	25									

FIGURE 283. SUMMARY OF COMMON RAW MATERIALS

the lamp manufacturer must keep track of the "releases" and the shipments by making systematic notation on the shipping record, but he must also provide storage space in which to temporarily accumulate any lamps produced at the established rate in excess of the week-to-week releases. Furthermore, it is necessary to keep in close touch with the automobile manufacturer to minimize the risks to both which may result from sudden reductions or cancellations in existing orders. Type 2 production depends upon the standardization of products throughout the duration of the planned schedule period.

Control Elements

All material requirements having been provided for and the orders prepared for them, the control functions will become operative as soon as the orders are issued. Usually, on the finished products, the production planned for a given schedule period will run over into the succeeding period by a few days, and that means that each new schedule will be slightly delayed in starting. That is a normal condition. Care has to be exercised, however, to ensure that the production rate does not greatly exceed, or greatly lag behind the planned rate. Should it do so, the whole planned performance may be thrown seriously out of gear and result in excesses of some parts mingled with shortages of other parts. Such unbalanced situations usually entail grievous confusion which it is the purpose of systematic control to avoid. Some regular control mechanism is necessary.

It is important to separate the control mechanism into two parts, that part which has to do with the finished products and that part which has to do with the elements; that is, with the parts and the materials. The planning office should maintain the control over the finished products while the purchasing department and the several manufacturing shops should maintain their respective controls over the details which fall to them.

Taking first the finished products, as listed on the manufacturing authorization, the control would be placed at the assembly operation, as illustrated at point *C* in Fig. 276. From this point there would be required a regular production report. Ordinarily a weekly report would suffice and reports at such intervals would not make the posting of the control chart at all burdensome. However, if daily postings of the important control chart are desired, these production reports would have to be turned in daily. Here, in the quarterly scheduling of the attachment plug, it is assumed that a weekly production report is adequate and its form would be as illustrated in Fig. 284. In the third column is shown the total production to date, which is obtained by adding the current week's production to the total to date shown on the

previous week's report. It is this total figure which the planner uses in extending the graph on the central control chart. By extending the chart from this figure, instead of trying to post each individual week's production, errors are avoided, and the control chart should always agree precisely with these production reports.

The planner will also need a weekly report of shipments in order to chart the movement of finished products out of inventory. To mini-

WEEKLY PRODUCTION REPORT

SCHEDULE NO. 141

DEPT. WD

WK. ENDING Feb 8

PART	PRODUCED	TO DATE	SCRAP	PART	PRODUCED	TO DATE	SCRAP
X-680 Plug							
X-742C	13350	93460					
X-742D							
X-742E							
Z-6273 Socket							
Z-7241							
Z-7257							
Z-7314							
Z-7319							
Y-4777 Outlet							
Y-5310							
Y-5444							
Etc.							

FIGURE 284. PRODUCTION REPORT

mize the necessity for scrutiny of these reports it is desirable to have the forms in close correspondence, with all products listed in the same rotation. Thus the form of the shipping report would be as illustrated in Fig. 285.

The assembly department would be interested in the total produced to date and therefore, on the production report, this total is figured in that department. The shipping department, however, would not be interested in the total shipped to date and therefore that department is not called upon to enter the total to date on its shipping report. This total is required only by the planner for convenience in extending the central control chart, and therefore the planning department should be called upon to figure this total on each report.

This completes the forms required for Type 2 control. The control consists of watching the various synchronized production rates to ensure that the finished product assemblies may proceed without in-

terruption and keep up with the sales demand, within the limits of the authorized cushion stock.

The planner may use simple summary sheets on which to tabulate the significant production rates, shipment rates, and incoming-order rates or, to simplify and greatly accelerate his supervision of all conditions, he may put the information in graphic form on a Type 2 control chart.

WEEKLY SHIPPING REPORT

SCHEDULE NO. 141

DEPT. 7 WK. ENDING Feb. 8

PRODUCT	SHPD.	To date		PRODUCT	SHPD		
X-680 Plug							
X-742C	24500	114750					
X-742D							
X-742E							
Z-6273 Socket							
Z-7241							
Z-7257							
Z-7314							
Z-7319							
Y-4777 Outlet							
Y-5310							
Y-5444							
Etc.							

FIGURE 285. SHIPPING REPORT

The Control Chart

The production schedule for the advance period was computed on the manufacturing authorization sheet from an estimate of expected sales, and an examination of the excess or deficit which resulted from the corresponding good or bad sales estimate at the beginning of the previous period. In order to be forewarned of changing conditions, as far as the actual sales are concerned, the planner will want to know how the actual sales compare with the estimated sales, week by week, throughout the schedule. He will therefore want to chart the incoming orders and, to avoid errors which arise when attempts are made to post each individual week's figures, it is more satisfactory to chart the total to date. It is for this purpose that the total to date is shown on the daily incoming order summary, Fig. 278, page 641.

The planner will also want to know how the actual production rates are keeping up with the stipulated rates which were based on his calcu-

lations of the period's requirements. The total produced to date, for each finished product, is shown on the production report.

It will also be necessary to know how the actual shipments are keeping pace with the actual production as a means of safeguarding the inventory from depletion or from excessive increase. The total shipped to date has to be figured and entered on the shipping report.

With all of these totals before him the planner is equipped to exercise expert supervision over all that pertains to profitable production control.

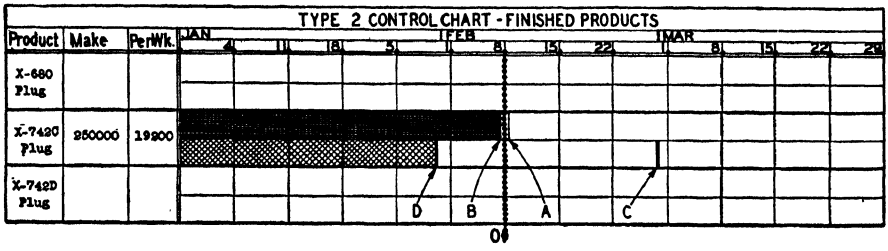


FIGURE 286. THE CENTRAL FINISHED PRODUCT CONTROL BOARD

The detail of the graphic summary of operations is illustrated in Fig. 286, the vertical divisions being days or weeks for the schedule period. For each of these vertical divisions there is a pin, or peg, from which a marking cord can be hung. The cord is moved along as the time periods close and the postings are made. The cord *O* in the illustration indicates that the period just closed is the week of February 8, for which the postings have been completed.

For each product there should be two horizontal spaces, one in which to post the data for incoming orders and shipments, the other for production orders issued to the shop assembly department and for production completed to date. The width of the spaces should correspond with that of the crayon used to extend the color bars. Referring to the illustration, point *A* indicates the sales to date, or the total to date of incoming orders, taken from the daily incoming order summary, Fig. 278. That total of 116,000, divided by the average of 19,200 per week, gives 6.04 weeks, at which point the vertical line *A* is drawn. Slide-rule computations are entirely satisfactory throughout this work since the liability of cumulative errors is eliminated. The position of this *A* line is very close to the marker cord and that indicates that so far, at least, the sales estimate was exceptionally good.

From the shipping report, Fig. 285, the shipments to date have been 114,750. That total, divided by 19,200 per week, gives 5.98 weeks, at which point the line *B* is drawn, and to which the color band is extended. If the shipping report is colored pale green, this color band

should also be made pale green to correspond. The indication is that the rate of shipment is very close to the anticipated requirements, since line *B* is close to the marker cord. The space between lines *A* and *B* indicates the unfilled sales orders on hand.

Referring now to the production space on the control chart, there is a choice between two alternatives for the line *C*, which indicates the assembly orders issued. If the manufacturing authorization is issued as a blanket order for all of the various assemblies required during the schedule period, then the line *C* would automatically fall at the extreme right end of the space, at the end of the week of March 29. If, on the other hand, for the convenience of the cost department, or for the convenience of the assembly department in which assembly equipment may be periodically needed for other orders which may be falling behind schedule, it becomes desirable to split the scheduled quantities into lots, then it would be necessary to issue individual assembly orders and to split them into lots. The position of line *C* in the illustration indicates that the assembly orders have been split into three lots, and that the second lot order has been released to cover production up to the end of February.

The line *D* indicates the actual production to date. The total to date of 93,460 is taken from the production report, Fig. 284 and, divided by the average per week of 19,200, gives 4.87 weeks, at which point the line *D* is drawn. The color band, corresponding to the color of the production report, is extended thereto. This line falls short of the marker cord and indicates that the required production of this attachment plug is about $1\frac{1}{4}$ weeks behind schedule but that this is not very serious, in this particular case, since the actual sales have not run appreciably in excess of the sales forecast.

Since the planning department does not attempt to exercise control over all of the details on which this master, or assembly, control chart depends, it would not be possible for the planner to explain why this attachment plug is running behind schedule. He would have to consult his control representatives in the various shop departments in order to obtain the answer. The difficulty may lie with some relatively inconspicuous part such as the fiber washer because in Type 2 production the whole synchronized and complicated flow of activities may be tied up by the default of even the slightest of the parts involved. In this particular case the fault lies with the inserts used in the cap, as will become apparent in the next figure which covers the operations in the plastics department.

This control chart is very eloquent to the experienced planner. By merely glancing at the chart with reference to the marker cord which indicates the time of reference, he can note the following:

The space from *O* to *A* indicates how incoming orders compare with the sales forecast.

The space from *O* to *B* indicates how nearly up to date are the shipments.

The space from *A* to *B* indicates unfilled sales orders on hand.

The space from *O* to *C* indicates advance production orders in the assembly department.

The space from *O* to *D* indicates whether actual production is behind or ahead of schedule.

The space from *C* to *D* indicates unfilled production orders in the assembly department.

The space from *D* to *B* indicates the quantity of finished products which has moved into or out of inventory, depending on whether *D* is ahead of or behind *B*.

The space from *A* to *D* indicates the degree in which actual production is running ahead of or behind actual sales.

When it comes to the corresponding control chart in the individual shop departments there is less complication since these departments are concerned only with the single production space. These shop departments need to know only how various production orders are running in relation to the scheduled rates. Each production order may be split into lots, and the planner may issue these lot orders for periods of approximately one month. That is, in quarterly scheduling the production orders may be split into three lots. Referring to Fig. 282 it will be noted that the production order for the cap, to be made in the plastics department, is No. 141–13. If split into three lots, for the convenience of the cost department or of the shop in which equipment may have to be made available for other orders, then the lot orders would bear the numbers 141–13–L1, 141–13–L2, and 141–13–L3. These numbers are readily translatable as the successive lots on production order No. 13 of the schedule for the first quarter of 1941.

As production orders are received in the shop departments they are posted to the control chart, illustrated in Fig. 287, for the plastics department. This is done by dividing the quantity shown on the lot order by the average required rate per week to obtain the number of weeks' production involved and then adding this to the last position of line *C*. Initially, the "Make" and "Per Week" columns are posted from the first production order released to the shop from the planning department. Referring back to Fig. 257 on page 605 it will be noted that the total quantity required is entered in the top left corner and below that are shown the quantity per tag, or lot, and the number of tags, or lots.

Should it be preferred to undertake the complete control in the central planning department, then both of these control boards would be set up there. The complete arrangement would then be something

like that illustrated in Fig. 288, which is an elaborately constructed board. The panels on which the production of parts and the procurement of materials are graphed are suspended from pulleys and counterbalanced by weights so that the panels may be easily raised and lowered. Both sides of the panels may be used.

There is obtainable from Keuffel & Esser quad ruled paper, 20 inches wide and put up in rolls. One ruling provides 8 squares to the inch, which is convenient for 8-hour day charting, and the other ruling pro-

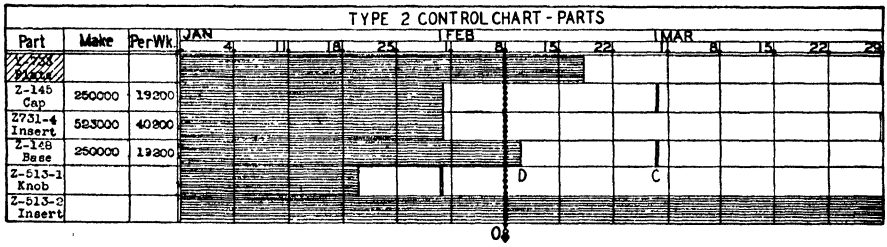


FIGURE 287. THE DECENTRALIZED, PARTS CONTROL BOARD

vides 10 squares to the inch, which is convenient for quantity charting. The panels may be made of thin fir plywood and covered with Armstrong cork carpet which takes map tacks satisfactorily when the paper is applied to the surface. The paper may be changed for each new schedule period.

In the shop departments there will come together on the control board all parts to be produced under Type 2 control for all of the various finished products, or for direct shipment orders, scheduled, including the common parts which will be used on two or more of the finished products. The common parts are proportionately more important since they have to sustain the production rates of two or more assemblies. It will, therefore, be of considerable help to the shop production-control operator if such common parts are flagged either by attaching a bead to the marker cord or by coloring the part number as indicated by the shading of common plate number Y–733. Such flagged parts should be kept up to, or slightly ahead of, schedule even though to accomplish that may call for extra effort.

Each week the control board is brought up to date. First the marker cord is moved to the next peg and then, from the department's production report showing the total to date, the line *D* is drawn just as was done in the planning department for the assembly production.

The space from *C* to *D* indicates the advance production orders released to the shop.

The space from *O* to *D* indicates the quantity by which actual production is running ahead of or behind schedule.

The planner, in ascertaining why attachment plug X–742–C is running behind schedule in the assembly department, would first check the major parts, which are the cap and base. On calling the plastics department control operator he would learn that the Z–148 base is running slightly ahead of schedule, which is entirely satisfactory, but the cap is 1¼ weeks behind schedule because of the lack of availability of the inserts required. The planner refers to the parts

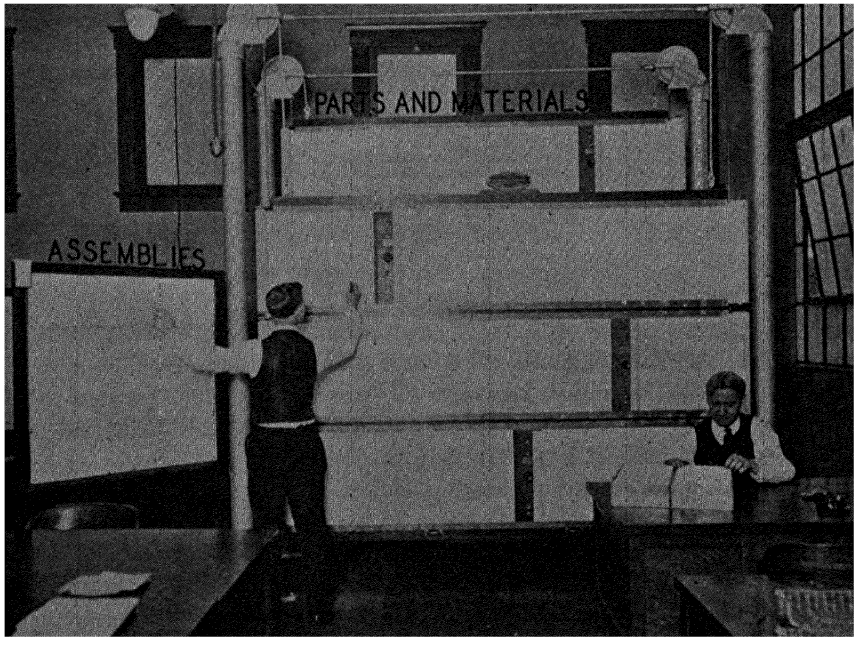


FIGURE 288. THE TWO BOARDS COMBINED IN CENTRAL OFFICE

schedule, Fig. 282, and observes that the Z–731–4 inserts were ordered through the purchasing department on purchase requisition No. P–1150. He accordingly has the vendor contacted. In doing this the purchasing department should inform the vendor what a complicated chain of activities becomes tied up because of such defaults in the supply of parts. In Type 2 production the filling of a purchase order is vastly more important than in Type 1 production wherein the purchase order may be merely to replenish a depleting stock.

This insert difficulty is introduced to illustrate one of the sore spots of plastics departments. In one large manufacturing plant the plastics department was engaged in turning out a wide variety of molded products involving inserts which were to be supplied by the purchaser.

The purchaser would agree to supply the inserts as required. The powerful presses were set up and the jobs started on schedule. Presently the supply of inserts would run low. The customer, who had agreed to supply the inserts, would be prodded day after day until, at length, it became necessary to stop the job, remove the dies from the presses, and set up for the next jobs in line. In the course of time a further shipment of the delinquent inserts would arrive but meanwhile all of the presses had become tied up on other jobs. After a shipping delay of a few days the customer would write in to explain that the inserts must have arrived last Thursday and that he had been looking for a resumption of shipments ever since Friday.

Such situations became so annoying that the manufacturer had prepared a brief explanation of the control system under which the products of the plastics department were governed. Once the time of a press had been mortgaged for an order the completion of that order depended on an uninterrupted flow of the materials required for it. Once interrupted, because of any such default as the interrupted supply of inserts, this job had to be taken out of line and the gap closed by moving up the next job in line. Should the new job require two weeks of the press's time then the interrupted job would have to wait for two weeks even though the delinquent inserts arrived only half a day after the job had been stopped. A copy of this explanation was sent to each district office for the customers who had defaulted and complained. The results were highly salutary and swiftly cleared the atmosphere of complaints and also of further defaults in the supply agreements.

In departments such as the plastics department, where equipment is expensive and not readily expandable, some provision has to be made for knowing at all times what the equipment availability is. That is, there must be load control. That is Type 3 control, and this will be illustrated in the following chapter. Thus in some productive shop departments which have to turn out products under Type 2 control along with other products on specific orders, and where the equipment is not readily changed over or expandable, there will have to be two control mechanisms, the Type 2 control chart for maintaining scheduled rates on which the rates of production in other departments depend, and a Type 3 load chart from which may readily be determined the starting and finishing of relatively long-run jobs.

It will be interesting to make a comparison of the above explained control board with an abridged form of Type 2 board used in an automobile plant. In Fig. 289 two heavy black lines have been drawn vertically to focus attention on only one of the four like sections of the board. "This board is the key to the mass production methods developed by the automobile industry and now called into the services of

national defense in advanced planning and scheduling. The flow of parts and supplies must dovetail exactly with the needs of the assembly lines and the various steps in the production process must mesh like so many finely cut gears. Shown in the picture is the huge board by means of which the flow of parts is controlled in the Chevrolet Motor Division of General Motors at Flint, Michigan."

FIGURE 289. ABRIDGED TYPE 2 CONTROL BOARD

The legend shown on the board is as follows:

Part No.	*Part Name*		*Schedule*	*Total Made*
	882–A10			
838277	Fan Blade Assy	Pass	136919	18090
838279	Fan Blade Assy	Pass	6019	7773
839020	Fan Blade Assy	T	34216	1817
	676–A5			
3657911	Front Fender Assy	Pass	150758	18210
3657912	Front Fender Assy	Pass	154310	16890

In the case of the first fan-blade assembly, against a scheduled quantity of 136919, there have been produced to date 18090. Is that good or bad? Obviously the board operator has to have more information, which his contact with the shops gives him, before he can say. The element which has been abridged on this control board is the measure of time which would enable the operator to judge at a glance how actual performance compared, day by day or week by week, with the scheduled performance rate. To reinstate this time element would transform the board into the form illustrated in Fig. 287.

CHAPTER XXX

TYPE 3 CONTROL

LOAD, OR AVAILABLE EQUIPMENT PLANNING

In Type 1 control, for the production of specific-order work, the material control covered a wide variety of parts and materials moving in relatively small quantities. For that there was a specially designed material list, the purpose of which was to simplify and accelerate the task of providing the necessary materials for each particular order. In the control of labor, that is, of the operations on the materials, the problem was one of simply assigning jobs to the most suitable work stations and of maintaining a reasonably balanced quantity of work ahead for each station. The fundamental record governing that was the master route card. Both of these fundamental records are permanent for all jobs which may be repeated from time to time. For jobs which may be special and therefore not repeated, these fundamental and permanent records were replaced by an individual estimate sheet which became the pattern for performance in the shop.

Of these two basic forms, the master route card is to the labor element in production precisely what the material list is to the material element. Their form is fundamental regardless of the type of production control, but they may have to be given some slight variation in order to abridge them for greatest suitability when they are used in control plans other than Type 1.

In Type 2 control, for the handling of mass production of a relatively few highly standardized products, in which all activities are reduced to rates of flow, the material requirements involve large quantities which have to be shipped in, or produced, at predetermined rates to mesh together with numerous other rates in order to meet current sales demand while at the same time safeguarding the inventory from excessive rates of inflation or depletion. For the convenient accomplishment of material planning the fundamental material-list form was varied slightly and was expanded to provide for the simple totaling of parts and materials common to two or more assembled products. In the control of labor, to be expended on the materials, the problem was not one of simply assigning various jobs to different work stations but was rather one of providing for the necessary output capacity and of

keeping tabs on the output so that each production rate, on the average, would not falter seriously enough to throw the whole synchronized program out of gear. For each standard product there would be the fundamental form of master route card but there would have to be provision for recording the standard rates of production for each operation, expressed in units per hour, or per day, and these established rates should be figured at some reasonable percentage of perfection so as to include some consideration of the difficulties which always arise. Eighty per cent of perfection makes a good starting point. If the shop atmosphere and conditions are exceptionally good, then this figure may be revised upward, and if it is found that the opposite is the case then the figure may be revised downward.

The control is designed to set against each part and material item the actual production, week by week, in comparison with what has to be expected in order to retain a balance in the numerous flow rates.

Now, when the character of production becomes that of assigning specific orders of considerable size to individual machines or work stations, which may have to be tied up for considerable lengths of time, we encounter Type 3 control, the primary purpose of which is to keep a check on the availability of facilities so that reasonably reliable delivery promises may be given for new jobs. Individual jobs are assigned to specific machines or work stations, just as was done in Type 1 control for jobs of relatively short duration. Production rates have to be recorded and quickly compared with the estimated, or standard, rates, just as was done in Type 2 control. But the fundamental problem is different in that there is not so much concern about keeping a supply of jobs ahead of each machine to prevent lost time nor is there concern about synchronizing the production rate of each machine with the rates of other machines. The problem is merely to utilize equipment to best advantage by seeing that jobs run off smoothly and on time so that the equipment may be available for jobs ahead.

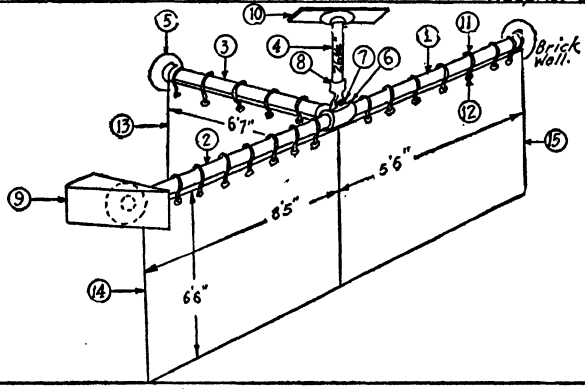
Typical of production processes which fall under Type 3 control are printing establishments other than small job shops, weaving on looms, automatic screw-machine departments, punch-press and forming-press departments, forging hammers, hydraulic presses, and numerous other processes which, like paper mills and roofing mills, have to depend on the availability of expensive machinery or inflexible facilities to turn out relatively long runs of work for specific orders, whether those orders are for stock or for direct sales.

The computation of material requirements is relatively simple and does not call for such an elaborate material list as is required for Type 1 control. Usually, though not always of course, the jobs are of a non-repeat nature. Material has to be figured for each individual job. The

same is true of the labor operations. Therefore, instead of the already described material list and master route card, there would be only the individual estimate sheet, a satisfactory form for which, whether for small jobs in Type 1 plants or larger jobs in Type 3 plants, is illustrated in Fig. 290. On the production order the planner would assign the machines best suited to the particular job and record the production

Date 9/23 **ESTIMATE** Order No. 41-600

Hospital Curtain



SUMMARY		
M	14.64	
L	3.09	
B	2.97	
FC	20.70	
S&A 9%	1.86	
TC	22.56	
SP	27.10	

	MATERIAL								LABOR				
ITEM	Req'd	Part No.	Description	S P M	Order No.	@	Cost	Dept.	Op. No	Operation	Time	Rate	Cost
1	✓	3/4 p.	Cut 5'5 5/8"	S	42600A	.12	2.90	P	1	Make Frame	1	.85	.85
2		"	" 8'7 7/8"	S		"				Enamel	20m	"	.28
3		"	" 5'11 5/8"	S		"		W	2	Make wedge & plate: en.	20	.75	.25
4		"	" 24½"	S		"		C	3	Cut & fold	20	.85	.28
5	4	#3	Flange	S		.13	.52			Seam	60	.50	.50
6	1	21	Tee	S		.11	.11			Layout	40	.65	.43
7	1	0	Hinge	S		.03	.03			Hem	30	.50	.25
8	1	5	Eye End	S		.07	.07			Grom. & ring	30	.50	.25
9	1	Sk. 71	Block	M		-	.20						3.09
10	1	-	Plate 3½ x 18 x ¾	M		-	.15						
11	35	1 3/8	Shower Hooks NP	S	42600B	.03	1.05			1⅓ @ 10 1.17			
12	35	#0	N.P. Grommets	S		20/6	.05			3 @ 60 180 / 1.97			
13	8yd		30" #12 Wh. Duck	S		.39½	9.28						
14	9½ y.		" "	S		"							
15	6yd		" "	S		"			4	Install 2 men	1¾h		3.65
16			Misc. Screws &c.	S		-	.10						
17			Thread				.03						
18			Enamel				.15						
19							14.64						
20													

FIGURE 290. SIMPLE ESTIMATE SHEET

rates and computed hours, or days, on which his estimate was based and against which to measure the actual performance as the job progresses.

In Fig. 291 are shown a floor of Harris offset presses and a floor of Miehle two-color presses in a large printing and lithographing company. The supervision of such spacious shops and of so many units becomes a difficult matter unless some means are provided for reducing the compass of the activities. Jobs may be in process on as many as six floors. Presumably 95 per cent of them may be running normally on

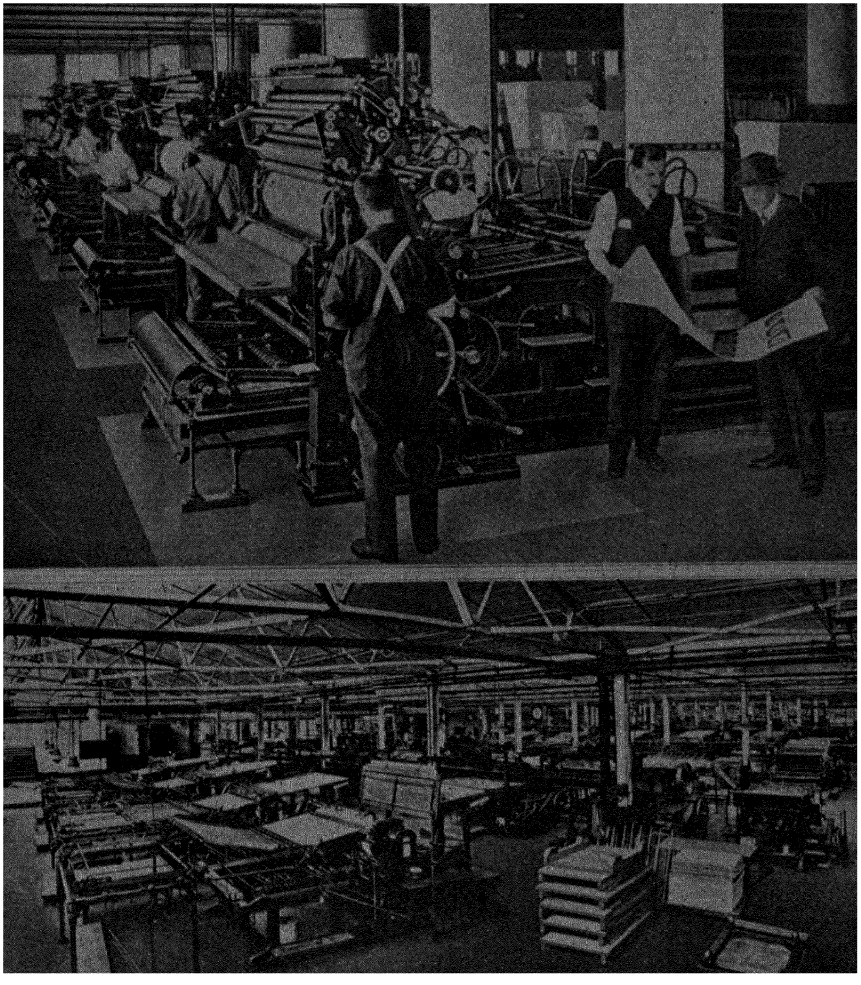


FIGURE 291. TYPICAL SITUATIONS FOR TYPE 3 CONTROL

schedule. It is a slow and costly process for the supervisor to have to travel throughout the whole area several times a day in order to locate the 5 per cent which may need some attention. Some central control mechanism is required to bring all operations within the sweep of the eye and to make stand out at a glance the few which may be in difficulty. The Type 3 control board is specially designed for that purpose and it is quite different from the types of board used in the previously described control schemes.

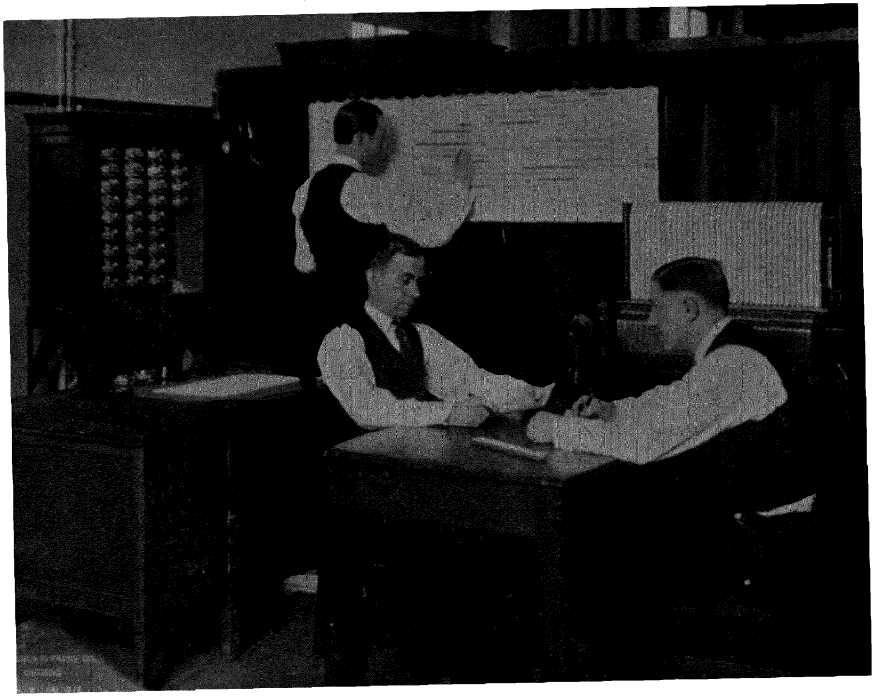


FIGURE 292. CENTRAL CONTROL IN A LARGE MODERN PRINTING PLANT

In such a printing plant the central control arrangement is illustrated in Fig. 292, there being the control board at the left of which is a bank of electrically operated counters, one connected to each press for recording the count of impressions run off, and at the right is an electrically operated production meter with capacity for recording the operating times of 34 presses. A ratio of the two gives the average impressions per hour. The illustration shows the start of a day when the production planner, the sales representative, and the control operator get together to plan new jobs and arrive at delivery promises. After the conference is finished the control operator is left to follow

production of jobs which are running and to report to the planner any which may require attention. This represents a very inexpensive method of control. The lengths of production runs in this case are not great, as may be noted from the lengths of the lines on the control board, and practically all jobs are independent of others.

In Fig. 293 is a corresponding setup for the control of the printing department of a mail-order house in which the runs are longer and require some coordination to get all sections of a catalog coming

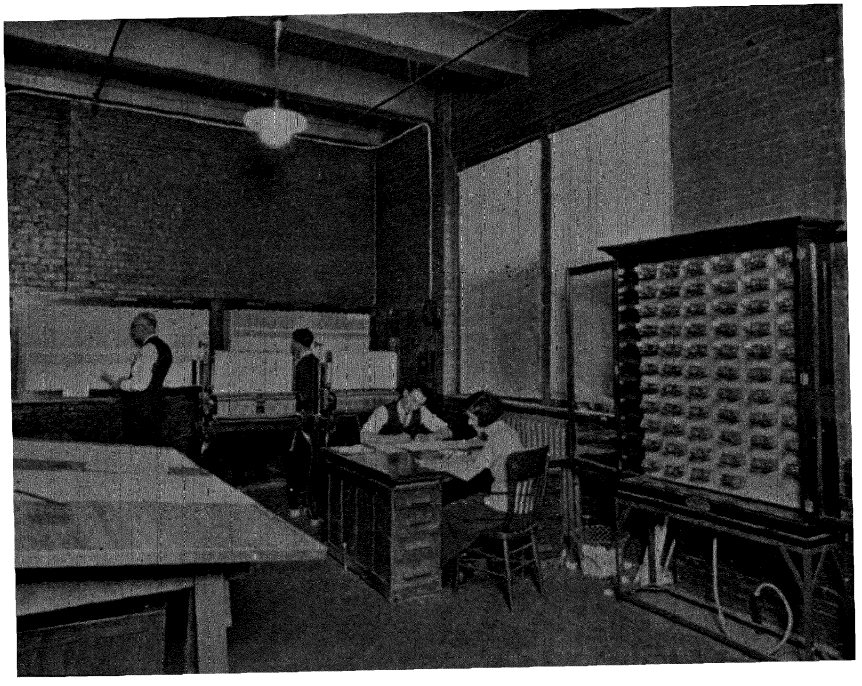


FIGURE 293. TYPE 3 CONTROL IN LARGE PRINTING DEPARTMENT

through in proper rotation. The control covers 64 presses, the surplus four-time recording units having been removed from the production meter at the left. From the counters, shown at the right, the control-board operator posts the control board as frequently as may be required and from the time-recording meter is figured the per cent operating time as a measure of practical shop capacity. It is well to plan jobs originally at 80 per cent operating time unless the record indicates higher than average efficiency.

The control board is a simple frame carrying a thin plywood panel over which is mounted a sheet of Armstrong cork linoleum which takes lils, or map tacks, readily. Over that is placed a sheet of cross-section

paper with 8 squares to the inch, for 8-hour days, and at the top is placed the strip on which are marked off the hour divisions. At proper intervals there hang removable plates marked "this month," "next month," and "third month." These plates are moved along as time progresses, and the board is used over and over again in circular rotation, just as a slide rule is used. That is, when a job runs off the right end of the board it is continued on from the left end of the board, and so on.

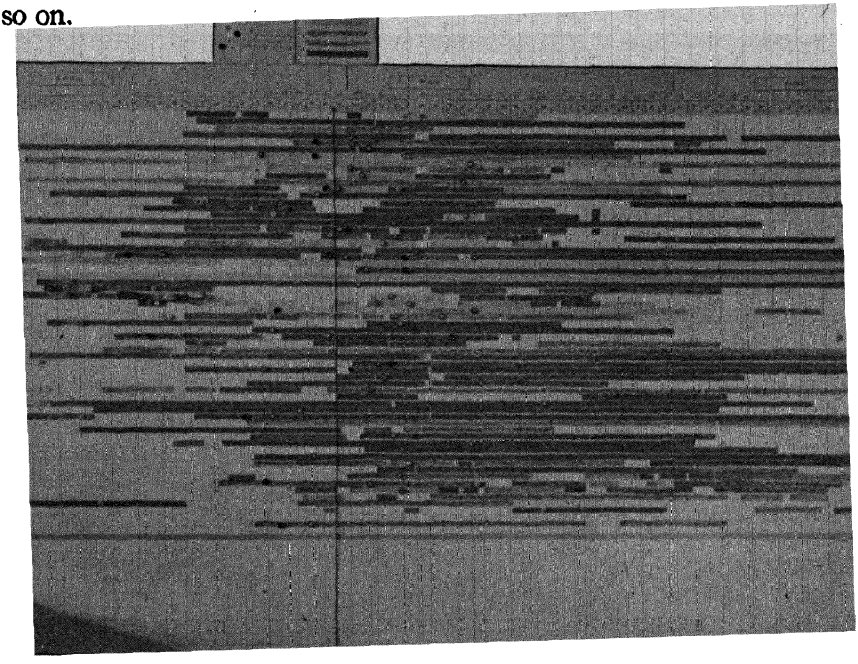


FIGURE 294. TYPE 3 CONTROL IN PLASTICS DEPARTMENT

The details of the control board may be somewhat better examined from the illustration in Fig. 294, which represents the control in a plastics department of a large manufacturing company engaged mainly in Type 1 work. Above the board is a panel with sample tacks which are used on the board. A tack with an I on it indicates trouble over inserts, R indicates the press is out for repairs, H indicates a customer's hold order, and so on. To the right of that is a key panel with samples of the various colors used on the board, green for No. 30 Thermoplax, pink for No. 15 compound, blue for No. 25 compound. In a printing plant the colors would correspond to ink colors.

The cord marker hangs at the close of Friday, April 25, for which date the postings have just been completed. Obviously, if every job were up to schedule there would be no job lines to the left of the marker

cord, or none beyond one week to the left. In this view there are numerous jobs to the left of the cord, indicating that that many jobs are in difficulty. This sort of thing results from figuring the shop capacity too optimistically. The resulting confusion can well be imagined. The way to correct such a situation is to start figuring all new jobs at 80 per cent of capacity; that is, if a job figures 10 days with the machine functioning full time, divide that by 0.8 and schedule the job as requiring $12\frac{1}{2}$ days. After a brief period that will clear many of these delinquent jobs. If the situation is not sufficiently improved, then assume 60 per cent capacity and figure all new jobs accordingly. Then, as conditions improve and a better grip is had on them, raise this capacity figure again until the appropriate figure is reached for that particular plant or department.

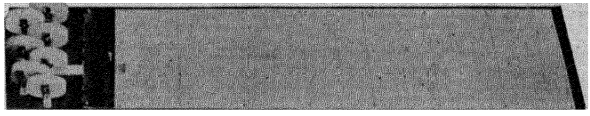


FIGURE 295. JOB TAPE CUTTING BOARD

On this control board there are somewhat over 50 jobs which are delayed because of necessary repairs to press or dies. There are 8 jobs which had been placed in position on the board but were held up by customers, and there are some 9 jobs which either could not start as planned or had to be interrupted because the inserts which are pressed into the molded products failed to arrive on time. That all means that the majority of the jobs shown on this control board are in difficulty, and that is a very common picture of the production man's problems. The conditions in this particular department are not any worse than in most departments everywhere. The difference is that on this control board the troubles stand out in bold relief while in other departments, where such control is not in effect, there are hours of conferences and miles of travel while the mental picture of affairs is still hazy.

It is convenient to use Dennison's serpentine ribbon for loading jobs on the board. A simple device such as illustrated in Fig. 295 may be constructed with small shafts at the left end on which to mount the rolls of colored $\frac{7}{16}$-inch paper ribbon. The tapes pass under a cutter blade out onto the measuring panel which, in scale, corresponds exactly with the cross-section paper on the control board. A tape of appropriate color is torn off so that its length represents the length of the job. It is marked, preferably at the right-hand end since the left-hand end gets torn off day by day, with the order number, part number, quantity, and the production rate at which the job was figured. Then along the

top of the tape there is marked off the time division and the production which should be completed at the end of each division. This production should be posted as the total to date, to correspond with the production report. The tape, with this legend on it, will appear as illustrated in Fig. 296 on which the order number is Y–719–Lot 8, the part is Y–Y–719 automobile piston pin, the quantity is 5000 which were figured to run at the average rate of 910 per working day so that the job should be $5\frac{1}{2}$ days long, tying up the machine for that time.

Usually there is one governing operation which is most important to the scheduler. In the case of printing it is the printing operation. Such other operations as perforating, folding, stitching, and trimming run much more swiftly and are consequently of less importance in the

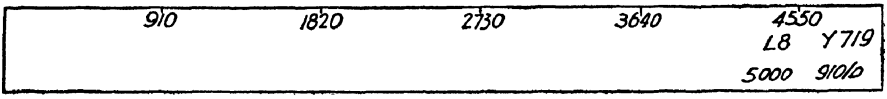


FIGURE 296. A SAMPLE JOB TAPE

control plan. In the case of the molded products there follow the press operation such other operations as cure, broach, grind, clean off fins, polish, and pack. In the case of the automobile piston pin there follow the automatic screw-machine operation such others as drill, countersink, burr, rough grind, heat treat, finish grind, inspect, and grease. All that is necessary for these swifter operations is to get them started on time and any elaborate control of that would be impractical since the control time becomes too expensive a proportion of the performance time.

Thus, for these swifter operations all that is needed is some convenient tickler file to bring operations to attention when they should start. The information required is all shown on the master route card (Fig. 248, page 588) with the exception that the standard time should be put down as the rate per hour or per day for convenience. The tickler card may be approximately $1\frac{3}{4} \times 4$ inches and designed about as illustrated in Fig. 297. This particular card is for the automobile piston pin. In the graphed lines it is important to remember that when a fast operation follows a slower operation its graph should be drawn backward from the finishing end so that it will not be started prematurely. Any convenient file arrangement may be used, depending on the degree of visibility desired. In one case a box with 31 divisions for each machine or work station may suffice, as shown in Fig. 298. The card is placed in the compartment of August 10 opposite machine No. 110. On that date, as soon as the operation has been started off, the card is transferred to the starting pocket of the next operation, or in this case, to the August 11 pocket of machine No. 113, and so on.

Another arrangement which accomplishes the same thing with greater visibility is shown in Fig. 299 for the piston-pin production. At the top is the regular load board with the job lengths marked on in pencil. It would be better to use the tapes which are pinned on, since, when a job has to be shifted to another machine, or removed from the

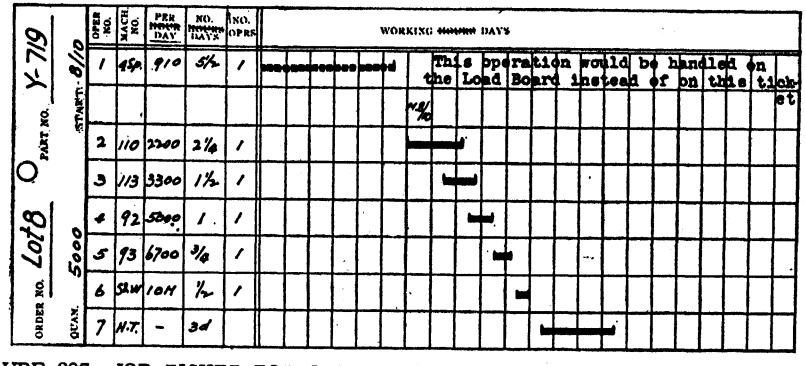


FIGURE 297. JOB TICKET FOR STARTING OFF OPERATIONS

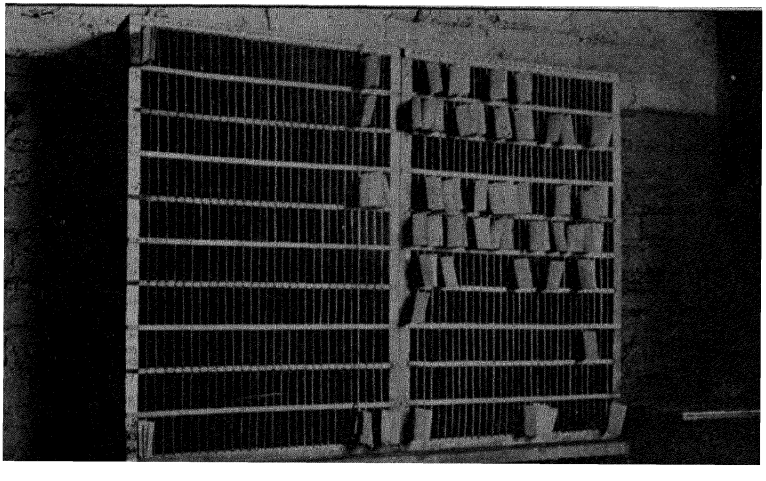


FIGURE 298. ONE FORM OF TICKLER FILE FOR JOB TICKETS

board entirely, the tape can be taken off without any erasing. At the bottom is the tickler board for starting off on schedule the operations of shorter duration. The tickler card is punched so it can be hung on the small pegs. Any operation which indicates a bottleneck can be detected immediately by the accumulation of several tickler cards on any peg. The marker cord indicates the time of reference. Periodically the total produced to date is marked on the job tape on the load board, and this posting should not be very different from the originally

scheduled production as indicated on the top of the tape in Fig. 296. If it is seriously behind, then the planner should be notified so that he may make inquiry and do what is necessary to help bring the production back into line.

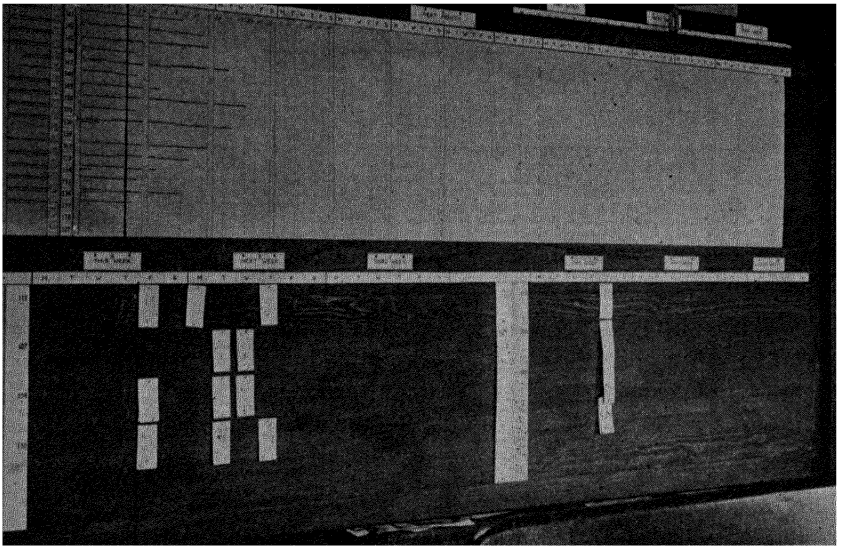


FIGURE 299. ANOTHER FORM OF TICKLER FOR JOB TICKETS

Lots

If the production-order quantity is split into appropriate lots, as explained on page 591, the various operations can be started at their proper times when the preceding operation has finished enough units to permit continuity in the shorter operations which follow. Each lot should have its identifying route tag, which is the third copy of the production order illustrated in Fig. 257 on page 605. When each lot has an operation completed the inspector or checker sees that it is properly entered on the operator's pay card, and that the operator's clock number is entered on the route tag.

In many plants it is the custom to handle small parts in barrels or large tote boxes. It is not uncommon for operators to have such a quantity of work set out so that the checker can weigh-count the lot and enter it on the operator's pay card. An informal piece of paper, with the count marked on it, is dropped on the top of the barrel or container. When no one is looking the operator shifts the position of the barrel, destroys the informal ticket, and has the lot weighed up again so he can get paid twice, or perhaps three times for the same lot.

With the formal route tag which has to accompany each lot throughout its course this duplicate paying defect is removed.

It is necessary to have in the office a progress record, which is nothing more than a production record sheet, for each individual order with the operations along the top and the tag numbers down the left side. The pay cards are brought in each day for posting this progress record. Thus if any tag number appears a second time it is promptly caught in time to make correction. The tags may not always be handled in numerical rotation in the shops, but that does not matter greatly as

NO. TAGS 10 — PROGRESS RECORD — ORDER NO. L8, PART NO. Y-719, QUAN 5000

TAG NO	OPER NO. 1			2			3			4			5					
	OK	REW	SCR	OK	REW	SCR	OK	REW	SCR	OK	REW	SCR	OK	REW	SCR	OK	REW	SCR
1	500			500			500			500			500					
2	500			500			498		2	498			497		1			
3	500			500			500			500			500					
4	500			500			500			500			500					
5	500			500			500			500			500					
6	500			500			500			500			500					
7	500			500			500			499		1	499					
8	500			499	1		500			500			500					
9	500			500			500			500			500					
10	508			508			508			508			507		1			
1													503					
2																		
3																		
4																		
8																		
9																		
0																		

FIGURE 300. PROGRESS RECORD FOR TYPE 3 CONTROL

long as there is a line for each individual tag on the progress record. The form for this progress record may be about as illustrated in Fig. 300, which covers the order for the automobile piston pins.

In the posting of this record from the operators' time cards the clerk glances across to the previous operation to make sure that there are not more parts turned in on one operation than were completed on the previous operation. At each work station there should be a job clip in which the operator may keep his time card. Fly sheets should be attached so that at the beginning of each day the old carbon-back fly sheet can be removed and a new one attached. The removed fly sheets are taken to the office for posting the progress record, after which the clerk prepares a production report and then files the fly sheets by operator number until the end of the week. Then, if it is not necessary to make any pay-roll check against them they may be destroyed.

The production report has to cover only the governing operation which is graphed on the load board and the final operation which indi-

cates the pieces finished. The posting of the control board is made from the production report, just as was the case in Type 2 control. This simple production report would take the place of any such electrical devices as shown in Figs. 292 and 293.

Type 3 control does not necessarily stand alone. It is all that is necessary in such industries as were mentioned on page 511. It may be of considerable value, however, in conjunction with either Type 1 or Type 2 control when, because of unbalanced equipment, it becomes necessary to chart the load against any machine or production center to make sure that a bottleneck may not arise without due notice.

It is sometimes suggested that if there are 10 machines of like capacity in any department, then a single line on the load board could be used for the whole group, as a production center. That would be perfectly possible of course, but the policy of using a line for each individual machine is vastly more helpful and is less confusing.

In such cases as automatic screw-machine departments, which turn out numerous parts under a coordinated Type 2 production program, the Type 3 control board would be entirely sufficient since the postings on the tapes provide opportunity for quickly comparing actual production with the required production rate. However, if conferences include representatives from the central planning office, where minds function in tune with a Type 2 board there, it may expedite results to have the screw-machine information displayed on a Type 2 board. Whether to use only the Type 3 board or both types of board in any department has to be determined in each individual case in accordance with the general observation of conditions and results obtained.

CHAPTER XXXI

TYPE 4 CONTROL

TIMING OF SPECIFIC UNDERTAKINGS

In Type 1 control we are concerned with the scheduling of relatively short jobs against individual work stations or machines.

In Type 2 control we are concerned with the scheduling of rates of incoming orders, outgoing shipments, and production against individual products.

In Type 3 control we are concerned with the scheduling of relatively long performance times against individual work stations or machines.

Now, in Type 4 control, we become concerned with the scheduling of performance times against individual people or groups of people. That is a very different matter.

In all of the first three types of control the planning function is largely centralized and executed by one individual, or a small group of closely associated individuals, who function under a common atmosphere of management and work conditions within their particular plant. All persons involved in the control mechanism are influenced by a sort of fraternal relationship in that they are all in the same boat with their helmsman, headed along a course the results of which are measured by the accomplishments of the month-by-month, or year-by-year, score. It is a continuing relationship, requiring no legal contracts, which tends naturally to encourage teamwork and cooperation. Any poor results, or good results, serve to reflect the quality of the helmsman's stewardship.

In Type 4 control the situation is entirely different, in that the undertakings are usually of a nonrepeat character. Each undertaking is different from the last and may involve an entirely different group of people who bear no other relation to each other than being temporary partners in a common contract. The relationship becomes impersonal and any poor results, or good results, while they may indicate the stewardship quality of the project leader, largely reflect the general state of our common cultural development.

Type 4 control does not always involve otherwise unrelated groups of performers. It may be helpful in an automobile plant when an experimental project of producing limited quantities of a new model as a

"feeler" of public acceptance is undertaken before venturing on Type 2 control for regular production. It is helpful in such cooperative undertakings as writing a book, rearranging a department for a different kind of production, moving a factory and its machinery to some new location, or in the task of trying to wring the maximum accomplishment from a limited appropriation or investment. In such cases there rarely arises such a question as "Who won the battle, the infantry or the artillery?" Usually all parties are closely related and the vision of all is focused on the common venture.

But Type 4 control becomes a more vital, a more valuable, mechanism in the broader field of coordinating the efforts of motley groups whose only relationship to each other is in being common and temporary partners in a specific undertaking. An interesting development has resulted in the course of such undertakings involved in the raising of money in communities for various purposes. Time was when there were maneuvers to see which of the various "drives" could capture the period nearest to the Christmas season when people were generally in the giving frame of mind. That situation was improved by consolidating various interests into one concerted, and more imposing, community fund drive. Now community-chest drives are centered around a permanent officer who remains on the job after the drive is finished to supervise the equitable distribution of the funds and to accumulate information which will help make the civic function more efficient. Such an evolution serves to put into Type 4 projects the element of continuity of relationship which is usually lacking because of the temporary nature of specific undertakings.

It is in the broad field of general contracting, where Type 4 projects abound, that our state of cultural development is most strikingly exhibited. In that field, more than any other, there is revealed the average, or cross-sectional, quality of contemporary mentality and character in terms of which we have to demonstrate the democratic idea of how to work together. There is a definite job to be done. The main, or general, contractor acquires a mental view of it. He divides up the operations and obtains bids from subcontractors, each of whom will handle his specialty part of the work. A general plan for the satisfactory coordination of efforts should be prepared and, after the subcontracts are let, a copy of the general plan should be given to each subcontractor or, as the alternative course, each subcontractor should approve his position in the general plan and allow the general contractor's office to carry out the follow-up work of getting each part of the job started off as originally scheduled. What usually makes this kind of planning rather unsatisfactory is the impersonal interest which threads through the whole procedure by virtue of the fact that the

parties involved often find themselves in the self-preservation position of trying to come through a rough-and-tumble scramble with a whole skin. The general contractor who survives and becomes successful over a period of years knows that and seeks to avoid such situations by intelligent planning and by becoming sufficiently well acquainted with various subcontractors to be in a position to surround himself with a selected group who can work together effectively and without friction, thus introducing a personal element into the equation.

The leadership in group endeavors in the contracting field may be broadly cataloged into four classes.

The first class is typified by an aggressive businessman who had made money, and acquired considerable land, through an automobile-wrecking company. His energy carried forward until he had in operation a fairly successful venture in landscape gardening. Then he made himself the general contractor for setting up an attractive diner to be managed by a member of his family. This transformed him from an enterpriser, whose businesses represented his own lengthened shadow, to a coordinator of the efforts of other people, and that led to difficulty. He let the subcontracts, after jockeying one against the other for lowest price. When the cement subcontractor tried to remove the forms from the cement there were edges which broke off. Arguments and profanity brought out a confession that having been forced to such a low price something had to be done, and so the proportion of cement had been reduced and labor effort was curtailed. Similarly with the subcontractor who put up the neon lights and the one who mounted the awnings. The sum total of the accomplishment came out when the superintendent on the job made his inspection. More cement was broken; in vigorously testing out the awnings the neon lights were broken; and a general atmosphere of disgust prevailed, so that the self-appointed contractor argued that inasmuch as the diner was not originally designed for the accessories which should normally be added, there was no reason why he should pay the full price for the diner. Inasmuch as the cement work did not satisfy him he refused to pay for any of that. Inasmuch as the neon-light specialist had not anticipated the possibility of awnings, he would have to whistle for the rest of his money, and inasmuch as the awning maker had left a possibility of danger to the light tubes he, too, would have to be content with only a part of his money. Litigations blossomed, the whole venture was highly unsatisfactory, and the whole project, instead of being managed by a member of the family, was disposed of at a loss.

The second class is typified by the main contractor who figures there is more profit in taking advantage of the gullibility of subcontractors than in becoming embroiled in the work itself. The yellow pages of

telephone books and the classified pages of city directories are consulted, and lists are prepared of numerous key-numbered subcontractors for each division of the work involved in the general project. All are sent postal cards asking them to come to the contractor's office, examine the blueprints and specifications, and submit their best quotations. The bids are carefully tabulated, indexed, and scrutinized. Selected bidders are called in and told that the quality of their product and workmanship are just what is wanted but the other fellow's price is much lower. Would they take the job at the other fellow's price? If not, then knock off a few dollars anyhow. Usually, in such circumstances, the subcontractor who declines to give ground can be harassed by numerous complaints which require enough additional attention to destroy any profit he might have made had he but been in a position to recognize the earmarks of the situation. On the other hand, under such conditions, there grow up a defective lot of subcontractors who seek to make profit in like manner by contracting for "a five-ply roof with copper flashings" and, when no one is watching, install a one-ply roof with painted galvanized flashings, and a corresponding lot of subcontractors who, as confidentially understood, put into their bids a portion of "gravy" which remains on the contractor's plate after the feast is over. Such contractors do not last long unless there exist political situations which enable them to enjoy a precarious existence.

The third class is typified by the contractor who is captivated by action and speed. There is not so much debate over price because he has a fair sense of about how much good work should cost, and he wants good work. So "hurry! how long will it take?" "There is going to be an inspection on Friday so your work must all be finished by Thursday — better make it by Thursday morning." The experienced subcontractor recognizes the difficulties he may encounter and cautions the contractor that he will perform by the desired time if conditions are ready for him at that time. The paint should be dry and the work on which his part of the job has to depend must be ready. "Will these things be ready?" "Yes, they should be ready; they are scheduled for completion Wednesday night." So, with all speed ahead the subcontractor interrupts his present schedules in order to accommodate this rush job (and all jobs are rush) and appears on the scene with his crew early Thursday morning only to find that the paint is wet, painting still in progress, and the work on which his part depended had been changed so that the dimensions which he recorded in the initial rush to get started are no longer right and he must either do his work over or resort to some makeshift "to get by." The main contractor may be entirely reputable and offer to pay for any additional work that is necessitated by changes which were made "during the night," but the whole picture is such as to stimulate the emotional side of cooperative

endeavor at the expense of the intelligent side. "Never mind the confusion, just hurry up!" This class of contractors, often successful and reputable, make their progress in a laborious and distressing manner.

The fourth class is typified by the contractor who tries to be slow and sure-footed. Like the student of anything who chooses the hard way because it looks to him like the surest way, he approaches a project with alert and analytical mind and recognizes that any accomplishment worth while means work. A definite project is to be undertaken and that project will be most efficiently executed if he surrounds himself with the right kind of people and coördinates their efforts in such a way as to minimize waste and emotional disturbance. Such a contractor becomes an expert in his field. His course is not an easy one because in the great majority of cases, wherein he has to submit competitive bids, decisions, whether by mandate or not, are given to the lowest bidder regardless of his policies or the quality of his performance. A contractor in this class feels ethically responsible for the financial safety of his associated subcontractors and tries, at the same time, to see that the purchaser gets what he wants at the best price. That means efficient planning and such planning means work.

The first problem of a contractor in this class is to get well acquainted with a group of subcontractors whose reputations and performance are dependable. Then the best practicable plan for coordinating their efforts is prepared, intelligently executed, and a record kept of actual performance for comparison with what was planned. To illustrate, consider the construction of a modest dwelling for which the architect's plans have been prepared and approved. The problem is to execute the construction in minimum time.

The knowledge required to start with is as follows:

Operation	*Time Required, Days*	*Notes*	*Subcontractor Selected*
1. Survey the lot	1		
2. Excavate	3	Can start immediately after operation 1	21
3. Masonry	10	Immediately after 2	48
4. Carpentry	34	Start 6 days after start of 3	113
5. Plumbing: piping	9	8 days after 4 starts	88
6. : set fixtures	5	7 days after 11 ends	88
7. Heating: piping	9	Start with 5	34
8. : set radiators	2	Finish with 5	34
9. Electric wiring	7	2 days after 7 starts	236
10. Electric hang fixtures	2	1 day after 12 ends	236
11. Plastering	7	2 days after 9 starts	3
12. Painting	11	1 day after 11 ends	27
13. Paper hanging	5	7 days after 11 ends	7
14. Clean up	3	1 day after 13 ends	–
Total	108 working days		

This minimum planned time is what he would aim at and by skilfully planning the starting times of the various operations so as to avoid conflicts and interruptions, the spread of 108 working days is reduced to 45 working days. Delivery would be promised for such a time as would allow some leeway for unanticipated delays, say 9 weeks after the start of operations. That would be equivalent to scheduling 80 per cent of perfection so that if the plan indicates a net construction time of 45 days this would be divided by 0.8 and delivery promised for 56 days.

It is desirable for each subcontractor to be informed of the master plan so that he may feel a due sense of importance in meeting his part of the work as scheduled. A graph is prepared as illustrated in Fig. 301. In this graph there is one line on which to draw the performance as originally scheduled and immediately below that another line on which to draw the actual performance. Notes should be made of any circumstances which make actual performance differ noticeably from the planned performance. In this way there is accumulated a record which is of considerable value in the planning of new jobs which may be similar.

If a copy of this graph is given to each subcontractor so that he may see the relation of his individual part to the whole program, and then if the main contractor carries on a systematic follow-up to ensure concerted attention to the program, there will be little cause for undue haste or for confusion in the profitable execution of the work.

There exists here the same difficulty as was mentioned on page 590 of Chap. XXVII on the Planning Department concerning the use of these bar graphs. If the dwelling project were the only job on the docket of each subcontractor there would be no difficulty whatever in arranging to meet the schedule. However, one or more of the subcontractors may be engaged in several projects simultaneously. Compare the carpenter, who is scheduled for 34 days, and the plasterer who is scheduled for 7 days. If both of them are engaged for three such projects which are scheduled by the main contractor to run in immediate succession, then, while the carpenter may have continouus employment the plasterer must lose 22 days before the first job is ready for him and 27 days before the next job is ready for him. Such difficulties are inherent in all ventures which require several operations of widely different performance times. They can be met only by making a separation between those jobs which have to be performed on schedule and those which can be sandwiched in with some degree of flexibility, or by hiring and firing experienced workmen according to the fluctuating demands.

The most satisfactory way for each subcontractor to meet this

Bldg. Dwelling	Owner C. E. Jones	Contr. Date Feb. 4, 1941	Contr. No. 377
Loca. 43 Prospect Lane, Crest Hills	Arch. B. Heath	Est. Cost $3500 Act. Cost	Comp. Date Wtd. May 14, '41 Act. Comp. Date

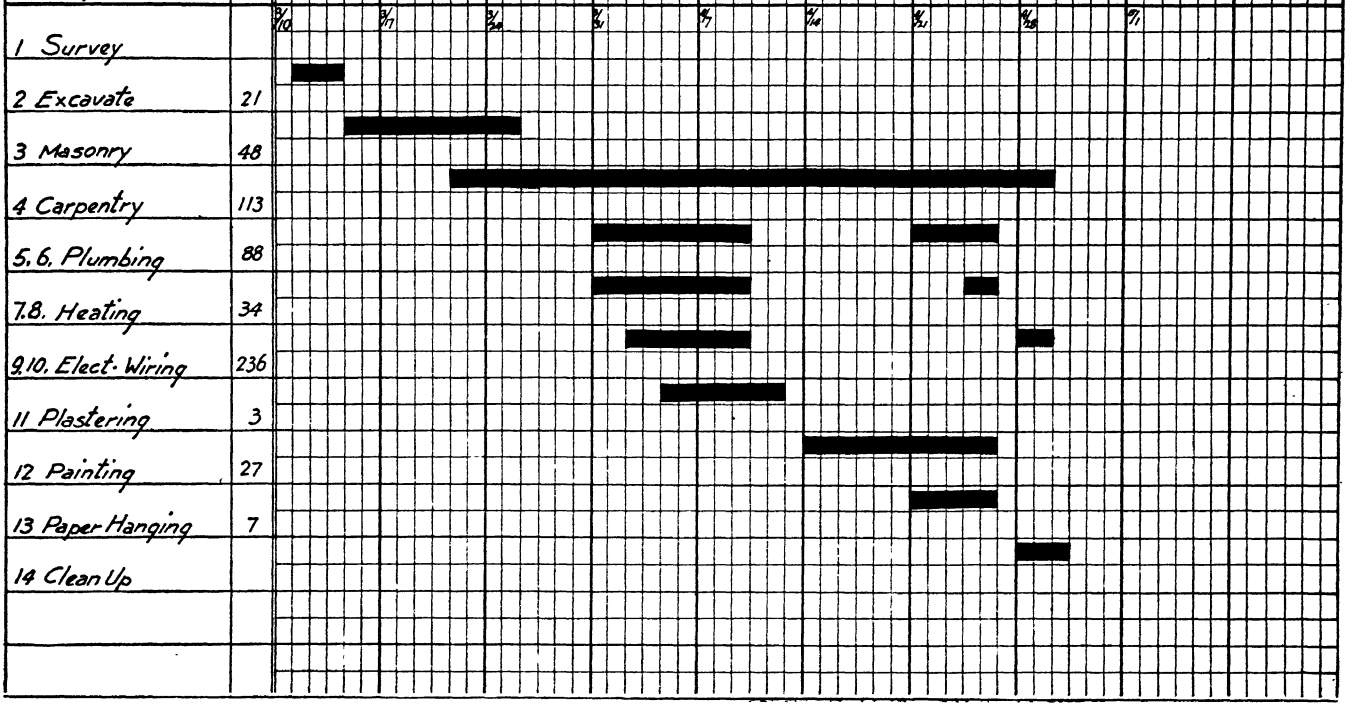


FIGURE 301. SKILFULLY PLANNED CONSTRUCTION PROJECT

Courtesy of L. P. Soule, Boston

continuity problem is to resort to Type 3 control, chart the times during which his crew will be occupied on coordinated contract jobs, and then make use of any gaps between these jobs to schedule other work which is not related to the performance times of other groups.

In the great majority of cases this is very feasible since, when a customer is informed of a contractor's problem and of his intelligent plan to handle it to best advantage for all concerned, that customer will accept a promised performance date even if it does not closely conform to what he had wanted in the beginning. If, however, the customer indicates that, after all, he is not particular about having any one contractor handle the job so long as he gets it done promptly, then in order to save the job a journeyman can be hired just for the emergency.

Skillfully handled, Type 4 control can be one of the most profitable mechanisms in the coordination of group efforts.

QUESTIONS AND PROBLEMS

CHAPTER XXIV. (NOMENCLATURE)

1. The sales department may issue repair-parts lists as a supplement to the sales catalog. Discuss the advantages and disadvantages of showing standard commercial parts on such lists by the stock numbers you have assigned to them.
2. The stores-record clerk frequently has to write out purchase requisitions for replenishing stocks of commercial parts and raw materials. On these requisitions should he show only the stock numbers which you had assigned or only the description or both? Why?
3. Should the purchasing department ask for a copy of your classification sheets, or parts index, so that the stock numbers of commercial items may be entered on purchase orders which are sent to suppliers?
4. You are called on to serve a new Type 1 manufacturing plant engaged in producing precision gauges. You want to expedite the clerical work of selecting, designating, recording and costing the numerous commercial items and therefore start to prepare a parts index. Three of the raw materials carried in stock are half-hard brass sheets hard-drawn seamless brass pipe, and round phosphor bronze rods.

   The first size listed for the sheets is No. 28– B and S Gauge, 0.012 = 10 in. wide.

   The fourth size listed for the pipe is $\frac{1}{2}$ in., 0.107 wall, 0.625 ID.

   The tenth size listed for the rod is $\frac{3}{4}$ in. diameter.

   Set up stock numbers for these three items.
5. In the pattern shop there are carried numerous sizes of steel brads, wood screws. finish nails, and wood plugs used to fill counterbored holes for screws. These are considered supplies, charged off to expense, and used as needed by the several patternmakers. One of the newer clerks in the cost department has taken quite an interest in your stock numbering system. It is his job to figure the costs for the pattern and tool departments and to post them to the development orders. He suggests to you that the numbering system should be applied to all of the supply items carried in the pattern department and that the patternmakers should be required to write out requisitions for all the brads and screws they need for the simple patterns they are making. Nearly every day you receive dozens of similar suggestions, concerning other matters, from all over the organization and these, while indicating that your work is being looked upon with enthusiasm, tend to tire you. You were extremely busy at the moment and your short answer failed to satisfy the ambitious youth.

   He puts it up to the head of the cost department who, thinking it might be a good idea, comes to take it up with you. Being mindful of management strategy, you suggest that the cost head call in his clerk who originated the suggestion so that he might feel himself an important part of the conference.

   Then how would you answer the suggestion?

CHAPTER XXV. (STORESKEEPING CONTROL)

1. The finished-parts storeskeeper complains that often he has to make repeated trips to the same location because the same item appears over and over again on the various material lists coming into his department each day. He requests

that individual requisitions be written out for all items on all material lists so that these may be sorted and combined. He is very nice about it and merely wants to ask your opinion of the suggestion, saying that in order to make the writing of the requisitions easy you could fit up a typewriter with continuous strip forms.

How would you answer him?

2. One of your opponents in the organization hears about this suggestion and sees in it an opportunity to "put you on the spot." He makes a quick survey of several material lists and finds that one item in particular, a locking lever, appeared seven times on the same day. He goes to the manager (who is also a director of the company) and the manager calls you in for an explanation.

   Recognizing that you may have to give a more penetrating answer than you gave to the storeskeeper, how would you handle the situation?

3. Upon getting a job in the production department of a machine-tool manufacturing company you learn that there are, in the several departments, six stock chasers whose job it is to run down shortages of materials and parts which are holding up production orders.

   What may be wrong? In such a company of, say, 500 employees, how many stock chasers would be appropriate?

4. In a Type 1 company making special packaging machinery the accountant claims that on the stores record there should be provision for making a financial record of the inventory. He wants you to add a column in which to show the dollar value of the inventory at all times, giving as his reason the simplifying of the computations in his department at annual inventory time. He argues that there are 40,000 items in stock and since your policy of always keeping the record and the actual bin quantities in agreement, by use of your bin-check tickets, makes it possible to take the inventory directly from the stores record, his department could complete its work in a mere fraction of the time if you would show the dollar value on the stores record.

   How would you answer that?

5. The Egyptian horn fiber which we use for making armature insulating punchings is purchased by the pound. In order to be able to predetermine the stock required for definite numbers of punchings called for on production orders it is necessary to specify it by square feet or by sheets. The sheets vary in thickness, not being uniform, since they are not milled to gauge, and therefore vary in weight.

   What information should be shown on the stores record?

6. In stock there are, under stock number 5924–3, 50 malleable iron pulleys which cost 15 cents each. A new lot of 500 is received into stock and the purchase price on these is 12½ cents each.

   What would be the new costing price shown on the stores card?

CHAPTER XXVI. (DEVELOPMENT AND ENGINEERING)

1. You are in the engineering department in charge of the parts index. Somewhat accidentally you discover that, as shown in Fig. 233, page 562, it appears as if only one size of drill rod is carried in stock. Yet you recall perfectly well that on ML X–150 (Fig. 239, page 570) you had noticed two other sizes — items 9 and 13 — which were specified as stock items. It appears that the draftsman, in preparing the material list, had either neglected to issue the new part notices or these notices had become lost.

   a) Enter on Fig. 233 the missing stock numbers.

   b) What further steps should you take to make sure that these two items had been properly set up?

c) Prepare a new part notice (Fig. 236, page 566) for the 11/16-in. size, recommending an initial quantity of 100 lb. for stock.

d) The stores-record clerk calls you back and says you have specified 100 lb., whereas the way this is carried in stock is in standard 3-ft. lengths. How would you handle that? (You might compare your answer with that for Ques. 5 of Chap. XXV.)

2. Referring to Fig. 234, page 563, it is approved by the development engineer that we may cancel part Z–1273–2 and substitute for it Z–1273–6. What steps are necessary to do that properly?

3. The shipper reports that a note was sent him by the sales department calling attention to complaints received from customers to the effect that in each shipment of transmitters there should be included four 5/16 in. × 2 in. steel lag screws for attaching the transmitter to its table. The shipper says he ought not to be expected to remember so many details of this kind and proposes that all such items ought to be shown on the material list and come to the shipping department with the transmitters all ready for shipment. You agree with him and you proceed to add this stock item to ML X–150. Upon looking up a table of sizes you find that this particular size of lag screw is the third size.

a) What stock number would you use?

b) Is anybody else concerned with this change? What records are affected?

c) Should you dictate notes to all department heads throughout the organization, or issue copies of a new part notice or copies of a changed part notice?

d) Would you ask the chief engineer to call a meeting of the heads of engineering, shipping, planning, stores, cost, and shop departments to get their approval of the suggestion?

e) What usually determines how far you should go with a simple suggestion of this kind?

4. The assembly-department foreman says that, particularly with his newer men, there is some anxiety that maybe they are not putting assemblies together in the quickest and easiest way. He suggests that on the material list, with which the assemblers are thoroughly familiar, you should print a list of the assembly operations.

How would you answer that suggestion?

5. A salesman brings in from the field a suggestion that with the Model 7 Transmitter we ought to supply a treadle hook which would connect the lever with the foot-operating treadle. This suggestion is approved by the development engineer without further ado, and he specifies that the hook should be 22 in. long, requiring 24 in. of cut wire. It is proposed to make this hook to drawing Z–1150, not to stock it at present, and to use for it 3/16-in. drill rod which ought to be carried in stock.

Print out the line for this item as it should appear on the material list.

CHAPTER XXVII. (PLANNING PROCEDURE)

1. "One type of machine gun being manufactured involves more than 1800 separate machining operations, of which 66 are required on the bolt alone."

The transmitter plant is to be converted to machine-gun production and you are delegated to set up the master operation cards. You find that your regular card provides only 24 lines, whereas for the bolt you will need 66 lines.

Should you try and list the operations on three separate cards and mark these cards No. 1, No. 2, and No. 3, or list some of the operations on the reverse side of the card, or would you provide a new and larger form?

2. Someone suggests that in view of a contract clause binding your company against the disclosure of "any information regarding equipment or materials of the model or kind referred to in any of the specifications, plans, or papers accompanying the order," you should not order any such routing form from an outside printer but should have a blueprint made up by the engineering department.

   How would you answer such a suggestion?

3. Schramm Incorporated is engaged in the manufacture of a variety of advertising novelties. One of the most popular items is a detachable calendar pad back on which an advertising message is embossed. The first four operations are always the same — shear to length, shear to width, remove burr, and punch three holes. The remaining six operations have to be held off until specific sales orders are received giving the details of the advertising message — emboss, hot wash, enamel background, overprint message, inspect, and wrap. For years sales have been more than a million units.

   What sort of production-control plan would you set up for that?

4. These calendar pad backs are cut from 20-gauge aluminum sheets which come 10 ft. × 5 ft. The backs measure 3 in. × 2 in., so that 1200 can be cut from one sheet. The first four operations, including setup time, run as follows:

   1. Shear 60 in. × 3 in. . . . 40 strips per minute
   2. Shear 3 in. × 2 in. . . . 60 backs per minute
   3. Remove burrs . . . . . 30 backs per minute
   4. Punch 3 holes . . . . . 50 backs per minute

   Stock has run low and you issue a replenishment production order for 600,000 backs. The first operation is of short duration and does not require any formal production-control provision other than the Type 1 job-sequence board in the shear department. Operations 2 to 4, however, will tie up equipment for a considerable time.

   On the basis of a normal 8-hr. day, and assuming that you will allow for 20 per cent delays due to various kinds of interruptions, compute the number of days that will be required for operations 2, 3, and 4, showing your times to the nearest half day.

5. The following four operations which follow the receipt of a specific sales order run, including setup times, as follows:

   5. Emboss . . . . . 1200 per hour
   6. Hot wash . . . . . Day work. Allow ½ day.
   7. Enamel background . . . 720 per hour
   8. Overprint message . . . . 360 per hour

   An order is received from R. O. Hooper Co. for 20,000 backs with a special advertising message in red over black. Without making any allowance for interruptions, compute and chart the planning record, using only one operator on each operation, as illustrated in Fig. 249, page 589.

   Immediately following this order there is received one from Rola Club Stores, Inc., for 10,000 with a special advertising message in gold over blue. Without making any allowance for interruptions, compute and chart this planning record.

   The manager asks you to try and run such jobs concurrently so that all equipment is kept busy all the time, and also to ensure immediate shipment on each order. Can you do that? What conclusions would you draw?

CHAPTER XXVIII. (TYPE 1 CONTROL)

1. In operation 3 of the notes it says that the draftsman should completely extend the material list. The management has called the chief engineer's attention to the

fact that the expense of operating the engineering department seems high. He gives credit to the department for having made skilful use of draftsmen as junior engineers but says that in the shop all of the foremen are old-timers who know the products well and wonders if the material-list work could not be abbreviated by merely specifying the drawing numbers of parts and allowing the foremen to requisition materials and parts as they are required and according to their knowledge of what is needed. This would make the material list merely a drawing list.

How would you reply to that?

2. In operation 5 it says that the clerk in charge of the parts index sees that from the new part notices each new part or material is recorded in the index and that its status is recorded. Yet, in Fig. 233, page 562 and Fig. 234, page 563, the status is recorded for only the stocked items.

   Is that all right?

3. In question 2 at the end of Chap. XXVI on Engineering, the cancellation of part Z–1273–2 is called for. Refer back to page 560 to see what "canceled" means.

   What is the difference between a canceled part and an obsoleted part?

   Turn to Fig. 234, page 563, and enter the new status for this part in the status column.

   Would it be more satisfactory just to erase this part from the parts index? Why?

4. When an order is to be issued to the shop by the planning department for, say, 25 X–150 transmitters, and a blueprint requisition is sent to the engineering department, what blueprints must be provided?

   Referring to Fig. 260, following page 608, how many blueprints will be required in addition to the two copies of the material list.

5. *a*) How many copies should be made of each production order and where do the copies go?

   b) Under what circumstances does the route-tag copy have to be reproduced for additional copies?

   c) The text explains that ordinarily only one "original" production-order copy is made but that other copies may be made, one for each department concerned. At a foremen's meeting it is suggested that all departments should get copies of all orders so that the shop may know what is coming through.

   How would you answer that?

6. A customer calls up the manager and complains that his shipment was promised for last Friday and its failure to arrive has seriously embarrassed him. Upon investigation by the superintendent it is found that an important part had been spoiled and that the inspector had prepared the customary defective-work ticket and specified that a replacement part was wanted. Unfortunately the planner had been mixed up in half a dozen other complaints of this kind and accidentally overlooked this ticket so that the replacement was not ordered.

   After making peace with the customer the manager said that a stock chaser must be added to look out for such cases and, since the fault rested with the planning department, the cost of the stock chaser should be charged to that department.

   If you were the planner, what position would you take in regard to this proposal of the manager?

7. The receiver, during wartime rush, noticed that his file of triplicate copies of purchase orders seemed to be growing faster than it was shrinking and wondered if his department were slipping. He decided to come in on Sunday and make an analysis of the file to see if he could find some clue. Pulling out all orders that were older than a reasonable date, he discovered that of these old orders 15 per

cent had not yet been filled and should be jacked up, 38 per cent had been cancelled and he had not been notified, and 47 per cent, on further investigation, showed that the goods had either been called for or had been delivered "rush" direct, without clearing through the receiving department.

The custom had always been to take a few days off near the end of each year and clean out the file, but this expense was apparent and was one which should not be charged against his department since he was not at fault. Upon putting it up to the manager the manager remarked that in talking the situation over at a Rotary Club meeting it seemed that this condition existed in all large manufacturing plants, but that if the receiver could think of any way of improving the situation to go right ahead and do it.

If you were the receiver, what would you do?

8. The finished-parts storeskeeper received from the receiving department a special gauge addressed to Accumulation Stall 16. Upon going to that stall he finds it empty. Where does he go from there?
9. Some of the difficulties with which the planner had become entangled in Ques. 6 were traceable to an ambitious foreman. It was his habit to look over all new jobs coming into the department. If one of his machines happened to be set up for a milling operation then he would put together all of the jobs calling for this particular operation, regardless of wanted dates, thus saving setup costs. That was one of the principal ways in which his department had made a better showing than other departments, since setup time was handled by special setup men whose time, rightly or wrongly, was charged to overhead expense.

How would you handle the situation?

CHAPTER XXIX. (TYPE 2 CONTROL)

Figures are disguised. Assume that in a stove manufacturing company the data are as follows:

Week Ending	*Net Sales*	*Units Produced*	*Labor Cost per Unit*
Jan. 6	$ 10,758	131	$43.40
13	15,823	323	40.80
20	17,852	873	21.00
27	21,071	498	49.35
Feb. 3	23,265	666	29.25
10	20,316	632	31.38
17	20,618	656	30.30
24	21,578	642	31.05
Mar. 2	22,014	567	34.80
9	21,986	700	29.40
16	21,242	673	31.05
23	21,272	578	33.90
30	24,075	720	28.20
Apr. 6	20,038	622	32.56
13	26,562	608	33.00
20	26,892	727	28.50
27	29,434	707	29.40
May 4	23,719	680	27.60
11	27,113	554	40.75
18	29,942	372	43.20
25	35,534	645	31.37
Jun. 1	37,096	584	29.70
8	15,548	704	29.55

Week Ending	*Net Sales*	*Units Produced*	*Labor Cost per Unit*
Jun. 15	$ 15,070	732	$28.50
22	14,925	680	30.46
29	18,980	519	38.40
Jul. 6	11,274	91	62.10
13	12,721	458	36.60
20	15,420	399	39.30
27	14,779	542	30.30
Aug. 3	20,281	322	46.35
10	13,852	478	32.70
17	26,701	519	33.90
24	35,581	499	33.00
31	51,840	454	43.20
Sep. 7	52,302	492	36.30
14	65,211	606	35.58
21	76,760	576	37.95
28	124,703	578	39.76
Oct. 5	95,768	723	33.15
12	79,620	809	30.00
19	80,339	747	31.80
26	78,216	712	32.57
Nov. 2	90,710	741	30.60
9	62,188	861	26.86
16	60,940	812	28.06
23	53,214	841	26.26
30	63,088	584	29.28
Dec. 7	65,901	803	26.27
14	62,421	879	24.30
21	48,993	814	25.06
28	32,257	389	21.30

A variation in the numbers of different models put through each week would make a difference in the units produced and the labor cost per unit. However, for the purpose of this problem, assume that the composition of production was the same throughout the year. Labor is paid on an hourly basis.

a) Plot a curve of the sales. Would you propose a quarterly, semiannual or annual production schedule?

b) Arrange the data in any way that is most convenient in helping you to a conclusion. Then compute the savings which might be possible through the introduction of Type 2 control.

CHAPTER XXX. (TYPE 3 CONTROL)

1. In the plastics department order number 2161 is received for 100,000 emblems which can be attached to automobile number plates. The emblems have to be molded with two inserts which are to be supplied by the customer as needed. The die is designed to mold two emblems at a time. One press will be used and, if everything runs perfectly, this will turn out 1000 per hour, or 8000 per day.

   Schedule the job to run at 80 per cent of perfection and prepare a sketch of the tape which will go on the control board for the emblem and the corresponding tape for the inserts.

2. The fact that this problem is entered under Type 3 control should not mislead you into thinking that only that type of control is the proper answer.

In an automatic screw-machine department work is done for other departments and also for outside customers. There are 100 machines of various types and capacities. Of these

25 are reserved only for outside work.

40 work on parts for the departments making standard radio sets and intercommunicating telephone sets.

20 work on various parts which are ordered to replenish stocks of standard parts which are stocked for other departments and ordered by the stores-record clerk.

15 machines are held in reserve so that any important jobs may be transferred onto them in case of necessary repairs to the regular machines.

What sort of production-control arrangement would you provide for this department?

In the event you suggest control boards draw sketches which will indicate how you would set them up and how you would have the job records recorded on them.

CHAPTER XXXI. (TYPE 4 CONTROL)

Using the data shown in Fig. 301, page 679, assume that under a housing project you are to build a row of 10 identical dwellings like this one, the only difference being in the color of the shutters.

a) Draw a new chart, arranging the various activities for quickest turnover — that is, for completion in minimum time — and, assuming that everything will go precisely as planned, compute the number of 5-day weeks that will be required.

b) Some of the subcontractors object to this scheme because you plan to interrupt their work. They say it would be only right to plan the project in such a way as to provide them with a continuous job, as nearly as possible. Redraw the chart on this basis and compute the number of 5-day weeks that will now be required.

PART VI

COST CONTROL

The control of manufacturing operations and the control of costs of manufacturing go hand in hand. When the physical plant is organized and the personal requirements provided for, it becomes necessary to establish controls which will not only see to it that manufacturing operations proceed according to plan, but that the costs incident to their completion are controlled so that the whole enterprise may be conducted at a profit. This part of this text deals with the control of those elements of total costs of manufacturing about which the manager needs particular knowledge and which do not require specialized knowledge of accounting for understanding and application. These topics are discussed in chapters under the following titles:

1. **The distribution of overhead expense.** The costs of raw materials may be controlled through keeping records of material requisitions; labor costs may be controlled through use of pay-roll slips and other forms which show the time spent in doing given jobs and the amount to be charged for them.

   The control of manufacturing expenses — overhead costs — however, requires special attention. It is necessary to determine these costs as totals and then allocate them to various manufacturing divisions or departments so that the overhead costs of manufacturing individual products may be specifically known. The hourly overhead rate method of adding overhead cost to the cost of manufacturing is used as a basis for discussion in this chapter.
2. **Control of variable costs.** Some manufacturing costs remain fixed in amount regardless of the actual time devoted to manufacturing operations. There are costs, however, which change with increases and decreases in the number of productive hours which the plant may operate. These costs do not always rise directly in relation to increases and decreases in production time (actual manufacturing time), but frequently rise and fall slower or faster than changes in productive time. The control of overhead expense items which are variable is essential to sound management and budgeting.

3. **The cost diagram and its ratios.** To control the exact amount of manufacturing cost does not completely fulfill the function of management in this connection. It is necessary also to determine to what extent managers can exercise certain action concerning organization activities. Managers are more or less restricted in their freedom of action by the sales income per dollar of direct labor pay roll. Consequently, it is necessary that controls be established so that each manager may have a clear picture of the relationship of the manufacturing costs of his organization in terms of income as compared to that of competitors. In general, the manager of the large organization has much more freedom of action than does the manager of the small organization because the sales income per dollar pay roll is so much greater. This is discussed and illustrated in Chap. XXXIV.
4. **The triangle diagram.** In the control of manufacturing costs also it is important for every manager to make an analysis of expenses in relation to changing production levels. It is more important to understand the probable outcome of manufacturing operations in terms of costs than attempt to make a refinement while manufacturing operations are under way. The triangle diagram is a tool of management which provides a basis for constructive action in deciding matters of production policy and cost control.

CHAPTER XXXII

DISTRIBUTION OF OVERHEAD EXPENSE

Cost control in a manufacturing plant is a sort of over-all measuring stick by which management judges the effectiveness of the application of principles of organization and control to physical operations. If an industry is to be run profitably, its income must not be "frittered away" for needless and useless undertakings; and expenditures must be kept at a minimum in keeping with the efficient operation of the entire plant. The degree to which both of these are accomplished throughout the entire organization is the final measure by which management, supervisors, foremen, and department heads are judged for competence and effectiveness in the positions they hold. Self-interest dictates, therefore, that those charged with managerial responsibilities have an understanding of costs.

MANAGEMENT COST CONTROL — KEEPING DOWN OVERHEAD

The cost of raw material in a completed product is simply the value of the materials requisitioned and used in its manufacture. (This cost includes materials spoiled, wasted, or lost through shrinkage in the process.) Pay-roll slips provide information needed in arriving at labor costs. The pay-roll slip shows the work to which the employee has devoted time, the number of hours worked, and the rate of pay per hour — or, if a piece-rate system is used, the number of good pieces completed and the rate of pay for each.

The management problem of cost control arises from the fact that it is not only necessary to keep at a minimum the material and labor costs in all departments, but also a host of items known as *overhead* — taxes on machinery, insurance costs, supplies, power, maintenance, and building expenses.

Except as managers know the techniques for doing this they cannot "spot" in the reports rendered to them costs which are improperly charged, let alone question them intelligently. It is desirable too that managers be able to understand what gives rise to overhead expenses as well as methods of handling them so as to establish policies and objectives for the cost department in keeping with the rest of the business.

For purposes of simplicity, the fundamentals of controlling overhead expenses through use of *the hourly overhead-rate method* will be presented in this chapter. This is one of the methods used to add overhead costs to other costs of manufacturing. The particular method used to add overhead expenses to the costs of manufacturing is not really so important as it is to arrive at an accurate overhead-expense cost for each step in the manufacturing process in order that this cost may in turn be assigned to each product made. The basic principles can be understood without knowledge of bookkeeping debits and credits, and with careful study almost everyone can apply them to arrive at accurate and usable cost data.

THE HOURLY OVERHEAD-RATE METHOD

Hourly overhead rates are a convenient means for approximating overhead costs for products at the time of their manufacture.

Overhead expense items are both variable and nonvariable. Those that are variable increase or decrease in amount with the volume of products being manufactured. Typical of such items are repairs and maintenance to machinery, and manufacturing supplies.

Nonvariable items include real-estate taxes, depreciation, and insurance on equipment, which remain constant in amount regardless of the extent to which the plant operates. (The totals of these items may change, however, from year to year.) Consequently overhead costs are never wholly accurate when they are assigned to the product being manufactured.

The mechanics of arriving at hourly overhead rates for a manufacturing department follow:

Total productive hours (machine or man):	
Working days in period	300
Times hours worked per day	6
Total working time for each unit (man or machine)	1800
Times number of units (man or machine) in the production center or department	200
Total man- or machine-hours in department or production center	360,000
Less idle time allowance — 10%	36,000
Total productive time (man- or machine-hours)	324,000

If a $100,000 overhead expense is estimated for the department having 324,000 man- or machine-hours, the hourly overhead rate will be $\frac{\$100,000}{324,000}$ hours or $0.3086. The significance of this figure is that a product processed in this particular department will have added to its labor and material cost an overhead expense of $0.3086 for each hour

it is worked on in the department. The total *factory*[1] cost of the product will be:

Raw materials	$2.00
Labor	2.60
Overhead:	
6 hr. @ $0.3086	1.85
Total department cost	$6.45

Before achieving this final result, a sizable number of cost-finding procedures and steps have to be completed to arrive at the total departmental overhead expense (the estimated $100,000 figure used to find the H.O.R.).

A mere record of the amounts of money expended for overhead tells nothing about the importance of each expenditure in relation to each product. Accurate unit costs of different products may be determined only when the overhead expense items are so split up that it is possible to assign a portion of each to all products manufactured. This is accomplished by a procedure known as the *distribution of overhead expenses.*[2]

The term "distribution" means collecting and breaking down the overhead charges of the factory so that each department (production center or machine) will have assigned to it only those overhead costs which are its proper share. The total amount of overhead costs to be borne by any department results from a distribution of both *known* and *estimated* costs based on previous experience and changes in costs expected during the period for which costs are being compiled.

In brief, the procedure is to assign portions of each expenditure to the factory services and manufacturing departments which are benefited by the expenditure. After the total cost of the factory services has been ascertained, these are also distributed among the manufacturing departments using these services, so that the total of all costs assigned to a manufacturing department may be found. The key to rapid and correct burden distribution is to obtain a concise and fair means of apportioning each expenditure among the various services and departments which caused the expenditure to be made. The maintenance department, for example, serves all the other factory departments. In reality, it is the remainder of the factory which causes the expenditures that are made for maintenance. In distributing this maintenance cost to the other departments the question arises as to *just what portion* of the total should be borne by each department.

Usually some one characteristic of the other departments is selected as the basis for this distribution — square feet or floor area, horsepower ratings of machines, or horsepower-hours operated.

[1] Excludes selling and administrative expenses.

[2] A synonymous term is *burden distribution.*

Regardless of the characteristic selected, burden distribution in the last analysis is a matter of judgment, and not of systems and rates. Rates per square foot or per horsepower-hour are used to facilitate the clerical procedure, but there is no check for the fairness of results except executive judgment, and the specific rates and characteristics used should always be subject to review and revision by those in charge of the work. The detailed mechanics of burden distribution are discussed in the following paragraphs.

PRELIMINARY STEPS

Preparatory to making a distribution of overhead expense, much time and effort may be saved if steps are taken in advance to obtain the following information:

1. The size and location of each manufacturing department (or production center). A carefully drawn plan should be made to show the complete layout of the manufacturing plant as now operated.
   a) Determine the area in square feet of each manufacturing department.
   b) Make an inventory of the number of units and value of each type of machine used for productive purposes in each of the manufacturing departments. List also the quantities and values of special equipment and tools, furniture, and fixtures.
   c) List the purpose of each item (machines, furniture, fixtures) in the inventory.
2. The space occupied and the equipment used by the service departments should be made. These include:
   a) Receiving and shipping departments
   b) Employee facilities and service areas (factory)
   c) Material-handling department (if centralized)
   d) Storage areas for raw materials, supplies, tools, finished goods
   e) Stair wells, corridors, unused areas
   f) Administrative departments
   g) Executive offices, sales division
   h) Employee facilities (administrative)

When the foregoing information is available, the departments and service areas whose expenses arise from the actual conduct of manufacturing operations should be separated from those which result from activities of an administrative nature. The so-called administrative burden expense is *figured separately* and includes costs of the following: factory executive officers' salaries, sales officers' salaries, shipping and delivery department expenses, and expenses of specific departments pertaining to administration (accounting, demonstration, or display room).

Following the selection of the factory departments and service areas, a so-called factory burden distribution sheet may be constructed for use in recording cost information as compiled. (See Fig. 302.) This form should be lined to provide columns as follows:

1. Column for expenses of each manufacturing department or production center.
2. Columns to record expenses compiled for the more important special service departments or areas, such as material handling, production planning, personnel department office, general factory areas, storage areas, and such other service departments as desired.
3. Column for expenses of a *general* nature which cannot be readily allocated to the departments for which there are columns on the burden distribution sheet. Typical of these expenses are the cost of lighting and heating of stair wells, and the balance of other expenses which cannot be specifically assigned to manufacturing departments. This column is designated as a *general* column.
4. Column to compile power-plant expenses.
5. Column to compile expenses for maintenance service.
6. Column for compiling the costs of housing — *building expense.*

		Productive Departments (Mfg.)			*Service Departments*				
Item	*Total*	*Dept. A*	*Dept. B*	*Dept. C*	*Material Handling*	*General*	*Power*	*Maintenance*	*Building*
Depreciation									
Taxes									
Insurance (various kinds)									
Supplies									
Indirect equipment expense									
General maintenance									
Building									
Power									
Material handling									

FIGURE 302

It will be found helpful in making the actual burden distribution if the following data is recorded on the burden distribution sheet at this point.

1. Area in square feet for each division or department represented by a column on the burden distribution sheet. Where service areas are so small that it is not desirable to have a separate column for them, they

may be combined and included with the area of stair wells and unused manufacturing space to be designated as the floor area for the "general column." (Obtain information from plant-layout drawings.)

2. Total direct and indirect labor pay roll of each manufacturing department for period under consideration. (Obtain from pay-roll slips or pay-roll department records.)
3. Summary total of power ratings of machines, as well as total horsepower-hours estimated for each manufacturing department for period for which costs are being compiled. The total horsepower-hours may be found by multiplying the horsepower rating of each machine by the hours it is used for productive purposes, and then a combined total made for all machinery in the department.
4. Total value of manufacturing machinery and equipment contained in each department or area represented by column on sheet. (Obtain information from inventories of machinery and equipment or accounting records.)

Among the foregoing, obtaining data on the values of machinery and equipment may present a problem and deserves special comment. The assignment of several items of overhead expense to the various manufacturing departments or production centers requires definite information with respect to the value of the machinery and equipment in use in the factory. Expense items, such as machinery and equipment insurance, machinery and equipment taxes, and depreciation on machinery and equipment are distributed most accurately only when the values of machinery and equipment are used as a basis. Unfortunately, however, many factory owners do not keep accurate records of the time of purchase and cost of acquiring their machinery and equipment. Where this situation is found, the person compiling the burden costs for the plant must arrive at some satisfactory machinery and equipment values.

When the cost value of machinery and equipment are not specifically known the value may be determined in one or a combination of three ways: (1) an appraiser may make an estimate of the value of all the equipment (installed) as of some given date; (2) records, catalogs, and manufacturers of equipment may be consulted to ascertain the cost of installing equipment in question as of the approximate date of its installation in the factory; (3) equipment manufacturers and their current catalogs may be consulted to learn the cost of installing like equipment at the present time. Figures found in any of the above ways will be satisfactory for purposes of burden distribution since a satisfactory distribution can be made in terms of the *equivalent relative* values of the equipment in the various manufacturing and service departments of the plant.

FACTORY OVERHEAD COSTS

For convenience in record keeping and cost control, the functional and physical division between the manufacturing plant and the administrative offices of the business is maintained when distributing overhead costs. The principles of compiling and distributing overhead costs are essentially the same whether the overhead expenses apply to the factory proper or the general administrative offices. Discussion of the principles of assigning overhead expenses to areas in the manufacturing plant will be followed by treatment of compilation and distribution of administrative overhead.

The *major expense items* in factory overhead are discussed in the succeeding paragraphs.

DEPRECIATION

As machines and equipment are used, they gradually become less valuable, and when they are worn out, they must be replaced. This is made easier by the creation of a fund (cash or money invested in other assets) which can be used for this purpose when it is needed. *Depreciation* is a means of doing this. It is the name given the cost of the wear, tear, and rusting of the machinery and equipment that takes place during each accounting period, and should be included in the overhead costs of each period. If the entire cost of a new machine or piece of equipment were to be listed as an expense in whatever accounting period it happened to be purchased, manufacturing costs would seldom reflect a true picture because each machine and piece of equipment actually wears out little by little, and the cost should be spread out over the accounting periods to be covered during their estimated useful life.

The usual procedure in accounting for machine and equipment depreciation is to determine an amount that should be charged each period — annually, quarterly — as a depreciation expense for each item or group of machinery and equipment; no money is paid out, but appropriate bookkeeping entries are made which set aside or "earmark" some of the assets of the business as belonging to a reserve fund which will be used to buy new machines and equipment when they are needed.

Depreciation must be distinguished from *obsolescence*, which is the expense of *charging off* to profit and loss the cost of machines and equipment which have become old-fashioned. Moreover, it must not be assumed that machines and equipment are useless just because they are depreciated, that is, a fund provided for their replacement. Machines which have been well cared for may continue to be useful

to their owners long after a fund equal to their cost or replacement value has been set aside in a depreciation reserve. New machinery and equipment might be more efficient in terms of speed and output, but the old machines are kept and used because it costs less to own them (depreciation, taxes, insurance, and so on).

Distribution. Machinery and equipment depreciation is based on value in terms of estimated life. For example, a machine having a cost value of $1000, a scrap value at the end of its life of $200, and an estimated life of 10 years, will have an annual depreciation cost of $80.

Machinery and equipment depreciation expense is usually allocated to the department where the machines and equipment being depreciated are located. This information should be available from inventories of machinery and equipment. However, some firms do not keep good inventory lists of machinery and equipment, as already discussed; therefore, they have no records of original costs or expected years of usefulness. In these instances the value of machinery and equipment contained in each department may have to be estimated as a total and the amount of depreciation expense for the period under consideration figured as a lump sum. The depreciation expense may then be apportioned among the departments on the distribution sheet in proportion to the lump-sum values of machinery and equipment estimated to be contained in each.

TAXES

The bill for taxes consists of tax expenses on real property (land and buildings) and tax assessments on factory machinery and equipment. This bill may be received either as an amount to be paid the town or city in a lump sum or without specification as to what is being taxed, or as an itemized statement indicating in detail what is taxed, the assessed value[1] of each item, and the tax rate applicable.

Distribution. Tax assessors seldom list and classify factory property values for taxation purposes to the extent that such information is needed for burden distribution purposes. The cost analyst should ascertain the basis of valuation for assessment on all land, buildings, machinery, and equipment as well as the tax rates, and then work out a careful allocation of the total tax costs to various manufacturing and service departments on the distribution sheet. This means that taxes on production machines and equipment will be assigned to the departments where located and taxes on power equipment, material handling,

[1] This is a value imposed for tax purposes only.

storeskeeping equipment, and so on will be assigned to each of their departments according to the tax cost each gives rise to.

Where tax bills are rendered as a lump sum and no basis of allocation can be readily obtained, the total tax bill may be divided up as follows: (1) the tax cost of land and buildings will be assigned to the building expense column of the distribution sheet; (2) the tax cost on machinery and equipment may be split up among the departments on the basis of estimated values of machinery and equipment in each. The values used for purposes of distributing *depreciation* expense should prove helpful in this connection.

FIRE INSURANCE

This cost is necessary to protect the owner against the loss from damage to physical property — buildings, machinery, and equipment — through fire.

Distribution. The cost (premium) is based on what is insured and probably can be determined and assigned accordingly. In any event, it will be very exceptional when building, machinery, and equipment insurance cannot be segregated. Building insurance cost can be assigned directly to this column. At times no relation will exist between the property values of machinery and equipment represented by the manufacturing department columns on the distribution sheet, and the insurance cost (that is, where the insurance policy does not cover specific items of property). In these instances the total premium or insurance cost for the period under consideration is divided among the departments on the burden distribution sheet according to estimated values of the property each department represents. (Here again values calculated for *depreciation* purposes may be used.)

OTHER INSURANCE

The insurance costs which have not been distributed thus far are (1) boiler insurance, (2) workmen's compensation insurance, and (3) unemployment insurance.

Boiler insurance. This expense arises out of the possibility of explosions of power-plant boilers and likely damages from such occurrences. Insurance is carried to cover the cost of possible loss or damage to property which might arise from boiler explosions.

Distribution. The premium or cost of insurance against boiler explosions is assigned directly to the power-expense column on the burden distribution sheet.

Workmen's compensation. This cost arises out of the need to protect employees against loss of income through bodily injury due to hazards of particular work and to pay for medical and other expenses which arise when accidents occur. A manufacturer may agree to provide his own funds and to cover the cost of accidents when they arise, but the usual practice is to transfer the liability to the insurance company by buying indemnity insurance. The cost of such insurance is found by multiplying the dollar pay roll by the rates established for the types of workers covered.

Distribution. The total expense of providing for this protection of employees is distributed among the departments on the burden sheet according to (1) the amount of workmen's compensation expense each gives rise to or (2) on the basis of the total pay roll in each. By total pay roll is meant the combined wages of direct and indirect labor (productive and nonproductive workers). Care should be taken in arriving at pay-roll figures used in making the distribution to learn what classes of employees are included in the provisions of the workmen's compensation policy; supervisors and factory office employees, for example, may or may not be included. (Where total pay roll is the basis of distribution, the cost of workmen's compensation expense per pay-roll dollar is found, and then the total number of pay-roll dollars of each manufacturing and service department is multiplied by this figure to give the workmen's compensation insurance cost for the department.)

Unemployment insurance. Manufacturers are required by law to contribute to state unemployment insurance funds to protect workers against loss of income while making transfers from one job to another when they have been dismissed or laid off. The employer's contribution to the insurance fund in behalf of factory employees is a factory overhead-expense item.

Distribution. The total amount of the contribution for this purpose can be determined from the *accounting records.* It is divided up among the departments on the basis of the share of the total amount of the contribution caused by the amount of the pay roll in each department. Contributions for employees whose departmental identity is uncertain may be split up among all the departments in proportion to the total known pay roll in each.

SUPPLIES (INDIRECT MATERIALS)

Every manufacturing plant uses a variety of items called "supplies." These include washroom soap, paper towels, oil emulsions, waste cloths, cleaning compounds, factory office supplies, and so forth.

Distribution of supplies. The amount of supplies used in connection with the process during a manufacturing period is easily determined in most instances by means of supply requisitions. These costs are allocated to each of the manufacturing and service departments where used. Where there are no records of supplies used in manufacturing departments, the total of this expense may be distributed either on the basis of direct labor pay roll, number of employees, or by estimate. General supplies' expense, such as those used by employees (washroom supplies, for example) may be distributed to all departments (manufacturing and service) on the basis of the total pay roll, that is, the part of the total pay roll caused by each department on the distribution sheet.

INDIRECT LABOR

The workers in a manufacturing plant are divided into two broad categories, *direct* and *indirect.* (These are also called "productive" and "nonproductive.") *The pay-roll expense of direct labor is never a part of overhead expense.* The salaries and wages of indirect laborers in the factory, however, are always a part of the total overhead. When a burden distribution is being made, it is necessary to study pay-roll records in order to determine which workers may be classified as direct and which as indirect. Broadly speaking, those who work on the product itself actually changing its physical characteristics and those who attend machines which are part of the manufacturing process are designated as *direct laborers. The cost of direct workers is treated as a separate cost and, therefore, must never be included as part of the total overhead expense.* (The total amounts of direct labor payrolls of the manufacturing departments are used, however, to distribute certain other overhead costs.)

The indirect laborers in the manufacturing departments are those who do supervisory work; those who help out in production work by assisting direct laborers and performing services; and those who do the necessary factory clerical work. Typical of these are foremen, supervisors, production helpers, material-handling men, and factory office clerks. Workers assigned to service departments are always indirect. These include maintenance workers, janitors, and watchmen, and the cost of their services is assigned to the departments of which they are a part, that is, building and maintenance.

For inclusion on the distribution sheet, indirect laborers may be grouped as expense items which represent broad classifications of workers. Suggested expense items and classes of employees to be included in the compilation of each item are shown in the following table:

INDIRECT LABOR

Expense Item	*Classes of Employees*
Factory, general	Supervisors, foremen
	Helpers, inspectors
Factory, office	Clerks, pay-roll clerks
	Factory cost accountants
Planning	Production manager
	Schedule clerks, tooling clerks
	Dispatchers
Engineering	Methods men
	Time-study engineers
	Designers, draftsmen
Power	Superintendent
	Power-plant attendants
	Firemen, engineers
Maintenance	Janitors, carpenters
	Plumbers, metal workers
	Electricians
Storeskeeping	Storeskeeper, clerks
	Tool-room clerk
Material handling	Truck drivers and assistants

Distribution. The wage expense of *indirect workers* is always included in overhead expenses either as a part of totals for various classes established or as individual items according to title of position. The cost of janitorial work is assigned to building expenses. The wages for maintenance force are part of the maintenance-department expenses. Power-plant labor is included in the total of the power-plant costs; the cost of material-handling labor is part of the total material-handling expense, and so on.

As far as the manufacturing departments are concerned, there are nearly always a number of indirect laborers who work in a single department exclusively and, therefore, the cost of their wages is an overhead expense of the departments where they spend their time. There may be some workers, however, whose time is not specifically assigned to any individual department. Pay-roll records ought to reveal just how the cost of these men should be split up. In addition, others may devote part of their time to making the product as direct laborers, spending the balance of their time in doing work classified as indirect. Again pay-roll records should be used to make an accurate breakdown of their pay cost as direct and indirect labor expense.

The allocation of indirect-labor expense should be in terms of pay-roll records wherever possible, but when records are not adequate to determine what is direct- and what is indirect-labor expense, the relative amounts to be assigned each department on the distribution sheet may be estimated. In some cases it will be necessary to make assignments on a purely arbitrary basis.

SPECIAL EQUIPMENT EXPENSE

Every factory has a sizable investment in tools, special jigs, and patterns. The overhead costs of these can be calculated only after an inventory has been made of them and their respective values determined. Each item of this inventory gives rise to the expenses of depreciation, taxes, insurance, and maintenance.

In addition to special tools, jigs, and patterns, many industries have machines and equipment which are important in production, which do not belong to any particular department but which, nevertheless, entail overhead expense. Such cases exist where machines are in use which require experts to repair them. In order to keep production flowing when the machines break down, it is necessary to have replacement units on reserve. In addition, some plants have machinery and equipment in development or experimental stages. The overhead costs of these must be recognized also as part of the total factory overhead expense. Each unit of such machinery and equipment entails depreciation, tax expense, insurance, and maintenance costs.

The term "special equipment" may be unusual to some manufacturers because special equipment is used for regular production. In burden distribution this classification helps to isolate costs which need careful scrutiny.

Distribution. The overhead expenses arising out of special tools, jigs, and patterns should be calculated on a separate schedule or distribution form and assigned to the manufacturing departments where they are used. Where special machinery and equipment are kept in reserve for a particular process or department, their overhead expense should be assigned to that department. When the special machines and equipment are used in several departments, however, their overhead expenses should be split up among these departments in accordance with the amount of use each makes of the special machinery and equipment. When a specific allocation of the costs of overhead expense on special equipment is difficult to make on the basis of use, they may be assigned on a basis to be agreed upon by the heads of the departments involved. In some instances special equipment costs are just assigned directly to the general column on the sheet. By doing this it is included in the total of the general-column items, and redistributed among the manufacturing departments on the burden distribution sheet when the column is closed out on the basis of the direct-labor pay roll.

There follows a table showing a summary list of the expense items, the sources of information about them, and the bases of distribution. (Elevator expense is included since it must be compiled separately to include as an item of cost in the building-expense column.)

Expense Items	*Source*	*Basis of Distribution*
Depreciation	Purchase-cost records	Value/Life
Taxes on physical property	Tax bill or estimated tax bill	Portion the value of the physical property in each department is of total value taxed. $\frac{\text{(Dept. value)}}{\text{(Total value)}} \left(\begin{matrix}\text{total tax} \\ \text{bill}\end{matrix}\right)$
Fire insurance on physical property	Insurance bill	Department where located
Boiler insurance	Bill	Assigned to power only — distributed to other depts. as part of power expense.
Workman's comp. insurance	Bill	Pay-roll × insurance rate
Unemployment insurance	Bill	Pay-roll × insurance rate
Supplies	Requisitions	According to recorded requisitions or estimated basis
Indirect labor	Pay-roll records	Pay-roll records
Special equipment expense	Calculated costs (depreciation, taxes, insurance, and maintenance)	Assign cost to department where used or to general column.
Elevator	Calculated costs (attendant, insurance, taxes, depreciation, and power)	Building expense

COMPLETING THE SHEET

All of the items which are distributed to both the manufacturing and the factory-service departments have now been taken care of, but the columns for the *manufacturing* departments should not be totaled at this point because the total overhead costs of a manufacturing department include also portions of the expenditures for factory services — power, maintenance, storeskeeping, handling, and buildings. The next step is to apportion each of the factory-service columns among the other departments which it serves. In cases where there is no interrelation between the factory services this is very simple. The total for the building column, for example, is distributed among the manufacturing departments, usually according to the square feet of floor area in each department. In the same way, the total power cost and total maintenance expense is distributed among the manufacturing departments according to some other characteristic, such as horsepower-hours. In other words, each of the factory service departments is closed out into the manufacturing departments. The simplified procedure described above applies only when factory services are not

interrelated — when power is used only by manufacturing departments and not to heat the building also, or when the maintenance department serves only the manufacturing departments but has nothing to do with maintenance of the building or power plant. These situations will sometimes be encountered in practice, particularly where different factory services are contained in separate buildings or when there is a high degree of specialization.

ESTIMATES NEEDED TO COMPLETE SERVICE-DEPARTMENT COSTS

In most manufacturing plants the factory services are interrelated — the maintenance and power services are housed in the same building with the manufacturing departments; the power plant furnishes heat and light for the building and serves the maintenance department as well as the manufacturing departments; and the building and power plant are kept in repair by the maintenance department. Consequently, it is necessary to distribute the costs of any one factory-service department among other factory-service departments in addition to the manufacturing departments. In the typical case where all three factory services are interrelated, it is necessary to make preliminary estimates in order to get started.

For example, the total building expense cannot be found until the cost of the power and maintenance used by the building is known. But the total cost of power cannot be found until the building expense (cost of housing) of the power department is determined, and the cost of maintenance is not complete until the cost of housing and providing power for the maintenance department has been ascertained.

When the compilation of expenses in each of the service-department columns is completed, they are redistributed one at a time among other departments on the sheet. The process of totaling a column and splitting it up among the departments that are not yet completed and totaled is known as *closing out* the column. Each of the service departments is closed out and divided up among the remaining columns until all the service costs are assigned to the manufacturing departments they serve. When this is done, only the manufacturing columns will remain on the sheet as *unclosed.* All costs will be assigned to manufacturing departments where they will be useful for costing purposes through assignment to products made, on the basis of hourly overhead rates.

Closing Out the Building-expense Column

The building expense is generally considered first because it houses and serves all other manufacturing and service departments. As none

of the other factory services have been distributed, two items — the power expense and maintenance expense incurred by the building — are missing from the building-expense column. These two items are estimated and distributed in advance to the building column so that it may be totaled. The building expense is allocated to the various departments on the basis of square feet contained in each. The total of the column is divided by the total number of square feet to find the rate per square foot, and this rate is then multiplied by the square feet in each department to obtain the portion of the building expense to be charged to the department.

Closing Out the Maintenance Column

The maintenance column is distributed next. Before this can be done, one missing item — the power expense incurred by the maintenance department — is estimated and distributed to maintenance in advance. The maintenance column is now totaled. Prior to distributing this total among the other departments it is necessary to subtract the amount of maintenance expense that was distributed as follows:

1. Maintenance-department labor is assigned to the departments or production centers on the basis of pay-roll slip information. These slips show where the work has been performed and for what purpose.
2. The material requisition slips show where the repair parts and supplies have been used.
3. The balance of the maintenance expense which is not assigned in the above ways may be split up and assigned to each department according to any one or a combination of the following:
   a) Value of equipment
   b) Direct-labor pay roll
   c) Floor area
   d) Productive hours

Closing Out the Power Column

In distributing the power expense it is also necessary to subtract the amounts which were distributed in advance, namely, the power expenses of the maintenance department and the building. The remainder of the power expense is then assigned to the other departments according to (1) horsepower-hours (horsepower ratings of machines *times* hours operated), or (2) horsepower ratings — when all machinery is operated at a constant speed or the same number of hours.

The mechanics of entering the estimates and deductions on the burden distribution sheet are shown in Fig. 303. The totals of the material-handling and general columns are distributed without making any deductions.

Expense Items	*Total*	*Dept. A*	*Dept. B*	*Dept. C*	*General*	*Material Handling*	*Power*	*Maintenance*	*Building*
Power distributed in advance	50							30	20
Maintenance distributed in advance	15								15
Building	200			No deductions					200
Maintenance	160	Less maintenance distributed in advance						175	
Power	250	Less power distributed in advance					300		

FIGURE 303

Closing Out the Material-handling Column

The next column to be totaled and redistributed is the material-handling expense column. The total cost of material handling is divided among the manufacturing departments without making deductions. The basis of assignment may be the amount of goods handled for each department (tons, gallons, units); or, in the event that figures for amounts of materials handled are not available, it is possible to assign material-handling expense to manufacturing departments on the basis of the volume of the output of each department. In some organizations the redistribution is made on the basis of the direct-labor pay roll.

Closing Out the General Column

The general column is totaled and split up among the manufacturing departments, according to the proportion of direct-labor pay roll in each. (The authors have not been able to find a good reason for this basis of distribution but industries use it as accepted practice.)

Alternative Estimates

In the procedure as explained above, building expense was distributed first and maintenance expense second, and the necessary esti-

mates distributed in advance were (1) the maintenance expense for the building, (2) power expense of the building, and (3) the power expense of the maintenance department. Any other order of distributing building, maintenance, and power may be employed with the accompanying changes in the items which it is necessary to estimate. Figure 304 shows all of the items which it is possible to estimate with

Services	*Expense Items*		
	Building	Maintenance	Power
Building		Maintenance needed by the building	Power needed by the building
Maintenance	Building needed for maintenance dept.		Power needed by the maintenance dept.
Power	Building needed for power plant	Maintenance needed by power plant	

FIGURE 304

various orders for distributing the factory services. Two estimates, named on the same horizontal line, are necessary for the factory service which is distributed first, and a third estimate is necessary for the factory service which is distributed second. This third estimate is found on the same horizontal line with the second factory service to be distributed, after eliminating the factory service which was distributed first, hence which does not need to be estimated. For example, if power is distributed first and maintenance second, then the two items opposite power — building needed for power plant and maintenance needed by power plant — must be estimated, and also the building needed by maintenance department. In this case it is not necessary to estimate power needed by maintenance department since power has already been distributed.

The order in which the factory-service columns of a distribution sheet are closed out should be determined by the ease with which various estimates can be made in the individual factory under consideration. In introducing the principles, building expense was distributed because this is probably the most typical case.

Making Estimates

Estimates should be based on considered judgment in addition to whatever factual information may be available. Maintenance department pay-roll slips and material requisition slips will show the cost of work and materials used in connection with the maintenance of building and power. Approximate power costs and housing costs can be

used in connection with estimating these services. Sometimes it is possible to obtain the cost figures of other industries in the field, or companies which are similar in size and have comparable products or production processes.

HOURLY OVERHEAD RATES

Each of the overhead expense items — building expense, maintenance, and so on — shown in the *item* column of the distribution sheet has been discussed from these standpoints: why each cost exists, how it arises, of what it is composed, and how it is split up among the manufacturing and other departments on the distribution sheet.

When the redistribution is completed, all of the overhead expenses are confined to the manufacturing departments only. A total overhead-expense figure for each department is now available for use in arriving at hourly overhead rates. To find these rates properly, it is necessary to know the number of productive hours each department operates. These are an expression of time spent in manufacturing the product and may be either man-hours or machine-hours, or a combination of both. Provision is made for calculation of the overhead rates of each department on the factory burden distribution sheet. The steps as outlined are these:

Number of units (man or machine) in the production center or department	200
× *Hours per unit* — total working time for each unit — man or machine — in department; working days in period (300) × hours worked per day by department (6)	1,800
Department total of man- or machine-hours	360,000
Less *idle time* allowance — 10%	36,000
Net operating time for department (productive man- or machine-hours)	324,000

In the calculation of the hourly overhead rate the total overhead expense for a manufacturing department is divided by its total productive time as follows:

$$\frac{\text{Total overhead expense for department}}{\text{Net operating time}} = \text{hourly overhead rate (H.O.R.)}.$$

The hourly overhead rate (H.O.R.) becomes the basis for adding factory overhead costs to the cost of manufacturing. When the H.O.R.'s of manufacturing departments are determined and a record kept of the number of hours any product passing through the manufacturing departments has been processed, it becomes simple to add factory overhead costs to other manufacturing costs as follows:

Material costs			$4.00
Labor costs			3.00
Overhead costs:			
Department	*Rate*	*Production Hours (Processed)*	
A	$0.45	6	2.70
B	0.56	4	2.24
C	0.80	3	2.40
Total factory cost			$14.34

(Not including administrative overhead expenses)

In figuring the total productive time for any manufacturing department it is advisable to use man- or machine-hour totals or both that are based on operations extending over several manufacturing periods. The amount of productive work rises and falls from month to month, year to year, in keeping with changes in the business cycle and success in making sales. Consequently, no particular period is ever exactly normal or average for purposes of making a burden distribution.

NORMAL RATES

By using net operating or production times which represent operations that are spread over several manufacturing periods it becomes possible to arrive at hourly overhead rates that are useful in good times and bad — through the ups and downs of business. Since these rates are based on normal expectancy of business they are often called "normal rates."

Normal rates cannot be changed with ups and downs in production expenses. The overhead per hour that is charged to the product must be kept at a constant figure during several periods. For example, if normal expectancy of productive time for a manufacturing department during any period is 10,000 hours and $5000 is the overhead expense, the H.O.R. will be $0.50 per man or machine hour. When the department operates 12,000 hours in a future period the overhead expense per productive hour is still charged to products manufactured at the same $0.50 rate. Similarly when productive time drops to 8000 hours in still another period the same H.O.R. or $0.50 is used. The result follows:

Manufacturing Period	*Actual Machine-hours*	*Actual * Overhead Expense*	*Normal H.O.R.*	*Normal Overhead Cost*	*Balance*
1.	10,000	$5,000	$0.50	$5,000	Normal
2.	12,000	$5,500	$0.50	$6,000	+ $500
3.	8,000	$4,200	$0.50	$4,000	− $200

* Based on records of expenditures.

In this illustration the products made and sold in periods when operation time is above the normal provides a *plus* balance in the overhead account which more than offsets the *minus* balance when the hours of production fall off.

Three Advantages

The use of normal rates has these advantages:

1. It permits a uniformity of manufacturing costs as far as overhead expense is concerned.
2. It avoids the necessity of making repeated distributions of overhead expenses which are apt to be compiled after the manufacturing operations involved are finished and are of no help in pricing.
3. It lessens price fluctuations caused by wide variations in overhead expense from year to year.

ADMINISTRATIVE BURDEN

The overhead costs of manufacturing plants are divided into two general groups. These are (1) the *factory overhead* expenses which are added to the cost of materials and labor by means of hourly overhead rates, and (2) the so-called administrative overhead expenses. These latter are the overhead expenses which do not comprise part of the cost of operating the manufacturing departments of the plant, but which are necessary to carry on the business. They are the expenses of packing, shipping, selling, and over-all general management.

In some industries, the areas which are used for each of these services are contained in the same building with the manufacturing departments. In others, however, the sales offices and executive offices may be located in a separate building or even another community.

A separate distribution sheet should be made for the administrative overhead expense items. It is sometimes convenient, however, merely to add additional columns for the administrative department to the factory burden distribution sheet.

In the compilation and distribution of the factory overhead expenses many of the items were first compiled as totals and then distributed to the manufacturing and service departments. In the compilation of administrative overhead costs, however, it will be found convenient to classify the expense items by listing them in the proper columns. The expenses so listed may then be added across the sheet to obtain figures for the "total" column. For example, it will be found that each administrative department has a labor cost. In the shipping department this will consist of laborers and helpers; in the sales department, clerks and salesmen; the clerical help and executive personnel will be classified

under the so-called general column. The total of the administrative labor cost may be found by adding up the departmental figures and then the grand total recorded.

In the compilation of administrative burden the following information must be obtained from the blueprints of the factory as was done in the case of factory overhead expenses:

1. Square feet areas occupied by:
   a) Executive offices
   b) Sales divisions
   c) Shipping and delivery departments
   d) Specific departments pertaining to administration (accounting, demonstration, or display rooms)
2. The areas given over to employee facilities for the administrative staff such as washrooms and reading rooms.

As in the case of factory burden also it will be found helpful to record this information on the burden distribution sheet.

The expense items which comprise administrative burden are:

1. Building expense (that portion of the total building expense that must be assigned to administrative departments on the basis of the square feet occupied)
2. Executive office expenses:
   Executive salaries (production managers)
   Executive secretaries' salaries
   Supplies, stationery (clerical)
   Private washroom expense
   Depreciation on office equipment of executives and secretaries
   Insurance on office equipment of executives and secretaries
3. Sales department expenses:
   Salesmen's salaries
   Commissions
   Advertising
   Sales manager's salary
   Branch-office sales expense
   Catalog expense
   Drawing accounts
   Supplies
   Depreciation of office equipment
   Insurance on office equipment
4. Shipping and delivery expenses:
   Packing and packaging expense
   Shipping clerks' salaries
   Depreciation of equipment used
   Shipping supplies
   Taxes on equipment in shipping department
   Delivery expense

Truck drivers' expense
Auto license expense
Auto insurance expense

Adding Administrative Burden

Administrative burden is primarily useful as a total figure in finding the total cost of manufacturing a product. It may be added to the cost of the product as a percentage of the combined total of direct materials, direct labor, and factory overhead costs. This percentage is calculated from the relationship of administrative burden to the combined total of these costs. In the example which follows, examination shows that the administrative burden amounts to 20 per cent of the total cost of manufacturing operations and 25 per cent of the combined total of the direct material, direct labor, and factory overhead costs.

Direct labor	$ 95,000
Direct material	115,000
Factory overhead expense	98,000
Total cost of manufacturing before adding administrative overhead (material, labor, and factory overhead costs)	$308,000
Administrative burden	52,000
Total cost	$360,000

Since administrative burden is found to be 25 per cent of the sum of the direct labor, direct material, and factory overhead expense, it may be assumed that this approximate relationship will exist in the calculation of the cost of individual products. An illustration follows:

Material and labor	$3.00
Factory burden: 4 man-hours @ $0.29	1.16
Total material, labor, and factory overhead expense	4.16
Administrative burden (25%)	1.04
	$5.20

COSTING THE PRODUCT

When hourly rates are established, there is a definite basis for adding factory overhead expense to material and labor costs. Products which require hand labor will have the number of hours worked on them by direct laborers multiplied by the man-hour rate. Products which are processed by machines will have the overhead expense per machine-hour time multiplied by the number of hours the product is processed on the machine. To this will be added an additional figure for administrative overhead costs. The steps for the complete cost of the product are as follows:

1. Obtain the material cost of the product from the material requisition slips.
2. Determine direct-labor cost from pay-roll slips.

3. Compute factory overhead expenses to be added to the product by multiplying the direct labor and/or machine-hours which represent the time spent on the product in each department by hourly overhead rates. For example, if the product is processed in a manufacturing department where hand labor only is the method of work, the factory overhead expense will be found by multiplying the number of man-hours (direct labor) spent on it by the overhead rate per man-hour.
4. To the total of steps 1, 2, and 3, add the *administrative burden.* This may be added on the basis of the percentage that administrative burden is of the sum of the costs obtained from steps 1, 2, and 3.

CAPACITY UTILIZATION AND THE DISTRIBUTION OF OVERHEAD EXPENSES

The procedure for obtaining burden distribution rates as already described in this chapter is one widely employed in practice. It possesses the advantages of using measures which are easy to obtain and the calculations may be performed mechanically once the system has been installed. Overhead costs are distributed according to a rate which is found by dividing the total cost to be distributed by some measure of the various things which give rise to the expense. The rate for housing cost (building expense), for example, is found by dividing the total housing cost by the total square feet of floor area. Using this rate, the building expense is distributed to the various departments (or machines) in accordance with the number of square feet of floor area they occupy. The housing cost in each department, together with other costs distributed to the department by the same method, is then used to find an hourly overhead rate for the department, and overhead is charged to the product in accordance to the number of hours it spends in the department.

This procedure assumes that all the units of square feet, in the case of housing, are of equal importance in giving rise to the total cost. There are many cases where this assumption is not true. Some units of floor area or power may have been added only because they provided for capacity utilization of other fixed investments previously made, and not because they would pay for themselves if they were installed alone. It is not fair to charge overhead expenses to items which did not cause expenditures to be made. For example, if a woodworking shop constructs a building to house its production floor, many of the expenses will not increase directly with increases in the size of the proposed building, and a review of the plans may indicate relatively little additional expenditure is necessary to enlarge the building so that it includes storage space for lumber which formerly was exposed to the weather. This is because the costs of planning committee meetings,

architects' services, construction of foundation, and so on are relatively fixed, regardless of the size of the building; and the principle of capacity utilization justifies the construction of additional floor space although the construction of this additional floor area would not be economical if it were carried on as an entirely separate project.

The fact that overhead expenses are caused primarily by the needs of one or two departments, and extended to others under the principle of capacity utilization, should be recognized in the distribution of these overhead expenses. Continuing the illustration of the previous paragraph, the primary cause for the building expense was the need of the production department; the addition of storage floor area was incidental. If it had not been necessary to erect a new building to house the productive operations, the lumber would still be stored in the yard. Consequently, the greater portion of the building expense should be charged to the production areas and not the storage areas, regardless of the number of square feet they contain.

A similar problem arises whenever the purchase of additional productive machinery results in greater capacity utilization of factory-service facilities. If the power plant of a factory is operating at 70 per cent capacity, the power for an additional lathe will involve little or no additional expenditures, and therefore, power should not be included in calculating the expenses of owning and operating the additional lathe. By the same reasoning, power should not be charged to it according to the standard horsepower-hour rate when the burden is being distributed.

If the principles of capacity utilization are observed when purchasing physical property, and straight square-foot or horsepower-hour rates are used in distributing the overhead, then it will erroneously appear that the original purchase was unwise, and the costs of production will also be distorted. On the other hand, if the principles of capacity utilization are disregarded when considering additional purchases, and costs of ownership and operation are computed using the standard overhead rates, then desirable purchases may not be made because they are charged with increasing manufacturing expenses more than they actually cause. Both of these seeming inconsistencies point to the fallacy of undeviating reliance upon square-foot or horsepower-hour rates for the computation of overhead expense.

BURDEN DISTRIBUTION A MATTER OF JUDGMENT

In the last analysis the entire problem of distributing overhead expenses is entirely theoretical and a matter of judgment. This is because no internal money payments are actually made; the entire

process is justified from the standpoint of controlling complex manufacturing operations and pricing the inventories and the products. No actual physical checkup can ever be made to test the correctness of the figures used in the burden distribution; the only test is whether or not the entire process is an aid to the successful management of the business.

Such being the nature of burden distribution, it might be well performed by a top executive who is thoroughly familiar with the business and able to assign burden expenses to various departments in proportion to the extent that the departments give rise to the expenses. That is, he would consider the total amount of expense to be distributed together with the reasons why the expense was incurred, and using his best judgment assign portions of the total to different departments.

A plan by which top executives make assignments of each overhead expense according to their best judgment would be impractical because of the large number of expenses that must frequently be distributed. According to the fourth item in the First Principles of Management, routines should be established so that relatively minor questions which are constantly recurring may be mechanically performed with a minimum of effort and judgment. For this reason, square-feet and horsepower-hour rates have been adopted, but further analysis shows that the results they achieve do not always stand the scrutiny of mature judgment. A system should not be arbitrarily followed once it has been established, but constantly modified so that it achieves correct results with a minimum of effort.

Once the extent to which each department and machine gives rise to a total overhead expense to be distributed has been determined, this may be expressed as a percentage of the total expense, and the percentage rate used in subsequent distributions. The amount of burden to be assigned to a department may be found by multiplying each department's percentage by the total expense, or the estimated total expense to be distributed.

WEIGHTING HOURLY OVERHEAD RATES

Up to this point attention has been focused upon the distribution of burden to various departments. Similar problems arise in distributing burden expenses from the departments to the products which pass through them. Under the procedure discussed in the first of the chapter, an hourly overhead rate is found, and burden is charged to a product in proportion to the number of hours it remains in a department. This method is subject to serious objections when both a product and a by-product are being processed by the same department. The main

product is the primary cause of the expenses of the department; the by-product was added in order to obtain capacity utilization of expenditures; it was not the cause of the expenditures. Consequently it is not fair to charge burden to the by-product at the same hourly rate as the main product. This would reduce erroneously the cost of the main product and raise the cost of the by-product, causing a large volume of the product to be sold at a loss and stagnate sales of the by-product because of its high price.

The solution here is probably a set of *weighted* hourly overhead rates — different rates for different products.

CHAPTER XXXIII

CONTROL OF VARIABLE COSTS

All of the topics of industrial management are interwoven, but none are more closely related than cost control and budgeting. Budgets in their initial stages are nothing more than advance estimates of costs. The completed budget report is a summary of what cost records show to be the results of operation. Both budgeting and accounting are made easier when both agree as to time considerations for record keeping and collecting information.

Production Volume and Variable Overhead Expenses

Aside from the problems encountered in splitting up fixed overhead costs among the manufacturing and service departments, these costs present no special problems of control. Whether production volume increases or decreases the amounts of taxes, insurance and depreciation remain fairly constant.

From the standpoint of controlling variable overhead expense items. however, all businesses tend to divide themselves into two major classifications: (1) those having practically the same amount of business from month to month and year to year; and (2) those which have a fluctuating volume of manufacture. Variable costs, it will be recalled, were defined earlier as those which change in amount as the production volume rises and falls. They must be controlled in all industrial enterprises regardless of fluctuations in production volume, but in those industries which have a changing volume of manufacture their control becomes an appreciable problem of management. The technique developed by managers to control these variable costs which has proved most helpful is the *variable or flexible* budget.

Budgeting Variable Costs

Budgets, or plans, are necessary because things in the future will not be the same as things in the past. If it were a foregone conclusion that everything about a successful business would be the same next year as it is this year, then no budget would be necessary. Merely by repeating the activities of the past year, success in the coming year would be guaranteed. This situation is never true because the general

social and economic situation is constantly changing, and each business must keep up the pace if it is to continue in existence.

Overhead costs divide themselves into two broad categories: (1) fixed or nonvariable costs and (2) variable costs.

Fixed costs are those which remain nearly constant in amount regardless of the volume of output and quantity of work done in the plant. Typical of these are depreciation expenses, taxes, and fire insurance.

Variable costs are those which tend to change in amount as the production volume rises and falls, that is, the quantity of work and output have a direct influence on their totals. Typical of these costs are labor costs for repairs to machinery and equipment, the costs of manufacturing supplies used, the cost of material-handling labor, and other types of nonproductive or indirect labor.

The budgeting of fixed costs does not present any problem; the very nature of these costs, as implied by their terminology, indicates that they will remain constant as long as the organization remains unchanged. If the business grows, there will be changes.

The problem of budgeting a variable cost may be simplified by finding the relation between its fluctuations and those of some other measure of the business which is easier to predict. The volume of production or the volume of sales are usually the cause of the fluctuations of the variable costs, and often one of them is used as the basis for budgeting variable costs.

It is first necessary to find the exact relation between production volume and the particular variable cost under consideration. The case which is easiest to understand is the one where there is direct variation; that is, a change in the volume of sales causes a proportionate change in the variable cost; if the sales go up 10 per cent, the variable cost also goes up 10 per cent.

It is only occasionally that a cost will vary directly with sales or production volume. Other cases will be found where the fluctuation of the variable cost is greater or less than the fluctuation of the volume of business. For example, it would seem reasonable to expect such items as supplies and indirect labor to increase in direct proportion to increases in production volume. Actually this does not always happen. Some variable-cost items change at a slower rate than changes in productive time, and others change more rapidly than changes in production time. When this happens cost items are said to have "rates of variability"; they do not rise and fall in amount in direct proportion to changes in production time, but at a rate faster than or slower than changes in production time.

Rates of variability. In order to have a useful budget which can be a guide to controlling variable expenses it must be made out in advance.

Where variable items are involved it would be nearly impossible to arrive at budget estimates except as *rates of variability* are worked out for each variable cost item. A rate of variability may be defined as the percentage by which an expense may be expected to increase or decrease in comparison to increases or decreases in productive hours.

Any percentage change is found by dividing the amount of change by the original size. Distinction should be made between percentage change and the percentage that a new size is of the original size. For example, if productive volume last year required 2000 productive hours and 2500 this year, the present year is 125 per cent of the previous year, but its percentage change is 25 per cent. "Percentage change" is the expression more frequently used and will be used in the remainder of this chapter.

The steps for figuring variability rates are:

1. Records are examined carefully to determine costs at given operating times.
2. These figures are compared with the costs for these same items at other operating times.
3. The rates of variability are then calculated as follows:

Item	*Period*	*Hours*	*Expense*
Supplies	Average 5 years	1000	$100
	Average 5 years	1500	130
		50 per cent increase	30 per cent increase

$$\text{Rate of variability} = \frac{\text{Percentage change in productive hours}}{\text{Percentage change in supplies expense}}$$

$$= \frac{30}{50} = 60 \text{ per cent}$$

4. The same procedure is followed for all expense items which fall in the *variable overhead-expense classification.*

In future budgeting operations, the particular supply item in question can be calculated in advance for any given time when it is known what the operating time is to be.

Budgeting Variable Costs by Using Per Cent Variability

When the rates of variability are established for each of the items of a manufacturing concern, it is possible to anticipate and calculate expected manufacturing expense regardless of changes in productive

time. The percentage change of the variable cost is found by multiplying the rate of variability by the percentage change in productive hours (independent variable). The amount of change in the variable cost is found by multiplying its present value by the percentage change (expressed as a decimal). This amount of change is then added (or subtracted if a decrease) to the present value in order to find the estimated amount of the variation.

The calculations for budgeting variable costs with different rates of variability are shown in the following table:

Production Hours (Independent Variables)				*Variable Costs (Dependent Variables)*					
Item (1)	*Present Value* (2)	*Predicted Value* (3)	*Percentage Change* (4)	*Item* (5)	*Present Value* (6)	*Per Cent Variability* (7)	*Percentage Change* (8)	*Amount of Change* (9)	*Budgeted Amount* (10)
Production volume	350	400	14%	Supplies	$ 90	60%	8.4%	$ 90 × .084	$ 97.56
				Indirect labor	300	40%	5.6%	$300 × .056	316.80

FIGURE 305

Column 1 contains the name of the item which is to be used as the basis for budgeting the variable costs. This item is production volume and in the terminology of the mathematician it is called the "independent variable," because it is assumed to be the cause of the fluctuations in the variable cost, or dependent variable, or else they both react from a common cause. The value of the production volume is easier to determine than the variable-cost item which may be based upon it.

Column 2 contains the present, known value of production volume, and column 3 its predicated value for the period for which the budget is being made. The percentage change in production volume, entered in column 4, is found by taking the difference between these two and dividing it by the present value.

Column 5 contains the name of the variable cost under consideration, supplies in this instance, and column 6 lists its present value, previously found from records as explained already. The per cent variability in column 7 is multiplied by the percentage change of the production hours (independent variable found in column 4) to obtain the percentage change of the supplies which is entered in column 8. This figure in column 8 is then multiplied by the present value of the dependent variable to find the amount of change, column 9. If this amount of change is an increase, it is added to the present value in column 6 to find the budgeted amount, and subtracted if it is a decrease.

There are important qualifications that must be kept in mind when using rates of variability for budgeting variable costs. Management should recognize that the procedure assumes that the rate of variability remains the same regardless of the size of the production volume. Even though this assumption may not be strictly correct, it is usually permissible for estimates within a relatively small range of variation. When there are large changes in the production volume, it is well to check carefully upon the rates of variability, and also to check the results with the considered judgment of those familiar with the business and the current business situation.

Another weakness of relying solely upon the mathematical procedure of budgeting variable costs is that the calculations are based largely on past performance and do not recognize any new elements in the picture. The rate of variability for indirect labor would no longer hold if migration of workers made it more difficult to obtain the required number of men with the type of skill needed. When statistics on previous performance cannot be relied upon, greater reliance must be placed upon considered judgment alone, perhaps supplemented with other techniques of analysis and forecasting. These are beyond the scope of this text, and will be found in the literature on business statistics and forecasting.

For purposes of simplicity in the above explanation, the estimations of two variable-cost items, supplies and indirect labor, are calculated upon the basis of changes in the volume of production. There are also many other variable-cost items which may be estimated by the same procedure, and the volume of production is frequently used as the basis for estimating all of them. However, this does not mean that the volume of production is the only thing that may be used for determining variable costs. Any other cost or measure of the activity in a business might be employed in a similar manner, provided it is an accurate indicator of the changes in the variable costs. For example, the depth of snow during the previous winter might be used as the basis of predicting the cost of harvesting a farm crop if it has been found that the quantity of the produce, and hence the number of workers required, depended upon the irrigation supplied by the spring floods. Here depth of snow, rather than volume of production, becomes the determining factor, but the procedure in making the calculations is the same.

For Mathematicians Only

The student of mathematics will recognize that the problem of budgeting variable costs is a matter of finding the relation between an independent variable, such as volume of production, and the dependent

variable that is the particular variable cost being budgeted. He will further recognize that the procedure previously developed assumes straight-line variation, with the line passing through the origin when there is 100 per cent variability and having a positive intercept when the variability is less than 100 per cent. The statement of known values of the independent and dependent variables (columns 2 and 5 on Fig. 305) fixes one point on the line, and its slope is determined by the percentage variability (column 7 on Fig. 305). Having one point and the slope, the line may be drawn, and corresponding values determined from given x values. The use of exponential curves for budgeting variable costs provides opportunities for interesting experiments with the application of mathematics to practical economics.

CHAPTER XXXIV

THE COST DIAGRAM AND ITS RATIOS

There is a serious tendency everywhere to overburden the productive enterprises and to make easier the lot of nonproductive pursuits which, in the last analysis, depend upon them. There can be no more wealth distributed than is created. This tendency, which is growing so threateningly in our economic life, discourages industry and makes more attractive the nonproductive services such as buying and selling, office work, and the professions. This is partly because they are more lucrative and partly because creative work is considered ignominious. Numerous incidents bear witness. A prominent manufacturer made a painstaking survey of "The Investment Required in the Electrical Manufacturing Industry" and then gave up manufacturing to sell securities. A small Type 1 manufacturer became discouraged and offered to sell his equipment and business to be free to make money buying and selling merchandise. However, there is seldom a case of a stock or merchandise broker seeking to improve his lot by transferring into a creative enterprise as a producer. This tendency cannot continue forever, of course, and a resetting of the stage may be anticipated.

With the passing of the early frontier days and the era of "get rich quick" through the rapid development of railroads, productive enterprises, and construction, there followed another kind of era in which practical developments have become the burden bearers in disproportionate degree. Great attraction is found in such other "get-rich-quick" pursuits as stock gambling, race tracks, real-estate ventures, insurance, buying and selling, all of which merely transfer wealth. The common counterpart of this tendency is the great confusion which harasses the minds of young people trying to choose a vocation. There exists an impression that for some reason or other creative work is not quite the thing; other pursuits appear more desirable. There is also the common attitude that whatever pay one is to receive seems pitifully small. No clear picture is had of the relation between what is received and the intrinsic worth of what is given in return. The general attitude is to get all one can, to charge all the traffic will bear, or to charge in proportion to the ability to pay.

Little does a job seeker realize that there are multitudes of manufacturing companies continually on the watch for men of an understanding point of view. The manufacturer may say he has no opportunity available yet he writes to his trade association and employers' associations in an effort to reach the right type of man, one who understands what it is that makes a business go and grow, one who, while holding fast like an anchor, can also "carry the message to Garcia." It is more a matter of character than brilliance.

An industrial engineer who had occasion to discuss a war contract with an executive of a large manufacturing corporation that was having some difficulty remarked that, through proper production control, it should be possible to save the company in the neighborhood of a quarter million dollars a year. The executive replied that he did not doubt it in the least, but that they had tried so many innovations without success that they could no longer find any interest in such ventures. He explained that numerous college graduates brought enthusiasm into the plant and tried to execute some ambitious improvement in control methods, only to lose heart when difficulties and aggressive opposition obstructed the trail. Back of all such experiences there lies resistance to change. Emerson summarizes the situation in his essay on "Power":

> When a new boy comes into school, when a man travels, and encounters strangers every day, or, when into an old club a new-comer is domesticated, that happens which befalls, when a strange ox is driven into a pen or pasture where cattle are kept; there is at once a trial of strength between the best pair of horns and the new-comer, and it is settled thenceforth which is the leader. So now, there is a measuring of strength, very courteous, but decisive, and an acquiescence thenceforward when these two meet. Each reads his fate in the other's eyes. The weaker party finds that none of his information or wit quite fits the occasion. He thought he knew this or that: he finds that he omitted to learn the end of it. Nothing that he knows will quite hit the mark, whilst all the rival's arrows are good, and well thrown. But if he knew all the facts in the encyclopaedia, it would not help him: for this is an affair of presence of mind, of attitude, of aplomb. 'Tis a question of stomach and constitution. The second man is as good as the first, — perhaps better; but has not stoutness or stomach, as the first has, and so his wit seems over-fine or under-fine.

In industry, the simplest of the eloquent diagrams is the cost diagram. Some study of it should precede all of the complex ventures which aim at improving the status of manufacturing enterprises. The small producer in particular should keep such a diagram before him to steady his judgment amid the host of demands and requests from organizations, institutions, and newspapers for donations and sub-

sidies. An industrial engineering betterment survey should start with a cost diagram in order to avoid such errors in judgment as were exhibited by the engineer who sold his service to Company No. 2 of Fig. 307 on the basis of a proposed program of time studies and piecerate reductions on direct labor. To know the cost diagram and to be experienced in marshaling thoughts, observations, and practices as illustrated in Figs. 213 and 214 is to be prepared to meet even stubborn opposition without losing heart and with substantial aplomb.

Industries, particularly small producers, deserve and need a far greater and more sympathetic understanding than is bestowed on them either by underexecutives within or by legislators without. They are

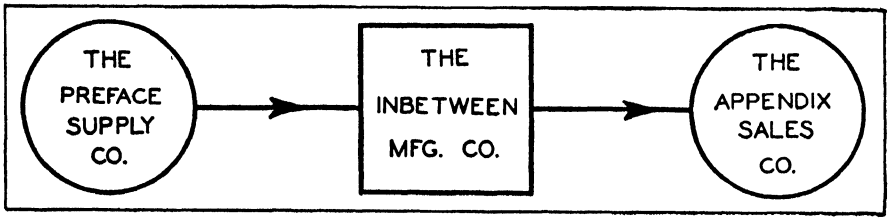


FIGURE 306. SHELTERING THE PRODUCTIVE UNIT

not likely to receive it. Only in the past year or two various attempts have been made to establish associations of small businessmen. Practically all of them came to naught; yet there is a tremendous field of important usefulness open to such associations. Large manufacturing enterprises can do much to help themselves; the condition of their size automatically helps them. Intermediate producers, trying to get their enterprises over the hill so that their existence may be more comfortable, often attempt to counter the oppressiveness of taxes and regulations by reorganizing to isolate the manufacturing branch. The arrangement is illustrated in Fig. 306. As one successful manufacturer explained it, "We take our profit at the extremes and operate the manufacturing unit at zero profit for the benefit of the government." Whatever may be said of the ethics of such a policy there is evidence of the need for a better understanding of the problems confronting manufacturers. In this case the manufacturer was in no great need of such reorganization because he operated a Type 2 plant. Had he been in a Type 1 manufacturing business there might have been much more reason for it.

A trade association sent to its members the specifications for a popular product common to them all, asking each to submit detailed cost figures so that a survey could be made of the differences in costing procedures. The costs varied greatly. One of the largest producers, who dominated the industry, showed a low cost. Asked how he could

justify it he remarked, "We are not particularly interested in whether or not we make a profit on our manufacturing operations; our stock is listed and we make our profit through the market."

Another trade association was to meet to consider a proposal from the dominant company in the field that prices be cut 5 per cent to stimulate sales. One of the small producers in the industry, who was having a very difficult time to show a profit from operations, made a painstaking analysis of the effect of such a price cut on small plants like his. At the meeting he explained that if the association were determined to adopt the proposal his plant would have to close. Discussion followed and the proposal was not adopted. The analysis of such situations will be explained in the following chapter.

Some of the factors which make life difficult for the small producer, and some which make life more comfortable for large producers, can be observed in the cost diagram. It would be more strikingly impressive if data were available for several sizes of units in the same industry. However, in Fig. 307 there are shown the diagrams for four distinctly different Type 1 manufacturing enterprises, varying in size from a very small unit having $85,000 annual net sales to a very large corporation in which the sales reach several million dollars annually. Each diagram represents the condition for a particular year — not the same year in all cases. The dynamic, or going, diagrams would take the form illustrated in the following chapter.

In the case of the small company, with its $85,000 annual sales, the income per wage earner was approximately $4700. This annual income would not be possible unless the company had one or more Type 2 products, a partial monopoly, or some patented product which commanded a high price. The company was alertly managed, paid good wages, had a low overhead expense or burden, but was confronted by a high cost of materials — something largely beyond its own control. More money might logically be spent for selling expense but the management found that the company business had grown faster than the human element, and it was decided to mark time until a higher caliber of underexecutive could be obtained. Four possible developments present themselves to such a company, when proper underexecutives become available: (1) more money might be spent on selling effort; (2) a survey should be made to ascertain whether or not a larger part of the materials might be purchased direct from their source on contract, thus cutting out the middlemen; (3) more Type 2 products might be obtained; and (4) the company might investigate the possibility of making desirable mergers with related small companies to achieve a combined total of $300,000 annual sales when it would emerge from the small producer class and begin to feel freer.

Company No. 2 has had a very difficult existence, being in an industry which is dominated by two large producers which set the pace in the field. It uses large quantities of cast iron, produced in its own foundry, thus accounting for the relatively low cost of materials. Its

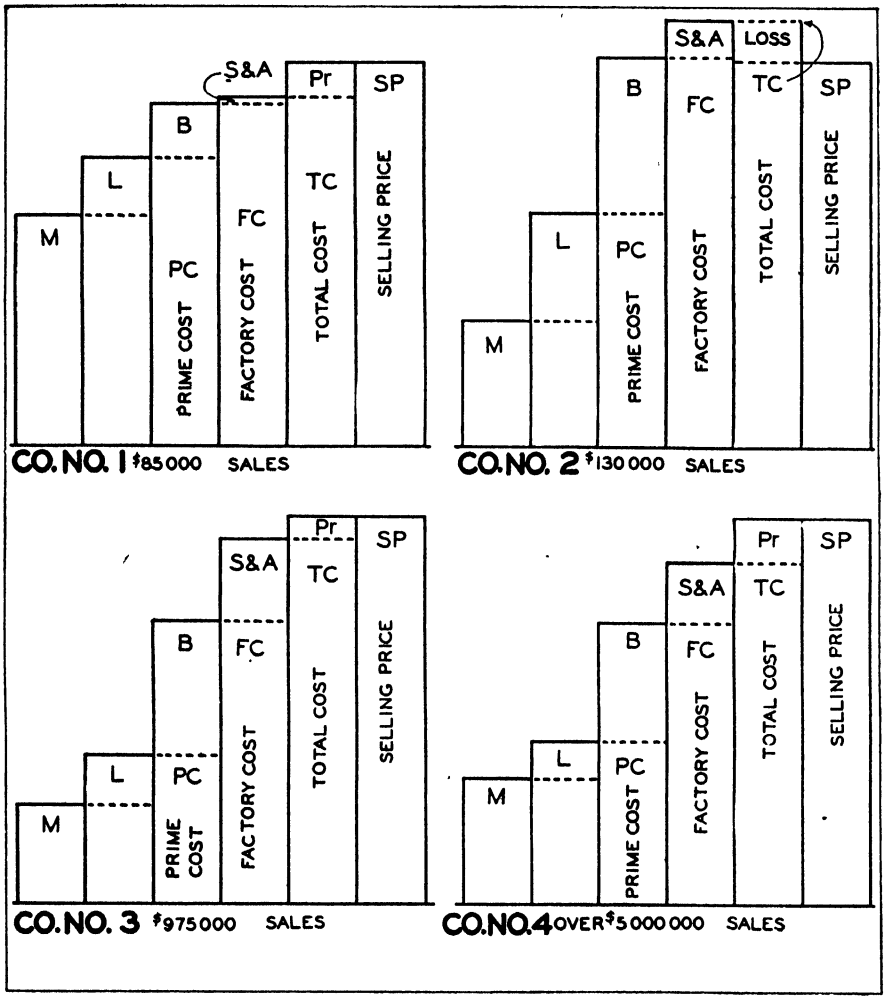


FIGURE 307. COST DIAGRAMS OF FOUR MANUFACTURING PLANTS

overhead expense, or burden, was disproportionately high, for several reasons. In an effort to boost the company into a more favorable position a fairly substantial amount was spent on sales effort. Prices having been dictated by the dominant companies, this small company had to try to attain a production of approximately 60 per cent of capacity in order to show a profit. In the offices the clerical staff was

highly paid, salaries running considerably in excess of any others in the whole community and in excess of what the company could stand. The superintendent, who had charge of the office as well as the shop, had never analyzed the cost diagram and, upon distributing advances in pay, never pondered where the money was to come from. He felt that when people had been with the company for a time they should automatically be given advances in pay. Yet, for every advance of $5.00 it was necessary to find some corresponding reduction in the total cost or some increase of $12.00 in the sales each week. Unfortunately, particularly in the case of small producers, there can be no pay advance beyond the top figure for each job unless there is some improvement in the job technique. It is tragically unjust to enact minimum-wage regulations without first taking into consideration the position of the company on the curve shown in Fig. 210, because what may be a very high wage rate for a small producer may be an extremely low rate for the very large producers who have nearly a three-to-one advantage in the annual rate of income per wage earner.

Company No. 3 also uses much cast iron, produced in its own foundry. Labor rates were low, overhead expense, or burden, was relatively high due in part to the necessity of maintaining an engineering department of considerable size. Selling and administrative expense was high due to the maintenance of district sales offices, some of which were unable to pay their way owing to comparatively limited demand in highly competitive territories. The profit from operations was thus small but the company enjoyed a half-comfortable existence because of its substantial sales of repair parts. In contrast with Company No. 1, whose difficulties were largely beyond its own control, this larger company's difficulties were entirely within its own control. Much could be done to reduce the overhead expense and the selling and administrative expense, thus bringing about a more suitable proportion among the cost elements. The company was generous in its donations to community campaigns because it was one of very few substantial enterprises in its neighborhood and occupied a place of dignity among them. A much less generous policy in this respect would have been entirely justifiable.

Company No. 4 is a large corporation engaged in the production of machinery and equipment of wide variety and numerous Type 2 products which are turned out by mass production on conveyors. Ordinarily its material costs would be high because of the expensiveness of some items, but the company owns some of the supply sources and is a large contract buyer of other materials so that its material costs are far below anything which Company No. 1 could even hope for. However, its burden is high, being, for some departments, nearly

four times the direct labor cost. Although the selling and administrative expense is not excessive the company maintains numerous district sales offices which do manage to pay their way, partly because of the variety and acceptability of the products and partly because of the high quality of the sales engineering. Such a company has little in its existence which constitutes a worrisome problem. Usually it is the dominant enterprise in its community, providing employment for considerable numbers of workers, and therefore is usually encouraged by tax concessions which are not bestowed on small producers.

Such a company might contribute $10,000 to a community fund or war chest and that would seem like a splendid and stimulating donation. Company No. 1, in order to be in line with that, should contribute approximately $6.00 on behalf of its 16 employees and that would not seem at all splendid or stimulating. It is probable that the small company would want to contribute at least $25, which would be out of proportion, thus indicating another of the numerous situations which tend to help the big to get bigger and the small smaller. To offset such a $25 gift the small company would have to turn out an additional $180 worth of sales or suffer a permanent setback; to match such a gift from the small company, Company No. 4 would have to contribute some $45,000.

What is not commonly borne in mind by underexecutives, and not understood at all by employees, is that the relations indicated in the cost diagram impose inexorable limitations on freedom of action. The management simply cannot do some of the things which employees expect or would like. In Company No. 1, for example, there is a long, uphill road before security is reached. The direct-labor cost is 17 per cent of the sales price. That is the same as saying that the direct-labor pay roll is 17 per cent of the net sales. It would be more than that percentage if there were not some Type 2 products or products which command a high price. It is due to no predilection that the management is forced to recognize that there must be nearly $6.00 of sales for every dollar paid out for direct labor. Assuming that the company is grinding watch crystals, if a job applicant says he would like to start work at $50 per week, it is the same as saying that he wants to start by turning out $300 worth of crystals each and every week. That may not be possible. If a bookkeeper applies for a job and says he would like to start work at $50 per week, it is the same as saying that he would like to start keeping score in such a manner that because of his work there would be freed or expedited enough productive effort to turn out an additional $365 worth of sales each and every week. That may not be immediately possible.

There is a definite relation between what we take and what we give

in any particular situation. Having pressed on to the top rate of pay in one occupation one must fit himself for the next higher grade operation. Having attained the limit of pay in the productive, or applied-time, classes of work, the only immediate hope for advancement is through such nonproductive occupations as accounting, planning, or sales. Beyond that it becomes necessary to get into the administrative branch of the business where competition is thinned out, and where it becomes possible to receive a share of the profits in addition to salary. Beyond that, strange as it may seem, advancement in money acquisition leads one out of creative fields into such nonproductive fields as merely transfer wealth.

Referring to Fig. 307, the elements of the cost diagram are probably clear to the student. *M* represents the direct-materials cost, *L* the direct-labor cost, *B* the burden cost, *S* and *A* the selling and administrative cost, *Pr* the profit, and *SP* the net sales price, all in dollars.

Taking two significant ratios, we have the following:

	Sales: Direct Labor	*Sales: Burden*
Company No. 1	5.8	7.3
Company No. 2	3.9	2.5
Company No. 3	8.3	3.3
Company No. 4	11.1	3.45
Average	7.3	4.14

It is not strictly correct to take a simple average in such a case but to do so does not impair the elementary conclusions which may be drawn from the situation. First, on the average, any productive worker has to turn out a sales value of 7.3 times his wage. If he wishes $50 per week he has to turn out $365 worth of production. If he works on some simple product such as electrotype plates, watch crystals, Venetian blinds, which he himself completes ready for sale, it is not at all difficult to see this relation. If he works on more complex products such as automobile crankshafts, locomotive wheels, or airplane propellers, this relation is lost to view. In Company No. 1 he would have to turn out $290 worth of production each and every week that his relation to the company and its situation may be economically sound. In Company No. 4 he would have to turn out $555 worth of production each and every week. That means that the company must be in a position to mechanize his work to increase his leverage through continuous, mechanically aided production of a single part or operation. This is the Type 2 element which makes life so comfortable for the large corporation with its national market and wide demand. The lack of it, through being out of reach, is what makes life so uncomfortable for the small Type 1 producer.

Second, on the above mentioned average, each expense worker has to perform his work in such a manner that for each dollar of wage there will be $4.14 in sales moving off the line. In Company No. 1, the office worker, for each $13.70 worth of wages, must do such work and in such manner as will enable the productive worker to turn out $100 worth of production for a wage of $17.30. That is as if a productive worker in Company No. 1 said, "If you will supplement my efforts with $13.70 worth of plant facilities and expense help per day, and pay me $17.30 per day, I will turn out for you $100 worth of production per day." In Company No. 4 he might say, "If you will supplement my efforts with $29.00 worth of plant facilities and expense help per day, and will pay me $9.00 per day, I will turn out for you $100 worth of production." Or, putting it somewhat more comparably — in Company No. 1 he might say, "If you will pay me $25 per week and supplement my efforts with $19.80 worth of plant facilities and expense help I will turn out $144.50 worth of production." In Company No. 4 he might say, "If you will pay me $25 per week and supplement my efforts with $80.60 worth of plant facilities and expense help I will turn out $278 worth of production each week."

The shrewd small producer would, in view of this comparison, say that his best policy is to put all of his surplus into added equipment so that he, too, may approximate $80 worth of plant facilities and expediting assistants. The difficulty is that his depreciation and personal-property taxes on the added equipment would rise, while his opportunity to keep the equipment busy on long runs would not rise, and, for the moment at least, his policy would have to be construed as either a hobby or a forward look to the time when he can add more Type 2 products and a national market.

It is not difficult to see here, in this different form, the tremendous advantage which accrues to large corporations over the small producer.

Originally the principle of the division of labor had in view the improving of productive efficiency through the separation of all such expense activities as maintenance of property, answering telephone and mail, planning the work, promoting the sales and preparing all reports. We are rapidly losing all sight of the relation between productive effort and expense effort. In a small company it is not at all difficult to see the relation. One partner, by effectively taking care of all office activities — and these are almost wildly on the increase — may double the productive capacity of another partner who concentrates on work in the shop. He would have little difficulty in seeing that relation. As the enterprise grows larger the relation becomes less clear until, at length, it is almost entirely lost to view.

Third, referring again to Fig. 307, the ratios of this overhead expense, or burden, to the productive, or direct, labor are as follows:

	L	B	Ratio $\frac{B}{L}$
Company No. 1	17.3	13.7	.79
Company No. 2	25.5	40.3	1.58
Company No. 3	12.0	35.0	2.92
Company No. 4	9.0	29.0	3.22

It must be borne in mind that these data have not been scientifically selected. They represent situations existing in several manufacturing plants, not in a single industry, before any tuning-up processes were inaugurated. Nevertheless, the picture they reveal is none the less noteworthy. The L and B figures represent the percentage of each net sales dollar devoted to the payment for direct labor and for burden. The ratio means that in Company No. 1, it requires a 79-cent expenditure for plant facilities and nonproductive effort in order to enable $1.00 of productive effort to turn out $5.80 worth of net sales. That low expense would not be possible except under such favorable conditions as the presence of one or more Type 2 products, a sales contract, or highly priced specialties. In Company No. 4, doing a business of several millions in sales annually, it requires a $3.22 expenditure for plant facilities and nonproductive help in order to enable $1.00 of productive effort to turn out $11.10 worth of net sales value. This ratio runs as high as 3.87 in some companies which have prominent engineering departments in which a substantial portion of engineering time cannot readily be charged directly to jobs.

An important executive in a large manufacturing corporation asked, "Have you ever thought what sort of spectacle it might be if you asked all of our productive workers to line up on one side of the street and all our nonproductive workers to line up on the other side?" At any rate, for every dollar of productive effort it has become necessary to spend from $2.00 to nearly $4.00 for maintaining plant facilities and expense workers. That is why, in Chap. XXIII, it was stated that the character of the productive process should determine the kind of production control, and why, in the chapters on types of control, the emphasis was laid on the designing of a control mechanism which should obtain maximum results with the minimum of expenditure for overhead expense.

There is another set of ratios relating to the cost diagram which is especially helpful to plants turning out a wide variety of products. Referring still to Fig. 307, if

FC is the factory cost in dollars,
TC is the total cost in dollars,
SP is the sales price in dollars,

P is the profit in per cent of FC, that is $\frac{P_r}{FC}$

S is the selling and administrative expense in per cent of FC, that is $\frac{S \& A}{FC}$,

then the ratio $\frac{FC}{SP} = \frac{1}{1 + S + P}$; the lower the better.

Taking various percentages of selling and administrative expense, it is not difficult to ascertain what this ratio of factory cost to net selling price must be in order to yield any desired profit. This particular ratio is stated from the cost man's standpoint. The cost man always thinks downward from the factory cost, and thinks of all expenses in terms of factory cost. The salesman always thinks upward from selling price, and thinks of all expenses in terms of net sales. The salesman would think of the ratio as $\frac{SP}{FC} = \frac{1}{1 - s - p}$ where s and p are percentages of the net selling price. The higher this ratio the better.

Tabulating the $\frac{FC}{SP}$ ratio for the cost man, we have for various selling and administrative expenses in per cent of FC and for various profits, the following:

For $P =$	*and with* $S =$			
	.10	.15	.20	.25
0	.909	.870	.833	.800
.05	.870	.833	.800	.769
.10	.833	.800	.769	.741
.15	.800	.769	.741	.714
.20	.769	.741	.714	.690
.25	.741	.714	.690	.667
.30	.714	.690	.667	.645

In Type 1 manufacturing establishments with numerous orders coming in for small unit quantities of a wide variety of products which are grouped in a limited number of product classes, this ratio is very eloquent and is readily obtained. It is of little value to Type 2 producers.

In Fig. 268 on page 131 there is shown the coding which is stamped on each incoming order by the order department, or whichever department receives the orders. The routine of entering the code classification numbers, price, and factory cost was explained. At the close of any period, say at the end of each month, the order copies are sorted in five ways — first by product class, then by industry or trade class, then by territory, then by dealer, agent, or other outlet, and finally

by discount base, if various combinations of discounts have been established. Reports are then prepared as illustrated in Fig. 308. In the subject company there were so few different grades of discounts allowed that it was not considered worth while to summarize a report at the time. It should have been done, however, to complete the important picture of what was wrong.

The particular period represented in these reports was at a time when going was difficult, as will be inferred from an examination of the ratios. The items indicated by check marks on the various reports are the only ones which are even slightly profitable. The company was practically an exclusively Type 1 producer. Either the prices are too low or the costs are too high. There is no telling which from the information contained in these reports. Competition, either in price levels or in salesmanship quality, could account for the situation, and high overhead expense and high selling and administrative expense could account for it. It is not probable that such a situation could be caused by high productive labor costs because there is no cost element which has received anywhere near so much attention as that.

In approaching the task of remedying such a situation it is well to keep in mind that we have drifted into the predicament of having to provide in the neighborhood of three nonproductive burden dollars for every productive dollar which pays the bills. The most enlightened approach to such uncomfortable situations as the one illustrated in Fig. 308 is by way of an engineering scrutiny of the items of manufacturing burden and selling and administrative expenses. To make the production-control plan appropriately fit the character of the productive process and, particularly, to make it effective with a minimum of overhead expense, will create such a general and favorable atmosphere that productive costs will often begin promptly to fall without any such conscious attention as is involved in the making of time studies. Merely to give evidence of orderly and mindful planning control will, as a rule, cut costs at a rate that is way beyond possibility in the laborious programs of individual time studies. That is the scientific-management way of going about betterment, and the method which should have been more clearly held in view during the evolution of the principle of the division of labor.

Large corporations, in most cases, do not find it particularly necessary to resort to internal betterment programs. Interest centers more in research, the creation of new devices and methods, the more complete control of material sources and of markets. Their annual income per wage earner is, on the average, some three times that of the small producer, and they can afford to be even conspicuously inefficient in their internal control mechanisms without suffering discomfort.

Furthermore, it is not an easy matter to find and maintain a personnel which can sustain itself for any length of time on the higher level of attention and concentration that is required by an efficient program of control. Our scientific and business developments are outstripping our human developments and here again it is the relatively small producer who suffers most since his business could grow much more rapidly if it were not for the limitations of the human element which constitutes its foundation.

At the end of Part VI there are presented problems aimed at giving the student a clearer comprehension of the savings which may accrue from the elimination of waste in our ways of handling production in industry.

CHAPTER XXXV

THE TRIANGLE DIAGRAM

The diagram illustrated in the previous chapter showed the relations between the cost elements for a given period, such as for a particular year. To combine a series of such diagrams for a number of years, with different rates of production, would yield the triangle, or profit diagram.

It is not difficult to see how some expenses change as production changes. Normally, if production doubles, the costs of direct materials and of direct labor double. The cost of taxes, however, does not change. An expense such as the cost of fuel oil, which heats tempering baths or furnaces, changes with production in a more complex manner. A certain portion, which is fixed, is required just to maintain the normal heat of the furnace. The fuel oil required beyond that is directly proportional to production passing through the furnace. That is, such compound expenses have both a fixed and variable component.

Before attempting to construct any such budget base as the triangle diagram it is important to make some sort of analysis of all of the expenses involved, in order to ascertain what relation they bear to changing production levels. During the early analysis it is more important to get started promptly than to undertake refinements at the same time. The refining process may well cover a period of months, or years. First obtain promptly some basis for constructive action. In some of the diagrams which follow it will be quite evident that there was made no attempt at refining. The diagrams as they stand provide abundant opportunity for well-directed action.

In order first to make some analysis of various expenses it will be convenient to have prepared a set of work sheets, one sheet for each expense item. It will also be desirable to ascertain the point at which operations break even — that is, the profitless point. To find this point simply obtain the profit-and-loss statements for a good year, a poor year, and some year in between. For these three years obtain from the statements the total costs, that is, the costs of materials plus labor plus manufacturing expense plus sales and administrative expenses. Then draw horizontal and vertical axes to the same scale in dollars. Let the vertical scale represent sales and expenses and the horizontal scale production priced at sales value. A line drawn at

45 degrees from the origin will represent the income line at various production levels. On the horizontal axis spot the three points representing the production (or sales) for the three selected years and measure up from these points the corresponding total costs. Through the three points thus obtained draw a line. If the line is not straight, as it probably will not be, then make it straight, using the most suitable approximations. This will be sufficiently accurate for a start. The break-even point is where this line crosses the income line.

Two illustrative work sheets are shown in Fig. 309. These are based on the hastily obtained break-even point of $100,000 per month. If data are readily available for a number of years they would prove more reliable; if not, then data for a series of months will be sufficient to start with. The sheet for gas shows that this item was found to be about half fixed and half variable and the sheet for other labor shows that this item was found to be approximately 30 per cent fixed and 70 per cent variable.

Proceeding in similar manner with each of the expense items there would be obtained a table such as the following:

	F	*V*		*F*	*V*
Direct material	0.00	1.00	Process gas	0.50	0.50
Direct labor	0.00	1.00	Water	0.50	0.50
General factory supervision	1.00	0.00	Electricity	0.00	1.08
Office salaries	1.00	0.00	Other losses	0.75	0.21
Stockroom salaries	1.00	0.00	Total assessed expenses	0.62	0.30
Shipping salaries	0.00	1.00	Foremen and assistants	0.89	0.15
Yard labor	0.50	0.50	Factory clerical	1.00	0.00
Watchmen	1.00	0.00	Indirect labor	0.00	1.00
Other labor	0.30	0.70	Idle time	0.00	1.00
Plant engineering	1.00	0.00	Welfare	0.00	1.00
General factory maintenance	0.00	1.00	Supplies	0.00	1.00
General factory supplies	0.00	1.00	Maintenance	0.00	1.06
Power plant expenses	0.58	0.42	Inspection	0.44	0.50
General factory inspection	1.00	0.00	Salvage labor	0.00	1.00
Miscellaneous	0.30	0.70	Defective work	0.00	1.09
Taxes	1.00	0.00	Total expenses within department	0.11	0.86
Fire insurance	1.00	0.00	Factory cost	0.14	0.88
Liability insurance	0.00	1.00	Sales and administrative expenses	0.72	0.29
Building depreciation	1.00	0.00	Total cost	0.21	0.70
Equipment depreciation	1.00	0.00			

Obviously these proportions will vary considerably in various enterprises as will be partly evident from a scrutiny of the diagrams which follow. In any case, however, the relation between the fixed element and the variable element in the cost has a very important bearing on the policy of management and on the ability of the business to withstand the effects of a price-cutting war.

The triangle diagrams for three manufacturing establishments in which the proportions of fixed expense in the total cost at the break-

even point are 10 per cent, 20 per cent, and 50 per cent respectively, are illustrated in Fig. 310.

In the first company it has been the practice to try and put all labor on piecework, as many of the office workers as possible on piecework, and to make as many expense items as possible directly proportional to output. When production rises, the majority of the expense items travel right along up with it so that the profit margin reflects slight gain. This management policy may be the easiest to administer but it is the least profitable. The third triangle suggests that if it were

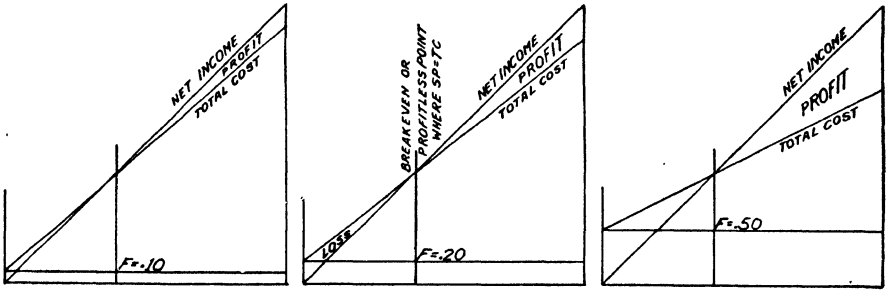


FIGURE 310. TRIANGLE DIAGRAMS FOR THREE CONDITIONS

possible to hold more of the expense items stable by improving methods as production rises, instead of by merely adding more help, there would be much to gain. Such a management policy is more difficult but more surefooted. Through mechanization of operations, particularly when its cost can be quickly written off, is about the only opportunity of even approximating this third triangle. The fundamental way of trying to approximate it, which should be the normal way, is scarcely open any longer.

The more complete diagram for a company engaged in the production of a variety of agricultural machines is shown in Fig. 311, indicating the initial situation before any betterment program was initiated.

The company was intelligently managed, as is evident from the diagram, but suffered through being mainly a Type 1 plant in which it was necessary to purchase materials in wide variety but in relatively small quantities.

When the diagram is constructed from the data of three years of different production levels the lines will invariably be broken, as shown in this figure. To simplify the chart the lines should be drawn straight, using the most suitable approximations, even though the expenses themselves could not be expected actually to follow straight lines. The straight lines provide the guide, or the budget mark at which to aim.

The fixed portion in the expense will be the intercept on the vertical axis and from that the fixed portion at the break-even point can be obtained. In this case $F = .293$ and $V = .707$. The improvement program here should be to examine the possibility of making more favorable purchases of materials and putting any saving into selling expense in an endeavor to keep sales well up on the chart.

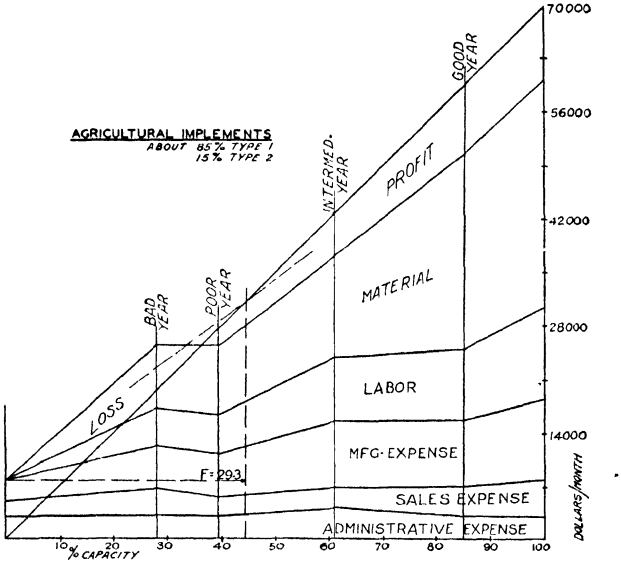


FIGURE 311. AN AGRICULTURAL IMPLEMENT COMPANY

Compare the situation of this company with that of the portable-conveyor company which is diagrammed in Fig. 312, a company of approximately the same size and, also, well above the "small-producer" level.

This company was more anxiously managed. Obviously something is wrong with the data on manufacturing expense. It does no good merely to transfer expense from the manufacturing group into the sales or administrative group. Such expenses are in the picture just the same, and to transfer them merely distorts the diagram and handicaps the judgment. The broken lines indicate graphing from the original data, just as they were available. One of the several factors which contributed to the high materials cost was the policy concerning gears. The management felt that "we have machines here which are capable of turning out gears and it is good judgment to keep them busy." Not necessarily. The machines were not modern gear-making machines, and it would have been better to have disposed of them and purchased the gears from a modern plant which specializes in them. Before much

can be done toward laying out a betterment program in this plant it would be necessary to analyze the cost figures and get the various items where they belong. $F = .286$, which is not very different from that in the agricultural implement company.

Dropping, now, the showing of original broken lines, one of the most satisfactory cases available at the moment is that of a plant engaged in

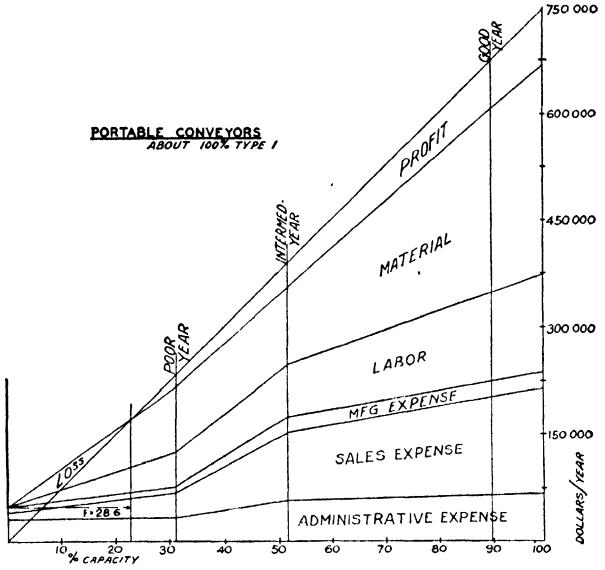


FIGURE 312. A PORTABLE CONVEYOR COMPANY

the production of automobile parts, largely from automatic screw machines. An examination of Fig. 313 will reveal that the company was very intelligently managed and was having a comfortable existence.

The company is slightly over the mark which was indicated in Chap. I as the turning point from small producer to large producer. It is therefore a shrewd policy to put additional money into sales effort in order to attain the next higher producing group. Competition with this company would be a worrisome job. The diagram has been smoothed out from the original data and it indicates the basis taken for the budget system in an aggressive campaign to rise to a place in the sun. $F = .385$, a decided advantage in the program.

In Fig. 311 the fight being made by the management of that Type 1 company for a profit is quite apparent. Here in Fig. 313 no such fight is necessary since it is a Type 2 plant, concentrating on a relatively limited variety of materials and contracting for them with quantity discounts. Whatever fight the management sustains can be directed, not to existence, but to maneuvering into a higher station.

In another plant, somewhat comparable but not closely so, the owner was both manager and salesman. He was tremendously energetic and planned to try and tie himself to a budget program in the hope of getting the most out of his relatively new and still struggling enterprise.

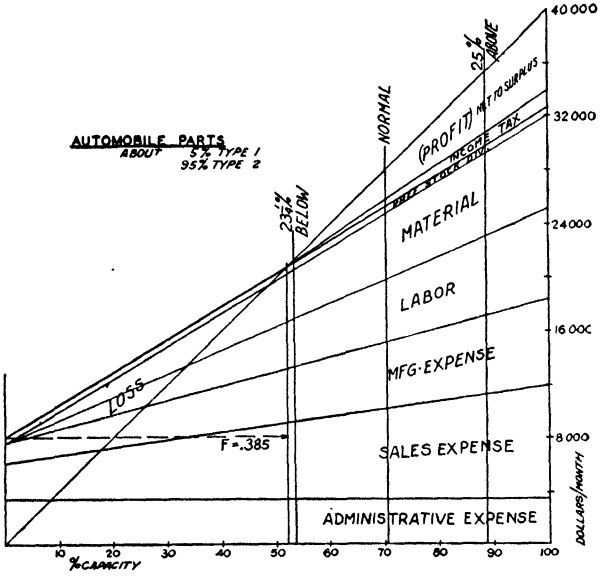


FIGURE 313. AUTOMOBILE PARTS PRODUCER

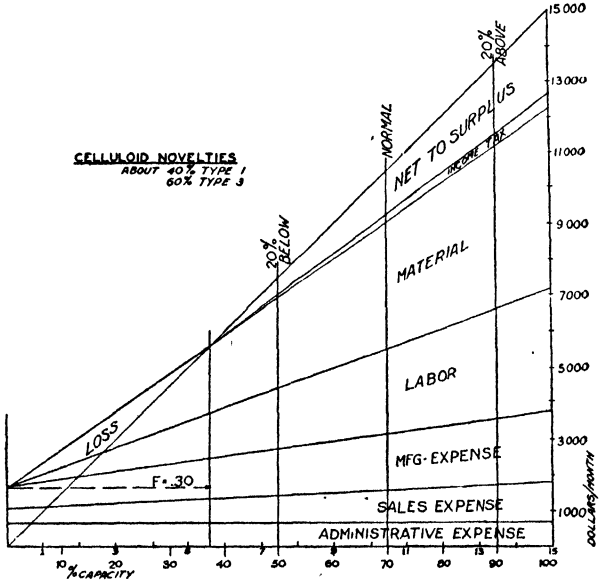


FIGURE 314. A CELLULOID NOVELTY COMPANY

His goal to shoot at is illustrated in Fig. 314 which, in spite of a relatively high cost of materials, is not at all bad for a small producer. The problem of attaining a comfortable existence would have been much greater for this company had it not been for a substantial proportion (some 60 per cent) of sales which could be handled under Type 3 production — such items as golf tees which were put through

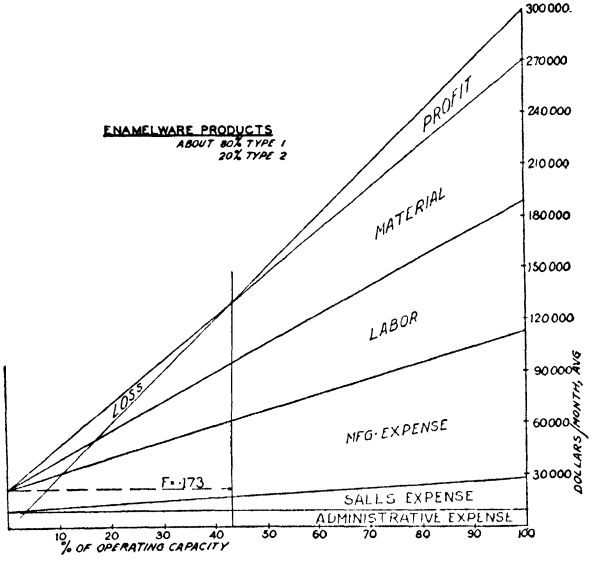


FIGURE 315. A SANITARY ENAMELWARE COMPANY

in long runs with appropriate mechanical aid. It is evident from the diagram that much of the labor in this company has to be hand work. The Type 3 products kept the manufacturing expense down and the energy of the owner-manager kept the sales and administrative expenses down. $F = .300$. If it could safely be made .400 the company could have a very enviable existence for a small producer.

A very uncomfortable situation confronted a company engaged in the making of enameled products, such as sinks, of considerable variety. Heroic effort had been made to bridge its difficulties and it would have been very favorable to devote more money to sales effort if the money could have been found. The situation is illustrated in Fig. 315, in which $F = .173$, a discouraging problem in itself.

Here there is not the disadvantage of high cost of materials, the company being in the large producer group, but the benefit of that situation is offset by the high manufacturing expense caused by the task of trying to handle such a wide variety of products on a Type 1 basis. Obviously the answer to difficulties existing here would be the

introduction of Type 1 production control along with a study directed toward increasing the proportion of Type 2 products.

If it were possible for the right kind of management, with the right kind of employees, to work out a partnership plan in which all productive workers would be paid by the week, in a good year, when production might run some 30 per cent above normal, all would willingly

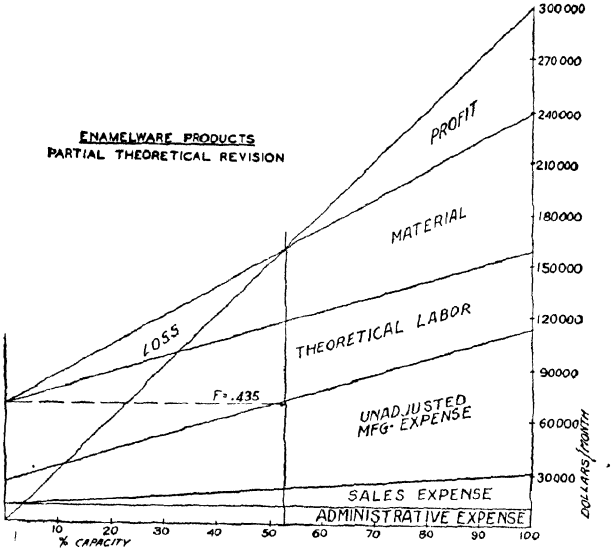


FIGURE 316. A DESIRABLE IMPROVEMENT OF FIGURE 315

work some 30 per cent harder or longer. To achieve that alone among the productive workers, not to mention the expense help in shop and office, would convert this diagram into Fig. 316, a very different kind of picture.

Even though this new arrangement might be predicated on a normal year when the profit might be the same whether working according to Fig. 315 or Fig. 316, it is highly improbable that such an arrangement could be attained under our democratic system of free enterprise.

In one very high-grade manufacturing plant such an undertaking was approached by attempting to budget all expense workers on this basis but not the productive workers, whose possible contribution to the success of such a venture is blocked by legislation. But in drawing the diagram for this company let it be assumed for the moment that, on a partnership arrangement, both productive workers and expense help willingly wanted to improve their security by taking a fixed weekly wage and to regulate their time or energy in proportion to sales demand. This would be precisely what any individual would do if he operated

his own farm or manufacturing establishment. In flush years he would work for a bumper crop; in normal years he would work normally; in lean years he would draw on his surplus.

The diagram for this company would then look like Fig. 317 and the company would be in a position to worry competition seriously, particularly if any competitor wanted to risk a price-cutting war. The

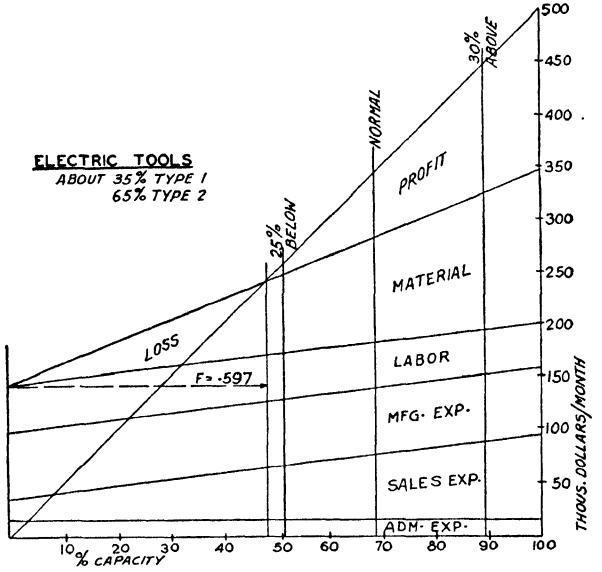


FIGURE 317. AN ATTAINABLE IDEAL IF ENTERPRISE WERE FREE

proportion of Type 1 and Type 2 products is nearly ideal for such a venture. Of course such an arrangement at present would never work. Accordingly one must be content trying to pick his way on the basis of the best average among the forces of management, legislation, and run-of-the-mill human nature. If it would work, then the attention of management would automatically be directed into the channel of making improvements in methods and mechanization principally for the purpose of consolidating fresh and normal gains. When production went up 30 per cent, and time or effort 30 per cent, then the policy would be to retain the gain in production but to restore the time or effort back to normal by appropriate improvements in technique. That course would entirely change existing management policies.

The curious part of this whole thing is that large corporations would not need the opportunity to exercise it since the condition of their size helps them sufficiently. Type 2 establishments would not need it, especially if they have risen above the small producer group. Type 3 producers would profit little by it since their direct- and indirect-

labor costs are relatively low in comparison with their machine costs. But Type 1 and Type 4 producers would profit noticeably from it and they are the long-suffering groups which most feel the need of some sort of relief. Even among them the arrangement would not work successfully in all cases, but it would automatically reward the highest types of management and bring endless difficulties to unqualified management. The desire for some such help is evident in the reply which a Milwaukee contractor made to a comment that in his field it must be difficult enough to make a consistent profit. He said, "It all boils down to the condition that if my men are willing to work a little more loyally for me than my competitor's men work for him, then I get along." That could only be the case with properly qualified managers.

A small producer undertook to try this high F venture. He launched it at a dinner meeting of his most concerned employees. In the course of time he was forced to conclude that it was too radical a departure from the customary ways of life and its dismal failure convinced him that possibilities through such ideal plans, even for a growing and promising enterprise, are, under generally existing conditions, "gone with the wind."

An important lesson to be learned from the triangle diagram is that a manufacturer would do well to have the diagram for his company clearly in mind before he becomes a party to any price war or to any contemplated program of price cutting for stimulating sales, as was mentioned in the previous chapter. To cut prices 5 per cent might not be at all uncomfortable for one company, but it might put another company out of business. It all depends upon the proportion of fixed expense at the point where the company breaks even.

In Fig. 318 there are plotted the significant curves showing how much a manufacturing plant must increase its volume of sales, and therefore production, in order to offset the effect of a cut in sales price. For a company having 10 per cent fixed expense at the break-even point a cut of 5 per cent in price necessitates a 100 per cent increase in volume, and that may not be possible. For a company having 50 per cent fixed expense it would necessitate a volume increase of slightly over 11 per cent, and that would not be at all difficult to manage.

The equation of these curves is

$$\frac{P_2}{P_1} = \frac{1 - V}{1 - x - V} \text{ or } \frac{F}{F - x}$$

where

P_1 is the volume or production at the time

P_2 is the new volume that will be required after cutting the price

x is the per cent cut in price

V is the variable portion and F the fixed portion in the cost at the break-even point.

The equation can be verified by very simple mathematics or, if the graphic method is preferred, the development can be more clearly followed from Fig. 319 which represents a company in which $F = .50$.

Suppose the company is operating at 60 per cent capacity. The income at that point, or the sales price, will be SP_{60} for a production of P_{60}, and the total cost will be TC_{60}. The present profit is the difference between the two. If the price is cut 10 per cent, it is the same thing as saying that for a given production the income is 10 per cent

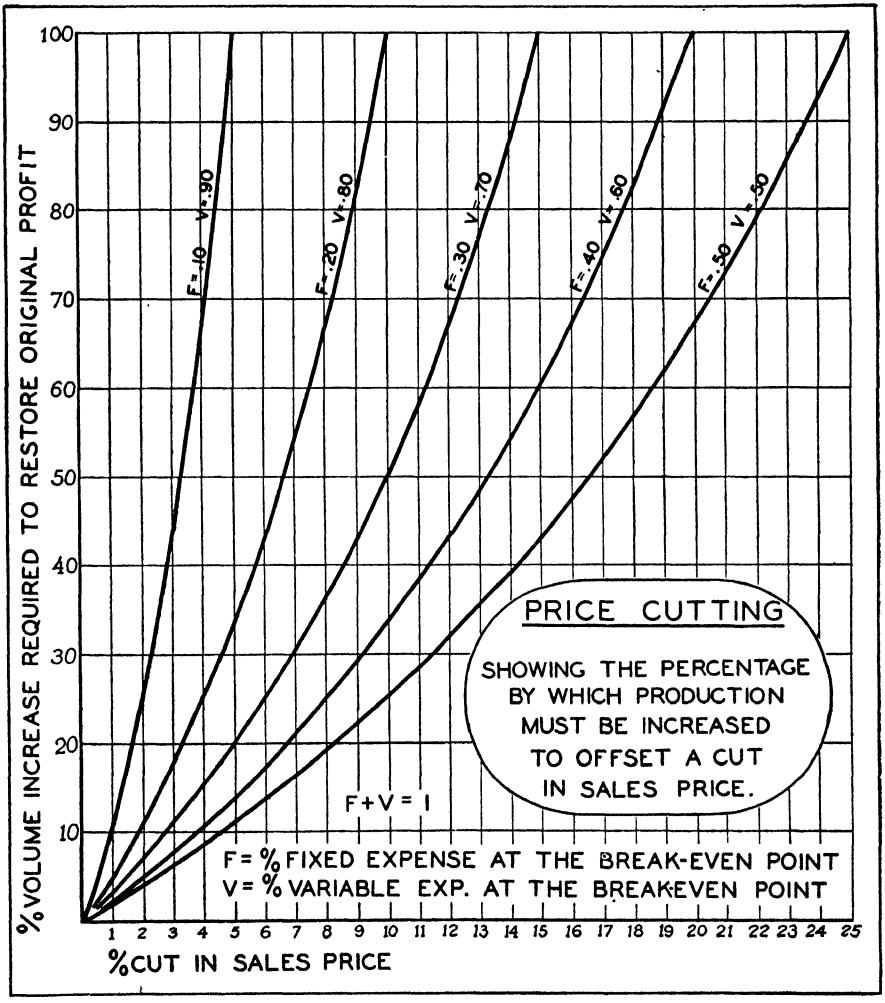


FIGURE 318. INDICATING THE SERIOUSNESS OF PRICE CUTTING

less; that is, the income line drops to the position shown by the dotted line. The total cost is in no way affected. In order to find the position on the new, reduced, income line where the profit will remain the same as before, a line has to be drawn from SP_{60}, parallel to the total cost line, until it intersects this new income line at X. Then by dropping

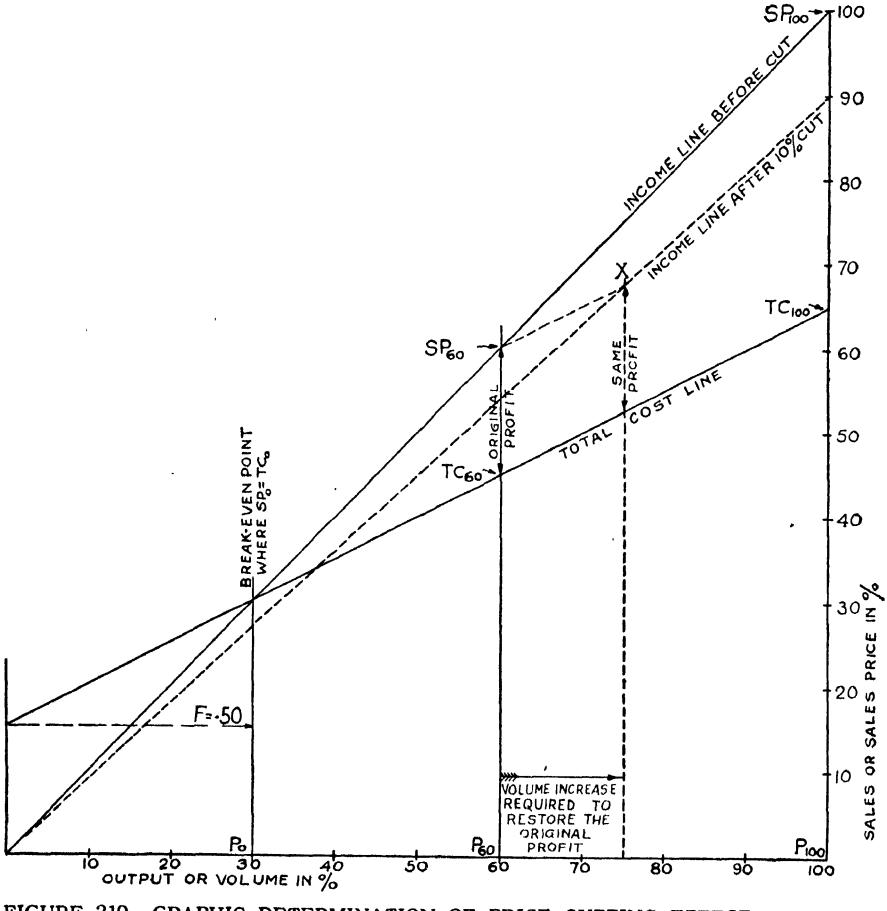


FIGURE 319. GRAPHIC DETERMINATION OF PRICE CUTTING EFFECT

the vertical line the new volume of production can be ascertained. Here, to cut the price 10 per cent means that production will have to be increased from 60 per cent of capacity to 75 per cent of capacity or 25 per cent, and that is not an impossible task. This corresponds with the curve in Fig. 318. It will be instructive to draw a similar diagram for a company in which F is 20 per cent. It is quite clear that price cutting, for some companies, may be a serious venture.

QUESTIONS

CHAPTER XXXII. (DISTRIBUTION OF OVERHEAD EXPENSE)

1. Why is it important for managers to understand overhead costs?
2. What is an hourly overhead rate?
3. Explain the steps for computing an hourly overhead rate.
4. Define the meaning of the term "general column."
5. Explain what is meant by "distribution."
6. Define the following expenses: depreciation, taxes on buildings, taxes on equipment, boiler insurance, workman's compensation.
7. Explain the distinction between administrative and factory burden.
8. What estimates are needed to complete a burden distribution sheet?
9. Explain the meaning of the term "closing out" the expense columns on the burden distribution sheet.
10. How is special equipment expense handled?
11. Explain what items of cost comprise power expense.
12. What is the relationship between capacity utilization and the distribution of overhead expense?
13. What is meant by weighted hourly overhead rates?

CHAPTER XXXIII. (CONTROL OF VARIABLE COSTS)

1. Define variable costs.
2. What are rates of variability?
3. Explain how per cent variabilities are used in budgeting variable costs.
4. Explain and illustrate the calculation of a per cent variability.
5. Why are variability percentages used in budgeting?

CHAPTER XXXIV. (THE COST DIAGRAM AND ITS RATIOS)

1. Why is it important for students of management to understand differences between cost and income of the small and large producer?
2. What is the significance of income per wage earner in relation to the size of the company?
3. In what way can a cost diagram be used to show limitations on the freedom of action of managers?
4. What is the significance of the ratios "sales to direct labor" and "sales to burden"?
5. Derive the equation, $\frac{FC}{SP} = \frac{1}{1+S+P}$.
6. Derive the equation, $\frac{SP}{FC} = \frac{1}{1-s-p}$.
7. Compute the table of $\frac{SP}{FC}$ ratios that corresponds with the $\frac{FC}{SP}$ table.

CHAPTER XXXV. (THE TRIANGLE DIAGRAM)

1. Analyzing the proportional triangles in Fig. 319, verify the equation,

$$\frac{P_2}{P_1} = \frac{F}{F-x}.$$

2. What is a triangle diagram?
3. Explain the steps for finding the break-even point.
4. Why is the triangle diagram valuable as a tool of management?
5. Lay out the axes only for a triangle diagram showing \$300,000 per year as the net sales at 100 per cent capacity. Draw a vertical line at the assumed break-even point of 33⅓ per cent capacity. Draw an inclined expense line to represent an expense item which has both a fixed and a variable component. That is, it will intercept the vertical axis somewhat above the origin. At the break-even point let E_1 represent the amount of this expense in dollars and P_1 the production. At 60 per cent capacity let E_2 represent the magnitude of this expense item and P_2 the production. Then show that $E_2 = E_1\left(F + V\frac{P_2}{P_1}\right)$ where F and V are the proportions of fixed and variable components at the break-even point.
6. Assume that in a manufacturing plant the power-plant operating expense is made up of maintenance costs and wages of two operators. The operators are paid 43 cents and 37 cents per hour for 12 hr. per day, 30 days per month. Their wages constitute a fixed expense, independent of production. The maintenance costs are directly proportional to production. Upon analysis you find that it is appropriate to budget the total operating expense for a production of \$100,000, which is the break-even point, at \$498 per month. Prepare a tabulation of the wages the maintenance expense, and the total, for production levels of \$100,000, \$150,000, \$200,000, \$250,000, and \$300,000. Applying the above equation for the points of P_1 = \$100,000 and P_2 = \$300,000, determine the factors F and V for this expense. Compare your answer with this item in the table on page 244.

PROBLEMS

Problem 1. The Lake Manufacturing Company

The Distribution of Factory Overhead Expense

The Lake Manufacturing Company wishes to distribute its overhead expenses for a typical manufacturing period. The information listed below has been brought together for this purpose. The company wishes its expenses distributed on a form which has three manufacturing departments — A, B, and C, a column to compile *material-handling* expenses, a column to compile *power* expenses, and a *general* column. Prepare the form.

Fire insurance: Building, $1.25 per $100 value (given)
Machine, $0.60 per $1000 value (given)
Workmen's Compensation, $1.45 per $100 pay roll
Boiler, $218 (total)
Unemployment Insurance, $29,400 (total)
Special Equipment Insurance, $115 (total)

Taxes: Buildings, $28,000
Special equipment, $65

Tax rates: Building, $35.00 per M dollars value
Factory equipment, $5.00 per M dollars value
Power, $5.00 per M dollars value
Material handling, $6,400 @ $30.00 per M dollars value
$20,000 @ $5.00 per M dollars value

Depreciation: Special equipment, $140

Depreciation rates:	Buildings	2½ per cent
	Factory equipment	5 per cent
	Power equipment	7½ per cent
	Material-handling equipment	$20,000 @ 4 per cent
		6,400 @ 25 per cent
Repairs and maintenance:	Buildings	$33,250
	Factory equipment	93,650
	Special equipment	125
	Material handling	610
	Power	1,480
Factory supply requisitions:	Department A	$ 2,786
	Department B	3,912
	Department C	4,605
	Power	483
	General	1,469
	Factory medical	1,486
	Employee (general)	4,816
	Material handling	845
Supervision:	General plant	$21,600
	Department A	14,210
	Department B	16,360
	Department C	22,600

Indirect materials:	Department A		$11,100
	Department B		9,200
	Department C		10,160
Heat and light expense estimated as follows:			
	Department A		860
	Department B		490
	Department C		620
	General		1,260
Special data:	Shipping expense		4,625
	Elevator expense		2,160
	Elevator attendant		810
	Water bill for period		285
	Yard expense		2,410
	Fuel — gas and fuel oil		6,040
Basis for distributing material-handling expense:			
	Department A	20 per cent	
	Department B	25 per cent	
	Department C	30 per cent	
	General	25 per cent	
Floor areas:	Department A		27,000
	Department B		38,500
	Department C		40,500
	Power		7,000
	General		14,500
Horsepower-hours:	Department A		14,500
	Department B		9,600
	Department C		16,300
	Material handling		4,600
	General		500
Value of equipment:	Department A		201,500
	Department B		318,600
	Department C		185,400
	Power		120,400
	Material handling		26,400
	General		13,000
Direct labor:	Department A		132,800
	Department B		97,400
	Department C		234,785
Indirect labor:	Department A		63,200
	Department B		41,700
	Department C		96,300
	Power		14,660
	Material handling		19,400
	General		15,500

NOTES. The Heat and Light Expense as estimated must be deducted from the total power expense before allocating the cost of power. Material handling equipment operating expense is not part of building expense.

No column is to be provided on distribution sheet for maintenance expenses since these are calculated already and will be treated as an ordinary expense in the column for expense items.

Problem 2. The B.C.P. Manufacturing Company

FACTORY BURDEN DISTRIBUTION

On the basis of the following information, complete the factory burden distribution sheet for the B.C.P. Manufacturing Company. The three manufacturing departments are A, B, and C. Provide columns in addition for the compilation of the following expenses: general, power, and building.

Boiler insurance	$ 100
Insurance on elevators	50
Workmen's compensation — indirect labor	800
Workmen's compensation — building service employees	25
Taxes on buildings	11,250
Supplies — Factory	5000
Power	1000
Building	500
Indirect labor	16,800
Fuel	2500
Building power costs (heat and light, elevator, etc.) estimated	750
Equipment repairs and maintenance	3000
Building repairs and maintenance	3000
Miscellaneous expenses	750

ADDITIONAL INFORMATION:

The tax rate is $30 per $1000 assessed value. Property is assessed at 75 per cent of cost.

Insurance on buildings — $1.50 per $1000
Insurance on equipment — $3.00 per $1000

Misc. expenses: Depts. A, B, and C — $200 each; power, $25; general, $50; buildings, $75

Direct labor pay roll:
Dept. A — $25,000
Dept. B — 15,000
Dept. C — 10,000

Floor areas:
Dept. A — 2000 sq. ft.
Dept. B — 1500 sq. ft.
Dept. C — 500 sq. ft.
Power Dept. — 1000 sq. ft.
General — 1000 sq. ft.

Horsepower hours:
Dept. A — 2500 H.P.
Dept. B — 2300 H.P.
Dept. C — 1100 H.P.
General — 1100 H.P.

Equipment: cost valuation
Dept. A — 15 machines @ $1000 each
Dept. B — 10 machines @ $1100 each
Dept. C — 5 machines @ $1500 each
General (Mat. Handling) $1500
Power equip. — 4 units @ $5000 each

Summary of supply requisitions shows: Dept. A, $2000; B, $1500; C, $1000; General, $500. Time card summary of indirect labor: Dept. A, $6000; B, $4000; C, $2000; Power, $2000; General, $1000; and Buildings, $1800. Power plant and equipment is housed in buildings. Depreciation rate of buildings, 5 per cent per year; equipment, 10 per cent.

Problem 3. The Eclipse Manufacturing Company

The Eclipse Manufacturing Company has a total pay roll as follows:

Pay Roll Classification	*Dept. A*	*Dept. B*	*Dept. C*
Direct Labor	14,000	25,000	21,000
Indirect Labor	18,000	19,000	23,000

The total workmen's compensation expense for the current year for the Eclipse Manufacturing Company amounts to $2780.

Show the cost per dollar pay roll and the total cost for Department B.

Problem 4. Mosnar Manufacturing Company

FACTORY BURDEN DISTRIBUTION

On the basis of the following information, find the man-hour rates for departments A and B, and the machine-hour rates for departments C, D, and E, for a 4-week period of operation.

		Labor Cost	
Depts.	*Floor Area Occupied*	*Indirect*	*Direct*
A	700 sq. ft.	$132.25	$ 90.20
B	1050 sq. ft.	476.66	132.46
C	1750 sq. ft.	514.17	212.11
D	2100 sq. ft.	703.92	283.71
E	1400 sq. ft.	682.07	218.99

Depts.	*Supply Requisition Summaries*	*Machinery and Equipment Repairs and Maintenance*
A	$21.82	
B	17.82	$6.23
C	15.61	5.75
D	7.47	7.34
E	16.18	

The total value of machinery and equipment is $2600, which is depreciated at a rate of 5 per cent per year, and allocated to the respective departments as follows: Dept. A, 10 per cent; Dept. B, 20 per cent; Dept. C, 22 per cent; Dept. D, 25 per cent; Dept. E, 23 per cent.

Supervision for the period amounted to $400; distributed as follows:

Dept. A, 10 per cent; B 25 per cent; C 15 per cent; D 25 per cent; E 25 per cent.

The total power expense for the period is estimated to cost $116, and is distributed on the basis of hp. requirements in each department as follows:

A	*B*	*C*	*D*	*E*
10	55	65	70	50

Workmen's compensation insurance expense is 3 per cent of the pay roll for the period. The heat and light expense for the period amounts to $75.00 for heat, and $42.00 for lighting. The remaining building expenses have been computed to cost $0.0415 per square foot.

Productive time in the various departments of the Mosnar plant is estimated as follows:

Department A	2 men @ 100 hr. each
	1 man @ 200 hr.
Department B	3 men @ 200 hr. each
	1 man @ 150 hr.
	1 man @ 50 hr.
Department C	4 machines @ 150 hr. each
	1 machine @ 100 hr.
Department D	3 machines @ 200 hr. each
	2 machines @ 120 hr. each
	1 machine @ 100 hr.
	2 machines @ 50 hr. each
Department E	4 machines @ 125 hr. each
	2 machines @ 50 hr. each
	4 machines @ 100 hr. each
	1 machine @ 120 hr.

INSTRUCTIONS:

a) Show all computations.

b) Compute hourly overhead rates to nearest fourth place.

Problem 5. The H. A. Hormell Company

THE DISTRIBUTION OF ADMINISTRATION BURDEN

The H. A. Hormell Company has determined the factory cost of manufacturing pies on a mass-production basis but has not determined satisfactorily what amount it should add to the factory cost in order to arrive at a total cost of manufacturing and selling the pies.

Administrative Burden

The Hormell Company has a new building constructed of reinforced concrete, costing $110,000 and having an estimated life of 40 years, at which time it is expected to have a value of approximately $25,000.

The total floor area of the plant is 52,106 sq. ft. Of this area the general administration and executive offices occupy 2687 sq. ft.; the shipping department, 3507 sq. ft.; the selling department, 10,379 sq. ft.; and the demonstration room which is used to demonstrate pie-making, 294 sq. ft.

It is estimated that the output of the plant will be 3,000,000 pies a year, which will be distributed to bakers in Greater Boston on a wholesale basis.

All other information and cost data pertinent to the compilation of the administrative burden expense of the Hormell Company have been tabulated below. (The expenses which arise from the conduct of the general administration and executive offices appear under the heading "Administrative Department.")

	Value	*Life*
Shipping department		
1 desk	$25	8
Selling department		
25 delivery trucks	37,500 (total)	5
3 delivery trucks	6,000 (total)	5
5 desks	25 (each)	8
2 typewriters	25	3
2 steel files	12	30
1 adding machine	110	25

Demonstration room		
40 chairs	5	5
2 tables	25	8
1 projector and screen	750 (total)	20
Administrative department		
2 lounges	50	8
3 overstuffed chairs	30	8
1 table	40	8
1 cash register	500	6
1 desk	75	8
1 typewriter	25	8
2 steel files	12	30
3 chairs	30	8
Production department office		
5 desks	25	8
1 adding machine	110	25
2 typewriters	25	3
2 steel files	12	30
Comptroller's office		
8 desks	25	8
1 adding machine	110	25
1 comptometer	60	25
1 billing machine	200	25
2 safes	1000	30
3 steel files	12	30

The labor expense is estimated as follows:

Shipping department	$ 9,048
Selling department	34,268
Executive office salaries (selling)	4,680
Office salaries (selling)	1,080
Demonstration — Labor performed by selling department (executive department)	$13,520
Administrative department (office salaries)	11,076

The maintenance-department expenses are estimated to cost $15,816.38; the basis of estimating the repairs and maintenance department is as follows: building, 10 per cent; plant, 20 per cent; machinery repairs, 25 per cent; truck repairs, 45 per cent.

The shipping department employs 9 men; the selling department employs 38, and the administrative department, 15.

The supplies expenses are estimated to amount to the following: shipping, $20; selling, $8000; demonstration, $750; administrative, $725.

ADDITIONAL INFORMATION:

Heat and light for administrative offices: $1325.
Building insurance: $1.50 per $100 actual value.
Building taxes: $25 per $1000 assessed value (¾ actual value).
Equipment taxes: $5.00 per $1000 actual value.
Building interest: 5 per cent of actual value.
Interest on equipment: 5 per cent per annum on actual value.
Workmen's compensation: $1.57 per $100 pay roll.
Commissions on sales: $13,520.
Advertising: $6000.
Delivery expense: $8260.

Insurance and registration of trucks: $1988.
Insurance on equipment: $1.60 per $1000 actual value.
Reserve for bad debts: $1482.
Public liability (insurance against public being poisoned): $11,085.60 (8 cents per $100 of sales).
General administration: $1500.

a) What will be the total cost of manufacturing and selling 10 dozen lemon pies, the costs of making which are as follows, excepting administrative burden: pie crust $\frac{1}{2}$ cent each pie; pie filler 4 cents each pie; labor $\frac{1}{4}$ cent each pie, and factory burden $\frac{1}{5}$ cent each pie.

b) What will be the selling price if the management wishes a margin of 11 per cent above the primary and burden costs?

Problem 6. The Timberlake Manufacturing Company

THE USE OF ADJUSTED BUDGETS

The Timberlake Manufacturing Company is a small plant located in the heart of an industrial center. Its business is highly competitive and it has been found that profits can be obtained no longer through application of rule-of-thumb methods. What appeared to be a hopeless situation in regard to control of manufacturing expenses was turned into one having brighter prospects when the company formally adopted a budgetary procedure in 1931.

The procedure now in practice is as follows: manufacturing expense budgets are prepared in two forms, one for each productive department and one for general plant expense. (Many companies prepare additional expense budgets for the service departments, incorporating in the general plant-expense budget only those items that cannot be directly allocated to any department.)

The manufacturing departments are analyzed as to the amount of expense incurred during the past year. A selection of the expense groups for one department includes the following representative items of cost:

Supervision
Inspection
General labor
Overtime
Reclamation labor
Tool-repair labor
Equipment-repair labor
Spoilage labor
Supplies
Reclamation material
Machine-repair labor
Tool-repair material
Machine-repair material
Equipment-repair material
Spoiled material
Depreciation
Insurance
Taxes
Power
Compressor
Other fixed charges

From the analysis of these accounts an average expense per accounting period is computed for each department, and placed on a form called an "expense schedule." The expense schedule is sent out to the foremen who place on it their best estimate of the cost necessary for the operations of their departments for the next period. The expense schedule is returned to the cost department and reviewed item for item by the factory manager, the cost accountant, the superintendent, and the foremen of the department in question. In a conference of these four executives, all contemplated changes during the next budget period are considered and a "standard expense schedule" is set up which is to stand intact for the budget period. (In this case the foreman's esti-

mate will be used as the standard.) These schedules are written on a prepared form, and several copies are made for the various executives.

For purposes of this problem, the average actual expenses for last year are not necessary. The other information necessary in order to prepare the schedule is as follows:

The Timberlake plant operates 6 hr. per day, except Sundays, during each 4-week budget period. Two supervisors receive a fixed salary of $4200 a year. One inspector is paid at the rate of $0.70 an hour; 24 laborers, who work on the product being manufactured, are paid $0.80 an hour. Three reclamation laborers are paid $0.52 an hour; one tool repair laborer is paid $0.60 an hour; two machine-repair laborers, $0.75 an hour; one equipment-repair laborer is paid $0.63 an hour; and one spoilage laborer is paid $0.52 an hour. It is estimated that in this department during the budget period there will be 200 hr. of overtime labor averaging $0.50 an hour in cost.

The foreman has estimated that the plant supplies should cost $0.087 a productive hour; reclamation material, $0.2625 a productive hour; tool-repair material, $0.234 a productive hour; machine-repair material, $0.463 a productive hour; equipment-repair material, $0.382 a productive hour; and spoiled material, $0.062 a productive hour.

The depreciation charge on all equipment and the plant is estimated to cost $1020 each budget period; insurance is estimated to cost $342 a year; and taxes are estimated to cost $785 a productive period. Other fixed expenses are estimated to amount to $562 a period. The power expense is estimated to cost $1.40 a productive hour and the expense of running the compressor is estimated to cost $4.50 per day.

When the expense schedule is completed, the standard estimated amount per period is transferred to a sheet called an "Expense Analysis and Budget Comparison Sheet." The value of this sheet is to enable the foreman of each department, as well as the production manager, to check estimated expenses with the actual expenses as compiled by the cost department for a budget period. The budget period is 1 month.

In the Timberlake Company the budget is based on the expected production, but is adjusted to actual production, and a monthly comparison of actual expenses with the adjusted budget is made up. The basic budget is adjusted through the use of rates of variability which have been assigned to each item of expense.

The amount of adjustment of each item in the budget is found by multiplying the rate of variability by the percentage increase or decrease in actual production above or below the estimated production. The comparison is made at the end of each month and each individual item of expense is compared with the budget allowance of that time after adjustment.

Although foremen use a variety of production-time estimates in calculating their costs for the "expense schedule," The Timberlake Company uses 4000 hr. as its basic budget operating time. (This is the estimated production spoken of in the foregoing paragraph.) If in any month the plant is able to step up production to 6000 hr., the adjusted budget-expense figure is found in this way: Let us assume that the cost of supervision is 100 per cent variable. The production time has been increased 50 per cent by adding 2000 hr., and now if the cost of supervisors is $600, the adjusted budget figure will be increased by 50 per cent or $300. If spoilage labor is 60 per cent variable, the adjusted figure for this item is found by multiplying the 50 per cent (increased production) by the 60 per cent (variability rate) and we find that this item of expense should be increased by 30 per cent.

If production time falls below the normal of 4000, the adjusted figure is arrived at in the same manner. Items which show 100 per cent variability will show a decrease of 25 per cent if the productive time falls to 3000 hr. Power in this concern is 50 per cent variable; therefore, if production drops 25 per cent below the budget allowance of 4000, we find that power expense will drop only 50 per cent of 25 per cent, or 12.5 per cent.

THE TIMBERLAKE MANUFACTURING COMPANY
EXPENSE SCHEDULE

(For Estimating Departmental Expenses)

Acct. No.	*Description*	*Number*	*Hours*	*Rate*	*Standard Amount*	
					Per Period	*Per Week*
	Supervision					
	Inspection					
	General Labor (Productive)	24	144	0.80	2764.80	691.20
	Reclamation Labor					
	Tool Repair Labor					
	Machine Repair Labor					
	Equipment Repair Labor					
	Spoilage Labor					
	Overtime (Non-productive)					
	Total Labor					
	Supplies					
	Reclamation Material					
	Tool Repair Material					
	Machine Repair Material					
	Equipment Repair Material					
	Spoilage Material					
	Total Material					
	Depreciation					
	Insurance					
	Taxes					
	Other Fixed Charges					
	Total Fixed Expenses					
	Power					
	Compressor					
	Total Other Expenses					
	Grand Total					

THE TIMBERLAKE MANUFACTURING COMPANY

Department..... Foreman..... Date.....

EXPENSE ANALYSIS AND BUDGET COMPARISON SHEET

Acct. No.	*Expense Item*	*Estimated Prod. Cost, Basis 4000 Hours*	*% Variability*	*% to Total Change*	*January*		*% Variability*	*% to Total Change*	*February*		*Notes*
					Adj. Exp.	*Actual Exp.*			*Adj. Exp.*	*Actual Exp.*	

In the Timberlake Manufacturing Company the rates of variability for each item of manufacturing expense are recorded as follows:

	Per Cent		*Per Cent*
Supervision	0	Tool-repair material	90
Inspection	100	Machine-repair material	50
General labor	100	Equipment-repair material	72
Overtime	25	Spoiled material	100
Reclamation labor	70	Depreciation	0
Tool repair	35	Insurance	0
Machine-repair labor	40	Taxes	0
Equipment-repair labor	65	Other fixed charges	0
Spoilage	95	Power	50
Supplies	75	Compressor	20
Reclamation material	100		

In January 1933, The Timberlake Manufacturing Company received so many orders that the productive time increased to 5000 hr. for the month. In February the production dropped off to a 2500-hr. month.

a) Prepare the expense schedule for the cost items shown in this problem on the accompanying form and show the schedule in its completed form.

b) Prepare the expense analysis sheet for these same items, showing the adjusted budget expenses for January and February.

c) Explain briefly how the "expense analysis sheet" may be used when actual cost data are recorded beside those obtained through adjusted budget calculations.

Problem 7. Richard Knight Company, Inc. (Part I)

THE TRIANGLE DIAGRAM

Among the interests of Richard Knight, an enterpriser, is a "small producer" plant engaged in manufacturing canvas products. You are called in to make a survey and recommendations concerning management policy. In your survey you find that about half of the volume is of Type 1 products and half is of Type 2 products. The principal item among the Type 1 products is awnings which involve a wide variety of patterns from which customers make selections and which have to be purchased, under such an arrangement, in relatively small quantities from wholesalers. The company has been featuring the patterns of five different mills but purchasing the goods from three different wholesalers.

Through conferences with the manager and accountant you estimate that the plant capacity, under normal 40-hr. per week operation, is $100,000 per year. Half the employees are paid on a piece-rate basis and half are paid straight hourly rates. The manager devotes only part-time to the company and part to other interests. The salesman is paid a straight salary, his work being principally estimating since practically all orders which are not contract orders come through the mail and by telephone.

Upon analyzing the profit-and-loss statements you find the following:

	Good Year	*Intermediate Year*	*Poor Year*
Net sales	$90,000	$75,000	$49,000
Material	56,000	46,750	30,250
Labor	13,400	11,200	7,500
Burden	12,400	10,800	8,500
Selling and administration	2,750	2,750	2,750
Total cost	84,500	71,500	49,000

Construct a triangle diagram and write out your recommendations on what the management should do to improve the company's situation.

Problem 8. Richard Knight Company, Inc. (Part II)

The Triangle Diagram

The manager takes considerable interest in your triangle diagram and says, "According to your analysis we are now operating at 60 per cent capacity. I am more concerned at the moment about making something of this company than about profits. Suppose I were to push production up to 100 per cent of capacity, how much could I cut our average sales price and still make the same profit we are making at present?" Tell him you will bring in the answer in a few minutes, then figure it.

Put in on Fig. 318 the curve for Richard Knight Company, Inc., as things stand today, according to your analysis.

Analyzing the proportional triangles in Fig. 319, verify the equation $\frac{P_2}{P_1} = \frac{F}{F - x}$.

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