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MODERN PRODUCTION CONTROL

BY

A. W. WILLSMORE

A.M.I.A., F.R.ECON.S.

AUTHOR OF

"BUSINESS BUDGETS AND BUDGETARY CONTROL"



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PREFACE

PRODUCTION control arrangements are something more than a mere matter of "putting an order through the works." They perform a vital function in industrial administration and deserve the application of just as much care and consideration as are given to the technical problems of production proper.

Unfortunately, this fact has been brought home to many industrial concerns through a virtual strangulation of productive effort resulting from a change-over to war-time production without a corresponding adjustment of systems and clerical methods. This must not be taken as an assumption that the technique previously employed is out of date, or even that there is anything wrong with the system, taken simply as a system. The trouble arises solely from the fact that the nature of the business carried out imposes different requirements on the paper-work of production control, and alters the relative importance and practical significance of the principles and practices involved.

Fundamentally, there are three broad types of manufacturing enterprise—jobbing shop production, batch production, and flow production. A paper-work system that was admirably suited to the production of single units of equipment to special customers' orders has been found hopelessly inadequate to deal economically with continuous production of a single design. On the other hand, a mass-production system that gave every satisfaction where the design of the product was reasonably stable has been found far too inflexible to deal with the problems associated with the production of an aircraft only just out of its development stages and subject to the usual spate of modifications and drawing changes. Concerns that have met and overcome difficulties of this kind tend rather to overlook the fact that the same considerations will work again, only this time in reverse, when a return is made to peace-time production.

This book represents, to the best of the author's knowledge, the first attempt in management literature to associate production control directly with production practice from this particular viewpoint. The conception of the book has been to define the principles

of production planning and control, and then to illustrate the application of these principles in actual practice in certain typical cases specially selected to bring out the significance of the various factors involved.

The author is fortunate in that his own business career has brought him into direct contact with the three fundamental types of manufacturing enterprise and has offered him first-hand experience of the different demands they impose. It is not, however, suggested that there is a set number of different systems of production control from which one may make a choice to fit any particular concern. Production control arrangements must be "tailor-made" to suit the peculiarities of the individual concern. To pursue the metaphor, this book is put forward as a guide to measuring the particular concern so as to ensure a good, practical fit.

It is hoped that the book will be of interest to the student who has yet to make his acquaintance with business, but it is intended primarily for those already engaged in factory work, whether on the shop floor, at the clerk's desk, or in the executive's office. The author hopes also that the book will be of assistance to members of the Joint Production Committees, both from the staff and the workers' sides, who find that their previous specialized experience rather handicaps them in the broader discussions in which they are now called on to join.

A. W. WILLSMORE.

LONDON, 1945.

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MODERN PRODUCTION CONTROL

CHAPTER I

THE FUNCTION OF PRODUCTION CONTROL

PRODUCTION planning and control as functions of industry are primarily concerned with the co-ordinative mechanisms of factory operation, designed to ensure that the required product shall be produced by the best and cheapest method, of the required quality, and at the required time. Just as tools and processes became inadequate as enterprises grew in magnitude, and as the application of scientific research opened up new techniques of manufacturing, so, too, the simple administrative methods of earlier days have been outgrown. Instead of relieving difficulties after they have occurred, the aim now is to prevent difficulties from occurring.

The operative mechanisms of factory production form so intimate a part of factory activity that the casual observer may be ignorant of their existence. Thus, the average visitor to a factory, while he may be intensely interested in what he sees going on about him, rarely gets any idea of "what makes the wheels go round." He sees the work a machine is doing, and though he may not follow all the mechanical intricacies involved, he gets a fair idea of how it is done. But why is that particular machine, rather than any other, doing that job; and why that *particular* job instead of some other? How does the operator know exactly what he has to do; does anyone see that he does it properly? If any portion of the job he is doing is spoiled, how are further parts made as replacements? Where does the material that is being used come from? Who sees that it is there when it is wanted? How actually does it get to the operator at the right time? When the operator finishes the particular job he is doing, how does he get another; and what happens to the job he has just finished? Does anyone in executive control know what is going on in the factory, other than by taking a walk round to see? And when, finally, the job is completed, how does anyone know for whom it was intended?

The Necessity for Planning. The obvious implication of these questions is that in any factory there has to be a lot of planning or forethought to the execution of each order. This act of advance planning may not be carried out in any scientific manner. It may, in fact, be of such rule of thumb nature that no conscious planning effort is recognizable. But somewhere, someone has to think out the what, where, how, and when of each job. And the thinking part finished, someone has to arrange that the plans and decisions are put into effect. This generally involves a system of shop orders and clerical routines for setting plans in motion and watching the progress of events to see that they work out right. This is production planning and control shorn of all its trimmings, and in its fundamental principles it is indispensable in any producing unit.

It will be shown that even in the one-man shop the nucleus of such a system can be detected. It is not a matter of something that can be practised or ignored to suit the whims of the proprietor of the individual business concerned. It just has to be there. The only difference is one of degree and method; that is to say, whether the need for production control and planning is recognized and systematic arrangements made, or whether a business muddles through by rule of thumb and hit-or-miss technique.

On the one hand you may have a system whereby, apparently automatically, as soon as a machine operator finishes one job he receives another, with all necessary instructions, materials, tools and fixtures required to do the job; and where on investigation you would find that that particular job was in fact the one that, in view of delivery commitments, should be done next. Or you can have a situation where an operator or his foreman has quite an expedition to make to find the next job, and perhaps has to search all round the shop to find suitable materials, tools, and information how to do the job. The fact remains that the operator has to be found a job, and has to be provided with the facilities for doing it.

The System to Suit the Needs. Unfortunately, there is a tendency to measure the merit of a production control system by the complexity of the forms and records involved rather than by the results achieved. Thus we often find small concerns unwittingly handicapping themselves by endeavouring to practise refinements of technique suitable only for the larger-scale manufacturing plant.

You cannot build a business round a system but must fit the system to the needs of the particular business. For this reason no attempt will be made to define an "ideal" production control and progress system. Instances will be given, but they should be read as illustrating various features of the system rather than as recommendations for actual practice. What is needed is a firm grasp of that which has to be done to meet the needs of the particular case, and established routines should constantly be challenged to ensure that they are adjusted as necessary to meet changing circumstances. For example, in the change-over from peace-time to war-time production, many firms continued to follow old practice without realizing that virtually they were in a new industry, demanding entirely new methods. A system designed to facilitate continuous flow production of a standardized line may need considerable modification before it is suitable for the intermittent production of a variety of products on a special contract basis.

Dual Nature of the Problem. Production control implies a dual problem. On the one hand, it requires a planning element to foresee each step in a perhaps long series of operations, and to arrange so that things may happen in the right place and at the right time with a minimum of effort and with maximum efficiency. On the other hand, a control technique is required to see that the plans that are made are actually put in hand. Planning consists essentially in the practical application of exhaustive information on actualities, against the requirements of the particular problem. It aims at reducing to a minimum the mental labour of production by performing this mental work systematically and in advance, to establish *what* work shall be done, *how* the work shall be done, *where* the work shall be done, and *when* the work shall be done. The decisions reached as the result of this analysis are indicated in a manner so that routine arrangements will suffice to cause them to happen in the right place and at the right time. The function of the control technique is to put into effect these procedures, determined in advance by planning, and to observe, inspect, and record progress so as to keep up a continuous comparison between planned and actual results. Having set the plans in motion by the release of orders, control will be effective in proportion to the accuracy of observation of every definite step in the series of changes in comparison with the planned programme, and in proportion to the

extent to which prompt action is secured when discrepancies between actual and plan are brought to light.

Planning Arrangements. The planning of the “what, how, where, and when” of production may conveniently be considered under the following headings—

1. Production material, specification and availability.
2. Standard of quality.
3. Operation method and equipment capacity.
4. Sequence of operations.
5. Operation time allowances.
6. Assignment of due dates, or scheduling.

Production Material. So that an operative who is to do the job may be supplied with the necessary raw material, a decision must be reached on what kind of material is required, what grade or quality is needed, and how much is wanted for each part. This specification of production material requirements is derived from an analysis of the product into its separate components and units. Often, the decisions arrived at in the other problems of planning (in particular, operation method) will also have a definite influence on material requirements. Direct losses and increases in cost flow from inexact materials estimating. If too much material is supplied on a manufacturing order, there will almost certainly be a loss through an excess of scrap, even though, in theory, the left-over material should be returned to store. On the other hand, if too little material is supplied, then the number of pieces produced will not satisfy the order, and a new issue of material, and maybe a new set-up, will be required.

Besides the physical specification of quality, type, and quantity of raw material, there is the question of availability of material. If the material is available, usually some arrangements must be made so that it can be allocated to this particular job, and not taken for any other. If the material is not in store, arrangements must be made that will cause the material to be requisitioned and its delivery to time assured. In planning this aspect of material availability, information is required from storekeeping and purchasing records to establish balances on hand, and time for delivery when not available in stock.

Quality Standards. The establishment of a desired standard of quality for each unit is an essential part of planning. The basis

may be derived from designs and specifications, or from practical experience of the class of work. In machine work it may be expressed as limits and permissible tolerances. The control of quality takes two main forms: first, as outlined above, as to precise kind, grade, and quality of material to be used; secondly, as to perfection of processing work to be done on this raw material in its progress towards the status of a finished part. The actual selection is not always the cheapest or most obvious material indicated by the use to which the product is to be put. Consideration must be given to the nature of the operations to be performed.

Control of quality of incoming material and supplies is made possible by setting up standard purchase specifications to fix definitely the characteristics and properties desired. These may include items such as strength, hardness, constituent elements, purity, finish, colour, unit weight, and may be accompanied by requirements for inspection and test. To enable the quality of the product to be controlled as it passes through manufacturing processes, the planning function must provide a specification of the limits of variability that can be tolerated. Having established such a standard of quality, or "degree of perfection," required, arrangements can then be made for inspection, so that the desired control of quality is maintained.

In the first instance, quality of product is related to the price that can be obtained for it. Precision of limits and finish beyond a certain point imply, as a rule, a much higher increase in cost than is justified. But, at the same time, technical considerations inherent in manufacture and assembly often demand a certain minimum standard of quality. Generally, it may be said that there is an optimum point where the costs of achieving a certain set quality standard are justified by the benefits obtained, either in process efficiency or sales appeal.

Operation Method. Having determined raw material requirements and quality standards, the next logical step in planning the job is to determine the most efficient procedure for each operation on each unit of product. This, in turn, demands grouping the product into sub-assemblies and assemblies, and determining the auxiliary equipment, tools, jigs, and fixtures required in the machine shops and assembly shops to enable the planned operations to be carried out. The information on which this planning is based is

derived from technical experience and a knowledge of machine capacity, particularly of units of work per hour capable of being handled by each machine or process. In this connexion, it is not uncommon for the planning function to specify certain alternative operation methods. This is because, in practice, the machine on which any particular operation may best be performed is not always available, and considerations of urgency may outweigh the relatively higher cost or inconvenience of using a slightly less efficient machine for the particular job. The question of quantity to be produced has a definite bearing on the methods to be used in production. Often this implies the establishment of the economic size of the lot to be put through in each batch, and may mean setting up entirely different operation methods to be used respectively for small batches, medium-sized orders, and long runs.

Sequence of Operations. The function of planning in determining operation method goes beyond deciding what operations are needed for the fabrication of the production. It is necessary also to determine the sequence in which the operations must be carried out. In establishing this order of operations, the planner will draw on his technical experience, aided by accurate knowledge of machine layout and records of previous work. Here again, it will often be found desirable to indicate permissible variations in sequence which later may allow the product temporarily to side-track an overloaded production station. Unless such flexibility can be provided, it is not uncommon for a "bottleneck" to be created at one particular operation, which, when cleared, creates further "bottlenecks" along the sequence of operations.

Operation Time Allowances. The need for the establishment of time allowances for each operation on each unit is primarily to provide a means of payment by results. In addition, a time allowance is required to measure efficiency in production; to facilitate the planning of the job from the viewpoint of machine occupancy; and to help ensure the maintenance of a required delivery date. These time allowances may be derived from time study, from tables embodying the results of machine analysis, and from technical experience.

Presenting the Data. The data so far established are usually embodied in operation sheets or instruction cards similar to that shown in Fig. 1. The actual type of stationery used for this purpose

<i>OPERATION SHEET</i>						<i>SCHED N^o</i>																							
<i>ARTICLE</i>						<i>PART N^o</i>																							
<i>PART DESCRIPTION</i>						<i>ITEM N^o</i>																							
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Op No	DETAILS OF OPERATION	M/C	CLASS	PREP LAB TIME	TIME ALLOWED			TOOLS, GAUGES, FIXTURES																					
					HRS	MIN	SEC																						

FIG. 1. OPERATION SHEET

differs considerably from factory to factory and will be considered in more detail in a later section (see page 48). The purpose in introducing an illustration at this point is not to suggest the type of form that should be used for conveying the information required, but only to indicate the origination of such forms from the planning arrangements.

It will be realized that the planning or engineering information developed above represents what might be called a standard manufacturing layout for the particular product. This information can be used again and again, every time this particular product has to be progressed through the factory. If the concern is manufacturing special lines to individual requirements, the use of the engineering layout may be confined to the one order. The question of whether repeat orders may be expected will have a large bearing on the degree of detail which may be incorporated, and may mean a continual review of standard manufacturing layouts to ensure that they are kept in line with developments in plant layout and productive equipment. At any one time these factors in planning may be considered as fixed, but they are subject to gradual improvement over a long period. They may conveniently be listed as follows—

- Layout of machines.
- Conveying, hauling, and transport arrangements.
- Storage and issue methods for materials.
- Storage and issue methods for tools and auxiliary equipment.
- Degree to which equipment is standardized.
- Degree to which product is standardized.
- Degree to which operations are standardized.

Assignment of Due Dates. Having established the necessary planning or engineering information, the next step that must be taken before production can start is to schedule the job. This means the assignment of dates for starting and completing each operation on each unit of production, and for the final assembly or completion of the order. Usually, this is derived from machine load charts, showing the volume of work ahead of each machine and production station involved in orders already released. In fixing these dates, however, due allowances must also be made for the situation so far as material availability is concerned. The other considerations affecting the scheduling are, of course, machine output capacity,

operation time allowances, the sequence of operations desired, and delivery commitments.

Control Arrangements. There are eight essential elements entering into successful control arrangements—

1. Control of activities.
2. Control of material movement.
3. Control of service.
4. Control of due dates.
5. Control of quantity and quality.
6. Control of replacements.
7. Control of labour efficiency.
8. Control of progress of orders.

Control of Activities. The control arrangements falling under this heading are commonly referred to as dispatching. They involve essentially the release of orders setting plans in motion at the assigned time. These orders must make clear to the individual operator what he has to do and when he has to do it. At the same time, they must provide for the identification of the job during its passage through the factory, both as regards what it is and for whom it is intended.

Control of Material Movement. This provides for the physical supply of the right amount of the correct material from stores when planned, and its delivery to the operator who is to work on it. Coupled with this, there must be arrangements for the movement of material from operation to operation within the shop, with provision for the identification of the material and ready association between a certain batch of material and a specific works order. This control and identification of material movement may be effected in practice by means of stores orders, identity labels, and move notes; or, more simply, by making the works order itself serve as the document to perform all these functions. This material movement control must extend far enough to see that goods are dispatched when ready.

Control of Service. Besides seeing that the individual operative receives at the right time the material on which he is to work and the necessary instructions to enable him to proceed, there are other essential shop service functions that must be performed by control. First, there is the provision of the jigs, tools, fixtures, and gauges needed for the job. It is quite common to find that the

worker himself is expected to procure these from stores. Without debating the wisdom or otherwise of such arrangements, it must be clear that when acting in this way, the operative is in fact performing part of the control function as distinct from his own function as a primary producer. The control function owes a service responsibility also to certain other departments in the factory outside production. In particular, this involves the provision of some means whereby costs can be collected against each individual job, and the provision of the primary information to be used for the payment of wages to the individual worker. Another need is the provision of arrangements to ensure that goods completed and dispatched are charged to the customer's account.

Control of Due Dates. The control function here is one of observation of machine loading, with particular reference to delays and stoppages interfering with the due dates of work assigned to each machine. This involves the maintenance of machine loading records showing the amount of work assigned ahead of each machine. In this connexion, it should be stressed that there is no clear-cut line between control and planning that enables them to be considered in practice as falling into two separate water-tight compartments. The results of the observations of control will be, or should be, a continual adjustment of planning arrangements to keep in line with the development of the actual situation. As an outcome of the continuous review of machine loading, all cases of idle machine capacity should be thrown into relief.

Control of Quantity and Quality. This involves the observation of work in process at predetermined stages to determine—

1. If the right quantity has been processed.
2. If the work done is in accordance with the standards of quality established by planning.

In practice, this element of control is commonly performed by a separate inspection department. It is, for instance, usual in machine shops to establish a requirement that the first part produced off each new set-up must be passed by the inspection representative on the machine shop floor before the batch is run through the machine. The function that he fills in this connexion is essentially a control function, but that, of course, does not necessarily mean that he must be part of the control department from an organizational viewpoint.

Control of Replacements. Arising out of the observation of quality and quantity is a separate group of control activities to deal with the situation where any quantity of raw material or work in process fails to pass any stage of inspection. This gives rise to the necessity of issuing orders for replacing such material or work, or of issuing orders to rectify or salvage the defective job. Here again, adjustment in planning may be necessary, as a decision must be reached whether the depleted batch is to continue through the remaining processes as originally planned, or whether it is to be held up to wait for the replacement material.

Control of Labour Efficiency. The significance of this element is apparent. It involves the observation and recording of time taken on each unit of work in process for comparison with the planned time allowance. Although a "control" function, in practice this activity is commonly assigned to some department other than the control department.

Control of Progress of Orders. Virtually, this activity is a consolidation of the previous controls, and involves marking-off completed work on production schedules and route sheets. It will be realized that specific customers' orders for certain products lose their identity as such in the factory, where they are recognized only as contributory elements to a group of orders on particular production stations. It is an essential control function to maintain the equivalent of a cross-reference index between these two aspects, so that a picture of progress against orders is always readily available showing whether the job in question is passing through each stage of operation to time and whether it will be finished when promised.

Control Mechanisms. The technique of control rests on a system of shop orders to originate action, with control charts and boards, dispatching, and inspection as the principal mechanisms by which observation of current happenings may be recorded and compared continuously with the planned programme. All information thrown up by this comparison should be promptly passed to the persons responsible for action in such eventualities. As an indication of the aspects of the situation that must be kept under continual review may be cited—

1. The degree to which each unit of work has been completed.
2. The assigned loading of each machine or production station.
3. The earliest free date for new work for each machine.
4. The amount of orders or quota for each period not yet filled.

Production Control Summary. Production control may be considered as a directive agency whose purpose, where production is divided into separate operations, is to co-ordinate those operations in the most effective fashion through the exercise of the functions of—

PLANNING	ROUTEING
SCHEDULING	DISPATCHING
INSPECTING	OBSERVING

These functions are organized so that movements of material, performance of machines, and operations of labour, however subdivided, are co-ordinated and controlled as to—

QUANTITY	QUALITY
TIME	PLACE

A more detailed summary is illustrated in the accompanying Fig. 2, where the control and planning techniques are analysed, as distinct from the functional analysis.

Yet another approach to the problem of a definition of production control is given in Fig. 3. This chart is the outcome of a meeting, held in London, of the Institution of Production Engineers, and represents the basic framework of production planning and control.

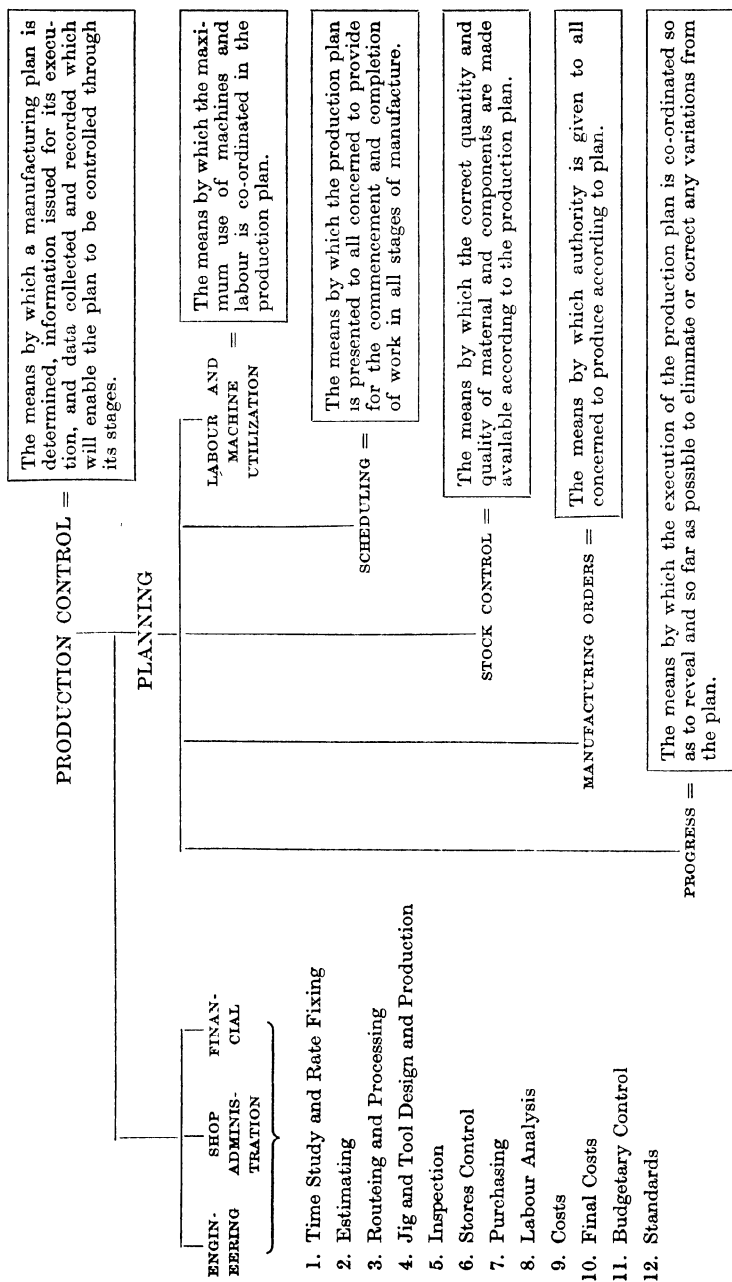
A Management Tool. The essential aim of production control is the provision of a better product at a lower cost. Production control is not a cure-all. It never is, and never should try to be, anything more than a means to an end—one of the tools of economical manufacture whose goal is the achievement of the highest efficiency in production through the production of the required quantity of product, of the required quality, at the required time, by the best and cheapest methods. Production control methods have been developed during periods of great change and improvement in industry. Consequently, it is not surprising that, on the one hand, production control is frequently identified with design, or, on the other, general improvements. Actually, by bringing deficiencies to light, new control methods have led to improvements in design, layout, methods of operation, and general organization. It must be realized, however, that the necessity for control will remain when every possible improvement has been effected in design, methods, and organization. At the same time, this necessity for control is not associated with the size of the undertaking. It is

OUTLINE CHART OF PRODUCTION CONTROL

MATERIALS	MACHINE PROCESSES	WORK IN PROCESS
ANALYSIS OF PRODUCT To establish material requirements per unit by quantities on order.	ANALYSIS OF PROCESSING To establish unit processes by number of pieces in each lot.	ANALYSIS OF WORK IN PROCESS Establish product "build-up" through lots of single parts, sub-assemblies, assemblies and final inspection.
PLANNING TECHNIQUE 1. Note kind of material. 2. Note grade or quality of material. 3. Determine quantities to order. 4. Ascertain availability. 5. Make reservation of available stock. 6. Requisition material not in stock. 7. Prepare material move notes.	PLANNING TECHNIQUE 1. Plan best method of processing. 2. Plan tools and fixtures required. 3. Determine time allowances. 4. Plan best sequence of operations. 5. Establish alternative sequences. 6. Schedule machine loads. 7. Prepare shop stationery.	PLANNING TECHNIQUE 1. Specify inspection standards. 2. Plan assemblies and sub-assemblies. 3. Prepare inspection orders. 4. Schedule due dates for each process on each lot and on each assembly. 5. Schedule due date for completion of whole order.
CONTROL TECHNIQUE 1. Watch delivery of purchased material. 2. Release material to shops at proper time.	CONTROL TECHNIQUE 1. Release tool and fixture orders to time. 2. Observe actual operation times. 3. Check actual with scheduled loading. 4. Release work orders and time tickets to schedule.	CONTROL TECHNIQUE 1. Check quantities passing inspection. 2. Put replacement orders in hand. 3. Release inspection orders when job is ready. 4. Observe and record completion of job. 5. Check actual against scheduled progress. 6. Observe that schedule dates are being kept.

FIG. 2. OUTLINE CHART OF PRODUCTION CONTROL

FUNCTIONAL ANALYSIS OF PRODUCTION CONTROL



1. Time Study and Rate Fixing
2. Estimating
3. Routing and Processing
4. Jig and Tool Design and Production
5. Inspection
6. Stores Control
7. Purchasing
8. Labour Analysis
9. Costs
10. Final Costs
11. Budgetary Control
12. Standards

FIG. 3. FUNCTIONAL ANALYSIS OF PRODUCTION CONTROL

as much present in the one-man shop as it is in the company employing 10,000 hands. The essential difference is in the technique and mechanisms used in the various concerns to carry out the functions of planning and control.

The One-man Shop. It has been suggested that the nucleus of a production planning and progress system can be detected even in the one-man shop. Before such a person could do any job he would be "up against" the need for raw material; he would require knowledge of how to fabricate it; and he would need machinery and tools available with which to do the job. This would involve considering what kind of material was required from the viewpoint of grade and quality; a calculation of how much material was wanted; and a check-up to see whether there happened to be any material about the shop or whether it had to be bought. It would have to be considered how the work was to be done on the available equipment, and the man would have to keep an eye on himself to see that the job was finished by the promised time. The promise for delivery would have been conditioned by the man's knowledge of the work he had in front of him, and his previous commitments.

There is no suggestion here that the one-man shop needs any production control and progress system in the usually accepted sense of the term. But, in fact, he does practice some form of planning control, and it is significant that even in this elementary stage of factory production we can recognize the fundamental requirements of a production control system.

Limits to Personal Control. As our one-man business grows, and its owner begins to take on assistants, he gradually approaches the stage where he can no longer attend personally to all the aspects of the business, and some technique becomes necessary to supplement his personal control. When the man who is to do the job has himself taken the order, he knows—or should know—what is wanted. But with the delegation of work to other people it becomes necessary to institute some form of instruction to the workman who is to do the job. This instruction may be merely by word of mouth; it may be a rough sketch on the back of an envelope; or it may involve giving the workman a sample to copy; but the principle served is the same as that of the most elaborate instruction sheet. For the same reason, ultimately it becomes necessary to introduce an independent element of observation to see that the

job has been correctly done. Here again, whether the shop foreman looks over the job to see that it is properly executed, or whether a special inspection order is originated to route the job to a specialized inspection department, the same principle is served.

Up to this stage there may be complete reliance on an individual's memory for the knowledge of the position of progress of any particular order, and for the identity of each job, but it will be obvious that ultimately a stage must be reached where some form of identification is needed. This is particularly so where specialization of labour is introduced with several individuals each contributing his share to the fabrication of the final product. In such circumstances there must be some means of identifying each particular batch of material or semi-fashioned product, and associating it with the appropriate instructions. It is also found advantageous to have some paper record of the progress of each job through the various processes involved, thereby obviating the necessity for a "hunt-the-slipper" game whenever a query arises concerning the present position of any particular order. Another problem created by the specialization of labour is the need for planning the sequence of operations, and for providing control arrangements for the movement of material from man to man to enable each to do his part.

All this time we may assume that we have been relying on the foreman to give out the work to the various men to meet the delivery requirements—which, in turn, were probably based on his own promises. Whatever means the foreman adopts to see that his promises are maintained, we have here the implication of a programme, or schedule of jobs to be done, and of observations of progress towards the desired end. As an offshoot, in the foreman's mind is undoubtedly some standard of time allowed for each job against which actual time taken is noted, perhaps only sub-consciously, as a check on the efficiency of the worker. This time element achieves greater significance when the methods of payment of labour are modified towards payment by results.

The prime aim of any business, large or small, is to make a profit. Towards this end there must be some technique, crude or elaborate, to enable the cost of each job to be calculated as a check on whether the price at which it was taken was worth while, and as a basis for future quotations.

The Paper-work of Production. In practice, virtually, production control and progress work amount to the paper-work side of running a factory, as distinct from the physical problems of production itself. It has been shown that the functions that have to be performed exist even in the smallest-scale manufacturing industry. The problem is one of finding the best practical combination of system and method to suit the needs of the particular concerns.

Installing Production Control. It is difficult to lay down any hard and fast rules to cover the job of setting up a systematic production control plan in the place of rule of thumb methods. Fundamentally, however, the procedure to be adopted may be considered as falling into four stages—

1. *First Stage—Analysis.*

- 1.1 Analyse types of product manufactured.
- 1.2 Analyse manufacturing methods.
- 1.3 Analyse inspection methods.
- 1.4 Make layouts of plant and equipment in each department.
- 1.5 List machine tools and equipment.
- 1.6 Study transportation methods.
- 1.7 Codify manufacturing procedure.
- 1.8 Plan materials control.
- 1.9 Plan time control.
- 1.10 Plan cost control.
- 1.11 Define the duties of all personnel as related to production control.
- 1.12 Assure co-ordination between production control and other departments, such as engineering, costs and accounts.

2. *Second Stage—Preparation.*

- 2.1 Set up standard forms and cards.
- 2.2 Establish master control boards.
- 2.3 Establish dispatch boards.
- 2.4 Set up dumps or bays for incoming and outgoing materials.
- 2.5 Set up stockrooms and tool stores.
- 2.6 Define work stations by some identifying symbol.
- 2.7 Organize a planning section.
- 2.8 Organize an ordering and scheduling section.
- 2.9 Establish operation routeing.
- 2.10 Provide for accumulation of data.
- 2.11 Arrange for a proper flow in the production of parts and assemblies.
- 2.12 Examine blue-prints.
- 2.13 Study idle machine time and waiting time.

3. *Third Stage—Change Over.*

- 3.1 Take over one production department at a time.
- 3.2 Change over stocks and stock records.
- 3.3 Change over all records to new forms.
- 3.4 Start dispatch boards working.
- 3.5 Educate foremen, charge-hands, and workers to new system.

4. *Fourth Stage—Refinement.*

- 4.1 Revise methods.
- 4.2 Review duties and functions.
- 4.3 Refine schedules.
- 4.4 Revise prices—originate time studies.
- 4.5 Start reports on idle machine time, overdue materials, broken schedules, etc.

Depending on the size of the factory and the degree of progress made before the establishment of systematic production control, the four stages may be spread over a period of from six months to two years. The success or failure of the system will depend on the skill with which it is introduced, and how far the management is prepared to give the scheme the backing that may be required. It cannot be too strongly stressed that, time and time again, systematic production control, as such, has proved itself. The weaknesses that may be found will be in installation, operation, incomplete preliminary survey, or in lack of proper organization. Above all, it is essential to provide for continual review and refinement of method, so as to keep in line with developments in the undertaking from time to time.

CHAPTER II

THE METHODS OF PRODUCTION

BROADLY speaking, manufacturing industry may be considered as falling between two extreme types, with, at one extreme, the special order or job production shop, and, at the other, the repetitive unit, commonly misnamed mass-production unit. The distinction to be drawn is not one of volume of production so much as of variety.

In the special order concern, the major part of the work on every order, including the design of the product, or the adoption of a standard design, is performed separately for each order. There is no finished stock, or stock of finished parts; material flows through the factory intermittently, from process to process, with, possibly, a wide difference in the order of flow of successive jobs. On the other hand, in the flow repetitive type of manufacture, instead of moving in intermittent lots, the material flows in a steady stream, whose volume may increase or decrease with fluctuations in demand, but is seldom interrupted. The factory comprises a closely articulated unit of specialized machines, as opposed to a group of general machines arranged for best average economy in handling varied orders.

Batch Production. Between the two extremes is a variation of the special order type of industry, manufacturing on methods of batch production or lot repetitive. As demand increases for certain of the patterns which a concern had previously made only to special order, it becomes profitable to put work through in larger lots. The unsold portion of the lot is carried in stock to fill future orders, being replenished by further manufacturing orders before the earlier lot is completely exhausted. The further an industry develops along these lines, the nearest it approaches the theoretical limit where the lot repetitive industry merges into the flow repetitive industry. Virtually, the stores become the sole customer of the factory, and it is usual, and correct, to refer to this type of enterprise as "stock order industry" as distinct from special order and flow production industries.

In practice, few individual concerns fall entirely into the class of flow production, batch production, or special order industry. There

are no sharp lines of demarcation between the three methods. One class easily overlaps another, and actually, all three may be present simultaneously in the same plant. The problems of day-to-day control of production are, however, largely coloured by the type of manufacture employed, and production planning and control arrangements must be very widely influenced by this feature. Where two or more different types of production are carried on simultaneously in the same factory, the production control technique must be accordingly modified. The problem of "specials" in a flow repetitive unit, where a customer demands some departure from standard, is a problem, largely because of the common failure to face this situation and adjust routines as required. The differences between the three methods may, with interest, be examined in more detail to establish more clearly the degree of influence they should exert on the production planning and control systems to be used.

Special Orders. The jobbing shop, or special order plant, is the one most usually found. Under this system, work is not put in hand until a bid has been accepted and an order received. Such a job production concern represents the most flexible form of manufacturing enterprise. A large percentage of its workers must be all-round men, capable of independent work. Similarly, its equipment must be designed with a view to general purpose utility. This feature of flexibility carries with it the corollary of inefficiency, if by inefficiency we imply a failure to utilize available facilities to the utmost extent, and a failure to achieve the highest level of efficiency for any one operation. But a clear distinction must be drawn between such questions of technical inefficiency, which are an intrinsic feature of all jobbing production shops, and the broader issue of the efficiency or otherwise of their management.

Technical inefficiency inherent in jobbing production is not inconsistent with the fact that the small jobbing shop can, and, from the commercial standpoint, often does, represent the most successful business unit. Unfortunately, it is also true that, in all countries, a good many of the smaller concerns lag far behind the times in outlook, methods, and equipment. The relatively small size of the unit offers a tempting opportunity for rule of thumb rather than anything in the nature of organization. Tradition, too, often exerts a stifling influence on any attempt to introduce new methods, and throws on the individual manager a personal

(though impossible) duty to supervise every single activity throughout the concern. Actually, the jobbing shop or batch production unit offers the widest possible scope for the profitable utilization of all that is best in the most modern techniques of production control, subject, of course, to the limitations on expense implied in the size of the individual enterprise. Each job handled in the shop is a new problem, and demands individual attention. There is no automatic rhythm in production that can be relied on to keep output flowing smoothly. Each job must be individually planned and progressed. Continuous watch must be kept on the constantly changing situation to ensure that all commitments are properly met. The problem of balancing requirements against production capacity, which is always present, is often rendered more acute by difficulties in actually measuring the task involved.

Flow Production. Compared with the production problems met daily in the special order and batch production shops, those encountered in the so-called mass-production or continuous flow unit, once it is running, are negligible. They are confined to ensuring that a predetermined quantity of parts of each type passes through each section each day. Beyond this, shop management can concentrate its attention exclusively on the improvement of manufacturing processes, and on shortening transport time from process to process. Where all work moves automatically through a standard established sequence of operations, production control arrangements have no need to be so detailed or elaborate as they are when each job presents a new problem in process scheduling and in control of the movement of material through the shops. In essence, production control in the special order and batch production shops amounts to the arrangement of some method of controlling this intermittent and varying movement of material through the production unit.

In the flow repetitive type of industry it is sufficient to start the right amount of material at the first process. In subsequent processes the men will know what to do without special orders. In the interrupted flow type, however, material must be directed from stores to the specific first process, and directions must be issued, either to the workman, or to a special "move man," for the movement of each lot to the next operation at the completion of each stage of manufacture. Similarly, by constant repetition, the operative in the flow production unit knows what he has to do to

the material, and, in fact, is often operating a machine that permits him to perform nothing other than the correct operation. Here again, in the interrupted flow type, specific instructions for each order must pass to each operative, showing what he has to do to the material. Instruction to the operative in the flow production unit is concerned with *how* to do the job, often as the fruits of elaborate motion study. As a rule, this particular feature is missing in the special order industry, and, usually, is met in the batch production shop only when the demand for a particular product has become sufficiently large to mean that a near approach to mass production has been made on that particular line.

Another problem arises from the desirability of identifying the material in its progress through the factory. The usual method in the jobbing and stock order shops is to give the material a lot, or shop order number. Usually, this number is shown on a tag attached to the goods, thus making it possible to identify any material which may have been misplaced and to differentiate between similar lots progressing through the factory simultaneously for different customers, or at different stages of progress for the same order. Usually, this problem is not encountered in the flow production factory except where it is desired to institute a control to measure the results of changes in specification. It is interesting to note, however, that the demands of aircraft inspection had the effect of forcing this problem home on flow production industries. In the aircraft industry it is regarded as essential that it should be possible to trace back any individual part of an air-frame or engine to the specific batch of material from which it was fabricated, and to preserve the possibility of establishing an unbroken chain of proof of inspection from raw material to finished product. This requirement is rigidly insisted on, as will be readily appreciated, for any highly-stressed part. It is perhaps significant that this preservation of batch identity is one of the major problems of paper-work control in the large-scale enterprise, whereas in the smaller concern it is carried out as a matter of ordinary day-to-day routine.

Programmes. The final, and most important, point of difference between the two extreme types is that of regulating and controlling the programme of each machine or producing group. In the flow repetitive type this control is virtually automatic. The only problem here is, in effect, to keep the various stages of the process in step

with one another, and to avoid accumulations at any one process, due to lagging, with consequent shortage at the next. In the intermittent flow types, however, the work does not come automatically to the machine and it is necessary to be able to lay out the work in advance, so that it may be distributed as evenly as possible between the available alternative processes. The ideal is to plan in advance so that arrangements can be made to have the next job ready for the operative before the completion of the job in hand.

The technique of production control necessary to meet these needs involves four distinct steps—

1. The preparation of a programme or schedule.
2. The establishment of dispatch arrangements.
3. The maintenance of progress records.
4. The establishment of some follow-up or chasing mechanism.

Working Schedules. The preparation of a programme or working schedule involves striking a balance between two opposing forces. On the one hand we have available capacity after allowing for the jobs already scheduled at the various machines; on the other, the requirements of jobs to be completed, date of completion, and amount of work to be done in each process. The decision of the planning executive on these points is embodied in a schedule or programme. The form this programme takes will depend on the circumstances of the individual concern. It may be simply a list of jobs to be completed in order during a given period. It may amount to an elaborate planning board, laying out the time for the performance of each of the specific operations ahead of every machine for the period.

Works Orders. The second step, referred to as dispatch arrangements, is to ensure that the programme is put into effect, and that jobs are worked in the sequence arranged. As the time arrives to start the various operations shown in the schedule, orders must be issued for their performance. Here again there is a wide difference in the methods that are adopted in practice to achieve the end. This may be done by giving copies of a monthly schedule to the foreman, leaving him to make his own detailed arrangements, so long as they meet the schedule dates. At the other extreme there may be a dispatch planning board on which the job programme is interpreted into a machine programme. Here the individual operative comes to the planning department with the instruction card

for the job he has finished, and receives from the dispatch clerk instructions for the job next in order in the machine schedule.

Progressing. The fact that the job programme loses its identity as such in the factory, and becomes a machine schedule, introduces the need for some form of progress record to show the exact location of any particular job, and how far it has proceeded, relative to schedule. Any job could, of course, be located by tracking it through each operation until it is found. But this would be impracticable where the number of jobs in the shop is large, and some form of systematic record then becomes necessary.

Finally, there must be some means for putting back on the rails the jobs which run into trouble, are delayed, or mishandled. Generally, this is met by assigning men to give their attention to certain groups of job orders, checking them by means of progress records, and taking any steps necessary to move them through smoothly to completion. This activity is commonly referred to as progress chasing. In short, the additional complications implied in interrupted flow production, as distinct from continuous flow, are that—

1. There must be some system for keeping machines and men constantly at work so long as there are jobs ahead of them.
2. There must be arrangements to ensure that jobs are passed through the machine in the right relative order.
3. A follow-up mechanism must be adopted to get back on the track the derailed or lost jobs.

Special Problems of Flow Production. Although the production control arrangements in a flow production unit need be nothing like so elaborate as those in the jobbing or batch production enterprise, this relative simplification of control technique is often counterbalanced by the problems of planning that have to be overcome in achieving the flow.

The essence of flow production control lies in the establishment of a rate of production, and in the physical arrangement of production facilities, in the manner best calculated to handle that flow. One of the major stumbling blocks encountered in this direction lies in the fact that whereas the annual turnover on a particular product may be sufficient to justify flow production methods, often the distribution of this demand from week to week, and month to month, is irregular. This problem of seasonal variation in sales calls for a dual approach. Obviously it is undesirable, even where practicable,

to have a flow production unit operating at varying rates of production from week to week. The aim should be to stabilize production on as nearly an even keel as possible. The obvious solution is to run the production unit at a rate representing the average of anticipated sales over the year, and to accumulate the surplus production in the slack period as a reserve stock to be used to meet the higher demands in the busy season. Towards this end, it is essential to establish some statistical measure of what actually comprises normal seasonal variation. This is necessary so that a reliable decision may be reached whether it is practicable and profitable to even-out these variations in production by using the stock-room as a cushion.

Business Forecasts. If in this way a decision is reached to run at an even rate of production, the decision automatically brings up the question of broader variations in demand due to cyclical fluctuations. In effect, the decision implies the necessity of making a forecast of the future year's turnover. If this estimate turns out to be too optimistic, then the seasonal high sale does not materialize sufficiently to reduce stocks to normal before sales fall below production, and a radical readjustment of the production level becomes necessary. Similarly, if too conservative an estimate is reached, then insufficient stock is built up in the slack period to meet the peak demand, with the obvious train of circumstances following from such a situation.

Combating Seasonality. The next logical step in dealing with the production problems implied by seasonal demands is a consideration of the possibilities of modifying the seasonal differences by stimulating sales in slack periods and correspondingly reducing the extremes in the highly active period. Virtually, this aims at a controlled sales turnover, and while it will hardly ever be found possible entirely to eliminate seasonal variations, often their violence can be reduced. For instance, intensified advertising may encourage out-of-season sales; a change in the date of trade shows, or the practice of arranging trade shows in slack periods, may have a similar effect; special discounts may be given for out-of-season orders; the introduction of new designs may be timed to encourage demand at the right period; and new uses may be developed for a product, thereby altering the seasonal characteristic of the combined turnover. All these devices have been successfully

adopted in certain circumstances. Most of them involve higher expense, or a slight reduction in profit margins; but these have been more than offset by the reduction in investment charges and storage expense following on a reduction in inventories.

The alternative approach, after exhausting the possibilities of reducing the severity of seasonal variations, is to pursue the possibility of developing a supplementary line of products with complementary seasonal characteristics, but sufficiently similar in production technique to enable the production programme as a whole to remain constant, although comprised of a varying proportion of the two lines of products. The classical example of such arrangements was the "ice-cream—hot-chestnut vendor"; other examples of such combinations are radio sets and electric refrigerators; overcoats and sports jackets; electric fires and electric fans; umbrellas and sunshades; fireside chairs and garden furniture; football boots and tennis shoes.

Under war conditions, these problems associated with sales forecasting and seasonal variation lose most of their significance. With an assured long-term contract, calling for regular and steady delivery, many concerns were able to concentrate almost exclusively on the physical planning of flow production. To a degree, it may be anticipated that a measure of control will persist after the war, but undoubtedly the problem of business forecasting will come back into the picture after the war, and the fact of its temporary absence should not be allowed to depreciate its significance.

Physical Problems. The physical problems of flow production are those connected with plant layout, handling problems, and machine design. The essential feature of true continuous flow production is that the demands on the production facilities are sufficiently large to justify allowing each machine to stand continuously set-up for the same operation. Since each machine is thus, in the extreme type, exclusively confined to one particular job, it becomes practicable to modify and specialize the design of the machine towards achieving the peak-point of efficiency in the performance of that particular operation. Often, a machine is specially designed to do a particular operation or group of operations. Next, since the product always follows the same path from operation to operation, the production machines can most profitably be arranged so that the product follows a reasonably direct route from process to process

through the factory, instead of doubling backwards and forwards along its own tracks. Finally, economy in handling can be secured by installing mechanical-handling facilities to convey the product from station to station.

The extreme case of continuous flow production of a single product on highly specialized machines, set up in a straight line and connected by mechanized conveyors, although representing the peak-point of production efficiency, is rarely met in practice. nevertheless, there are thousands of instances where an advantageous approach has been made towards this condition by adopting principles of product control, as distinct from process control. Process control involves separating the manufacturing operations and grouping those involving similar processes. There would, for instance, be a general machining shop, a general punch press department, a general plating department, and a general finishing shop. The various products are moved in and out of these departments (often returning several times to one particular department), usually passing through stockrooms and inspection departments at each step. All this involves highly organized planning, routeing, scheduling, and dispatching arrangements, often, unfortunately, with more "system" than system. In a measure, such an arrangement may be an archaic survival from the earlier days of factory organization.

Factory Layout. Years ago, factory machines were belted to one long lineshaft, running the full length of the building, and driven by a water-wheel or steam-engine. The development of the electric motor offered the key to changing this situation, but in many plants the only change was one of pulley ratios, belting the new source of power direct to the lineshaft. The next step was the evolution of group drive and individual motor-driven equipment. In spite of this revolutionary development, the average factory still follows the customary procedure of laying out equipment in straight lines, with ample aisles between each two rows. Such arrangements are, in fact, often found as standard practice in shops set up for progressive manufacture and assembly. Even the installation of mechanical handling was not always associated with a change in equipment layout. Conveyors were installed near the existing lines of machines, and it is common to see the operator compelled to make a complete turn, walk several steps, procure or dispose of stock, and then reverse the procedure.

The alternative practice is one of product control. Under such arrangements the equipment required actually to perform the operations on a particular product or line of products is set up in correct sequence, and the product itself is transported as little as possible. This type of set-up is not necessarily confined exclusively to the so-called mass-production factory.

Product Control. Product control is not the same as straight line production, although it brings many of the advantages of straight line production. These are: smooth routine, ease of supervision, ease of inventory control, elimination of many records, specialization of men, and ideal conditions for group bonus. If there is no individual line with sufficient volume of turnover to occupy entirely an integrated chain of machines, it is, nevertheless, often practicable to change the layout of machines to suit the general direction of flow of the majority of the different products handled. Some firms have even gone so far as to equip each individual machine with all control equipment, and to arrange for wiring through overhead ducts so that the plant layout is flexible and can be altered overnight. With such arrangements it is found economical to set up a line of equipment, and to run even a comparatively small order through this set-up. The substantial reduction in manufacturing time, with associated savings in handling, reductions in stocks, and simplified control, have more than offset moving costs.

It is not intended to suggest that product control is a panacea which will cure all factory troubles. The alternative, process control, involves a lower investment in equipment, lower power costs, and makes easier the technical problems of supervision. It should be emphasized, however, that no individual factory should be considered as falling entirely into any one water-tight compartment. Progressive management will always keep an eye open for the possibilities of adopting the best features of planning and control arrangements used in the various types of manufacturing undertakings. In particular, the batch production, or intermittent flow production unit, frequently offers golden opportunities for the adoption of modifications both of flow production practices and of jobbing shop methods. The one danger to be avoided is that no system or technique should be adopted just because it is good, and works well in some other factory. As stated in the preface, systems and methods should be "tailor made" to fit the particular plant.

The merit in a study of the individual methods used elsewhere lies in the establishment of sound principles for meeting and overcoming the difficulties that are always encountered in practical factory management.

CHAPTER III

BATCH PRODUCTION

It has already been pointed out that manufacturing enterprises fall between the two extreme types of special order and flow production, with an intermediate group of intermittent flow, or batch production units. The feature of the batch production business is that goods are ordered on the factory in lots rather than against individual customers' orders. Generally speaking, the aim is so to order that there is at all time stock available to meet customers' requirements, and to put orders through in workings of such size that they represent the most profitable manufacturing proposition. In this connexion, it will be realized that a factory can be its own customer, where, for instance, the ultimate product is an assembly and it is desired to maintain stocks of the parts needed to make the assembly. In fact, it is not at all uncommon to find instances where the final assembly work is carried out on the basis of special orders, but where several standard sub-components are produced in batches.

The Question of Lot Sizes. In flow production factories, parts and assemblies are produced continuously to meet the requirements of a production programme. Machines are designed to perform one specific operation, and are kept tooled up to do that job and none other. If there is sufficient volume of business to justify this step, then it can be demonstrated that such a state of affairs represents the optimum, or most economical condition of manufacture. But usually the volume of business is insufficient to justify allocating any particular machine continuously to perform a given operation on a given part. Probably, the demand for the part is such that, after a quantity has been manufactured, representing a reasonable anticipation of future requirements, it becomes necessary to change over the equipment for the performance of some other operation on another part. Obviously, the problem is one of deciding what represents reasonable anticipation of demand in the light of the particular circumstances. This question is of considerable significance from the economic standpoint. At the same time, however, it is often a question that is all too lightly decided.

When to Order. Associated with the problem of deciding in what batches to produce is the kindred problem—at what point to order. Since the aim is always to have parts in stock, obviously there is a last-minute point at which fresh ordering can no longer be delayed. At this point the balance left in stores from the preceding batch has fallen to such a level that, unless that order is placed immediately, stocks will become completely exhausted before a

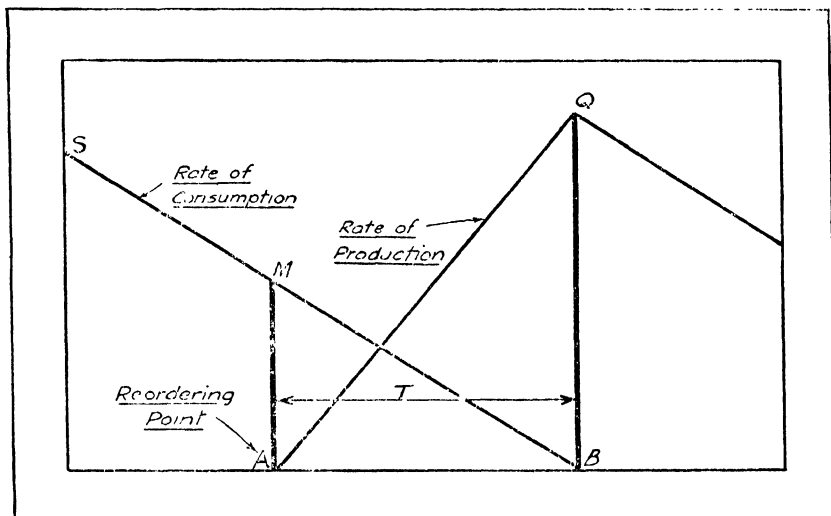


FIG. 4. THE ORDERING POINT

fresh order can be progressed through the factory. This situation is shown graphically in the illustration Fig. 4. It will be seen that there is a definite relationship between the theoretical minimum ordering point and the time taken to process the fresh order, and since the time taken to process the fresh batch is obviously affected by the size of the batch, this in turn has its influence on the minimum ordering point. The relationship, shown on the chart, can be expressed as follows. Starting at point A to manufacture a quantity Q at a rate of production implied by the slope of the line AQ, will involve a delay of time T (shown by the line AB) before the new batch comes into stock. During this time, a rate of consumption implied by the line SB will have meant a consumption of M. That is to say, starting at A with a stock of M, and placing a fresh order

Q , the existing stock M will gradually reduce, until at B it is exhausted just as the fresh batch comes in to stock. Later it will be found necessary to develop certain refinement to this statement. Sometimes, for instance, it is desirable to carry an additional reserve of dead stock as a safety factor. Again, where the new batch order starts to arrive in stock before the completion of the final process on the last part in the batch, a modification of the concept of minimum ordering quantity becomes necessary. For the time being, however, the relationship can be allowed to stand as expressed above.

Cost Factors. Reverting to the question of the size of the batch to be ordered, we have here two conflicting groups of factors affecting costs, apart from the costs of direct labour and materials required to produce the job. On the one hand, it will be readily appreciated that for any given rate of consumption, the larger the batch put through the longer will be the period before another batch falls due to be ordered. This fact is so obvious that it may seem hardly worth mentioning, but it is curious how many factory executives fail to realize the converse, that the longer the delay between batches the higher are the carrying costs on the stock investment implied in the size of the batch. With steady consumption, a system of regular batch ordering implies an average stock of one-half the size of the batch. Increase the batch threefold, and we increase our stock investment threefold, and since the rate of consumption remains the same, cost must go up in direct proportion. We then have the feature that interest charges on stocks of finished parts increase directly in proportion to the size of the manufacturing batch.

Against this interest element, we have a group of what are usually called "preparatory expenses," which are fixed for the batch irrespective of its size, and which, therefore, decrease per part proportionately with the number of parts put through in the batch. There are, for instance, the costs of clerical labour and stationery in preparing the manufacturing order; costs of setting up machines and tools to handle the order; costs of planning the order, and of transporting materials from process to process. This group of set-up or "make-ready" expenses is, within reasonable limits, a fixed amount for the batch regardless of the quantity worked. The problem, briefly stated, is to determine what quantity of parts to run to offset this preparation expense, consistent with avoiding undue interest charges on idle stock.

Combined Costs. In Fig. 5, these two opposing elements of cost are shown, together with a curve representing a combination of the two. It will be noticed that the combined curve falls to a minimum value which coincides with the point where the interest line and the set-up cost intersect, and it can be proved mathematically that this is an essential feature of this type of relationship. The economic lot size can be determined then by drawing a graph of the two

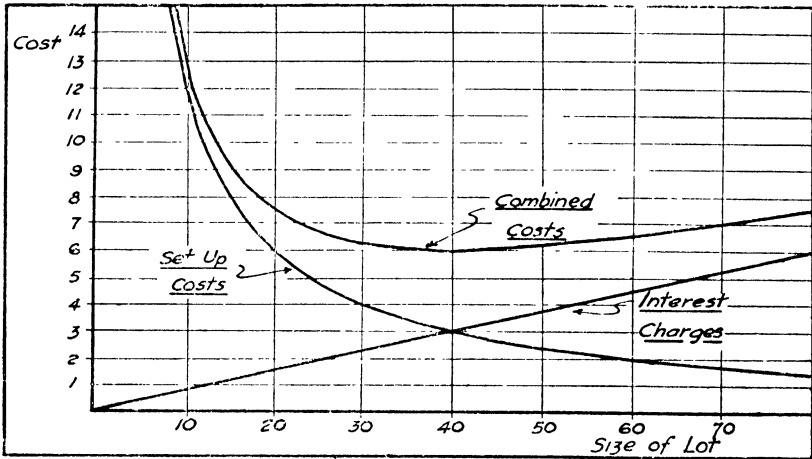


FIG. 5. OPPOSING COST ELEMENTS

cost elements. If, for instance, the set-up cost was 120d., then the cost per part would be 6d. for a batch of 20, 4d. for a batch of 30, and so on. Similarly, if the cost of carrying a part in stock was $1\frac{1}{2}$ d. per month, and the rate of consumption 10 per month, then, for a batch of 20, each part would stay in stock on average 1 month (that is 2 months to nothing) at a cost of $1\frac{1}{2}$ d. each, while, put through in a batch of 80, they would stay in stock four times as long at a cost of 6d. each. Combining the two curves we arrive at a minimum cost of 6d. each for a batch of 40 pieces. This cost is made up of 3d. a piece for set-up costs and 3d. a piece for carrying charges. Both these cost elements are, of course, additional to the costs of direct labour, materials, and general overhead expenses.

If the batch is increased to 60, the set-up cost element is reduced from 3d. to 2d., through spreading the fixed preparatory charges over a larger volume. This reduction is, however, more than offset

by an increase in carrying charges, brought about by the fact that each piece stays in stock, on average, half as long again, giving a combined cost of $6\frac{1}{2}$ d. Similarly, if the batch is reduced to 20, the more frequent ordering reduces the time each part stays in stock by one-half and thereby cuts carrying costs from an average of 3d. a piece to one of $1\frac{1}{2}$ d. This saving, however, is more than offset by an increase in set-up costs resulting from spreading the fixed set-up cost over a total of 20 pieces instead of 40, giving a combined cost of $7\frac{1}{2}$ d. instead of 6d. It should be realized, of course, that there is no suggestion intended that these particular figures are in any way typical of those met in practice. They are used merely as an illustration.

Economic Order Formula. Although production order quantities can be determined by the use of such graphical methods, it will be found in practice more convenient to use a general formula for this purpose. The simplest type of such formulas is given below. Let—

S = set-up cost per order.

C = cost per piece (labour, materials, and overheads) in the same monetary units as S .

D = rate of consumption per week, month, or year.

I = carrying cost per piece in the same money unit as used for S and C and for the same period chosen for D .

Q = ordering quantity.

The general formula is then—

$$Q = \sqrt{\frac{2DS}{I}}$$

This formula is developed as follows. The set-up cost per piece is $\frac{S}{Q}$ and the carrying cost per piece $\frac{Q \times I}{2D}$.

The total cost per piece is therefore—

$$C + \frac{S}{Q} + \frac{Q \cdot I}{2D}$$

Since C is unaffected, within the present terms of reference, by the question of the quantity progressed in one batch, it can be ignored, and the problems become one of finding that value of Q which will give the expression $\frac{S}{Q} + \frac{I \cdot Q}{2D}$ a minimum value. This expression is, of course, the equation of the combined cost curve illustrated in Fig. 5, and the minimum point is where the curve stops falling and

starts to rise. At this point a tangent drawn to the curve would run parallel to the base. The tangent to such a curve is, of course, represented by its differential coefficient, and the problem, therefore, can be resolved into one of determining the value for Q that will make this differential coefficient equal zero. In any individual case, S , I , and D will represent constants, and to make the process of differentiating more recognizable, the expression may be re-written—

$$\text{Total cost} = \frac{a}{x} + \frac{bx}{2c}.$$

In these terms, the differential coefficient is the sum of the differentials of $\frac{a}{x}$ and of $\frac{bx}{2c}$, that is

$$\left(-\frac{a}{x^2}\right) + \frac{b}{2c}$$

This can be restated in the original terms as

$$\left(-\frac{S}{Q^2}\right) + \frac{I}{2D}$$

We now require the value for Q that will make

$$\left(-\frac{S}{Q^2}\right) + \frac{I}{2D} = 0$$

Solving for Q we get—

$$Q^2 = \frac{2DS}{I}$$

$$\therefore Q = \sqrt{\frac{2DS}{I}}$$

Confirming the Graph. As a matter of interest, it may now be shown that this value of Q satisfies the feature already established graphically, that at the minimum point the two elements of cost are equal. Thus, using the value of $\sqrt{\frac{2DS}{I}}$ in place of Q , the set-up cost per piece $\frac{S}{Q}$ may be rewritten—

$$\frac{S}{\sqrt{\frac{2DS}{I}}}$$

Similarly, the carrying cost $\frac{I \cdot Q}{2D}$ may be rewritten—

$$\frac{I \sqrt{\frac{2DS}{I}}}{2D}$$

If $\frac{S}{\sqrt{\frac{2DS}{I}}} = \frac{I \sqrt{\frac{2DS}{I}}}{2D}$ then $2DS = \frac{I \cdot 2DS}{I} = 2DS.$

Alternatively, if we accept the graphically demonstrated feature that $\frac{S}{Q} = \frac{IQ}{2D}$ we can establish the value of Q without reference to differential calculus, thus—

$$\begin{aligned}\frac{S}{Q} &= \frac{IQ}{2D} \\ 2DS &= I \cdot Q^2 \\ Q^2 &= \frac{2DS}{I} \\ Q &= \sqrt{\frac{2DS}{I}}\end{aligned}$$

It should be noted that the function I represents the period cost per piece for investment in stock and storage space, and could, if desired, be written $C \times i$ where C would be the manufacturing cost of the part (materials, labour and overhead) and i the monthly rate of interest. In any individual concern the interest charge percentage can be considered fixed. Assume, for instance, that 12 per cent per annum is taken as the rate to cover interest and storage. This is equivalent to 1 per cent or 0.01 per month, so that for the term I in the equation can be substituted 0.01 C to get

$$\begin{aligned}Q &= \sqrt{\frac{2DC}{0.01C}} \\ &= \sqrt{\frac{200DS}{C}}\end{aligned}$$

In practice, the use of the formula will often be simplified by developing the general formula into such a special form.

The Weaknesses of Mathematical Treatment. Perhaps the most

common error encountered in the use of formulas in business calculations is the tendency to expect a higher degree of accuracy in the answer than can be claimed for any of the individual factors involved. In the particular case chosen, for instance, we have an estimate of consumption. In certain cases it may be possible to arrive at such an estimate that will approximate actual fact. On the other hand, the figure may be little more than a guess. Then again, we have an estimated cost of setting up and making ready. Here it would seem that we were on more reliable ground, but in fact there may again be an element of uncertainty. For instance, the job might involve performing an operation on a machine where the estimated cost of breaking down the machine and resetting to run the new part was 4 hours. In fact, it might be found that, as a result of accident, or of careful planning, the previous operation was so similar to the new one to be performed that only minor adjustment to the existing setting was called for, at a cost of, say, 1 hour.

This should not be taken to imply that the results obtained from the mathematical treatment of ordering quantities are unreliable. On the contrary, it is almost certain that they will show a substantial saving compared with any other method of arriving at such quantities. To check this, take the past history of any particular part as shown on the stores records. Calculate the set-up and investment charges involved in the orders actually placed. Then use the formula to arrive at how the ordering would have been done had this method been used. Calculate the corresponding costs on this basis, and an £ s. d. value can be set against the alternative methods which will give a good measure of the desirability of making a change. The purpose of pointing out the weaknesses of a strictly mathematical treatment is to stress the fact that the formula must be used intelligently, not blindly.

More Complicated Formulas. Considerable thought has been given to the mathematical determination of economic lot orders and formulas have been developed to give due weight to other cost factors not included in the scope of the general formula developed above. These more complicated formulas have a definite value in certain specialized cases. Where they are suitable, they will give a more accurate result than could be obtained from the general form. But one does not get a more accurate result merely by using a more complicated formula. The circumstances must be such that the

refinements introduced actually contribute to a closer approximation to the true position. With this word of warning, it may be interesting to consider one of the more highly developed formulas.

Perhaps the best known of these is that developed by an American, Professor Raymond. To avoid unnecessary confusion, the symbols already used have been incorporated in place of those used in the Raymond formula. As above—

S = set-up cost per order.

C = cost per piece (material, labour, and overhead).

D = rate of consumption.

Q = ordering quantity.

In addition—

P = rate of production as distinct from consumption.

X = interest earned on invested capital,

K = stock coefficient.

c = cost of batch in process.

k = ratio of c/C .

B = cu. ft. storage space per piece.

V = cost per cu. ft. of storage space.

A = time factor for split workings.

N = number of workings in the batch.

Using this terminology the formula is—

$$Q = \sqrt{\frac{SPD}{CX \left[KP - D \left(\frac{1 - \frac{1}{N}}{2} \right) \right] + CXD \frac{k}{A} + VB \left[P - D \left(1 - \frac{1}{N} \right) \right]}}$$

Additional Features. It will be noticed that investment charges on stock and storage costs, instead of being treated as one group, are treated individually. Another essential difference is that the investment in work in process is taken into account where, in the original scheme, this feature was ignored. In this connexion it will be noted that allowance is made for those cases where the batch is so large that it is put through the factory in several successive workings. For instance, an order for, say, 250,000 pieces might actually be put through in 10 batches of 25,000. This means that the process time is affected where the job involves more than one process. In the one instance we have to wait while 250,000 go through the first operation before we can start on the second operation, whereas with the split workings we can make a start on the second operation as soon as we have finished the first 25,000 off the first operation. This time factor is arrived at as follows. Let—

T = complete process time for the first working in the batch.

t = process time for first operation in the batch.

F = ratio t/T .

A = time factor = $1 + FN - F$.

Another refinement is the distinction between cost per piece as delivered to stores and cost in process. In the first, the full labour and overhead elements are added to the material cost so that—

$$C = M + L + O$$

while in process, on average, only half the labour component has been contributed, and therefore only half of the overhead expense is chargeable, so that—

$$c = M + \frac{L + O}{2}$$

Finally, a stock coefficient is introduced to arrive at the average quantity carried in stock as distinct from the quantity ordered. It will be readily appreciated that with steady consumption this factor is $\frac{1}{2}$, but special circumstances, for example, in seasonal industries, may imply the need for a different factor.

Practical Example. It may be desirable to illustrate these features of the more complicated formula by a hypothetical example. Let—

S = set-up cost = 600d.

C = cost per piece = 4d.

D = rate of consumption = 30 per day.

P = rate of production = 600 per day.

X = interest rate = 12 per cent p.a. = 0.0004 per day.

K = stock coefficient = $\frac{1}{2}$.

c = cost of batch in process = 3d. per piece.

k = ratio c/C = $\frac{3}{4}$.

B = storage space per piece = 0.005 cu. ft.

V = cost per cu. ft. of storage = 0.08d. per day.

N = number of workings in batch = 5.

F = ratio of process time on first operation to complete process time = $\frac{1}{2}$.

A = time factor = $1 + FN - F$ = 2.

Substituting these figures in the formula, we get—

$$\begin{aligned} Q &= \sqrt{\frac{600 \times 600 \times 30}{0.0016 \left(300 - 30 \left(\frac{2}{5} \right) \right) + 0.0016 \times 30 \times \frac{3}{4} + 0.0004 \left(600 - 30 \left(\frac{4}{5} \right) \right)}} \\ &= \sqrt{\frac{10,800,000}{0.7092}} \\ &= \sqrt{15,229,977} = 3903. \end{aligned}$$

Using only the factors incorporated in the simpler basic formula on page 24, we should have obtained—

$$\begin{aligned} Q &= \sqrt{\frac{2 \times 30 \times 600}{4 \times 0.0004}} \\ &= \sqrt{\frac{36,000}{0.0016}} \\ &= \sqrt{22,500,000} = 4743. \end{aligned}$$

The difference between the two answers is the measure of the results of ignoring in the latter case refinements such as the cost of storage that were introduced in the more complicated formula. The reader may find it of interest to calculate by the alternative formulas, with variations in the individual figures. Thus, if the rate of consumption is doubled, while the other figures remain the same, what would be the relative effects on the answers to the two calculations? What would be the results of the assumption that storage costs were five times as expensive? This assumption would of course have no influence on the result obtained from the simpler formula, since here the storage cost element is ignored.

Investment Limitations. In the above discussion, order quantities have been considered solely from the angle of minimum cost considerations. The basic aim has been the determination of an ordering quantity large enough to yield the optimum reduction in preparatory costs per piece. A larger quantity would still further reduce these costs, but the reduction would be more than balanced by an increase in investment and carrying charges. It must be appreciated, however, that in certain circumstances the liquid capital situation in a particular concern may make it impracticable to operate in this way. Obviously, the larger the order quantity the larger will be the implied investment in stocks. And while this increased investment can be proved statistically to pay its way, through compensating reductions in unit preparatory costs, it may not always be desirable to sink the required amount of capital in stocks. This aspect of the problem has been translated on a mathematical basis for incorporation in a formula for determining economic lot sizes, but this, and other more elaborate formulas, are outside the scope of the present work. For practical purposes it is often found convenient to work on the basis of a range of production quantities for each part. In this way a certain amount of scope is provided for the exercise of personal initiative in planning production schedules, while at the

same time assuring that a reasonably low production cost can be obtained, together with a proper conservation of capital. The reader interested in pursuing this subject more deeply is referred to *Quantity and Economy in Manufacturing*, by F. E. Raymond, where the matter is exhaustively treated.

Assembly Problems. Cases are often met in practice where attempts are made to determine joint economic production quantities for a combination of fabrication and assembly work. Although it is possible to develop a special formula for this purpose, it can be demonstrated that the economic balance for a combination of articles cannot produce a manufacturing situation as economical as could be obtained for each separately. In all such cases the lot size must be determined separately for each stage of manufacture, with, if necessary, an interval where storage is required in anticipation of the next stage. Indeed, in such circumstances, these separate lot sizes form the only logical basis for the economic conduct of operations.

In the aircraft industry, for instance, there is little difference in cost in progressing airplanes through their final assembly operations in singles or in batches of ten. So far as the component details are concerned, however, process conditions are usually such as to mean that a large batch is required to justify the elaborate set-ups involved. It is an unfortunate feature of the industry that so many firms continue to progress all details through the shops in batches of the same quantity, irrespective of whether that quantity is an economic proposition for all of the separate parts involved.

Ordering Methods. It will be readily appreciated that the determination of ordering quantities is only half the ordering problem. Equally important is the question of *when* to order. In the jobbing shop, where work is done solely to customers' special orders, this problem does not arise, since the shop orders are originated and controlled by the receipt of customers' orders. Batch production conditions, however, demand executive decision to control the actual issue of the stock replacement orders. The fundamental principle is that such replenishment orders should be issued when stocks have fallen to a figure representing the sales that are expected during the period of time that will be taken for the new order to progress through the shops to stock. This is graphically illustrated in Fig. 4 (page 31).

In many concerns, replenishment orders are originated as the result of a periodic review of stock records and sales returns; where sales are irregular and uncertain this is perhaps the best practical solution. Such a review, however, involves the individual determination for each article—

1. What stock, or stock in progress, remain unsold?
2. How long is this stock likely to last before being exhausted by anticipated sales?
3. How long would a new order take to come through the factory?
4. What quantity should be re-ordered, bearing in mind probable sales and the economics of the manufacture of the product?

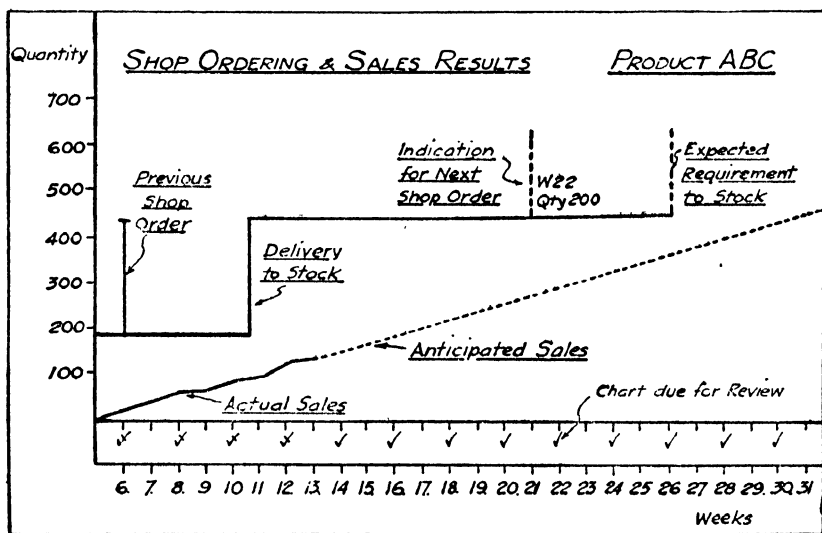


FIG. 6. ORDERING AND SALES RESULTS

Ordering Charts. It will be readily appreciated that, for any particular part, such a review might be made on several separate occasions before a decision was reached to release an order. Often, the interval between these periodic reviews is so long that, in the meantime, a sudden rush of orders has reduced stocks to such a level that an out-of-stock position is inevitable. This danger can be avoided, and the actual consideration of the problem simplified, by the maintenance of a set of graphical records similar to that illustrated in Fig. 6. Such a chart shows the ordering position and indicates the trend of sales results. The ordering executive can

reveal his decisions by pencilled additions to the chart (shown dotted in the illustration); the remainder of the work of ordering can be left to relatively junior labour. Actual sales are entered on the chart each day, and when these depart appreciably from the estimate, the chart can be brought specially to the notice of the executive authority. When the indicated time arrives for placing the stock replacement order, this order is put through without reference to the executive, and confirmed by inking in the pencilled lines on the chart. When the time arrives for the normal review of the position on this particular product, the pencilled additions can be further extended to cover a period as far forward as seems desirable.

Minimum Stock Control. Where sales conditions are reasonably stable, a similar result can be achieved by establishing for each part a minimum control figure as a signal for the placing of a replacement order of a certain quantity. These figures can be used in conjunction with properly designed "balance-of-stores cards" to control replenishment orders. Such a card would show—

1. How much of the item is in stores.
2. How much is on order, but not delivered.
3. How much is reserved for orders in sight.
4. How much is available for new orders.

As soon as the available stock and process fall to the minimum control figure, a stock replacement order is issued. In arriving at this minimum figure allowance is made for the time that will be taken to obtain fresh supplies, plus whatever margins of reserve may be deemed desirable to cover contingencies. A typical balance-of-stores card is shown in Fig. 7.

Cyclical Ordering. Obviously, in a flow production unit, the consumption of component parts is controlled, and in such circumstances it is possible to prepare an ordering programme for these parts, irrespective of whether the parts themselves are produced by flow production or in intermittent batches. A similar condition may be reached where a factory is working on a long-term contract with certain definite delivery requirements. Thus, a factory producing 20 tanks per week would be able to analyse the drawings of the tank down into component details, and plan its ordering ahead for the duration of the contract. Where the process justified a perpetual set-up, daily or weekly orders would be automatically

BALANCE RECORD OF RAW MATERIALS

Description *Sheet Iron 6' x 3'* Bin or Stores No. *A20*
 Material or Symbol *16G* When Balance in Stock falls below *56 lb.* re-order *560 lb.*

Quantity Requisitioned on Buyer				Quantity Allocated		Balance	Quantity Received in Stores			Quantity Issued to Shops				Balance Actually	Reserve	
Req. No.	Date	Quantity	Job No.	Quantity	Avail-able	Insp. Note No.	Date	Quantity	Req. No.	Job No.	Date	Quantity	In Stock	Job No.	Quantity	
1476	25/8/	560 lb.	1117	500 lb.	60 lb.	1373	30/8/	560 lb.	124	1117	1/9/	125 lb.	435 lb.			
			1120						125	1118		125 lb.				310 lb.
1490	5/9/	560 lb.	1410	30 lb.	30 lb.				130	119	4/9/	125 lb.	185 lb.			
									131	120		125 lb.				60 lb.

FIG. 7. BALANCE-OF-STORES CARD

released. On certain other parts, a batch of, say, 200 sets might be found to be an economic quantity. In this instance, an order would be released every ten weeks. The time for placing this order would

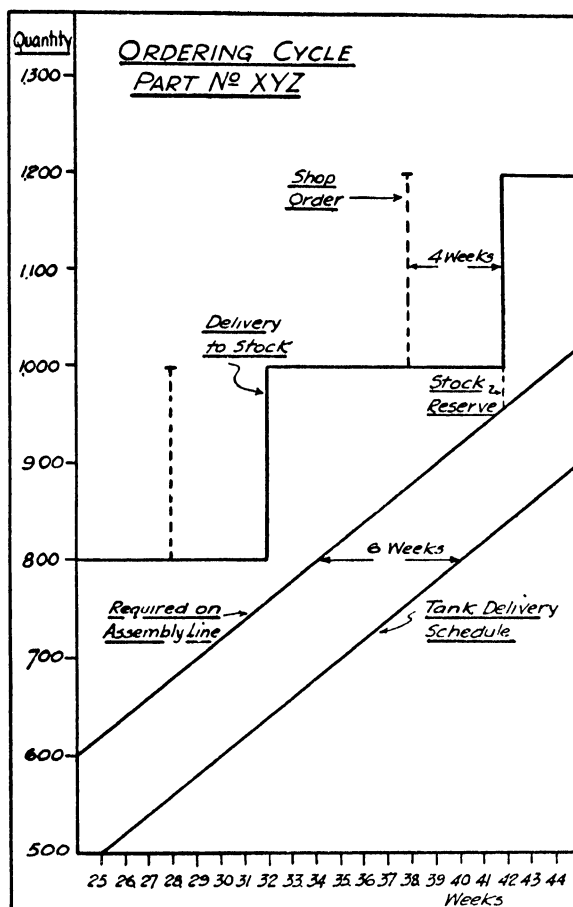


FIG. 8. ORDERING CYCLE CHART

be fixed with reference to when the first piece in the batch was required for assembly (derived in turn from the assembly diagram). If, for example, the part was required on the assembly line six weeks before a tank was delivered, and itself took four weeks to make, an ordering programme similar to that shown in Fig. 8 could be

established to control the ordering of the part throughout the contract.

Care must be taken, however, not to fall into the error of assuming that having established such an ordering cycle the ordering position can be left to look after itself. From time to time parts will get lost in the shops, or in the stores; batches will be delivered to stock short; parts will be scrapped or spoiled. From time to time the replacement orders must be adjusted to reconcile the ordering programme with these discrepancies. In the case illustrated a reserve stock of two weeks has been allowed to cater for these contingencies. In the absence of any such reserve, a combined loss of 30 parts would mean that any particular stores order would be required $1\frac{1}{2}$ weeks earlier than programmed. This situation could be met by placing the next replenishment order $1\frac{1}{2}$ weeks earlier, but this step might not be desirable as the order may have been planned for the particular week chosen so as not to clash with demands on shop facilities made by orders for similar parts. The reserve factor allows the order still to be placed on the planned date, but this time for 230 parts instead of 200, thereby correcting the situation.

CHAPTER IV

PRODUCTION PLANNING

The Customer's Order. It will be readily appreciated that, in the special order industry, a customer's order, in the form usually received, seldom presents in itself sufficient information to enable it to be met. Even when the order is accompanied by a full specification, and a detailed set of drawings, considerable further engineering work is needed before the factory can start to produce the job. In effect, the job must be broken down into its individual component parts, and instructions issued showing what material is needed for each part; what processes are required to fabricate the material to the desired form; and where and how those processes are to be carried out. Frequently it is desirable to break the final assembly down into a group of sub-assemblies as intermediate stages between the individual component parts and the final assembly. Coupled with this engineering analysis, there must also be some means of breaking down the originating master order into separate shop orders for individual component parts.

Stock Order Analysis. With the stock order type of industry this engineering analysis element is not conspicuous at first glance. The customer's order often contains sufficient information to enable it to be met by withdrawing the appropriate article from the stock racks. Exactly the same procedure is, however, involved in the initial translation of the designer's conception of the article into the necessary information and shop instructions to place the article in stock. Similarly, the customer's order is not sufficient to ensure the replacement of the articles taken from stock. The warehouse stock must be regarded as a buffer whose purpose is to even out erratic demands so far as the factory itself is concerned, or to allow such demands to be accumulated until they represent a sufficient quantity to progress through the shops. The essential difference in this respect between the special order and stock order industries is that in the former this detailed engineering analysis has to be worked out individually for each order, while in the stock order industry, when the initial shop order has been worked out, the information is a matter of record and can be taken off the files.

Actually, a business enterprise rarely falls completely into either of the two categories. Usually, the special order concern takes advantage to a degree of a range of standard parts which repeat themselves in the various patterns and products sold; the stock order company is often faced with special orders demanding a departure from standard.

The Engineering Documents. In practice, the forms that are used to convey this engineering information come under such a variety of different titles that it may be desirable to indicate a few of those commonly used. They are—

Master parts record	Process sheets
Part sheet	Operation layout
Part list	Layout sheets
Instruction sheet	Operation analysis
Production detail form	Bill of materials
Blue-print	Sub-assembly sheets
Specifications	Assembly sheets
Drawings	Routeing sheet
Schedules	

It would, of course, be convenient, from certain standpoints, particularly that of the writer on factory organization, to have some form of standard terminology that would be universally recognized. But the differences are consistent with the fact that forms must be designed to suit the needs of the particular case. What is important is that, irrespective of the name they are given, the engineering documents should provide the information required without a lot of other unnecessary detail.

Blue-prints. The function of these engineering documents is to provide all those particulars needed to carry out the order. In the engineering industry the father of all these various forms and schedules was the so-called blue-print. This, as the name implies, was a copy of a drawing, made by a special process, which resulted in a white print on a blue background. This method of taking prints from drawings is rapidly being replaced by other methods, which give clearer impressions, in the form of brown or black lines against a white ground. It is interesting to note that the term blue-print is becoming a part of common parlance at a time when the object itself is disappearing. But whatever name is given to it, a copy of an engineering drawing is still a commonly used means of conveying to the shops the information they require for the production of the

part or assembly. This method is used, for instance, throughout the aircraft industry.

Aircraft Drawings. After the preliminary designs of an aircraft have been approved, specific parts of the machine are assigned to engineering groups or sections for detail design and stress analysis. Stress analysis is a calculated determination of the size and proportions of the various parts needed to assure, not only that they will fit together, but also that they will be strong enough to function properly in the completed aircraft. In certain circumstances a "mock-up," or model, may be made from these drawings to determine the exact arrangement of instruments, controls, petrol and oil tanks, and other accessories, in those parts of the machine where space is at a premium. The next step in design is the preparation of reference layouts, usually called "layouts," from the detail designs. These layouts are made complete in every detail, so that all the parts of the aircraft can be assembled without interference.

The final production drawings are made from these layouts, and copies of them go into the shop, where they are used to instruct the craftsmen in the fabrication and assembling of the parts required for aircraft construction. These final production drawings are usually referenced together in a form of genealogical tree, giving more and more detail as individual parts of the aircraft are broken down into sub-assemblies. For instance, the production drawings for a wing may key back to a general arrangement of the wing itself, on which will be given the essential information for the construction of the wing. On this general arrangements reference will be made to other arrangements, each for specific portions of the wing, such as front spar, rear spar, ribs, aileron, flap, controls, etc. Each of these arrangement drawings may in turn refer down to drawings showing certain parts of the assembly in more detail; these again in turn may resolve down into a drawing of an individual part giving the specification of the material from which it is to be made, the cutting-out sizes, or amount of material required, with all dimensions and tolerances.

The degree to which this detail drawing is carried is by no means standard. Sometimes a drawing may give details of one single part. Or one single drawing may contain all the information that is necessary for fifty separate detail parts.

Detail Sheets. Although aircraft drawings such as those described

above are sufficient to enable a skilled craftsman to produce by hand methods the details and parts involved, they often leave much to be desired when the demand for high output entails the use of relatively low-grade labour. Similarly, a need is often felt for further information to facilitate machine production of parts. For instance, the essential information for a particular part may appear on a drawing containing thirty other details. A copy of the drawing could be used by all of the individual operators handling the various detail parts, but obviously it would be more convenient to have separate drawings of the individual details. Even then, this individual drawing does not itself provide all the information required for the production of the part, and the next logical step is to associate with the drawing an operation schedule. This may result in the preparation of a document similar to that illustrated in Fig. 1 (page 7). An individual detail sheet of this type is commonly met with in firms who carry stocks of certain standard parts. The essential information it provides is—

1. The identity of the part, its appearance, and the measurements to which it is to be made.
2. The material required to make the part.
3. How the part is to be made.
4. How long a time is to be allowed to make the part.

As an indication of how long this list may grow in an individual case, however, it is not uncommon to find Part Sheets, Master Part Records, Production Detail Forms, Process Sheets, Layout Sheets (or whatever name is given to the document) giving the following data—

1. Detailed drawing of the part, with permissible tolerances in key dimensions.
2. Part number.
3. Specification of raw material.
4. Amount of raw material per part.
5. Amount of raw material to issue per (say) 100 parts.
6. Description of each operation to be performed.
7. Department to perform each operation.
8. Grade of labour to be used on each operation.
9. Running time allowed per 100 parts each operation.
10. Set-up time for each operation.
11. Individual machine to be used on each operation (with second and third options).
12. Rates of feed and speed for each machine operation.
13. Jigs, fixtures, and tools required for each operation.

14. A separate instruction sheet for each operation, explaining exactly how the operation is to be performed.

Engineering Expense. It is not suggested that this degree of engineering information is invariably necessary. But as the stock order industry approaches the so-called mass-production stage, detailed analysis of this type is often found necessary to obtain optimum results. It should be realized that a larger engineering expenditure can be justified on a stock item that is expected to have a long life, and to be required in large quantities, than could be tolerated on a special line. On the other hand, in certain special order industries, the engineering expense, as a whole, is so high by virtue of the nature of the product, that as a ratio to production it would be unbearable in any stock order concern, no matter how highly developed. The application of sound common sense is needed to limit engineering expense to the level where it is justified by results. At the same time, however, so-called practical common sense should not be allowed to lead to the elimination of all drawings and technical information.

The Principal Systems. It may be of interest at this stage to outline the principal features of the different treatment of this engineering paper-work problem in various businesses. Broadly speaking, most systems fall into one of the following four groups—

1. For each assembly, a list of the part numbers involved (commonly called a Part List); together with a separate sheet for each part number (commonly called a Part Sheet), giving a drawing of the part and all essential production information. In addition, there may be an Assembly Sheet, giving shop instructions for the assembly work.
2. A list of drawings (Drawing Schedule or Specification); with a set of drawings (Blue-prints) variously comprising one or several parts, each part having a reference number; with an associated list (Bill of Materials) giving against each part reference information on raw material requirements for each part. Sometimes this bill of materials also carries operation routing for each part; sometimes this information is given on separate Routing Sheets, and in some cases it is not included in the stationery at all.
3. A similar system to that outlined in (2), except that the Bill of Materials is dispensed with by incorporating in a corner of each drawing the information this normally provides.

4. Again similar to (3) and (2), except that the list of drawings is dispensed with by providing a master "General Arrangement" drawing which provides sufficient indication of what other drawings are required to complete the set.

Sample Part System. Many small concerns have used with success a system whereby specimen sample parts take the place of paper records. In the works where the management can keep conversant with the daily progress of every individual detail, and where any part is not likely to be the subject of a repeat order, this type of sample part system works well. But as soon as any such concern expands its capacity beyond a certain point, the potential errors in the sample part system almost invariably force a more systematic treatment of the problem.

One works endeavoured to operate a sample parts system along the following lines. The company, which was marketing a range of fairly simple instruments, maintained an experimental department of skilled mechanics whose job it was to develop verbal ideas for new or improved instruments into an actual sample instrument. This sample was tested for performance, rebuilt to incorporate any modifications suggested by the test, and built and rebuilt until finally approved. Following the normal engineering procedure, a part list would then be got out, listing the parts required to produce the instrument, and a part sheet made out for each detail part not already covered in this way as part of a previous instrument. Alternatively, of course, an engineering drawing could be made of the instrument giving the corresponding information. In this particular case, however, no attempt was made to follow this engineering set-up. Instead, the sample instrument was dismantled and each component piece wired to a "part board" for future use as a substitute for drawings. When it was decided to make a hundred instruments, the shop mechanics were told to make enough pieces like those on the board.

Difficulties of Production to Sample. The first difficulty met was that the part board gave no indication of the exact class of raw material required (there are, for instance, many different specifications of brass, each with its own particular good and bad features in any individual case). Next, there was no control on the amount of raw material to be drawn by the mechanic for any particular part, nor on the type to be used, whether rod, sheet, strip or bar.

If he chose, the operative could turn a $\frac{1}{2}$ -in. washer out of $1\frac{1}{2}$ -in. bar. Again, there was no indication of what, if any, heat treatment was called for in the production of the part. Each operative worked to measurements that he himself took off the particular part on which he was working and worked to his own idea of tolerances. One man would make a particular part that could be anything between 1.010 in. and 1.030 in. to as near as he could get to 1.018 in. because that was what his micrometer-reading gave him. Another would be making his part about $2\frac{1}{4}$ in. long, whereas a plus or minus tolerance of 0.003 in. was actually required on a dimension of 2.240 in. Coupled with this problem, since the shop was on piece work, it was not uncommon for the mechanics to delay production by avoiding parts with tight prices, and to produce an excess of parts showing a good price. Finally, there was the problem of identity of the various parts when the pieces were ready for assembly. Even with the simple product and a relatively low output the sample part system failed, and was abandoned in favour of a paper record system.

Summary. It may be advisable to summarize the fundamental features of engineering records of the type considered above—

1. They should be positive, plainly written in unmistakable language, and simply arranged.
2. To lessen confusion and mistakes, so far as practicable, each drawing should be confined to one part.
3. No additions or alterations should be made to the records except by the Engineering Departments, and great care should be taken to see that two different issues of the same drawings are never in circulation at the same time.
4. Positive identification of each part, tool, material, working station, and department should be provided. Part number systems can be developed so that each figure in the part identity gives information on the part, besides establishing the fact that it is in an individual part. In some cases (e.g. typewriter spares) the part number system must preserve identity over a long period of years. In others it may be practicable to duplicate part numbers after a reasonable period of time.

CHAPTER V

DATE PLANNING—THE TIME ELEMENT

THE chief aim of manufacturing enterprise is to achieve prompt delivery and low production cost. Towards this end the numerous variables affecting the situation have to be kept under control, to avoid delays, to avoid building up excessive or unbalanced stocks, and, so far as possible, to use plant facilities to capacity. These objects can be achieved only through careful attention to the time element expressed in date planning.

The First Step. It has already been pointed out that in the process of pre-planning an order it is exploded or broken down into its component sub-assemblies and individual parts; and that each of these is routed to establish the operations to be performed and the sequence in which they are to be done. The first step in date planning is to establish a date when each of these processes must be performed to fit in with the desired delivery of the finished product. Obviously, this demands a detailed knowledge of process times, but it should not be assumed that process time alone determines the date to be set for each operation. If a study is made in an intermittent flow production factory it will usually be found that although the total process time for a certain part amounts to a matter of hours, actually it takes several days or even several weeks to pass through these processes. In a continuous flow factory, particularly in one where power conveyors are used, a part or assembly moves directly from one machine to another, is processed with no appreciable waiting period, and passes automatically to and through the next process. We have here a line of machines set up to handle the particular part, and continuous flow is the essence of the factory arrangement.

In the intermittent flow production factory, however, each machine has to be set up especially to handle the particular part, with a consequent delay in processing. On top of this, there is almost invariably a float of work behind each station waiting to be processed, and if different parts are handled in turn, at each process they must have a waiting period equivalent to the volume of prior work waiting behind the machine. Generally, with a wide variety of different orders to be handled, each usually demanding a different

sequence of operations, it is impossible to ensure continuous operation of any particular machine (either in set-up or running) without sufficient reserve of work behind it to counterbalance the fact that the individual jobs do not arrive at that particular process regularly or in a constant stream. This feature introduces the need for some measure of machine loading in intermittent flow types of manufacturing, and incidentally makes it very desirable when routeing individual orders to indicate, wherever practicable, alternate processes and alternate sequencing. There is also an obvious benefit to be obtained from any means practically possible that will enable the sequence in which individual jobs are handled at each process to be adjusted to fall in with delivery requirements. In addition, there must be some means of measuring and keeping under continual review the actual volume of the balance of work behind each machine. Only by so doing can bottlenecks in production be detected early enough to enable action to be taken to minimize their effects on delivery; and only through so doing can arrangements be made to keep at a minimum the losses implied by idle equipment.

The Opposing Factors. It will be realized that in arriving at a date programme for any particular job we have to strike a balance between two opposing sets of factors. We have first an analysis of each order, showing the amount of hours' work to be done in each process, and when certain key stages of progress must be reached to enable the job to be finished to time. In the second place we have the implications of these job programmes when they are laid out in terms of machine programmes. This involves the reclassification of the work on the job programmes under individual machines. The final date plan for each job can be laid out only on the basis of these two programmes, with due allowance for the time that will be taken to complete any jobs already in process. The problem of date planning, therefore, resolves itself into a consideration of the following factors—

1. The new jobs to be completed.
2. The required date of completion for each job.
3. The amount of work to be done in each process on each job.
4. The available machine capacity after allowing for the jobs already scheduled on the various machines.

Preserving the Customer Identity. It will be appreciated that customers' orders as such tend to lose their identity in their progress

through a factory. Generally speaking, the individual components involved in the order are handled separately with similar components for other orders. The foreman of the relay winding shop in the telephone manufacturing concern does not recognize a particular batch of special relays as those required for, say, the Tottenham Automatic Telephone Exchange for the General Post Office. To him they are works order number so-and-so, just one of several orders for special relays, each to be completed by him at a certain specified date. But although the individual foreman may not be concerned with the ultimate destination or purpose of any particular works order he may have to handle, it is a vital link in the chain leading up to the desired result of delivery of certain equipment by a certain time. This feature of loss of identity is even more significant where certain component parts of a special order are made on a stock order basis. In such a case we may have an order progressing through the factory which was intended, when placed, to provide so many parts for Job A, so many parts for Job B, so many parts for Job C, and so many parts to stock to be held against future orders. If everything goes as planned, and if the plans were correct, all may be well. But if the plans break down, or if there is a change in requirements, and only half the desired quantity is going to arrive to time, then how are they to be allocated to the various jobs to make the best of the situation?

The answer to this problem lies in the establishment of some form of "follow-up" technique to enable the customer-identity of the job to be preserved. This must reflect the significance of anticipated shortcomings in machine programme achievements in their probable effects on the job programmes that have been set up, so that the necessary arrangements can be made to secure optimum results.

Flow Production. All the above is an indication of the difficulties inherent in intermittent flow production that in this type of industry tend to make the problems of production control so much more complicated than those met in flow production. At the same time, however, date planning has a vital part to play in flow production industry, more particularly so in the early stages before the flow has really started. Once the regular flow has been achieved it can be maintained by ensuring a regular balanced input to the individual sub-stages. But to achieve the flow much careful planning is

called for to determine the different times at which each sub-flow should be started. In the motor car industry, for instance, it will be obvious that chassis frames must reach the conveyor line long before, say, the floor boards to be fitted to that particular unit. It may be rather less obvious that not all the component parts of the individual chassis require the same time to process, with the result that the slow-moving parts must be started on their way that much earlier than the associated parts that can be more quickly machined. This may mean, for instance, that a certain component of a unit that is fitted to the car as the last item on the conveyor line may actually have to be started at an earlier calendar date than the very first component to make its appearance on the belt. Still further complications are introduced where the demand for one of the component parts is insufficient to justify flow production, so that intermittent batch production has to be reverted to for that and similar parts. The basic principles to be followed are the same, with the added complications of reserve stock requirements and the time lags inherent in batch production.

Unbalanced Ordering. What the problem amounts to in practice is to put the ordering out of balance to such an extent that its "out-of-balance" exactly reflects the lack of balance in the individual component process times.

This problem is a particularly topical one in the aircraft industry, where many firms not previously experienced in flow production have failed to grasp the significance of the necessity to unbalance their ordering in this way. The parts that should be put in hand first are not necessarily those that take the longest to make, nor necessarily those that go into the final assembly at the earlier stages.

Having outlined the problems and implications of date planning we can now proceed to an examination of the mechanisms and systems used in practice.

The Assembly Diagram. It has been found that one of the most convenient aids to date planning is to express the problem in pictorial or graphic form. The degree of detail to which this graphic analysis is to be carried will depend on the degree of precision of control that is practised. The fundamental principles to be followed in its preparation are, however, always the same. First, the desired finishing date is decided, the product being then worked backwards through the various stages of manufacture to determine the time

at which each stage must be completed in order to achieve the required final date, and hence to establish the length of time that may be allowed for the performance of each stage.

A simple illustration of the assembly diagram is given in Fig. 9. This shows the time facts for a product XY comprising components X1, X2, and Y. The manufacture of X1 involves in itself three separate processes taking a total of ten days; X2 involves two processes taking six days; the assembly of X1 and X2 to form X

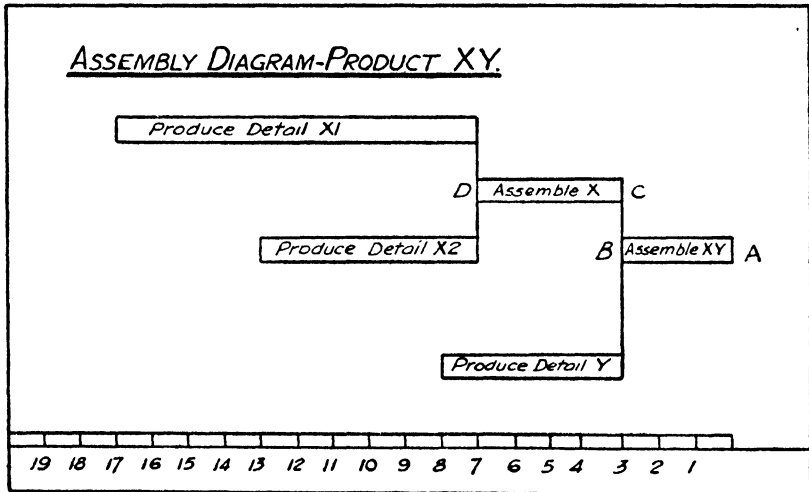


FIG. 9. ASSEMBLY DIAGRAM

takes four days; and the final assembly of X with Y involves a further three days. The manufacture of Y itself involves one process taking five days. This data would, of course, be obtained from an analysis of the operations as shown on the route sheets. To put the data in graphic form, it is necessary to start with the finish of the product and work backwards.

The final assembly of XY takes three days, so a line *AB* is drawn to represent this time. Then, if this assembly is to start at *B*, it is necessary for products X and Y to be completed by that date. As we have seen, the product X comprises two components X1 and X2, taking four days to assemble, so a line *CD* is drawn to indicate this time. Similarly, lines must be drawn to allow for the time taken to manufacture X1 and X2, and to manufacture Y, and the chart

finishes with the operation which must be begun first. It must be particularly noted that the times charted for each operation are not the hours that the job will be on the machine or assembly bench, but the calendar time they will take to route through the shop or department where each operation is to be performed.

Although the particular instance chosen is an ideally simple one, it will be obvious that the same technique can be used for complicated assemblies. The advantages of this chart in the special order industry will be apparent. For instance, an order may have been taken for completion by 15th November. With this date as a starting point, the product can be worked backwards through the various assemblies, sub-assemblies and processes, to give a complete picture of how each item ties in with the completed product, and when each part of the work must be started to ensure that the job is finished on time. Obviously, such a picture would be of the greatest value in assisting the preparation of the shop plans and schedules for completing a job on the due date.

The Purpose of the Chart. It must not be assumed that the preparation of such an assembly diagram will automatically solve the problem of date-planning in the special order industry. What the chart *will* do, however, is to give a very good picture of the task that has to be achieved; it will show what special arrangements are called for to achieve the desired result; and it offers a good means of checking at any time the significance of the degree of progress that has already been made. In practice, it will often be found that working back from the desired completion date, and allowing the normal time taken to route through each department, one arrives at an impossible starting date. In such circumstances an executive decision must be taken whether the final date is to be kept by "rushing" the job through one or more departments instead of allowing it to take its turn behind the normal balance of work in progress at each stage. This decision should, of course, be made with due respect to any prior commitments. You cannot rush every job through every operation, and if any one job is given priority it correspondingly delays all those other jobs that normally would have been handled before it.

Reducing Delivery Times. Assembly charts often provide a key to the possibility of reducing delivery periods in a special order industry. These charts will show exactly what work should be

started in advance of the receipt of an order to ensure shorter deliveries, and also whether a particular item is required at such a late date that advance manufacture is unnecessary. For instance, if a particular component is not required until one month before the completion of an order, and the order is to take six months to complete, it is not necessary to do any advance work on this particular component unless its individual manufacture takes more than five months. So far as shortening delivery dates is concerned, the

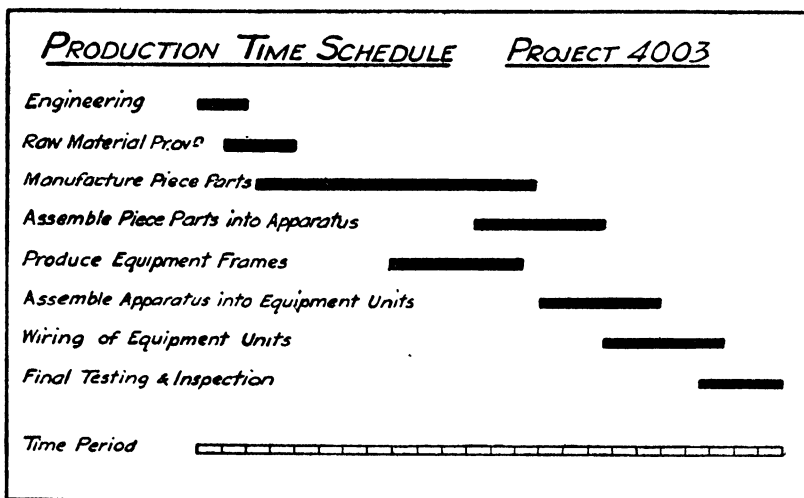


FIG. 10. PRODUCTION TIME SCHEDULE

necessary action is indicated by ruling a line down the assembly diagram at the proper point. If, for instance, the normal delivery period for a particular type of equipment is nine months, then a line ruled down the chart six months from the completion date gives a clear picture that, if the delivery date of six months is to be met, all the work on the left-hand side of the line must be completed before the receipt of the order. Often, it may be a practical proposition to put in hand such preliminary work at the inquiry stage in anticipation of receipt of an order—particularly where the work is such that the parts may later be used on some other contract if the particular order in mind fails to materialize.

Manufacturing Time Schedules. It is sometimes found that the degree of precision of paper-work control in the special order industry does not justify date-planning by individual processes. The

principles of the assembly, however, are often used in such cases to establish a time schedule as a programme for the various departments involved. Fig. 10, for instance, shows the planned manufacturing time schedules for a telephone exchange equipment. Such a schedule gives each department a picture of when they should start; when complete, their portion of the work involved; and allows provision to be made in advance to deal with the task when it arrives.

At the other extreme of manufacturing industry, in the flow production factory, or large scale intermittent flow production factory, date-planning can with advantage usually be carried out to an extreme degree of detail. If, as it should do, the flow production factory is to represent a closely interlocked group of manufacturing units, then a great deal of planning can be justified if it will achieve this desired result. In fact, the necessary degree of articulation can be achieved only through such planning. The facts that the assembly chart illustrates in such a case are actually the basic data on which the factory must be planned. The chart is the key to the secret of getting the various processes going sufficiently in advance of each other to establish the desired flow. The chart also shows how the manufacturing equipment should be physically laid out with a view to ensuring a straight line flow and minimum handling charges.

An Aircraft Example. It may be of interest to illustrate in a little more detail how this date-planning, or programming, is carried out in modern aircraft manufacturing plants. This industry is chosen as an example because it represents a mixture of batch and flow production. The main assembly of airplanes is carried out on a flow production basis. Some of the component details from which they are built are also made in the same way, but the general rule is for batch production, or intermittent flow production of these parts to stock, for withdrawal from stores to the final assembly lines.

Manufacture of aircraft is based on a system of dividing and subdividing the aircraft and its components into progressively smaller units, which are interchangeable. For instance, there may be separate production of front fuselages, rear fuselages, wings, ailerons, flaps, tailplanes, elevators, fins, and rudders. But since all these components are to be interchangeable, that is, for instance,

any pair of wings must fit any fuselage, and must fit to very close limits, each pair must each be built in fixtures that will ensure the necessary accuracy of their individual pick-up points.

Jig Capacity. The key to the production capacity for any particular unit is a function of the number of main assembly jigs available, and the time that will be taken to build a job in each. If, for instance, a tailplane occupies a main assembly jig for four days during manufacture, and there are eight tailplane jigs available, then the limit to production is equivalent to two tailplanes per day (eight every four days). Such main assembly jigs are expensive, and occupy relatively a large area. The solution to increased capacity is not, therefore, sought in additional jigs until all avenues have been explored to reduce the time taken in the jig. Cut the time from four days to two, for instance, and you have the equivalent of double the number of jigs.

This has led to doing as much work as possible "out of the jig." As a result, the larger components, such as main planes and fuselages, are further sectionalized, and actually are in an advance stage of completion before they begin to take shape as a single unit. The time and number of operations required in the final assembly fixture are thus reduced to a minimum. One large machine, for instance, is broken down into nineteen major units, thirty sub-units, 650 sub-assemblies, and 30,000 individual parts, excluding rivets, nuts, bolts and washers, literally by the million. These parts, assemblies, and units must travel through fabrication and inspection in exact order and sequence, and must keep arriving in the right place at the right time, to keep production moving. The planning to achieve this end is based on the assembly diagram. Fig. 11, for instance, gives a very summarized picture of the supply problems involved in the assembly of a bomber wing. It will be noticed that the arrangement provides for what virtually is flow assembly of spar booms and webs, continuing on through the main assembly jig. At the various stages of assembly other parts are fed into the assembly from stock. It should, of course, be realized that in itself each of these parts represents an individual problem in planning. The nose ribs and tail ribs, for instance, would be made by batch production, the problem here being to put through in the sub-assembly shops workings in such quantities and at such times that will mean that ribs are always available for main assembly, without, however,

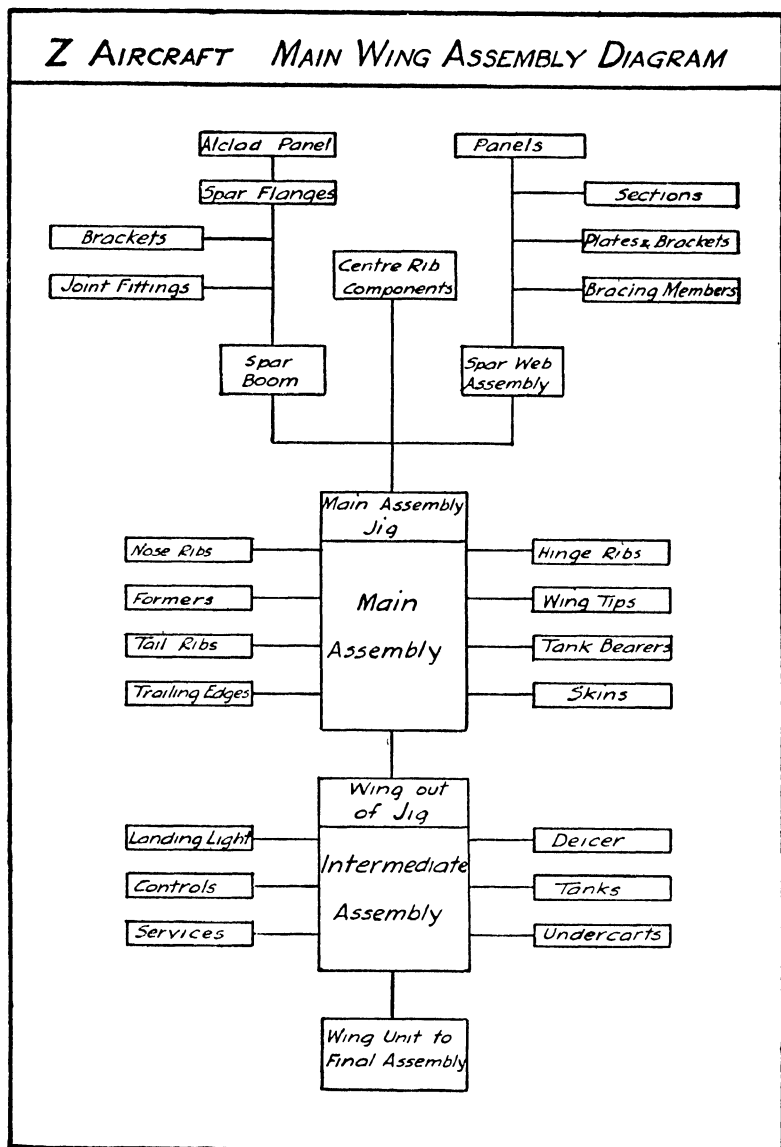


FIG. 11. MAIN ASSEMBLY DIAGRAM

involving more than a justifiable amount of material and labour locked up in stocks.

The production of wings themselves is tied in with the production of the other major units by working them all back from the desired overall result. Thus, if a machine is required for service tests at a

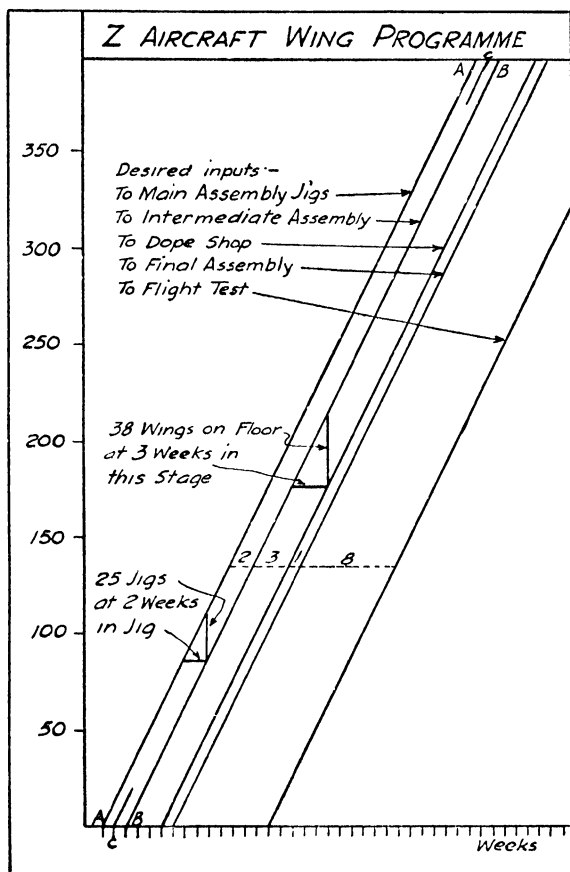


FIG. 12. WING PRODUCTION PROGRAMME

certain date, its component wings may have to be available on the final assembly and rigging floor eight weeks earlier (these times are hypothetical). Then, if one week is required before this in the dope and fabric shop, and three weeks before this in the wing intermediate assembly shops, we have the requirement that wings must be delivered from the wing assembly jigs twelve weeks in advance of final

aircraft completion, and must flow out of these jigs at a rate equivalent to the direct rate of final production. Such a situation is illustrated in Fig. 12.

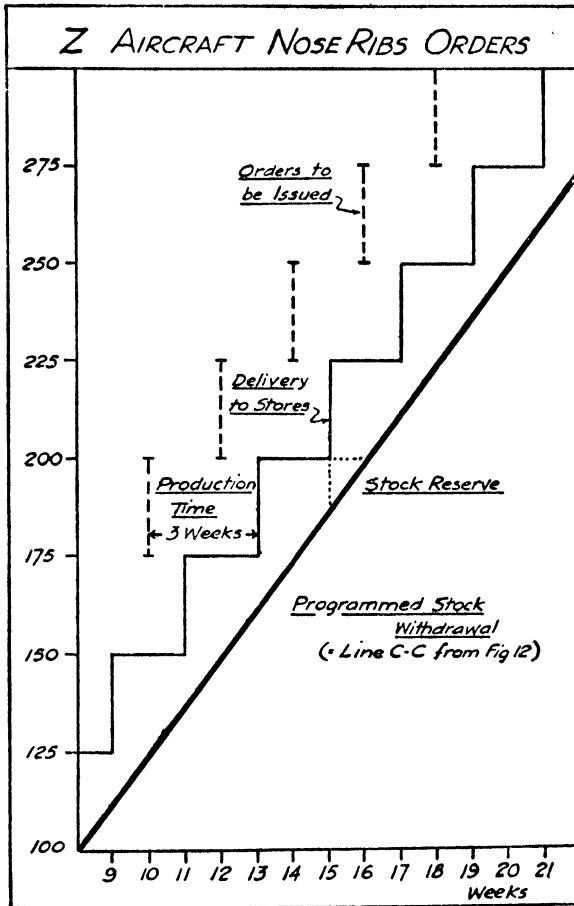


FIG. 13. DETAIL ORDERING PROGRAMME

On this chart, the line *AA* represents desired input to main wing assembly jigs. It will be appreciated that a horizontal reading between this line and the line *BB* for output from wing jigs indicates the time allowance for jig occupancy by each job. Reading vertically from *AA* to *BB*, we see how many jigs must be available

to achieve the desired programme. The two features are interlocked. Similarly, the number of components that will be carried in each stage can be read off the chart, together with the time allowance for occupation of the stage. As drawn, for instance, the programme entails three weeks in intermediate assembly, with a total of thirty-eight jobs on the floor in this stage.

Key to Production Requirements. If we revert to the skeleton assembly diagram shown in Fig. 11, we note that the assembly programme shown in Fig. 12 gives the key to the production requirements of the miscellaneous sub-assemblies that are fed into the job at the various stages. If, for instance, the nose ribs are required for use about half way through the wing main assembly stage, then we can establish as *CC* the task to be met in the supply of these parts. It may have been decided that these nose ribs are to be produced in batches of twenty-five at a working, and that the shops will take three weeks to produce each batch (allowing for process and waiting time). Then, if it is planned to hold one week's minimum stock as a reserve, we can now establish the production programme for nose ribs as shown in Fig. 13. If, in turn, the manufacture of these nose ribs demands the prior completion to stock of, say, a component web, then, by the same principles, we can work still further backwards to the production of a similar programme of these parts.

When manufacture is planned in this way it is possible to issue each batch order with a planned delivery date to guide the production shops in sequencing their work to the desired end. This aspect of the problem has already been discussed in an earlier chapter.

CHAPTER VI

WORKS ORDERS

In the previous chapters we have examined in some detail the preliminary planning operations necessary to determine the best practical means of production and to establish the technique whereby any particular item is to be manufactured. It remains to consider how these plans are carried into effect through the release of orders and instructions on the various sections in the factory.

The Works Orders Office. The responsibility for the issue of shop orders is usually centred in a works orders office, whose objective is to meet the requirements of a production schedule and at the same time to maintain an evenness in the flow of work in process. This production schedule may be a reflection of orders received from customers; it may represent requirements for delivery to stores to maintain desired stock levels; or it may be a programme of production laid out with reference to a budget forecast. The function of the works orders office is to provide official authority and information for—

1. The movement of material from stores to the first process, and from process to process, with adequate provision for the identity of the material to be recognized throughout its progress through the shops.
2. The collection and preparation of tools, jigs, and fixtures in advance of the time at which each particular operation is to start, and their movement as necessary from process to process.
3. The beginning of work on each operation.
4. The recording of the times of beginning and completing each job for the calculation of the duration of work on the job.
5. The control of progress of all operations in accordance with the routing established, and the making of necessary adjustments in plans to meet unforeseen emergencies.

The Personal Element. It will be realized that a single item on the production schedule may break down into a requirement for several parts, each calling for a variety of operations. While, therefore, the personal element can never be entirely dispensed with, it is only on the very smallest scale of manufacturing enterprise that

the day-to-day activities of a factory can be run on a purely personal basis of verbal instructions and orders. Mechanical control of operations by means of power and gravity conveyors reduces the need both for personal supervision and for paper-work control. So long as the conveyor runs smoothly, it tends to pace the operators along it, and automatically eliminates many of the tickets and forms that otherwise would be needed to bring materials and tools to the points where they are to be used. There still remains the problem, however, of getting the material to the conveyor in the first instance and of disposing of the product when completed.

In consequence, although it is impossible to put forward any particular system as suitable for universal adoption, the day-to-day control of factory operations usually demands a blending of "paper-work" controls and personal supervision. The tangible evidences of the paper-work control element are tickets, forms, and cards, directing that certain actions be taken. In its most elaborate form this may involve a separate piece of paper for each of the interlocked aspects of production control. But each concern must devise its own method of control, suited to its own peculiar operating conditions, with forms and tickets specially designed to suit the needs of the particular business.

Since each separate operation requires several documents, the result is usually a large accumulation of working papers. The mechanisms of the dispatching or works order section centre mainly on the creation of the best possible arrangements for preparing, filing, and handling this mass of paper-work.

Control Paper-work. An outline of the fundamentals of production control paper-work is given in Fig. 14. It will be noted that the basis of the system illustrated is a route sheet for each part, giving a full specification of the material required to allow the part to be made, and the details of the operations to be performed in its production. From the information on this route sheet the following documents are prepared—

1. Stores issue order (for each part).
2. Identity tag (for each part).
3. Tool order (for each operation on each part).
4. Job order.
5. Inspection order.
6. Move order.

OUTLINE OF WORKS ORDER ROUTINE

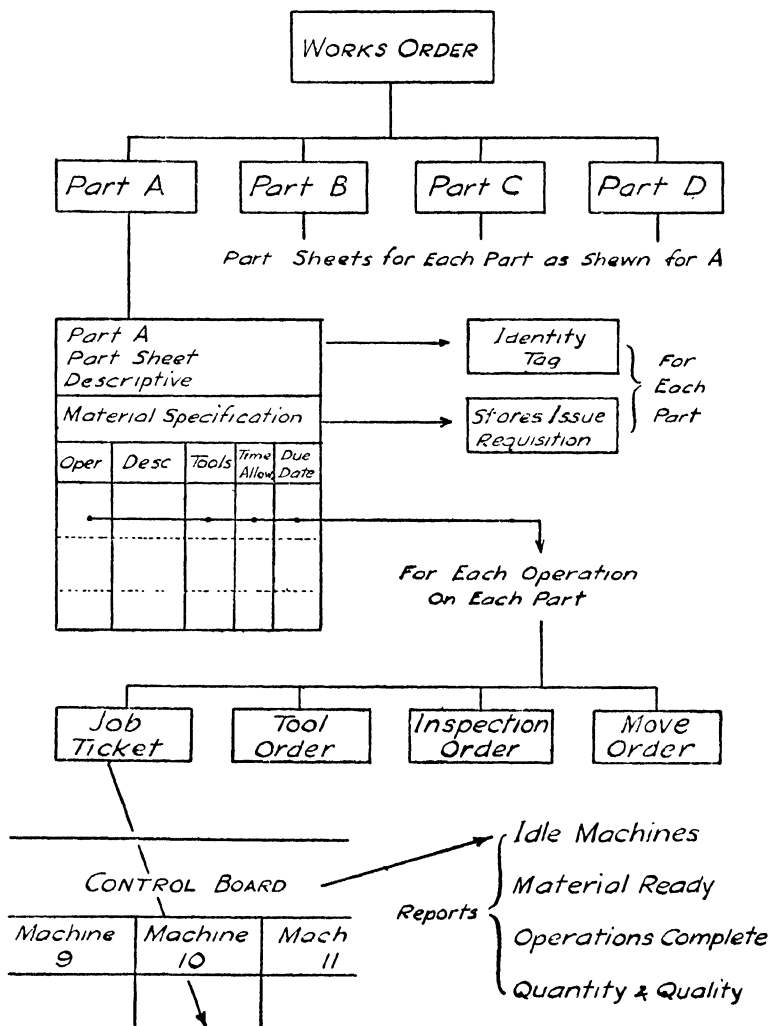


FIG. 14. WORKS ORDER ROUTINE

These working papers are designed to give effect to the information contained on the route sheet, which should include—

1. The time allowance for each operation and the dates scheduled for its commencement and completion.
2. Tools and fixtures required.
3. Corresponding blue-print data on tolerances and limits for inspection.

Stores Requisition. The purpose of the stores requisition is to initiate the movement of material from stores to the location of the first production process so that it will be available to enable work to start at the time scheduled. The information on these stores issue orders must be sufficient to indicate—

1. The account to which the value of the material is to be charged when issued.
2. The quantity of material required.
3. The description of material required.
4. The location to which the material is to be delivered.
5. Time when delivery is to be made.
6. Approving signature.

As mentioned above, these stores orders would be made out as soon as the corresponding route sheet was available, but would have to be held until the time arrived for action to be taken. It is very undesirable to move material on to the shop floor too early in advance of the time it is needed. At the same time, the stores will generally require some advance period in which to prepare the material for issue. There is a choice of two methods for dealing with this situation. The first is to stamp all stores issue orders with the date at which they should be delivered to the shops and pass them to the storekeeper, when they will be kept in a "tickler" file in order of due date. When this date approaches, the material is prepared so that it can be transferred on the due date, and a duplicate is sent to the planning department, thence to the dispatching section to signal its arrival. The alternative is to file the orders with the other working papers for the part and to hand them to the dispatcher a day or two before the date. The dispatcher then passes the order to the storekeeper to prepare the material ready for issue to the shops when authorized. Of the two methods, the second is to be preferred because of the greater flexibility it provides in dealing with changes in planning, routing, and scheduling—particularly in the jobbing and batch production shops.

A typical form of stores requisition is depicted in Fig. 15. This type of order is quite suitable for cases where only one or two items of material are needed for a particular order, but where the stores issue is for an assembly operation needing several different parts, it is more convenient to use a form similar to that shown in Fig. 16.

STORES ISSUE ORDER							
DATE		UNIT			No.		
PART NO.	PART NAME OR KIND OF MATERIAL				QUANTITY (Pieces, Lb., or Ft.)		
THIS MATERIAL TO BE CHARGED		JOB NO. SHOP ORDER EXPENSE No.		DEPARTMENT		PRICE	£
						EXTN.	s.
							d.
							UNITS
IF SUPPLY ITEM—REASON FOR ISSUE:						PRICED BY:	
						EXTENDED BY:	
						O.K.:	
SIGNED		DEPT.					
ENTERED	DELIVERY TO:		DELY. DATE		CREDIT A/c:		

FIG. 15. STORES REQUISITION

Even though the greatest care may be taken in preparing material specifications, cases will invariably arise where surplus material is left in the shops after an order has been filled. It is very desirable that some routine should be established to enable this surplus material to be returned, and a corresponding credit to be given to the job account. A form of stores order in reverse is needed for this purpose, similar to the example, Fig. 17.

Tool Order. It is standard practice in machine shop work to specify the tools, jigs, fixtures, and gauges that will be required for each job. The function of the tool order (Fig. 18) is to ensure that

RETURNS TO STORES						
UNIT		DATE		No.		
PART No.	PART NAME OR KIND OF MATERIAL			QUANTITY		
THIS MATERIAL TO BE CREDITED		JOB No. ORDER No. EXPENSE No.		£	s.	d.
REASON FOR RETURN :						
POSTED :	RETURNED FROM :	DATE :				

FIG. 17. RETURNS TO STORES

TOOL ORDER						USED ON PART No. :
No. REQD.	REFER- ENCE	DESCRIPTION	SECTION	BIN	CHECK	
						OPERATION :
						DEPARTMENT :
						MACHINE :
						ISSUED TO :
						FOR ORDER No. :
DATE REQUIRED :			RETURN DATE :			

FIG. 18. TOOL ORDER

gives an indication of when the tools should be expected back. In this way the tool order fills the function usually served by the "tool check" system, with the added advantage of providing a tighter means of control over the return of tools as soon as the job for which they are required is completed. Usually, all the tools and fixtures required for a particular operation are listed on one tool order. It is not uncommon, however, particularly when expensive jigs are employed, to have a separate order for each item. In such cases the tool order may take the place of the jig as soon as it is removed from the shelves as an indication of the present location of the fixture.

The Job Order, Inspection Order, and Move Note. The job order serves the prime function of providing the authority for proceeding with an operation. In practice, however, this order is often combined with other forms, such as timing cards, inspection orders, and move notes, and is met under a variety of titles such as work ticket, job card, production ticket, pay-roll card, and time ticket. Some examples are given in Figs. 19, 20, 21, and 22, from which it will be seen that the features included are—

1. Part number identity of job to be worked.
2. Order number identity.
3. Operator's name and clock number.
4. Operation and operation number.
5. Number of parts to be produced.
6. Time allowed for job and price, if fixed.
7. Time at which operation is scheduled to start.
8. Space for recording time actually taken.
9. Inspection report—quantity good and bad.
10. Next operation to which material is to be moved.
11. Previous operation from which material is to arrive.

The question of the amount of actual information to be provided will depend on the nature of the job to be done. If adequate information is already available on blue-prints, route sheets, or part sheets, the actual data to be given on the job card need be no more than that needed to assist routing; otherwise, the job must be described in sufficient detail to enable it to be carried out.

Usually, job orders are prepared in duplicate, with one copy intended for the operator and the other, as outlined above, for use on the dispatchers' control board. When the job order is released, it is date-stamped and used as authority to withdraw any jigs or

DEPARTMENT No.:		EMPLOYEE'S No.:	
NAME:			
PART NAME:			
PART No.:			
ORDER No.:		OPERATION No.:	
GOOD PIECES:		SCRAP PIECES:	
ACTUAL HRS.:	STANDARD HRS.:	% EFFICIENCY:	
BONUS:	LABOUR:	EXPENSE:	
P.W. CHART No.:		STD. HOURS PIECE:	
LABOUR RATE:		EXPENSE RATE:	
START:		EQUIPMENT No.:	
STOP:		DATE:	
QUANTITY TO RUN:		QUANTITY TO DATE:	

FIG. 19. JOB CARD

tools required. When the order is finished, it is again date-stamped, and after passing through the planning department, to signal the

PRODUCTION TICKET		CLOCK No.:	
PART No.:		D.W. HRS.:	
DESCRIPTION:		START:	
THIS OPERATION:		P.W. HRS.:	
ORDER No.:		STOP:	
QTY. REQ.:		AMOUNT EARNED:	
QUANTITY GOOD:		No. OF REJECTS:	
MOVE TO OPERATION:		RATES:	

FIG. 20. PRODUCTION TICKET

CLOCK No.:	OPERATOR:	ORDER No.:	0	0	0	0	0	0	0
			1	1	1	1	1	1	1
			2	2	2	2	2	2	2
DEPARTMENT:	PART No.:	DATE:	3	3	3	3	3	3	3
			4	4	4	4	4	4	4
			5	5	5	5	5	5	5
OPERATION:	PIECE RATE:	QUANTITY:	6	6	6	6	6	6	6
			7	7	7	7	7	7	7
			8	8	8	8	8	8	8
			9	9	9	9	9	9	9

FIG. 21. PUNCHED CARD TICKET

completion of the operation, it is available for costs and pay-roll work. Virtually, this amounts to a double analysis of the job tickets. From the one angle, the tickets are analysed under order numbers to

establish the direct labour costs chargeable against each order. From the other angle, the tickets are analysed operator by operator. The purpose here is to establish that each operative's working day is fully accounted for between the times he clocks in and out of the factory. Where any system of payment by results is practised, this same analysis also establishes the payment due to the worker.

SORT FOR JOB NO.			
TIME TICKET			
JOB. No.:		QUANTITY:	
CLOCK No.:		TIME ON:	TIME OFF:
NAME:		HOURS WORKED	RATE:
MACHINE:		EXTENSION:	
SORT FOR OPERATOR'S NO.			

FIG. 22. "PARAMOUNT" PRODUCTION TICKET

The "Ticketograph" pay check, shown in Fig. 23, is an interesting combination of job ticket, time ticket, and identity tag. It will be noticed that the centre card is made up of a combined identity tag and operation summary for, in this case, sleeves, backs, and fronts of shirts. For each operation there is on the side an operator's pay check. All these pay checks carry the order number, 46957 in this instance. This ticket is used in a shirt manufacturing company. As each bundle of material passes from the cutting room, to be made up, one of these tickets is attached; thence, onwards, the main central portion accompanies the bundle. As each operator completes her operation, she clips the particular check for that operation. Her own clock number is recorded in the corresponding section, in the centre of the ticket, so that the "Ticketograph" enables defective work to be sent back for correction to the particular operator who did the imperfect job.

Inspection Order. Where, instead of being combined with the job order, a separate inspection order is used, a form, along the lines of

21		Price	46957	FRONTS BUNDLE		VOID 2		46957
20		Price	46957	T 181A		VOID 2		46957
19		Price	46957	Pockets on Tracer		VOID 2		46957
18		Price	46957	31 Oper No. 43 TRUMP 127		VOID 2		46957
17		Price	46957	Match Pockets		VOID 2		46957
16		Price	46957	20 Oper No. 51		VOID 2		46957
15		Price	46957	C P		VOID 2		46957
14		Price	46957	19 Oper No. 128		VOID 2		46957
13		Price	46957	Hem and Under Face		VOID 2		46957
12		Price	46957	462		VOID 2		46957
11		Price	46957	Face Under		VOID 2		46957
10		Price	46957	17 Oper No. 311		VOID 2		46957
9		Price	46957	Face or Hem Upper		VOID 2		46957
8		Price	46957	16 Oper No. 214		VOID 2		46957
7		Price	46957	BACKS BUNDLE		VOID 2		46957
6		Price	46957	T 181A		VOID 2		46957
5		Price	46957	N B or Collar on		VOID 2		46957
4		Price	46957	14 Oper No. 212 TRUMP 311		VOID 2		46957
3		Price	46957	Join		VOID 2		46957
2		Price	46957	8 Oper No. 71		VOID 2		46957
1		Price	46957	Tracer		VOID 2		46957
		Price	46957	7 Oper No. 64		VOID 2		46957
		Price	46957	Yoke		VOID 2		46957
		Price	46957	11 Oper No. 510		VOID 2		46957
		Price	46957	Hem Backs and Tops		VOID 2		46957
		Price	46957	8 Oper No. 321		VOID 2		46957
		Price	46957	SLEEVES BUNDLE		VOID 2		46957
		Price	46957	T 181A		VOID 2		46957
		Price	46957	Face		VOID 2		46957
		Price	46957	4 Oper No. 116 TRUMP 4		VOID 2		46957
		Price	46957	Flats		VOID 2		46957
		Price	46957	20 Oper No. 19		VOID 2		46957

FIG. 23. "TICKETOGRAPH" PAY CHECK

that shown in Fig. 24, is used. It will be seen that the essential information is—

1. Order and part identity.
2. Operation identity.
3. Inspection report—quantity O.K., quantity scrap, quantity bad, but repairable.
4. Move order.

These inspection reports replace the job card in signalling the completion of an operation to the planning department, thereby

INSPECTION ORDER		
PART No.:		ORDER No.:
OPERATION:		
OPERATOR:		NUMBER:
PIECES GOOD:	BAD:	SCRAP:
REPORT CAUSE AND RESPONSIBILITY FOR REJECT:		
DELIVER TO:		

FIG. 24. INSPECTION ORDER

MOVE ORDER		ORDER No.:
QUANTITY:	PART No. AND DESCRIPTION:	
MOVE FROM:		
Machine	Building	Bay
MOVE TO:		
Machine	Building	Bay

FIG. 25. MOVE NOTE

enabling the job ticket to go immediately to the costs and pay-roll department. They also act as separate departmental credits that can be checked off against the actual job ticket presented for each

operation, and provide means whereby the planning department can take up the question of replacing defective, and repairing faulty parts.

Separate move notes, similar to that illustrated in Fig. 25, are met sometimes where the transport problem justifies their use, although they are more commonly combined with the job, or inspection order. If it is desired to keep a check on the transport man's time, or if a piece-work system of payment is used, such a move ticket would also incorporate timing information similar to that provided on the specimen job tickets.

Documents Prepared in Advance. In some concerns, no attempt is made to prepare these various orders until the time comes to use them. In such circumstances, the dispatching system may present an impressive air of bustle and activity, but, usually, the associated hurry is associated with confusion, delays, and much risk of error. It has been found preferable to arrange in advance for the preparation of these documents, with adequate time for a proper concentration on detail, and modern technique is more and more towards making out material, tool, job, inspection, and move orders as soon as route sheets are completed and assigned dates are known.

From a consideration of the examples of works orders, move notes, stores requisitions, and other shop forms given in earlier pages, it will be appreciated that much of the information on the various forms in a set is identical. Thus, the works order number, part description, order quantity, and similar details, are repeated on the various orders in the set, the technical process information for each operation being a replica of that appearing on the original operational planning sheet. It is quite possible for all of the forms and cards involved in any particular set of works order paper-work to be produced by longhand or individual typing. At best, however, this is a laborious process, calling for careful checking if errors are to be avoided. This, naturally, has led to the adoption of mechanical means for the reproduction of shop information.

Preprinted Tickets. In Fig. 26, an example is shown of part of a complete set of shop forms reproduced mechanically by the Ormig Simplex system, developed by Block & Anderson, Ltd. This system, an adaptation of the hectograph principle of copying, centres round a permanent master for each part, on which is recorded its operational layout, the raw material requirement for its production,

A

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

B

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

C

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

D

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

E

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

F

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

G

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

H

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

I

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

J

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

K

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

L

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

M

ITEM NO. 1
 DATE 12/15/55
 DRAWN BY 12/15/55
 CHECKED BY 12/15/55
 PROJECT 1
 SHEET 1
 CARBON STEEL STEAM SPINDLE
 1/2" Dia Carbon Steel
 15 ft. 6"
 (5 ft. 6" at 5 ft. 6")
 (1 ft. 6" at 5 ft. 6")

FIG. 26. "ORMIG SIMPLEX" SHOP FORM
 By courtesy of Block & Anderson, Ltd.)

part number, unit piece-work rates payable for each operation, and all other shop information relevant to the production of the part.

This master, indicated A in the illustration, is supplemented by a batch master (B) containing the variable information of quantity and order number specific to the particular works order rather than to the particular part. The two masters are passed to the Ormig Simplex equipment, all the works documents being produced in turn by selective reproduction of the information shown on the batch master, with the relevant part of the information on the static master. After reproduction, the static master is held in file until again required, this time with a new batch master, for the production of a set of works forms for a repeat order. The system offers an obvious economy in clerical effort, and ensures accuracy of all predetermined information on production tickets. Particularly suited to batch production undertakings, it is being successfully operated by many of the largest firms of engineers and aircraft manufacturers in the country.

Another system for the mechanical reproduction of shop stationery, now widely used, is that built up by Addressograph-Multi-graph, Ltd., round their familiar Addressograph printing plates. Besides providing a speedy service and considerable economy in clerical work, it offers the valuable prize of 100 per cent accuracy and 100 per cent legibility. It will be noticed from the accompanying illustration, Fig. 27, that the information specific to the particular order, as distinct from that peculiar to the part, is confined to the right-hand side of the form. This information is not actually incorporated in the printing plate, but is set up on a separate number box, which is adjusted to conform to the details of each order passing through the machine.

In the example illustrated, the material requisition and final inspection report are first imprinted from the same plate which is used to produce the heading of the route card. The body of the route card is then completed from the following three plates in the set. From a separate plate, the Addressograph machine then prints in succession an operator's ticket, wages ticket, and progress ticket, for each of the eight operations on the part. The complete set of twenty-seven forms is produced in 1 min., 40 secs., and after printing, the plates fall automatically, in correct order, into a tray for filing until again required for a repeat order.

Master Card Systems. The amount of clerical work involved in the actual preparation of the large volume of paper-work for a shop order has set a premium on doing this work by machine methods, where possible. An alternative solution has been found in

MASTER ROUTE CARD						PART NUMBER :		
DESCRIPTION :						ORDER NUMBER : *		
						QUANTITY : *		
MATERIAL SPECIFICATION :						STORES TO ISSUE :		
OPERN. No.	DESCRIPTION	OPERATOR	JIGS AND FIXTURES	TIME ALLOW.		SCHEDULED DATES	INSPECTION	
				SET	RUN		O.K.	REJ.
		*				*	*	*

(Information marked * is specific to order.)

FIG. 28. MASTER ROUTE CARD

expanding the scope of the operation route sheet itself, so as to make it also fill the function of some of the usual shop forms.

The form illustrated in Fig. 28 is an example of a route sheet that has been so far amplified that, by producing a special copy to progress through the shops with the job, much of the ordinary shop stationery can be dispensed with. The only supplementary forms and orders required with such a document may amount to no more

than an operator's time ticket, on which he can be clocked on and off the operation, with a copy for use as a control ticket on the control board. Separate inspection orders, move notes, and tool orders are not required, as the master card gives all the information and instruction required to carry out these functions. It will be appreciated that the information marked * is specific to the individual order, otherwise the card is an exact copy of the route sheet.

Apart from the economy in clerical work involved in this practice, the risk of errors inherent in the constant repetition of information on many different documents is avoided. Where a standard part is involved that will be ordered on many separate occasions, a supply of master cards is printed on translucent paper. One of these master cards is taken for each order, the additional information specific to the order being typed in. Copies of the document are then produced by one or other of the so-called "blue-print" processes and distributed as follows—

1. Shop planning copy, to be used as a progress record by marking off operations as they are completed.
2. Dispatching copy, to be mounted on a stiff card or board, to progress through the shops as an instruction and order and authority to collect material from stores and jigs and tools from the tool room.
5. Inspection copy—where advance notice is needed.
4. Stores copy, to be used in preparing material for issue on presentation of dispatching copy (subsequently passed to cost office).
5. Cost copy, to acquaint cost office that the job is progressing through the shops. This copy often carries cash columns for cost extension.
6. Tool room copy—where advance notice is needed.
7. Delivery copy—where the part in question is to be delivered to an outside address instead of to stores.

Progress Card System. The effect of the master card system outlined above is the circulation of copies of the same route sheet each time an order for a particular is released. If the interested departments are serviced with a permanent file copy of the route sheet, to which reference can be made when desired, this duplication of information can be avoided by using a special card containing the information that is specific to the particular order, with a reference to the associated route sheet from which all necessary additional information can be obtained. A typical example of such a

progress card is shown in Fig. 29. The routeing is similar to that used for the master part system, with a separate cost copy, control

PROGRESS CARD <i>(Quote Card No. and Unit No. on all Job Cards used for Work Done on this Order)</i>								
DRAWING No.:				UNIT No.:				
DESCRIPTION:								
QUANTITY:								
MATERIAL SPEC.:								
STORES TO ISSUE:								
DELIVERY PROMISE ON MATERIAL:								
OPERN.	FIXTURES	M/C No.	QUANTITY		OPERATOR'S SIGNATURE	DATES		
			O.K.	SCRAP		LOADING	ACTUAL	
DELIVER TO:								

FIG. 29. PROGRESS CARD

copy, stores copy, and tool, inspection, and delivery copies as required. These progress cards may be produced from printed blank forms on the typewriter, but more usually, the Ormig, or some

similar reproducing system is used, to enable the forms to be reproduced on a paper stouter than would otherwise be possible. Sometimes, the system is modified to provide a separate progress or control card for each production department in which an operation has to be performed, or even for each separate operation. A more detailed analysis of the progress card system is given in a subsequent chapter.

Codified Operations. Much clerical labour can be saved in the preparation of shop stationery if a codified system of numbers is used to describe operations, working stations, parts, and orders. For instance, a three-figure series of numbers might be used to describe operations so that the first figure indicated one of the main departments in the factory, and the remaining two figures a particular production station in that department. Thus, operation code 354 might indicate a cogging mill (No. 54) in the rolling mills department (Dept. 300), while code 826 might be the blacksmith's shop (No. 26) in the general services department (Dept. 800). Such a system can be further extended by arranging that operatives' clock numbers key in with these departmental numbers. For example, if the cogging mill number is 354, then all the production men in that department can have the clock numbers prefixed by the number 354, so that if a scaleman's number is 52 then his complete number is 354/52. It will be obvious that the existence of such a coding scheme considerably simplifies work in the costs department, and also provides all the information required for the physical movement of parts from process to process throughout the factory.

Similarly, instead of allocating part numbers to new parts in straight arithmetical progression as they are created (that is, so that a new part becomes part number 6738 if the previous part drawn was 6737), a system of numbering may be adopted that will describe as well as identify the part. Thus the part number 634056 might signify that the part—

1. Falls in the 600000 group of products, as distinct from the other 8 main groups.
2. Is in the 34 section of this group, as distinct from the other 98 sections.
3. Is the actual part number 056 out of the potential 999 different parts in this section.

The preparation of a codified system of numbers along these lines

calls for much thought, but the results are well worth the effort. As already indicated, it is, of course, essential that the system should be specially designed to suit the particular factory in question. In itself, no such system is good or bad, but only in so far as it makes a genuine contribution to the work of management and control.

Filing Shop Orders. Where shop paper-work is produced in advance, this automatically brings up the problem of filing and controlling the papers until the time comes to put the job in hand and release the orders to the various people concerned. If the system is to run smoothly, the various orders and forms must be kept in some classified order for release in due sequence and at the right dates. Further, it is necessary to establish a reliable method for signalling the progress of work in the shops and reporting the existence of unoccupied machine capacity.

The first problem that arises in connexion with filing shop orders is one of geographical location, that is to say, whether the papers are to be held in a central planning office or in local dispatching cages, or service stations, spread throughout the factory. The modern tendency is to hold all papers in the planning office for release to local service station two or three days before the individual orders should become operative. Virtually, these local service stations, or dispatching cages, are the operating outposts of the planning department. Only in the smallest factory can actual control of shop paper-work be handled from a single location. Generally, it will be found necessary to set up such a service station in each department; often several separate stations are found in one single large department. It is, however, essential to provide a reliable and speedy communication service between these outposts and the central department. This may be arranged by direct messenger service, but where there is considerable traffic it is often found profitable to establish communication by pneumatic tube or overhead gravity conveyor.

There are two methods of filing shop orders and associated papers—either according to order numbers, subdivided into parts or lots, or according to the machines or groups of machines on which the work is to be done. From the viewpoint of shop control, the papers are most conveniently grouped under machines, as, generally, a file in order number sequence provides no guide to sequence.

From the viewpoint of progress chasing, however, it is more convenient to keep the papers in order number sequence. Often, it is found practicable to arrange a compromise between these two considerations by holding papers under order numbers until advice is received from stores that the material is ready, and then withdrawing the papers to a file, under classified machine numbers. Alternatively, the papers may be kept under order numbers and controlled by the preparation of an order of work list, made out daily by the planning department from loading schedules and route sheets, as an instruction to the shop foremen. These order of work lists, which define the specific order numbers which are to be worked on each particular day, must not be changed or departed from without planning approval. The actual method to be adopted must be influenced by local circumstances in the shop in question. No cut-and-dried methods can be put forward. The test of the system is that it must permit the instant finding of the papers next in sequence.

Control Boards. Usually, the actual assignment of jobs to particular production machines is performed through the use of control boards, which are designed to facilitate the shuffling of orders from machine to machine, and at the same time to provide a visible picture of the position of shop loading. These control boards, or dispatching boards, amount to a space allotted to each machine in the shop, and divided into three sections which are used as follows—

- (a) To hold a card (usually a copy of the job order) representing the job actually being worked on the machine.
- (b) The next job in sequence to be worked on the machine.
- (c) Several jobs ahead of the particular machine, one behind the other, and so far as possible in the order in which they are to be worked.

As the work progresses, the job in section (b) is transferred to the top compartment, and the next job held in section (c) is moved up to compartment (b). It will be realized that such a control board gives an immediate picture of—

1. Whether all machines are engaged, an idle machine being recognized where the top compartment against that machine is empty.
2. Whether any machine lacks a next job, as shown by the absence of a card in the second compartment.
3. Whether each machine has a fair reserve of work behind it as indicated by the number of cards in the bottom compartment.

The Shop Picture. As the outcome of the picture given by such a board, it is possible for an approaching shortage to be reported in advance to the planning department so that they can confirm that such a situation was expected, or can take action to rectify the situation if it has been brought about by an error. Similarly, in certain circumstances, advantage can be taken of the picture to relieve pressure by re-routeing jobs from overloaded stations to relatively idle machines. The actual construction of the boards may amount to nothing more elaborate than three hooks in the wall under each machine number with the job orders hanging from them. Alternatively, a construction may be used to provide a separate pocket for each set of cards. The essential feature of the system must be to preserve visibility, so that the entire picture can be taken in at a glance. Sometimes the idea is elaborated by providing along the top of the board a black section on which may be chalked the number of working hours the machine has to run on the particular job in hand, with similar spaces for the follow-up job and for the reserve of work.

The value of such information, and, indeed, of the whole control board itself, lies in the fact that the board must be kept up-to-date, and actually used in shop control activities. Often an elaborate control board is installed merely as a piece of window dressing. Frequently, such boards are so complicated that the control clerk finds he can get along better with a private system of his own. From time to time an attempt is made to bring the board up-to-date, but its real value as a control mechanism is negligible. Usually, when one encounters a control board that does not, in fact, provide an up-to-date, accurate picture of the shop floor position, it is a sound indication that the shop management is less efficient than it should be. It often means, moreover, that the local management is alive to its inefficiency, but, instead of seeking improvement, is looking for camouflage.

Idle Machine Times. Besides the provision of shop service, the dispatching section has a responsibility for drawing attention to idle machine time, so that appropriate remedies may be worked out. Generally, the shop control board enables a report to be made in advance of actual idleness, when the reason for this is lack of work. Often, this advance information enables the idle time to be avoided by routeing or diverting work from other machines. Idleness due to machine breakdown can, of course, only be reported as it occurs,

and must, therefore, be treated as urgent. In the planning department, these reports of idleness must be carefully studied, and the

DEPT. No. :		IDLE MACHINE CARD		MACHINE No.
DATE :		MACHINE DESCRIPTION :		HOURS IDLE
No Operator	No Material	Out of Order	Awaiting Instructions	Remarks
No Orders	Defective Material	No Power	Others	

FIG. 30. MACHINE IDLENESS REPORT

REPORT ON INTERRUPTIONS	
RECEIVED	
<i>Report any delays holding up progress of work, waiting time affecting workers' bonus earnings, damage to materials, machine repairs or changes.</i>	
PROGRESS OF WORK ON ORDER No.	
NOW IN OPERATION AT	
Is hold up because of:	
Delay	
Change	
Waiting	
Repairs	
Damage	
Cause	
Remarks	
EMPLOYEE'S NAME	No.
OPERATION	
REPORTED BY :	

FIG. 31. PROGRESS REPORT

causes classified, so that all possible action can be taken to ensure continuous operation. A report form used for acquainting the planning department with machine idleness is shown in Fig. 30.

Progress Chasing. In addition to reporting idle machine time,

the dispatching section must draw attention to any interruptions in the progress of work on the various orders passing through the shops that are likely to prevent the completion of the order on its scheduled date. A specimen form is shown in Fig. 31.

Purely from a theoretical point of view, the arrangements of the dispatching section should ensure a steady flow of work through the various shops in a factory unit with all jobs passing through to completion on the desired date. In fact, however, usually there is found a need for the exercise of personal initiative to ensure that this desired result is achieved. This "progress idea" is becoming more and more regarded as an essential part of factory organization, although differences are met in the practical application of the idea. Fundamentally, the route clerk does not *make* progress but *records* it. On the other hand, the progress chaser is responsible for ensuring that the desired progress is actually achieved. As a rule, his duties involve him in making a continual round of the shops, with the idea of getting information on work in progress, urging material and parts when required, and reporting to his superior when there is any possibility of delay beyond his own powers to remove. At the one extreme we find that this progress man occupies a high executive position, directing and controlling the administrative side of the works organization. At the other, the progress man may hold a position no higher than that of the shop clerk. But in either instance his broad duties are the same—to facilitate the progress of the various parts through manufacture by obviating avoidable delays. The difference, in practice, amounts to one of the question of the stage at which it is necessary for the progress man to call on higher authority to rectify a situation beyond his own authority to correct.

CHAPTER VII

PAPER-WORK SYSTEMS

PROBABLY there is not one factory in a hundred that would fail to benefit from a "spring cleaning" of its paper-work system. Almost invariably, an examination of the printed paper in use will show that most of the work is being done on old forms which have long ago lost their suitability and which are being used simply as writing blocks. This does not mean that there is no necessity for properly printed, simple cards and forms. The printed form always commands a certain degree of respect, and a clerical staff can be relied on to enter up with regularity and accuracy a simple printed form where, if the same return were to be demanded on a sheet of scribbling paper, the matter would tend to be considered as unimportant and not worth regular attention. At the same time, however, work carried out by daily routine is inclined to follow the line of least resistance, and if a certain form or card calls for information that is really unnecessary, it is surprising how soon that part of the form falls into disuse.

The document in question probably originated with some enthusiastic official who sat down to draw up a new form, whereby, in his opinion, the routine would be simplified or the records made more accurate. Column is added to column, and space to space, until provision has been made for the entry of every piece of information likely to be of any importance. The form is printed and put into use. In six months' time, probably not more than three or four columns are being used. The clerical staff, while still following the main scheme arranged for them, have found out how their work can be carried out most quickly and most effectively so far as their own activity is concerned. They have become accustomed to filling in only a portion of the form. No complaints are made. In fact, no one any longer needs the rest of the information—if, indeed, it were ever needed. Yet the old forms continue to be printed and used, because it is no one's job to take the trouble to see that they are simplified and brought up-to-date. Much the same situation follows where a form has been "lifted" from a book or an article on business management.

Need for Regular Review. For efficiency, there should, however, be a regular review of all paper-work. No organization will remain efficient for any length of time without alteration. Outside conditions imply that all organizations are, or should be, in a state of flux. This demands a continuous review of systems and method. No practice should be allowed to continue just because things have always been done that way. Fixity implies stagnation, with, generally, a cumbersome and inefficient organization.

The forms and cards used in a business should be simple and properly printed, coloured, wherever possible, and linked up with one another by some kind of easily understood chart which explains to all interested parties exactly how the paper system works. This chart should be reviewed regularly, at least once a year, all forms reconsidered, and all obsolete columns and spaces discontinued, so that nothing is left except what must be filled in. Forms incompletely used point to information that is not required, and suggest where existing routines may be simplified.

If paper-work is regarded in this way it will be appreciated that sample forms as a guide to works systems are of little real advantage beyond the feature of illustrating principles to be followed. The particular examples may be in actual use under similar working conditions. But they will have been drawn up to meet a set of special circumstances. And since almost certainly you will never find two organizations that are exactly alike, it follows that the forms which can be used with success in one organization are possibly quite unsuitable for any other concern.

Production Control Relationships. The paper-work system of any particular undertaking provides the means through which all orders and instructions are issued, and through which records of performance are obtained. It is the mechanism of administration by which the efforts of the various departments are co-ordinated. Obviously, then, the actual forms in use will in a large measure depend on the peculiarities of the particular organization. The character and type of industrial organizations vary widely, depending on the size of the individual production unit, the degree to which it is specialized, and the character of the industry itself. The organization of the personnel of a small-scale continuous flow production unit—say a small cigarette-making factory—is a simple matter, for instance, compared with the organization required to handle successfully the

affairs of a large factory including continuous batch production and special order features in the same unit. Generally speaking, it will be found that the simpler units can effectively be controlled by the so-called military or line and staff organization with the lines of authority and instruction running directly from manager, through foremen, to the workers. With increasing complexity, however, special skill and knowledge have to be incorporated into the organization. Usually, the outcome is a functional organization, with the direction of work divided by functions rather than by simple authority. The functional specialists and the executive foremen are placed on the same authoritative level, and the worker receives advice and instruction from each in his own special field. This implies a definition of responsibility, and proper delegation of authority consistent with that responsibility, and may involve an extremely complex structure compared with the simple line of staff type organization tree.

Paper-work systems must, therefore, be considered in the light of a designation of the departments and personnel that are to carry on the work, a definition of their functions and a specification of the relations that exist between the various departments and individuals. Fig. 32 shows a simple example of the fundamental features of a production control system from this particular viewpoint.

It will be seen that the production control department operates through a control office and works issue section. The department receives from the sales department information on which to base a forward programme of work, and looks to an engineering department for the technical assistance required in the creation of shop orders (as indicated in an earlier chapter).

The executive foremen in charge of the production centres receive from the production control office a copy of the shop loading programme and from the works issue section of the production control department complete service on individual shop orders. This works issue section draws all material from the stores department against material requisitions and passes requisitions to the purchase department for items not covered in store. The purchase department also receives purchase requisitions from the stores department for items of stock controlled on a minimum stock basis.

The cost department requires to know the material issued from stores against each particular works order, the productive labour

PRODUCTION CONTROL RELATIONSHIPS

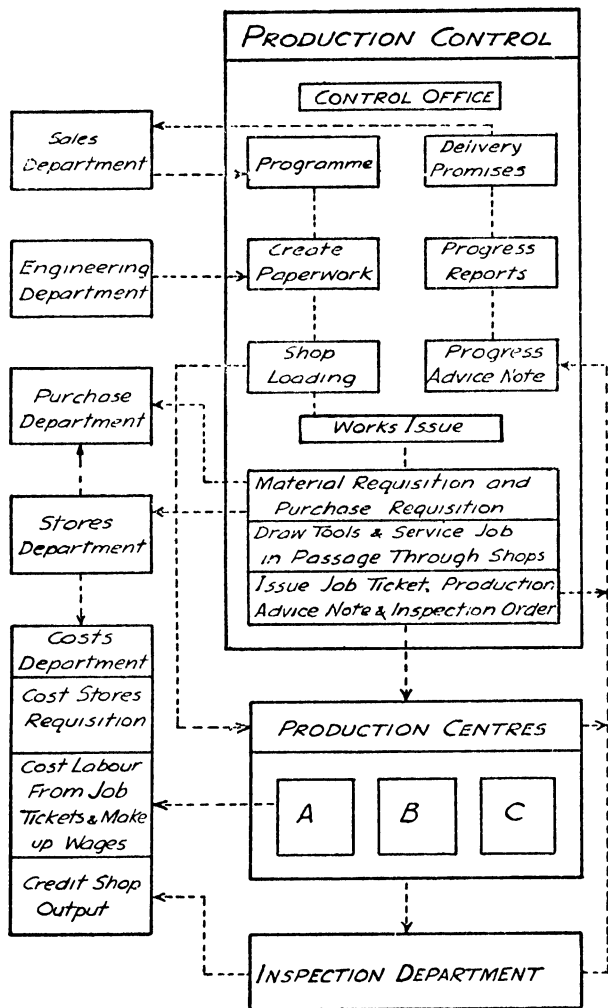


FIG. 32. PRODUCTION CONTROL RELATIONSHIPS

utilized on the order, and the resulting output from the production centre, and obtains from the sources shown on the chart this information and the information required for making up the pay-roll.

The broken lines on the right-hand side of the chart indicate the sources from which information on the progress of orders through

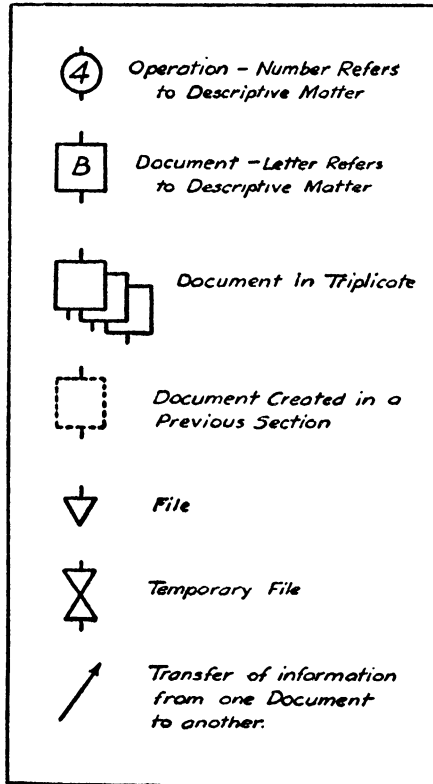


FIG. 33. CLERICAL ROUTINE SYMBOLS

the shops is fed back to the production control office for incorporation into progress reports and for passage to the sales department in the form of delivery promises.

This description of the paper-work of a production control system indicates the skeleton of the structure, but does not explain in any detail how the various integral parts in the routine work. One of the difficulties of describing any paper-work system of control is that so much goes on simultaneously in different parts of the

factory to different forms in the same set, that often it is impossible to present a clear verbal picture of the operation of the system. This same difficulty is encountered when one is investigating any particular system with a view to effecting improvements, but the difficulty can be overcome by converting the description of the routine to graphical form.

Charting the Routine. Towards this end it has been found convenient to use a series of symbols shown in Fig. 33. By the use of these symbols it is possible not only to show in pictorial form the most complicated routines imaginable, but also to confine attention to any particular aspect of a routine without losing sight of other aspects which, for the sake of convenience, are left for separate consideration. Ultimately, every document must end in a file or in the wastepaper basket. This means, therefore, that no routine is completed until it ends in one of the triangular symbols. Similarly, a form can be created only through the initial appearance of the circular symbol, which, in the absence of an explanatory prior chain of symbols, automatically prompts the question "how?"

Works Order Routine. In Fig. 34 these symbols have been used to illustrate a routine described in an earlier section of this book. At first glance this chart may appear very complicated, but if studied in conjunction with the following descriptive matter, it will be found that as soon as the fundamental principles of the technique are grasped, the chart gives a much clearer and more comprehensive picture of routine arrangements than can be gleaned from any written description. Obviously, the chart in itself must be just as complicated as the routine it illustrates, but even this difficulty can be overcome, where necessary, by breaking down the master chart into a series of sub-charts for separate consideration.

The basic principle of the chart is to provide a separate column for each department involved in the routine, and to indicate the relative order, or time sequence, of the various steps involved by their vertical position. For easy reference the various operations are referenced with a serial number, and the different forms given an alphabetical identity.

Beginning with the production clerk, we would read the chart as follows—

1. The production clerk receives a memo of order (Form A), together with a master card of operational routing (Form B),

TYPICAL WORKS ORDERING ROUTINE

PRODUCTION CLERK	CONTROL BOARD	STORES OUTWARDS	SHOP FOREMAN	STORES INWARDS	COST CLERK	PAY ROLL CLERK
Order Master Sheet Work Ticket Shop Order Control Board Material Works Ticket Truckers Tag Reports 9 15	2 Control Board 4 5 7 11	Receives - C3 Shop Order D1 Work Ticket B Master Card Material 5 7 11	Receives - Material C3 Shop Order D1 Work Ticket B Master Card 6 10	Receive - B Master Card D1 Remainder of Work Ticket Post. From G Material Received Note 14 16	Receive - C3 Shop Order Job Cost Record 3 8 13 16	Receive - Stub of Work Ticket F 12 16

FIG. 34. WORKS ORDER ROUTINE

and from the information contained on these documents he originates—

3 copies of a shop order (Forms C1, C2, and C3), and
2 copies of a work ticket (Forms D1 and D2).

These forms are distributed—

- C1 copy of shop order to production clerk's file, with original memo of order.
 - D2 copy of work ticket to control board.
 - Remaining copy of work ticket and C3 copy of shop order to stores outwards, together with the master card itself.
 - Remaining copy of shop order to cost clerk.
2. The control board copy of the work ticket is cut up into its individual strips for each operation, and these are posted to the appropriate pockets on the control board itself.
 3. The cost clerk, on receiving his copy of the shop order, opens a job cost record.
 4. The stores outwards clerk who receives the stores issue copy of the shop order, with the work ticket and master card, gets out the necessary material (Box E) and sends this and the forms to the shop foreman.
 5. In getting out this material, the stores clerk posts the issue on the bin stock card, and if the requisition reduces stock below the minimum control figure he signals this fact to the production clerk.
 6. On receiving the material, the shop foreman signs the stores copy of the works order and returns this to stores outwards with the trucker's tag from the work ticket.
 7. Having thus received confirmation of the receipt of material in the shop, the stores clerk sends the work ticket tag to the control board, and the stores copy of the works order to the cost clerk.
 8. From this information, the cost clerk makes the appropriate entries in the job cost record, posts the stock ledger and confirms the low limit stocks to the production clerk, who
 9. Now initiates a replenishment order.
 10. Meanwhile, as work proceeds through the shops, the shop foreman fills in the individual stubs of the works tickets, and passes these, operation by operation, to the control board.
 11. As these stubs are received, the control board clerk uses them to keep his board in a condition where it faithfully reflects the condition of all the jobs in the shops, and makes the necessary reports on jobs behind schedule, etc., to the appropriate authorities.
 12. The stubs of the work ticket pass from the control board to the

pay-roll clerk for the preparation of pay-roll sheets (Form F), one copy of which goes to the wages office and the other to the cost clerk, who

13. Makes the necessary postings to his job cost record.
14. Ultimately, on completion of the job, the fabricated material is passed to stores inwards, with the master card and the remainder of the work ticket, where the clerk makes out a materials received note (Form G), enters receipt on a bin card, and sends the master card and work ticket to the production clerk, while a copy of the material received note goes to the cost clerk.
15. The production clerk can now close his records of the works order and return the master card to file, while
16. The cost clerk can also now close his job cost record and credit the shops with the appropriate output.

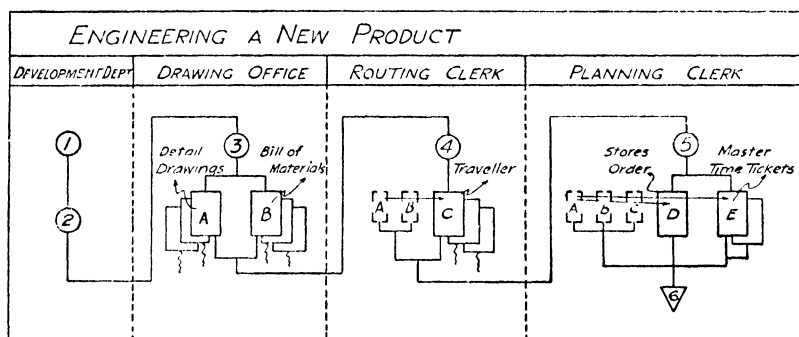


FIG. 35. ENGINEERING ROUTINE

Engineering Routine. In Fig. 35 the technique is slightly modified by dropping the idea of making the relative vertical positions of the figures indicate the time sequence of the operations involved. This routine shows the main path in the process of preparing the engineering documents for the manufacture of a new product, and, by omitting the details of what happens to certain copies of various forms, it is possible to include all the succeeding stages of the routine under question on the same vertical plane, without introducing any degree of confusion.

This chart shows—

1. A new item is adopted for inclusion in the catalogue, and
2. Preliminary planning completed and approved in the development department.

3. The design passes to the drawing office for the preparation of detail drawings (A) and bill of materials (B), with three copies of each. (Distribution not completely shown.)
4. One copy of each passes to the routing clerk, who prepares three copies of a traveller (C) for each part giving operation routing and time allowances.
5. One copy of the traveller, with the originating copy of drawings and bill of materials, then passes to the planning clerk, who prepares a stores order (D) for each item of material and master time tickets in duplicate (E) for each operation.
6. All papers are then held in file until a shop order is originated.

Purchase and Goods Inwards Routine. As a further example, Fig. 36 shows a typical routine for dealing with purchase orders and the receipt of goods. Following the same technique as before, we have—

1. Stores control and progress originate a *stores order* for standard material (stock having fallen to the minimum control level) or for special material (against a departmental requisition). One copy is kept on file; the other passes to the purchase office.
2. On receipt in the purchase office, the stores order is date-stamped and passed to the record section, where it is linked to the *purchase office record card* for that particular material.
3. If no previous purchases of this particular material have been made, a new record card is made out.
4. A decision is next reached whether tenders are required (if not, skip to operation 6), and if so an *inquiry form* is sent out to suppliers, one copy only, carrying a full list of the firms to whom the inquiry has been sent, being attached to the stores order and purchase record card and filed pending the receipt of quotations.
5. As quotations come in they are examined, and the quoted prices detailed on the file copy against the suppliers' names, all copies being kept in file until a decision to purchase is made.
6. When this decision is reached, the file copy of the inquiry form is date-stamped, marked to indicate the supplier on whom the order is to be placed, the papers then passing to the order typing section for the production of the official *buyer's order*. The typist copies the specification, order details, stores references; the order is checked, signed, and the necessary information entered on the purchase record card. The successful tender is filed, remaining quotations are scrapped (a record of prices quoted is available on the file

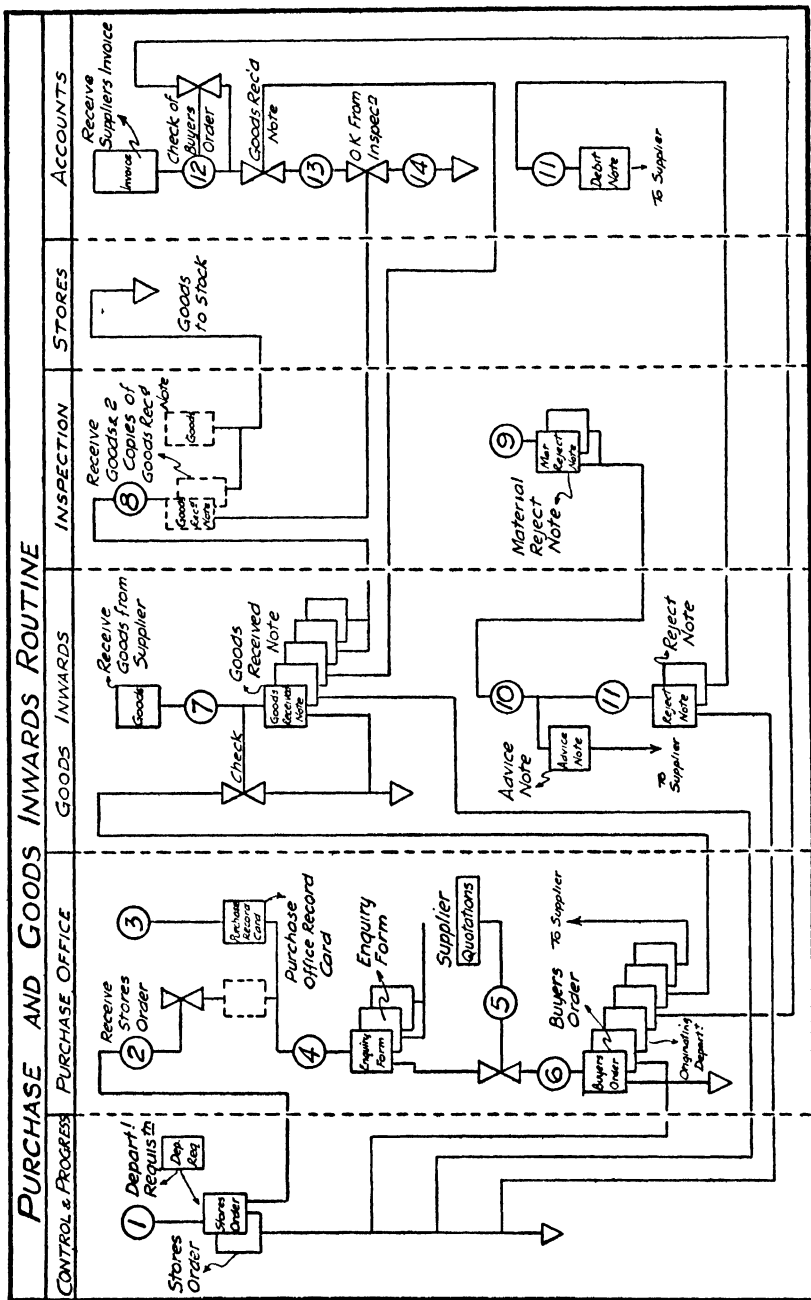


FIG. 36. PURCHASING ROUTINE

copy of the inquiry form) and copies of the buyer's order are distributed—

- To the accounts department
- To goods inwards
- To stores control and progress
- To inspection department
- To the originating department
- To purchase office file with remaining papers

7. On receipt of goods in the goods inwards department, the filed copy of the buyer's order is taken out, and, if everything is in order, a *goods received note* is made out in five copies (distributed to accounts department, stores control, inspection, storekeeper, and goods inwards file). All quantities are omitted from the inspection copy and from the storekeeper's copy, both of which accompany the goods themselves to inspection (the remaining copies being distributed in the usual way).
8. The goods are inspected for quantity and quality and the necessary information added both to the inspection and to stores copies as to quantity submitted and quality accepted. The inspection copy is then passed to the accounts department to authorize payment, the stores copy accompanying the goods to the storekeeper for packing away on the shelves.
9. Faulty goods are returned to goods inwards, accompanied by two copies of a *material reject note*, made out by the inspection department, giving the reason for rejection.
10. Goods inwards then create an *advice note* which is sent with the rejected goods to the supplier.
11. Details of this rejection are entered on the records, one copy of the reject note going to the accounts department for preparation of a debit note to suppliers, the other copy going to the chief inspector, via control and progress department.
12. When the *suppliers' invoice* is received in the accounts department, it is attached there to the file copy of the buyer's order, and prices are checked. Any discrepancies are referred to the buyer for confirmation that the revised price is in order. The invoice is then filed pending receipt and inspection of the goods themselves.
13. The arrival of the goods is signalled to the accounts department by the receipt of a copy of the goods received note (see 7 above) and a comparison made between the quantity advised and that received.
14. When the inspection copy is received, quantities are again compared, and the invoice is passed for payment.

CHAPTER VIII

INTERMITTENT MANUFACTURING SYSTEMS

BROADLY speaking, intermittent manufacturing may be considered as falling between two extremes—producing exclusively against customers' special orders, or producing by the batch for sale from stock. In between the two extremes is the compromise group, where a stock of standard parts is maintained by batch orders, but actual assembly work is done only against customers' orders. To a great extent the planning and control arrangements that are used in any particular concern will be influenced by the manufacturing policy that is followed in this direction. It must not be assumed, however, that this is the only controlling factor, or that shop control arrangements fall conveniently into three water-tight groups. The actual size of the concern also plays a large part in deciding what techniques are needed for successful operation, and, even more so, the physical nature of the product being handled. For instance, the production of typewriters, or calculating machines, involves a more complicated problem in the production of component piece parts than it does in the actual assembly work of putting together the parts, whereas radio set manufacture implies a bigger problem in assembly and sub-assembly than it does in the production of piece parts.

Fundamental Features. Considerable emphasis has already been laid on the fact that the production control systems and routines to be used in any individual factory should be designed specially to meet that factory's own particular needs. So great is the number of factors that play a part in affecting this choice, that it might almost be expected that no two concerns would be found operating the same system, and that no useful purpose would be served in giving examples from actual practice. In fact, however, in spite of all the differences in the detail of shop control arrangements, the fundamental requirements that they must satisfy are reasonably standardized. These fundamental principles have already been outlined, and in the following pages illustrations will be given of the systems used in five different manufacturing concerns. These systems have been chosen, not as examples to be copied, but rather as a cross-cut section of production control and planning arrangements

DISTINGUISHING FEATURES	CASE A	CASE B	CASE C	CASE D	CASE E
Size of concern	Medium	Small	Medium	Small	Large
Main product	Electric floodlights	High-voltage switch-gear	Sewing machines	Commercial machine tools	Light engineering
Complexity of product . .	Simple assembly of a few simple parts	Complicated assembly of complicated parts	Straightforward assembly of complicated piece parts	Complicated	Complicated
Variety of patterns . . .	Large	Large	Small	Small	Large
Origination of designs . .	Producer (catalogue of standard models)	Producer (research or customer contact)	Producer	Jointly producer and customer	Customer
Stability of design . . .	Stable	Continual development	Stable	Continual development	No stability
Size of customer's order (quantity)	Large	Small	Small	Small	Varied
Stock arrangements and origination of shop orders	Small stocks—shop orders originate from sales orders	Limit controlled stock of component parts—assembly to sales orders	Limit controlled stock of components and assemblies	Order parts against sales orders but in economic workings with balance to stock—assembly to customer's order	Produce only to special orders except for standard piece parts ordered on limit—assembly to controlled stock
Planning paper-work . . .	Drawings, bill of materials, and route sheet	Drawings, bill of materials, and route sheet	Drawings, master part sheet, assembly sheet	Drawings, master part sheet	Drawings, part list, part sheet, and assembly sheet
Control paper-work . . .	Route sheet, stores order, time ticket	Shop order (+ foreman's and tracer copies), time card	Shop order (+ cost and stores copies), work ticket, machine schedule	Shop order (+ stores copy), time card	Engineering drawings and job ticket (+ control, costs and stores copies), stores requisition, time card
Physical control arrangements . .	Control board and chasers—no date schedule	Racks holding material to be worked—no schedule	Date schedule, machine schedule boards	Control board—no date schedule	Date schedule and control board
Control vested in . . .	Planning department	Stores department	Shop clerical	Foremen	Planning and control department
Executive control . . .	Personal contact	Personal contact	Through written reports	Personal contact	Through written reports

FIG. 37. FUNDAMENTAL FEATURES AFFECTING PRODUCTION CONTROL METHODS

encountered in typical intermittent production factories. A key to the selection of these particular examples is given in Fig. 37. In this illustration the five particular concerns are analysed to establish the significant features that have affected the systems employed. They represent, as it were, five "ready-to-wear" systems that, with proper adjustment (and only with proper adjustment), can be made to fit most concerns falling within this group. But it must be realized that they would never fit as well as a "tailor-made" system, designed specially to suit the peculiarities of an individual firm—provided always, of course, that the "tailor" knows his job.

CASE A. This first example is an outline of the system used by a medium-sized company manufacturing a large variety of electric appliances and apparatus, electric floodlights being the main product. About 80 per cent of the turnover is derived from items listed in a catalogue which, from time to time, is revised by adding new models and new products, and dropping old designs. The balance of the turnover is from special orders. Individual orders are fairly substantial in size, but customers expect quick delivery. In themselves the products sold are fairly simple in so far that each is comprised of a relatively small number of parts.

Although in theory it would be possible to carry a stock of finished assemblies from which deliveries could be made against customers' orders as received, in fact shop orders are put out almost entirely at the initiative of actual orders received. This is an outcome of the fact that usually the individual order is so large, and the range of catalogue components so varied, that it would be uneconomic to carry the required volume of assorted stock which would be necessary to meet any need immediately it arose.

The system employed may be broadly summarized as follows—

1. A new item is adopted for inclusion in the catalogue.
2. All necessary preliminary planning is done before the receipt of any orders.
3. When development is finished, detailed drawings and bills of materials are prepared.
4. From these drawings and schedules, a "traveller" is made out for each part and each assembly, detailing the production routing (i.e. the sequence of operations and the machines on which they are to be performed), and standard times or rates for each operation as determined by time study.

5. A copy of the traveller is forwarded to the shop planning department, with a copy of the necessary drawings and bills of materials. Shop planning produces from the information on these records stores orders for each item of material required and time tickets (in duplicate) for each operation to be performed. All forms are then filed until instructions are received to issue an order on the shops.

It will be realized that the result of the system so far outlined is to make available in the shop planning department a complete set of shop ordering documents for each article carried in the catalogue.

Control by Customer's Order. When an actual customer's order is received for one of these catalogue items, it passes first to the order department, who re-write the order in shop terms and pass the re-written shop order to the shop planning department. Here the order is checked against the finished stock records. If stock is available, the order passes to the finished stock room, where the product is taken from store, packed, and delivered. If stock is not available, and parts have to be made and assembled to fill the order, a delivery date is established and the customer informed. If the delivery date is satisfactory, production is started.

In addition to shop orders originated in this way directly by individual customers' orders, normal stock replacement orders originate from a daily check of balance-of-stores records to determine which items are nearing exhaustion.

The first step in actual production is to withdraw from the file the set of forms outlined above and to record on the stores orders and time tickets the order quantity and all necessary identifying information. These are accompanied by a copy of the shop order carrying the date on which delivery to stock is due. No information is added to the traveller, bill of material, or drawings themselves, as these documents, after accompanying the order right through the factory, return to the shop planning department for file and re-issue with the next order for that particular product.

The order is started by sending the traveller and the stores orders to the stockroom, and the remaining forms to a central production control section. In the control section, the time tickets are filed on a control board containing a group of three slots for machine or production station. Material is delivered from stores to a control dump, with the traveller.

The order of work for each machine is determined by shop control, who lay out the work on a planning board to establish when each operation should be completed on each order so that the established delivery date may be kept. The three slots on the control board are used to distinguish between the job in hand on the machine, the jobs available to go in hand, and inactive tickets. As soon as the material is received, the time ticket for the first operation is transferred from the inactive slot to the jobs available slot. When this first operation has been completed, the ticket for the second operation is similarly advanced, and so on. One copy of the time ticket is used on the control board; the other goes to the worker.

At the completion of each operation, the material itself is moved to the next works station indicated by the traveller accompanying the material. Actual control of work is exercised through the foreman, who receives the worker's copy of the time ticket from control and assigns men to machines as necessary. Immediately after each operation, the man's time ticket is returned to control, where it is time-stamped, and a ticket for a new job on that machine is stamped and issued. The progress of orders through the factory is followed by a chaser, who is given a copy of the original works order.

Special orders differ from catalogue lines only in the preliminary work of planning. Obviously, in such cases work can be started only when drawings and bills of material are available, and these can be made out only after the order is received.

The essential principle of the system outlined above is one of centralized control shared with the foreman. Paper-work is kept to a minimum by attaching the traveller to the materials to serve both as an identification tag and as an indication of the sequence of operations and the machine at which each is to be performed. Apart from stores orders for material, only one other form is used, a time ticket to control labour, prepare pay-roll and secure direct labour costs.

CASE B. Among the big advantages held by the small company over the large-scale manufacturing unit are its potential flexibility, quickness of action, and ability to give individual attention to the needs of its customers. Almost invariably, the systems and routines necessary for the successful operation of a big concern involve so much rigidity in the structure that there is a serious risk of crushing the initiative of subordinates through the ponderous processes of

decision along the gauntlet of committee and executives. Every care must be taken in the small concern to see that the planning and control arrangements adopted will enable it to take the fullest advantage of its special strength.

This does not mean that in the small concern there is no place for operating standards, nor that the small concern can neglect organized research aimed at keeping it abreast of technical and style developments. It *does* mean, however, that the concern should concentrate on its own particular field, and, above all, should not fall into the temptation of slavishly copying systems and methods practised by its larger competitors. The following example is based on the routines used in a small electrical manufacturing concern specializing on high-voltage switchgear and control equipment. This company appropriates a fixed maximum percentage of its total expenditures to a research programme of experimental work and manufacturing development based on the results of active contact with users of the product. Operating standards are largely employed. Route sheets are worked out for stock items; standard times have been set for many operations; and adequate data are available on manufacturing drawings to enable quality standards to be maintained.

The whole manufacturing system is based on the conception of the stores department as the key control department in the factory. The company carries a stock of standardized unit parts, and executes assembly and the production of special parts to customers' orders. Stock is controlled by balance-of-stores cards, which provide space for a summary of monthly and annual requirement, with minimum and maximum control limits. When an item reaches the minimum limits, a requisition is put in for its replacement. This requisition carries a standardized description, a summary of use of the article, and is approved by the factory manager before it is released to the shops.

Control through the Stockroom. When an order is received in stores from the sales department, a detailed bill of materials and instruction sheet is made up. For standard items, a supply of these instruction sheets is carried in file, ready-duplicated. The bill of materials is checked against stock records, and a shop sub-order made out in triplicate for any items or sub-assemblies not in stock. One of these copies accompanies the material, instruction sheet,

and drawings from stores, through all the operating processes involved, back to stores on completion. A second copy goes to the general foreman; the third is used as a combined cost record, time record, and tracer. The tracer copy is filed in a visible index in the production office, and at a glance shows the status of the work. Each sub-order also carries a reference to the other sub-order numbers required to complete that particular job.

The decision to carry any particular part in stock originates from a request from the sales or engineering department. A special form is used for this application, giving information regarding material and labour costs of the parts, cost of necessary tools, patterns, and other expenses of manufacture.

If the application is approved by the chief engineer and the factory manager, the articles are put into production for stock, and automatically re-ordered from stock when the minimum quantity is reached. A still more important provision is the application for decrease in stock when the engineering and sales department feel that certain articles may soon become obsolete.

Foreman's Responsibility. Scheduling is simple. The shop is strictly departmentalized; each foreman is given full responsibility for results produced by his department. As a job is delivered to a foreman, he refers to his sub-order for instructions, and places the job in a rack provided for each department (large jobs are left on the floor). This rack is divided into sections, one for customers' jobs, one for back-orders for stock, and one for regular replacement orders.

The foreman is instructed to work first on customers' orders, or those with a special "urgent" tag; next, on back-orders; finally, on stock orders in numerical sequence—the oldest job first. By frequent trips of inspection through the plant, the factory manager can judge by the appearance of the shelves the condition of work in each department, and make the necessary adjustments if work is piling up, or a department is running out of a job. Also, he goes through the file of tracer copies weekly to check progress of all orders.

Each worker has two time cards, filed one above the other on a rack near the department time clock. The top card has written on it, by the foreman, the job number and rate per hour of the job in work. The lower card bears the number of the job ahead. These

cards are changed twice daily by the production department, the man's number and time being posted on the tracer copy of the sub-order to indicate progress of the job and its cost.

Work is kept moving through the department, most jobs leaving the day they are received; many going through several departments in a day. When a job is finished, the foreman makes out a transfer order, and it is moved to the next department, and finally to stores.

Personal Control. It will be noticed that the essential feature of the system is that the factory manager is the sole source of executive decision, and that each shop foreman has a clear-cut and comprehensive responsibility for results in his department. The factory manager is in intimate touch with sales and development plans and, through his approval of stock replacement orders, a close control is kept on stock quantities that keeps losses on obsolete stock down to a low figure and avoids the accumulation of excessive inventories. The actual mechanism of control is linked up with maximum and minimum stock limits, but here again the factory manager has the ultimate word in deciding what these limits shall be.

This high degree of personal control is, of course, practicable only in the smaller-scale manufacturing unit. As a company expands, it becomes necessary for the shop superintendent to be serviced with reports on shop conditions, to take the place of the picture of the condition of work in each department that he formerly obtained by frequent visits of inspection through the plant. Similarly, the amount of clerical work that devolves on the shop foreman may reach the stage where he ceases to function effectively as a foreman and becomes instead little more than a shop clerk.

CASE C. The system outlined on the following pages was designed specifically to meet this condition, and, in its basic details, is being used in several different concerns employing variously from 200 to 500 workers, and making a variety of products, such as typewriters, sewing machines, and calculating machines. In this particular case, it was felt that the minimum of reports necessary to assure effective control were—

1. Reports on idle machines and on machines with an inadequate volume of work planned ahead—to enable better balancing of load.
2. Reports on low stocks—to enable delays at the assembly line, due to shortages of parts, to be forestalled.

3. Reports on machines and work stations behind schedule—to locate shop troubles and ease overloaded machines.
4. Reports on orders behind schedule.
5. Reports on discrepancies between current operations and past or standard performance.

In this concern the basis of the engineering information is a master part sheet for each piece part. These master cards are similar to the illustration given on page 84, and give the full operation route for the production of the part, including the tools and fixtures required, material specification, and standard production times. These are permanent documents, kept on file in envelopes, which are transparent on one side, to enable shop men to read the sheet without removing it from its envelope. The envelope contains a pocket on the other side to hold the associated ordering paper-work.

Central Control. The actual decision behind the placing of each shop order originates from the planning executive in the form of a memo. of orders to the production clerk. In reaching this decision he is guided by the stock position and sales conditions, the process being similar to that outlined in the description of the quota system (page 123). The stationery used by the shop clerk in writing out the order comprises a shop order form in triplicate and work ticket in duplicate. The stores order and cost sheet copies of the shop order are identical except that the operation schedule summary appears only on the shop order. Its place is taken on the cost sheet by a cash column ruling, and on the stores order by a space for foreman's signature on receipt of material. The two work tickets are identical, except that one is described as a control ticket. They are made up of a group of perforated tags, one for each operation.

When the production clerk makes out the set of forms, he files the shop order copy by part number, and tears off the stubs of the control ticket for distribution to the appropriate pigeonholes in a machine control board. The cost sheet is handed direct to the cost clerk, and the remaining forms (stores order, work ticket, and master card) are sent to the stockroom. As the stock clerk issues material against the stores order, he enters the requisition on the bin card. This bin card carries a minimum stock figure, and whenever a requisition reduces stock below this limit the production clerk is notified by memorandum. This acts as a danger signal, and is followed up by a similar advice from the cost clerk, originating from

the posting of the official stock records. A replenishing order is then initiated.

Progress through the Shops. The materials required for the job are transported by a trucker to the first department named on the master card, with the work ticket, stores order, and master card. The foreman of this department signs the trucker's portion of the work ticket, and the stores order, and these are returned to the stock clerk. The stores order then passes to the cost clerk, and the trucker's work ticket stub to the planning department. As work proceeds on the material the foreman fills out the work ticket stubs for each operation, and sends them by messenger service to the production clerk.

The completed work, the master card, and the remainder of the work ticket are placed in the outgoing trucker pick-up, from which they are delivered to the next department and handled as before, until the material reaches the stockroom.

The stock clerk, on receiving the finished part, master card, and remaining section of the work ticket, fills out the remaining blanks in the work ticket. He makes out materials-received slips, and enters the receipt on the appropriate bin tag. He sends master card and work ticket to the production clerk, and materials-received slips to the cost department. The cost department posts the information to the perpetual inventory records.

Meanwhile, work tickets for each operation have been sent to the pay-roll clerk. The pay-roll clerk makes up the pay-roll sheet daily, and sends it to the cost department, which posts the information to the cost sheets. Each month the cost department prepares a comparison between actual costs and the pre-estimated cost by operating departments. The cost department also prepares memoranda on all jobs in which actual costs deviate markedly from standard.

It will be realized from the above description that a work ticket stub is received by the production clerk as each batch of material in the factory clears through each process along its operation routing. As these stubs are received, the corresponding machine control stub is removed from the control board and the schedule time compared with the actual result. This control board provides a continuous picture of the work ahead of each machine, and where the picture indicates that a particular machine is likely soon to be idle, this fact is reported to the planning executive. The planning executive

is guided by these reports and other relevant facts in originating orders. Where the comparison of work ticket and control ticket shows an unduly large difference, the two stubs are clipped together and turned over to the planning executive, with the file copy of the shop order. If necessary, the remaining operations are then re-scheduled on the shop order and the corresponding adjustments made to the remaining control tickets.

CASE D. In both the previous two cases, production centred round a limit controlled stock of piece parts, with standard engineering data always on file for the production of further stock. Circumstances are frequently met, however, where the volume of turnover is insufficient to enable this type of control to be practised. In such cases production, even of piece part details, originates direct from the receipt of customers' orders, but this does not necessarily mean that purely jobbing shop methods must be practised. The system described in the following pages is actually in use in a concern employing fewer than fifty workers. It will be seen, however, that, in many features, it is identical with the systems used in a concern operating on an infinitely larger scale.

Stock of Standard Parts. The concern in question produces commercial machine tools, including sawmill machinery, polishing and buffing lathes, and electric knife-sharpening machines, not involving any fine precision work, but of a nature and variety, in view of the size of the undertaking, such as to preclude the possibility of manufacturing for sale from stock. Although no finished machines are carried in stock, however, a large variety of component parts are, in fact, carried in stores, sometimes as much as two years' supply of one particular part being put through in one working. This stock originates from the fact that when the need arises to put in hand a production order for parts, instead of ordering bare requirements implied by the sale, a working is put through for whatever lot quantity it is thought economical to run. Obviously, the system has to provide for the utilization of these stocks, where they exist.

The basic engineering information used for manufacture is a master parts record showing standard practice operations with special set-up and operating instructions, the materials to be used, size and weight, pattern number, and rates for each machining operation. One copy of this master parts record is kept by the production clerk in a master file, a second copy is kept in the

engineering department, and a third copy, attached to the blueprints, is used to travel round the shops. Thus, engineering records are always available for standard models of machines, with shop rates based on time studies. When an order for special work is received, it passes first to the engineering department, for drawings to be made, and specifications showing all operation routeing and tools required, with any special instructions. Where no previous rate-fixing information is available, a clerk makes out a "request for rate" card, which passes to the production manager to clear, either by reference to previously-studied similar jobs, or from a new time study. All such information on the special order is passed to the production clerk.

When a customer's order is received, an order clerk makes out a production order in five copies, each on different coloured paper. One copy serves as an invoice, another is sent immediately to the customer, as an acknowledgment, a third is held as an office record, the other two copies are used in the shop. One of these two copies progresses through the factory with the material, and acts as a signal to release the invoice copy when the goods have been dispatched. The other copy is used first as the basis for the production of time cards for each operation, and then as a control docket on a shop planning board. The purpose served by this board is to assure that each machine operator always has one job ahead of him. Before going to the shop, however, the production order passes first to the stores clerk, and if stock of parts is available, the planning board is by-passed, the parts going direct to assembly.

CASE E. The control devices described in this case, which are typical of those employed in the larger-scale manufacturing enterprises, centre round three types of works instruction sheets. First, a part list or schedule for each job handled by the factory; second, a part sheet for each special part to be manufactured in the factory, or by outside contractors; and thirdly, an assembly sheet for sub-assembly, or final assembly operations, which it is planned to carry out in the factory. In preparing these sheets, a codified nomenclature is used, so that a three-letter part symbol indicates—

1. Who is responsible for design.
2. Which department in the factory is responsible for the manufacturing of the part.
3. Who is responsible for material supply.

Similarly, a tool symbol defines the responsibility for design, and for manufacture of tools, with a third letter indicating the responsibility for costs involved. Thus, a part code B K R might indicate a sheet metal part, made by the firm, to customer's design from material supplied free-issue by the customer. The tool code against this part might be A L P, indicating tools to be made in the firm's tool room to designs produced in the firm's drawing office, with the firm bearing the cost.

The part sheet also gives—

- (a) The description of the part.
- (b) Part number, drawing number, and drawing issue number.
- (c) Material specification.
- (d) Detailed description of each manufacturing specification.
- (e) Preparation time per production batch, and time allowed per 100 parts.
- (f) Description of jigs and tools required.
- (g) The works order number to which the part relates, and the assembly description on which the part is used.
- (h) Any special instructions.

The assembly sheet is similar to the part sheet, except that, instead of the material description, a list of the standard and special parts which are required for each assembly is given.

Paper-work Control. These part lists, part sheets, and assembly sheets form the key to the whole production system. Subdivided sets of sheets for each works order are bound in loose-leaf ledger form and distributed to all foremen, progress clerks, and store-keepers. Complete sets, bound in the same way, are issued to the works manager, works accountant, and progress manager. Copies, mounted on boards, are lodged in the tool stores for use by the work-people. They are issued against tool checks in the same way as tools, so that they can be recalled when changes become necessary. For convenience, estimates for new work are prepared on dummy part sheets and part lists, so that, if the order is obtained, the works order number and other particulars can be added to produce sheets from which the official works instruction documents can be prepared. A target date sheet is also prepared for each works order, giving a schedule of planned completion dates for the various stages of production of each production batch. These target sheets are re-issued when circumstances cause the job to be re-scheduled, and form the

operating instructions for progress clerks and foremen, as well as the basis for all delivery promises.

Job tickets are made out in quadruplicate, to cover all operations or series of operations which can be carried out consecutively by one workman at one time.

Copy A goes, first, on to the shop control board.

Copy B goes to the workman when he starts the job.

Copy C goes to the works accountant.

Copy D goes to the stores.

Each of these job tickets refers to but one production batch, and bears a series of symbol numbers which "key" them with the works order number, works instruction sheet number, and the production batch symbol number, as indicated on the works instruction sheet.

Complete sets of job tickets are duplicated, and issued to the progress department at the same time as the works production sheets. The progress clerks retain these, however, until copy A can be placed on the shop control board, i.e. when the material and man hours are available.

When this moment arrives, the progress clerk enters the workman's clock number, and the time allowed, in the spaces provided on copies A and B, and sends copies C and D to the works accountant and storekeeper, with the object of warning the storekeeper that certain material and parts must be prepared for issue, and warning the works accountant that authority has been given for the work to be started.

When he is ready to begin the job, the workman presents his copy of the job ticket at the clocking-office window. The clocking-clerk then enters the serial number of the job ticket, and records the clock-time and date, by means of the job time clock, on the workman's weekly analysis card, which is in the rack beneath the workman's clock number on the inside of the clocking-office. These cards, which provide a complete record of each employee's weekly performance, are used primarily for compiling wages.

The workman then draws the copy of the applicable works instruction sheet, with any necessary jigs and tools, from the tool-stores, which are adjacent to the clocking-office. Next he goes to the material-stores, where he presents his copy of the job ticket,

possession of which is regarded as authority to issue the material as indicated on the works instruction sheet.

The storekeeper clips the job ticket with standard railway-type clippers, to indicate that the material has been issued, and so prevents the same job ticket from being re-presented at the stores.

When the work for which the job card is made out has been completed, and passed to the inspection department, it is accompanied by A and B copies of the job ticket.

When the inspector is satisfied that the work is correct, he clips both tickets with his individually-shaped clippers, and passes copy B to the works accountant, and copy A to the stores, with the finished work.

The works accountant then calculates the incentive bonus on the back of copy B, and writes on copy D the plus or minus variation from the standard time cost.

In this way, copy A ends up in the stores, copy B in the works accountant's office, with the incentive and overtime allowance payments calculated on the back, and copy D with the cost variation noted on the back. Copy C is sent back to the progress department as an indication that the material has been issued, and the parts completed.

Copies of unissued job tickets which remain in the possession of the progress clerks, therefore, represent work that cannot be started owing to lack of material, parts, man-hours, or equipment, and are classified in that order.

Shop Control Arrangements. The function of the shop control board is to present a graphic picture of the complete volume of work on hand in any department, in relation to the available labour and equipment. It provides a means of forecasting job-completion times and checking jobs that are exceeding the allowed time.

These devices consist of large, vertically-mounted boards, with both of their main surfaces visible to the shop. These surfaces are intersected by a series of horizontal and vertical lines. The longitudinal lines are evenly pitched to match the top-to-bottom dimension of the standard job ticket, and the vertical lines evenly pitched to correspond with the centres of a series of punched holes, which are provided along the top edges of these tickets.

The space between each of the vertical lines represents the time period of one hour, and sufficient lines are provided on each board

to denote 100 factory hours. Each of the horizontal lines represents a man, or, where workers are operating machines, a machine attended by a man, sufficient lines being provided to represent every man or machine in the department.

The o'clock which each vertical line represents is sign-written at the top of the board, and in a similar way, the clock number and occupational grade number of each man or machine is sign-written at the extreme left-hand end of each horizontal line.

At the intersection of each of these longitudinal and vertical lines there is a steel pin which protrudes at right angles from the surface of the board. This means that the pitch of the steel pins corresponds with the pitch of the holes which are punched along the top edge of each job ticket.

The extreme right-hand hole on each job ticket is indicated by a vertical arrow printed on the card, below which appears the words "Completion Time." This permits the job ticket to be hooked on to the pegs protruding from the control board, with the completion-time arrow immediately below the vertical line, which indicates the theoretical time when the job will be completed, as calculated from the hours allowed stated on the job ticket. At the same time, the horizontal line on which the card is placed indicates the machine or men engaged on the work.

The position of these job tickets for work in hand on each man or machine line automatically indicates the available man- and machine-hours which are not already allocated, and so enables the progress clerk concerned to book time ahead for jobs that are ready to start, by placing further job tickets on the appropriate pegs.

It is important when placing "work ahead" job tickets on the board to observe the rule that the distance between the completion-time arrows on adjacent job tickets placed on the same man line must always be equal to the estimated operation time for the right-hand job ticket.

The whole of the job tickets on the control board are moved up twenty-four spaces once in every twenty-four hours (during the lunch break). At the same time, job tickets for work that is running in front of, or behind, calculated completion times are re-positioned, and the job tickets for work ahead are adjusted, so that the board gives an up-to-date picture of the job and labour situation in the shop.

CHAPTER IX

FLOW PRODUCTION PRACTICES

It is generally agreed, and in fact can be proved by mathematical analysis, that continuous flow production represents the ideal state of manufacturing industry from all considerations of technical efficiency, low costs, and speedy production. At the same time, however, the circumstances encountered in practice rarely permit the fullest advantages of the continuous process to be realized throughout the factory, by dispensing completely with all requirements for storing raw material, fabricated parts, or finished products. But if this ultimate state is often unattainable, there are really valuable advantages to be secured all along the path of progress towards this end, and in consequence it is common to find factories in a transitional stage between intermittent and continuous production.

Interim Stages. In the field of machine shop production it is often found that although the demand for a particular part does not reach the stage where it is equal to the eventual capacity of the manufacturing equipment required to produce it, it is big enough to justify leaving equipment continually set-up for its production. That is to say, it can be demonstrated that the cost of the idle equipment is less than that incurred by the accumulation of preparation charges over the same period of time. Often the achievement of such a state of affairs can be accelerated by greater standardization and elimination of variety. Similarly, it is often possible to gear up a particular group of sub-assembly operations as an articulated flow production unit, although the individual piece parts used in the sub-assemblies may still have to be produced by the batch. The practical possibility of such change-overs from batch to flow production is not always readily apparent. Frequently they come to light only as the result of a vital necessity to produce a higher output in a shorter time from existing equipment. But whether brought about as the result of assiduous research by an enlightened management, or as the only possible practical solution to a difficult situation, the successful introduction of such a change is rarely effected without the necessity for overcoming a great many difficulties.

In selecting the examples given in the following pages as illustrations of the systems and routines used in flow production plants, a deliberate choice has been made of compromise cases where, at first glance, it might not appear possible to operate on a flow production basis. The practical difficulties that lie in the path of flow production methods centre round the questions of sales volume and plant layout. It is not intended to discuss the problem from the viewpoint of stimulating sales by advertising and other promotion methods towards obtaining an increased volume, although obviously this is an essential part of the picture. What we are here concerned with is rather the problem and finding means of overcoming the difficulties implied by a variety of lines, the volume on none of which is in itself sufficient to allow anything more than batch manufacture, by taking advantage of the overall combined volume of sales. This is a situation most commonly encountered in practice and may with advantage be considered in detail.

Flow Production Shoe Factory. The Nunn Bush Shoe Company makes three grades of shoes in nine different widths, and in fifteen different styles. This gives one hundred and thirty-five possible combinations of width and style in every model of shoe, every colour leather, and different leathers, or combinations of leathers. About 75 per cent of the total turnover is derived from the thirty most popular of the range of one hundred and fifty models, but the make-up of the thirty, and of the total one hundred and fifty, is continually changing. When sales records show a decline in volume of any model to a certain point, a new design is introduced to take its place, so that the total range at all times includes one hundred and fifty models. All told, therefore, there is a variety of more than ten thousand different combinations of styles and sizes, and it would appear that such a situation must automatically rule out any question of flow production. The situation is further complicated by the fact that sales are not spread evenly over the year, being substantially higher in certain seasons than in others. They also vary appreciably from year to year in sympathy with general business conditions.

In spite of these difficulties, production throughout the factory is "conveyorized," and the whole plant operated on the basic conception that every lot of shoes must move through the factory as part of a steady stream of production. The make-up of the stream

varies considerably from day to day, although its aggregate volume is substantially the same. Certain popular models may always be represented on the assembly lines, but the less popular styles may be worked only at intervals of several weeks. The basic problem lies in the determination of the rate at which the factory should run, and in the question of what particular models to include in each day's production. This aspect is controlled on a quota basis.

Quota System. Twice a day a quota of shoes goes to the cutting room. A quota is a half day's work. The size of this quota is adjusted weekly in a manner described later, but for the immediate purpose it may be considered as remaining steady and equalling 100 dozen pairs each morning and each afternoon, day in and day out. The company has satisfied itself that the economic batch of any particular style and size of shoe to be put through in one lot is twelve pairs. This obviously allows only 100 of the 10,000 possible styles and sizes to be included in any particular quota. To assist in this selection process, a perpetual inventory of shoes on hand is kept, under styles and sizes. From it, sales are deducted twice daily; to it are added shoes gone into the works. This gives a new total every morning and every afternoon, thus enabling the planning department to see a manufacturing picture of stocks, sales trends and process which is within half a day of actual. The problem of making up the half-day's quota is, however, by no means confined to an analysis of the perpetual inventory, although this stock situation is of primary importance.

Raw Material Availability. It is obvious that any particular batch of shoes can be started only if material is available. This introduces the necessity of reading the raw material stock records in conjunction with the perpetual inventory. Besides this, however, there are many special factors bearing on the necessity for ensuring that the quota as selected represents a balanced and practicable load for the factory, as distinct from a desirable and practicable requirement from the sales and stocks viewpoints.

Practical Complications. It is possible to make three distinct grades in the same plant only because, in the progress of the work through the various departments, only certain workmen are allowed to work on the two better grades. Since these preferred workers have a limited output, the planner, if the entire quota is to move steadily, and without delay, through the various operations of

cutting, stitching, lasting, and so on, must hold to a set ratio between the top and the lowest grades. This ratio will vary over long periods, but is generally on a 50-50 basis. The fact that certain shoes are machine-cut and others are cut by hand introduces another complication. It would be a saving if all shoes could be cut by machines, but dies are costly, and sales on a pattern must reach the 20,000 mark before a set of dies will return the original investment. The result is that 65 per cent of the production is cut by hand, and that factor must be considered in making up the quota. Again, watch must be kept for factors such as the amount of perforating and heavy stitching. It is also necessary to check the number of kid shoes, since only the most skilful cutters are allowed to work on that particular upper material. Finally, it is necessary to watch for certain special styles, because they require more pieces and take longer to cut. Having established the quota, which is usually prepared in skeleton form a few days ahead, and finally completed only immediately before issue, the quota editor must insure that a supply of lasts will be available when the shoes have passed the cutting and finishing stages. Usually, there are forty active styles of lasts, each in a variety of sizes, in use in any particular season, and since each pair of lasts costs at least 10s., it is obviously impossible to have an unlimited supply available. The business is run on a reasonable basis by maintaining a running inventory on each size of each style of last. Each day as shoes come off the lasts, the lasts which have been released are added to the supply on hand. Similarly, the lasts on the new quota are subtracted.

Control Tags. When the quota is completed, copies are sent to the various executives in the firm who are interested. In addition, however, a work tag system is used to make sure that soles, heels, and other supplies are available as needed. These work tags provide operative instructions and would also constitute a means of determining wages. The tags are prepared in sufficient number of copies to provide for circulation in advance to the seventeen control points in the factory, thus ensuring that each department will be in readiness to handle the work exactly as it comes along. The routing of the tags is deliberately excluded from the description of the system, to leave the programme and quota elements in high relief. Similarly, the type of systems used to ensure the provision of soles, heels, etc., is deliberately left out of the picture.

Overcoming Seasonal Variations. The sale of shoes is subject to marked seasonal changes, and the programmed production has to steer a middle course through the spring and autumn peak sales and the summer and autumn slack periods. In the Nunn Bush Company this result is achieved by basing the production programme on a moving year's total sales. The planned production for any week is based on the number of shoes sold for that week, plus the number of shoes which must be made to keep stocks up to normal (or actual sales, less the number of shoes that should be withdrawn from stocks to bring stocks down to normal). This total number of shoes for that week is added to the total number of shoes actually produced during the last fifty-one weeks. This provides a production total for the year ending one week hence, and is divided by the number of working days in the year to get the daily production necessary for this next week. This year moves forward one week each week, and in this way production is tied to the demand which has existed for the last year. In making up the actual half day's quota, stable lines of shoes are used to fill in production valleys when the sales are not up to production possibilities.

Long-term Changes. It will be realized that although the method outlined may satisfactorily smooth out seasonal variations, it still leaves the programme subject to the effects of cyclical and secular variations. The Nunn Bush Company is developing by experience and experiment a technique for dealing with these variations. Cyclical falls in sales have been countered by reduced prices to consumers, in order to bring stocks down to new normal levels based on the lower volume of business. Special incentives are given to persuade buyers to make their purchases far enough in advance to have shoes made to order. The significance of this step is that it reduces what was formerly the normal stock needed to ensure proper deliveries, and leaves a larger factor of stock space and investment available to cushion sales trends. Further, since the moving annual average smooths out irregularities, a lot of the violence of the movements is eliminated. If business declines, the factory production declines slowly, and the warehouse absorbs the surplus. At the same time the natural labour turnover in the production department is allowed to operate to reduce the working force. That is, deaths, marriages, and other causes of people leaving the factory gradually reduce the number of employees. On the

other hand, when business is increasing, the factory backs up the load slowly, while the warehouse absorbs the shock.

Although in times of severe downward adjustment some of the factory workers may have to be out on a short week, the factory itself attempts to produce shoes every working day. This enables better service to be given to customers than would be given were the plant shut down for two days a week.

The Wage Payment System. The reader will probably have noticed in the description of the Nunn Bush production system an implication of something a little out of the ordinary in the wage payment method. The Nunn Bush Company have constantly striven for better economic relationships between their labour and its management. An analysis of any business organization almost always discloses that the office and executive personnel is loyal and faithful to a business. The security in their jobs, and fixed yearly salaries, have made them feel they are part of the organization. Factory labour, on the other hand, is the first to be separated from the pay-roll when business declines, and feels responsible only on a day-to-day basis.

This suggested the desirability of finding a method of paying annual salaries to factory workers instead of a more or less variable weekly wage. At the same time, an element of flexibility during economic changes, and some form of incentive correlating payment with results, had to be provided. In studying this problem, Nunn Bush found that the ratio of factory wages to sales revenue varied in itself by no more than two points in a hundred over a past period of several years. At first it was found necessary to exclude several departments to get this fine agreement, but later these excluded employees were analysed and placed in separate groups to be paid in similar fashion from a percentage of the gross income. The outcome of this study was an agreement to pay a set percentage of gross receipts into a wage fund and guarantee employees fifty-two pay slips a year regardless of business conditions and factory shut-downs. Since the exact amount of annual salaries cannot be determined until the end of the year, a system of drawing accounts for each employee was set up. These drawing accounts were based on the estimated volume of business and adjusted up or down periodically as business exceeded or failed to meet estimates.

New Employees. Because sudden increases in production may

require additional personnel, it was necessary to have provision for adding men to the pay-roll. In consequence, new employees come in on a different basis before participating in the annual salary. A new employee is subject to lay off without pay until he has served two years and is accepted both by the management and by the workers already in Class A as a member of the permanent force. The percentage of employees in this B group has varied between 5 per cent and 12 per cent of the production employees.

Each month the workers' executive committee is furnished with figures showing the economic status of the business as it concerns the distribution of the salary fund. At the end of each fiscal period the workers employ a certified accountant to verify the figures which have been furnished by the management.

The results of the new wage payment plan, which has been in operation more than six years, have been to make the management of the plant more efficient, and the plan has withstood the test of an upward and downward trend in business activity. Wages are tied to productive efficiency, and labour costs per unit of output are stabilized. The plan is not a profit-sharing plan. The workers get the same percentage irrespective of whether the company makes a profit, and the controversy that might be expected to have accompanied the discussion of company operations and expenditures has not materialized beyond the stage of educating the workers to the fact that the capital of the business cannot pay the salaries, and that wages are dependent on the sales turnover, which, in turn, is related to the number of shoes produced.

Although the Nunn Bush payment system and their particular production plan are unique, the basic principle—one of taking advantage from the assembly viewpoint of the fundamental similarity of a group of different products—is met in several other industries. Many examples of such plans are to be found in the wireless receiving set business, in furniture assembly, and in domestic electric appliances manufacture.

Eliminating the "Specials" Problem. Many concerns that could in fact operate on a flow production basis so far as a substantial part of their output is concerned are found, however, where the associated number of special orders for small quantities has had the effect of precluding consideration of anything other than production on a jobbing or lot basis. The following description of an actual

case where this difficulty was faced and overcome is introduced in the hope that it may suggest a new angle to concerns similarly situated.

The concern in question specialized in the production of small electric motors and products, such as fans, in which an electric motor is the principal component. These products are built in a variety of voltages, phases, and current-types, and to fit a wide range of motor-equipped appliances. An analysis of the production orders for motors developed some surprising facts. It was found that small orders, from for one to five units, constituted over 60 per cent of the number of orders, but accounted for less than 5 per cent of the motors manufactured. The solution found to overcome this difficulty was the creation of a special short-order department, fully equipped for the complete manufacture of motors. All orders for less than six units, all service and repair orders, and all experimental machinings, are sent to this department. In this new department highly skilled mechanics build the complete units, without special tooling, although standard parts are used from stock. Little attempt is made at functional or progressive manufacture. A "specials-chaser" follows the work personally, thus eliminating general office scheduling and follow-up, and the result of the simplicity of the system is that deliveries are good, averaging six days for an order. As might be expected, costs are high, although lower than they would be were not stock parts used wherever possible. These high costs have served to focus attention on the economic value of small orders, and the sales department endeavours to eliminate such orders so far as is consistent with sales policy. The elimination of the details and worries of small orders from the general production department left a situation where flow production was obviously indicated.

Standard Sequence of Processes. Although motors vary greatly in size and shape, the basic parts, shafts, bearings, windings, and cases exist in practically all motors. It was found possible to lay out a standard sequence of processes that was approximately uniform for all jobs. Following on, it was found possible to arrange a fairly uniform rate and direction of flow through the various processes to inspection and dispatch, with an approximately balanced capacity at each stage. Processes were not quite so well balanced as in the typical one-product line, and from time to time minor adjustments

had to be made at specific points. Detailed instructions were also necessary for individual jobs, with the associated necessity for the operative to change his set-up more or less as a new job came down the line. Mechanical handling facilities were provided, and a new layout adopted to give as near straight line production as practicable. This automatically reduced clerical costs of follow-up, and at the same time provided more than enough surplus floor-space and equipment to provide for the establishment of the special order department, apart from a few supplemental small purchases.

The business is not markedly seasonal, and as yet the concern has not attempted scientifically to forecast sales ahead with a view to maintaining production on an even keel, undisturbed by fluctuations in sales demand. Input to the conveyor lines is controlled by reference to a load record book in the production office, showing just how much work is ahead of each group. Standard times for all operations were available from previous time studies, and on the basis of these times and the load record each job is assigned to the machines and workers' groups throughout the factory for commencement and completion on specific dates.

In making the change-over, the short order department was set up first. Then reliance was placed on this department to meet any urgent demands while the remainder of the factory was in process of physical reorganization.

Change-over from Jobbing Basis. This question of the change-over from a jobbing basis to flow production, with the associated changes in plant layout and methods, may with advantage be illustrated by reference to yet another actual case.

This particular firm was engaged in manufacturing engine manifolds, but although jobbing shop methods were satisfactory for dealing with peace requirements, a change-over to flow production was found to be the only practicable method of providing the increased volume demanded as a result of war conditions. Before the change, the production system depended to a large extent on the individual initiative of the department heads as well as on practices which were standardized in terms of personalities, rather than in terms of good production practices. Obviously it was impracticable to expect to run a production line on the basis of leaving such and such an operation to Bill Jones, as he was an operative who would know exactly what to do at that stage, and the first

<u>FLOW PROCESS CHART</u>			
<u>MANIFOLD DEPARTMENT-OUTLET SEC^N</u>			
<i>Distance</i>	<i>Operation</i>	<i>Description</i>	<i>Remarks</i>
	▽	Stamping Storage	
30	o	To Trim Template	
	①	Mark for Rough Cut	
22	o	To Temporary Storage	
	▽	Wait for Trim	
6	o	To Trim Machine	
	②	Trim Parts	
6	o	To Temporary Storage	
	▽	Waiting for Move	
45	o	To Store	
	▽	Stamping Storage	
30	o	To Tacking Department	
	▽	Wait for Tacker	
8	o	To Tacker	
	③	Tack Bottom Seam	
9	o	To Temporary Storage	
	▽	Wait for Jig	
32	o	To Jig	
	④	Fit Part to Jig	
	▽	Wait for Tacker	
	⑤	Tack Seam	
32	o	To Temporary Storage	

FIG. 38. FLOW PROCESS CHART

necessity was found to be changes in engineering and tool-planning to ensure co-ordination in production and interchangeability of individual component parts. This was achieved by keying the production of jigs to a master layout, and breaking down the jigs to enable the operations on production to work round them with ease and convenience. The question of the amount of work to be done in each jig, or at each working station, was also studied, so that more jigs could be made of the difficult sections, to enable the sections that required more man-hours to complete to be produced in balance with the sections that were less complicated. Arrangements were made so that as each jig was produced it could be "proved" by the immediate production of a sample part to be checked against a master assembly. Similarly, sample parts were struck off each new die for proving.

Flow Process Chart Analysis. Under the old jobbing shop basis, the component parts for manifolds were produced in various departments specializing in a particular class of work, such as the general machine shop, the sheet metal department, the welding department, and so on. It was found necessary to revise the physical plant layout to co-ordinate these efforts, and to find a more satisfactory method of handling the large volume of the parts which went into manifold making. Towards this end, an examination of the existing manufacturing methods was made by means of a series of flow process charts similar to that illustrated in Fig. 38. These charts were made up to provide a complete history of all parts, from their inception in the form of engineering drawings to their completion as finished parts. The charts indicate every operation, every movement of material, every storage, and all inspection stages, using, for convenience, groups of symbols shown in Fig. 39.

With this picture of manufacturing procedure many errors in past practice were revealed, particularly in the direction of unnecessary movement of material. In passing, it should be noted that, to be of real value, charts of this type must record every movement of the part. They cannot be produced by the arm-chair expert. All the parts must be physically followed through each operation, and no operation, however small, nor any movement of parts, however slight, should be omitted.

Manufacturing Layout Analysis. For convenience in visualizing the flow of each particular part, rough diagrams of the manufacturing

space were made. By filling in on these diagrams the actual movement of the parts, excessive distance travelled showed up as a group of many parallel lines, and the existence of bottlenecks and backtracking became obvious. In this particular case, it was found unnecessary to carry out this flow process analysis for every individual part, as often the study of one particular part was found to be representative of many other parts.

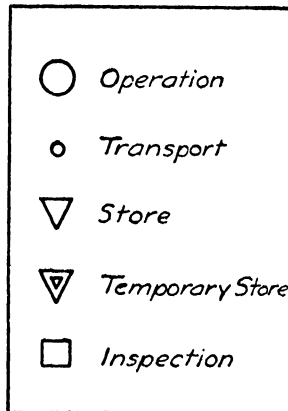


FIG. 39. PROCESS CHART SYMBOLS

The next step was to challenge every step shown on the chart, to determine whether it could be eliminated, whether it could be simplified, or changed to advantage, and whether it could be combined with some other step. This resulted in a new chart against which (using the conventional template layouts of manufacturing space available) the welding equipment, machine equipment, and assembly fixtures were redistributed throughout the manufacturing space in their most convenient and natural locations to intercept the flow indicated by the revised flow process charts.

Progressive Assembly Line. The progressive assembly line is such a common feature of flow production shops that it is not unusual to find the opinion expressed that mechanical handling and flow production are synonymous. In fact, mechanical handling is only one feature of flow production methods. It was developed mainly as the results of studies in flow production factories, but its use is not confined to such factories. One of the features of the progressive assembly line is that operatives are located along a straight line,

or looped conveyor, on which the work moves automatically to the next operator. The system is planned to ensure a properly co-ordinated supply of piece parts, assemblies, and general supplies to the conveyor, and to ensure a proper subdivision of work between individual successive operations. But although a progressive assembly line presumes a product where the major element of manufacture is assembly work rather than process work, there have been some interesting applications of the basic principles to the general machine shop.

The General Machine Shop. In some factories, layout is arranged so that machines can be moved about in the shop as the scheduled production changes, thereby ensuring that the plant is always centralized around the products being handled. Such arrangements are, however, practicable only in the exceptional cases. In the general machine shop the flow ideal of successive operations adjacently disposed so that no pause need exist between their performance is usually impossible. Different orders for components dodge about from machine to machine and department to department. Control is by process instead of by product. But in some factories a compromise has been found through the utilization of the selective sorting conveyor to carry components quickly from process to process. The feature of such a conveyor is that the trays it carries are equipped with an arm bearing a number of keys. A simple trip mechanism is installed at each unloading station, and is operated, or not, dependent on the key-setting of the individual tray. The conveyor installation circulates round the general machine shop, inspection and viewers, and stores, so that a box can be sent from any point to another with automatic discharge. The possibilities opened up by this arrangement are—

1. No longer is it necessary to complete a batch before proceeding to the next operation, as a part working can conveniently be sent to inspection, and thence to the next operation, when the box is conveniently full.
2. Speedy transport being assured, schedules can be arranged for a quicker follow-on from one operation to another.
3. It is necessary to hold on the shop floor only the actual job being worked at each station.
4. Paper-work can be considerably speeded-up and reduced in volume.

It is not, of course, flow production, but it is a definite step in this direction from normal batch production.

CHAPTER X

THE PAYMENT OF LABOUR

FUNDAMENTALLY, maximum productive efficiency in a factory unit can be achieved only through the attainment of the highest individual productivity of the worker. Obviously, the systems and methods of production control employed play their part in achieving this objective, but alone, all the most modern improvements in technique would prove insufficient without the fullest co-operation from the workers. It is being realized that this result can be secured only through an enlightened wage policy aimed at this specific objective.

Fundamentally, there are two methods of rewarding labour—either by payment for the amount of time spent at work, or by payment for the amount of work performed. The modern tendency is more and more towards a basis of payment by results rather than for time put in, and it is generally agreed that the adoption of such a method can be a valuable means of increasing output, reducing costs, and, at the same time, increasing the earnings of the efficient worker. The system of payment by results has, however, certain inherent dangers, which must be guarded against if the policy is to be successful.

Piece Rates. The most serious of these dangers is the tendency towards rate-cutting by the employer. In earlier days it was a common practice for managements to set piece rates by guess-work, having no standards, and then to correct errors by cutting any rate that appeared to result in excessive earnings.

For a long time organized labour was frankly opposed to piece-work systems, and even now trade union agreements make a strong point in their working rules that alterations to rates shall be made only as a matter of mutual agreement between the workers and the employers. Even so, the tendency towards rate-cutting has not completely disappeared, and is often effected in the disguise of a change in production method. When a worker imagines that he is confronted with a situation where a certain “ceiling” has been set on his earnings, and where, irrespective of his output, his rate will be adjusted to ensure that his earnings do not exceed that

amount, his reaction is to arrange to get that amount with the least possible effort. If, however, the piece rate is based on a scientific study of the process, and of the working conditions, then the earning of high wages by operatives is a condition from which the employer benefits in equal measure through the reduction in the burden of overhead expense that has to be carried by each unit of production. The discovery and elimination of all weak points in the existing production organization is an essential preliminary to any successful straight piece-rate system. A lot of the opposition shown by organized labour towards piece-rate systems has been thoroughly justified by the actions of unenlightened managements, who, having struck bad bargains, have been unprepared to foot the bill. At the same time, it is only fair to state that there have been instances of attempts to get something for nothing on the part of the workers. It should be freely recognized that, to be successful, a piece-rate, or similar system, has to be of benefit to both sides. The management must be prepared to pay a reasonable premium for the exercise of extra effort; labour must be prepared really to earn the extra reward. Again we are faced with the difficulty of establishing the standard.

Reasons for Fundamental Inefficiency. It must be recognized that the industrial worker left to his own initiative is frankly inefficient. In part, this is due to faulty inherited methods, in part to a lack of appreciation of the maximum capacity of machine tools and processes; but, fundamentally, to the fact that the worker's interest in increased production can be stimulated only by appeal to his own interests. Generally speaking, this implies a financial incentive for increased effort, but there are other means of appeal to the worker's interest, one of the most potent being to ensure that he is given the highest class of work for which his natural abilities fit him. Only when this condition is coupled with the establishment of a definite task to be done in a certain time does real productive efficiency begin to be a practical proposition.

Efficiency Criteria. One of the difficulties in incentive payment plans is to establish some criterion whereby individual efficiencies may be compared. It is generally agreed that the only reliable criterion is that of human perfection, which may be taken as the equivalent of automatic machine capacity. For human work this limit is purely theoretical, in that it is in practice unattainable, but it does provide a standard against which individual efficiencies may

be compared. On the efficiency scale this unattainable peak of efficiency has been allotted a value of 180 per cent. Compared with this, a "super-worker" falling slightly below the limit would rate 145 per cent; occasionally workers of extra skill would make 125 per cent; good normal workers regularly make 110 per cent; and all who are suited should, when trained and rewarded, make 100 per cent, day in and day out. This 100 per cent is the so-called "high task" of the various incentive plans. Similarly, though less scientifically, "low task" is established by assuming a discharge point of 60 per cent and putting "low task" a little above this figure, say, $62\frac{1}{2}$ per cent.

Financial Stimulus. The amount of the financial stimulus needed to bring forth the so-called "high task" of 100 per cent efficiency on the above scale will depend on the nature of the work involved. It was originally suggested that for the average machine shop operative the equivalent of 30 per cent over day rates was required to get maximum output. Where severe bodily exertion was called for, 50 per cent to 60 per cent was suggested, with 70 per cent to 80 per cent for delicate and difficult work, and 100 per cent for work demanding skill, brains, strength, and close application. These suggestions were put forward by Taylor in the early days of scientific management, when the worker had by his own efforts to overcome a lot of difficulties that have since been removed by improvements in general management technique. These percentages are too high for present-day practices, and a range between 20 per cent and 50 per cent seems indicated, rather than the wider range of 30 per cent to 100 per cent. It should be appreciated that a payment system calculated to give 120 per cent of day rate to the normal trained worker at 100 per cent "high task" would give time-and-a-half to the worker of extra skill, rating 125 per cent efficiency, and 174 per cent of day rate to the "super-worker" with his 145 per cent efficiency. Similarly, with a basis of 50 per cent over rate (or time-and-a-half) for 100 per cent efficiency, the extra-skilled worker would get $188\frac{1}{2}$ per cent, and the "super-worker" $217\frac{1}{2}$ per cent of day rate.

Implications of Efficiency Scale. The implication of the efficiency scale outlined above is that, with proper management and good supervision, day-work efficiency is $62\frac{1}{2}$ per cent compared with 100 per cent for incentive or piece work. This implies a potential increase of rather more than 50 per cent in output from the installation

of incentive. This fact is borne out in practice, but care should be taken not to lose sight of the implication that proper management and good supervision are needed to obtain the so-called "low task" under day-work conditions. In many factories, where the day-work basis of remuneration is in being, output efficiency falls far below the 62½ per cent. It has, in fact, frequently been found that piece-work output has risen to more than three times the day-rate output, implying a day-rate efficiency of only slightly more than 30 per cent. One can imagine the difficulties in such a situation, were the facts known, of trying to convince the workers that a threefold increase in output was for one thing possible of achievement, and if so was justifiably to be expected from an increase in the weekly pay-packet of 20 per cent. Expressed in another way, with a straight piece-work system such an exceptional situation would mean a reduction in earnings to 40 per cent if no increase over existing day-rate production was achieved. Similarly, if the situation were as described, but the management was not alive to the potentialities for increased output, piece-work earnings of 240 per cent of day rate would become possible for the normal worker. It is just such circumstances that led to the opprobrium that for a long time surrounded the piece-work payment system, with its unhappy history of cut rates and general ca'canny attitude.

With this background, it may now be advisable to consider in more detail the question of day-work and piece-rate payment, and those special combinations of the two systems that have been adapted to meet special circumstances.

Incentive Payment Systems. The first step in incentive payment systems, as distinct from straight day work, is represented by multiple time plans and measured day work. In such systems a standard is established representing what is expected from the worker as a basis of normal efficiency. If the worker reaches this standard he receives an increase, or bonus, of, say, 20 per cent in his rate of pay. If he fails to reach the standard he takes the ordinary flat day rate. Obviously this represents a strong incentive to reach the standard. To the really efficient worker there is, however, no benefit for appreciably exceeding the standard; and by the worker at the bottom end of the efficiency scale the standard may be unattainable. Sometimes this difficulty is met by introducing intermediate standards of production, with correspondingly different percentage bonuses.

The fundamental difficulty, however, remains, until the intermediate standards are put so close together that a continuous scale is obtained corresponding to straight piece work.

Piece Rates in Terms of Time. A straight piece-rate system implies a direct relationship between wages and output, but not necessarily a set cash price per piece produced. In fact, it is common to calculate piece rates in terms of time. That is to say, a price of, say, ten minutes per piece may be agreed. This does not mean that, to produce the piece, a time of ten minutes is allowed, but that the wages for a ten-minute period will be paid for producing the piece. The practical advantage of such a scheme is that it avoids any necessity of changing piece rates in line with changes in basic rates of pay.

Obviously, piece rates, whether in terms of time or money, are tied up with some standard of efficiency. In other words, there is a certain production standard of output where the wage earned at the piece rate is equivalent to ordinary flat day rate. Usually, though such arrangements are not universal, this day rate is paid where output falls below this level.

Special Variations. There are scores of variations on these two systems, all developed to cater more or less specifically for certain particular cases. In the accompanying illustrations (Figs. 40–48) the basic features of the most commonly met incentive plans are shown,

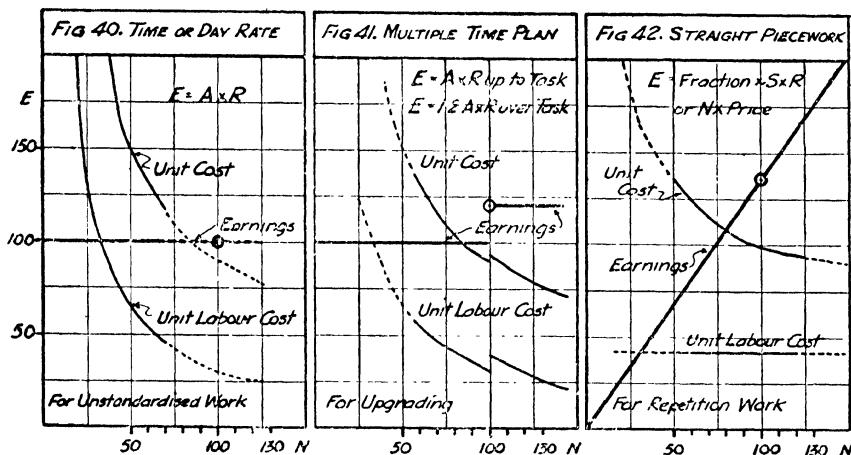


FIG. 40. TIME RATE COSTS

FIG. 41. MULTIPLE PLAN COSTS

FIG. 42. STRAIGHT PIECE-WORK COSTS

with their basic formulas. The key to these formulas is as follows—

E = total earnings (vertical variable).

A = actual hours worked.

R = basic rate per hour.

N = number of pieces produced (horizontal variable).

S = time saved per piece comparing allowed time with time taken.

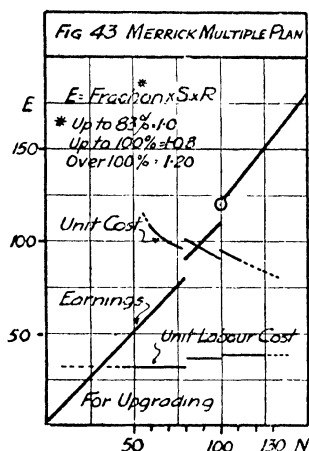


FIG. 43. "MERRICK" MULTIPLE PLAN COSTS

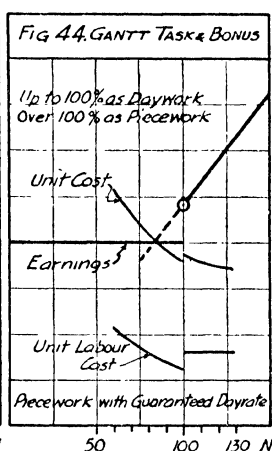


FIG. 44. "GANTT" TASK AND BONUS PLAN COSTS

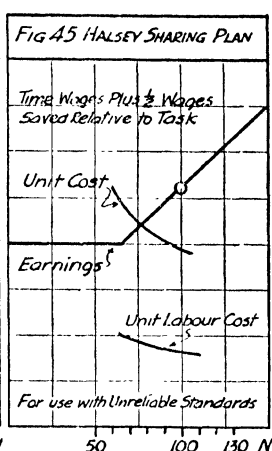


FIG. 45. "HALSEY" CONSTANT SHARING COSTS

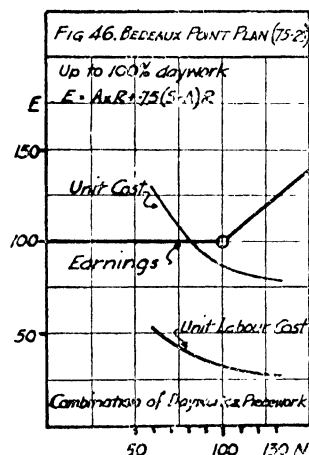


FIG. 46. "BEDAUX" POINT PLAN COSTS

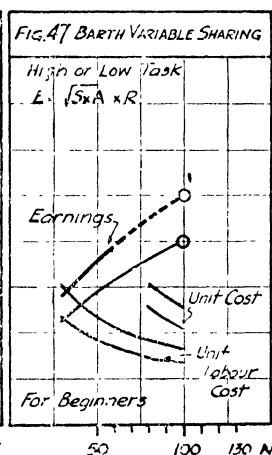


FIG. 47. "BARTH" VARIABLE SHARING PLAN COSTS

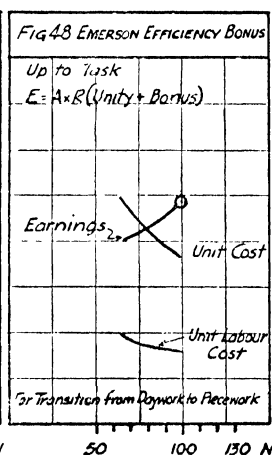


FIG. 48. "EMERSON" EFFICIENCY BONUS PLAN COSTS

Costs, Wages, and Output. Each illustration comprises three curves, one showing the effect of increased output (along the horizontal variable) on total earnings, the other two showing average labour costs per piece, and average total costs per piece, as affected by increased output. In all cases output is measured against the efficiency scale outlined on page 136.

Fig. 40 shows the effects of straightforward time or day rates. The system has the advantage of simplicity and is the only possible plan where work is not measured. It will be noticed that reductions in cost consequent on increased output are not accompanied by any alteration in earnings; similarly, increased unit costs on small outputs are not accompanied by any reduction in earnings. In other words, the employer takes all gains or losses on variable outputs.

Fig. 41 illustrates a multiple time plan, with a bonus of 20 per cent where 100 per cent task is achieved. The incentive offered by this type of system is strong round about task point (or points), is simple, and easily understood. It is suitable for upgrading labour formerly engaged on day work, but it needs careful management to secure best results. In common with all the following plans, increased output brings gains both to employers and to employees.

Fig. 42 gives the results of straight piece work. This is the simplest of all incentive systems, and the soundest within the limits of its application. It will be noticed that the labour cost per piece is a constant at all output levels, the reduction in total cost coming solely from the reduced burden of overhead expense when spread over a larger volume. In consequence, the rate of fall of the total cost curve is not as steep as it is in the other illustrations.

Fig. 43 brings out the features of systems of the Merrick Multiple type. This species of plan is suitable for upgrading inefficient labour that was formerly on a low piece rate. Virtually, it provides three separate piece rates between various levels of efficiency, and is, in effect, a combination of the two systems previously described. The system is simple and flexible, but, for practical application, it needs the use of tables.

The Gantt Task and Bonus Scheme shown in Fig. 44 combines straight time work up to 100 per cent task, with straight piece work thereafter, calculated on 20 per cent bonus at 100 per cent of task. This type of scheme is very useful where unavoidable waiting time, outside the operative's control, is to be expected.

The Halsey (50-50) Constant Sharing scheme, illustrated in Fig. 45, is another combination of guaranteed day rate and incentive payment. It is useful where standards cannot be accurately determined, and offers a continual incentive through intermediate production efficiencies. The effect of inaccuracies in task or rate setting is reduced by sharing the direct saving equally between the employer and employee. The distribution can be varied from 50-50 to any desired proportions. It should be realized that if 100 per cent of the saving is given to the worker we have a straight piece-work system.

Fig. 46 illustrates the Bedaux Point Plan. The basis of this system is day work up to 100 per cent task, and straight piece work thereafter. As a payment system this is commonly used—it is, after all, merely straight piece work with a guaranteed day rate. The merits of the Bedaux system lie more in the improvements of general management and production control that are usually introduced with the system, with scientific rate setting.

Fig. 47 shows the Barth Variable Sharing scheme with high and low task figures. This system is suitable for learners, only offering smaller earnings than day work until the selected task is reached, but higher earnings than piece work. Tables are needed for the calculation of wages.

Fig. 48 illustrates another special system, Emerson Efficiency Bonus, designed to provide a gradual transition from day work to piece work, instead of the abrupt step involved in, say, the Gantt Task and Bonus system. It should be used only within these limits.

Background of Incentive Plans. It is not suggested that the above group of special incentive plans is exhaustive, nor that, in itself, any of these schemes offers the key to industrial success. Actually, management literature tends to over-rate these systems. If one studies the historical background behind the origination of these systems it will be found that they are the fruits of the "efficiency expert" days. All the various systems are tied up with the difficulties commonly encountered in turning over from day-work production to some form of piece-rate production. It is unfortunate, perhaps, that the resultant compromise systems used to tide over the period between inefficient day-work and efficient piece-work production should have received so much publicity. The systems are

good for the purposes for which they were developed, but care should be taken not to fall into the error of assuming that they are by themselves the means whereby those purposes were achieved.

Throughout the discussion on incentive payment, stress has been laid on the need for the determination of proper standards of efficiency based on expert investigation into the best method and the shortest time for performing the operation with the available appliances. But the real need goes further than this. It is necessary to find men who can work to the standard, and act as pace setters to the rest, and from these efficient workmen to find individuals who can act as teachers to the rest of the operatives. Above all, it is essential for the whole of the factory methods to be overhauled to ensure that the highest possible stage of efficiency has been reached in every respect, particularly as regards material supply, factory layout, and production methods.

Time and Motion Study. The successful operation of piece work, or any other system of payment by results, demands as an essential corollary the existence of logical methods of rate setting.

Usually, it will be found necessary to employ specially-trained men for time and motion studies and rate setting. A new man doing this work must act with considerable diplomacy, in view of the effect of his work on the habits and feelings of the workpeople. If, before starting his rate setting and operation studies, he had been engaged on studies in non-controversial fields such as storage and tool supply, the showing of results in this direction would tend to disarm the natural suspicions of the workpeople, and he would have made acquaintances that would stand him in good stead in his later studies.

But apart from the value to a new man of such studies as training, a survey of the general factory methods is a vital auxiliary to time and motion study and to rate setting. It is patently absurd to endeavour to save a few seconds on an operation when the auxiliary and supply functions on which it depends involve delays of hours or minutes, nor is it reasonable to pay an employee on piece-rate basis when there is no machinery to see that the work passes smoothly through the factory from operation to operation.

Scope for Improvement. Usually, the operating officials in a factory are absorbed in routine and have no time to consider new methods, and, due either to a suspicion of change, or to an

inadequate grasp of the production problem as a whole on the part of the management, the average factory presents a surprising showing of opportunities for improvements. Frequently a study of material supply questions will indicate that there is no proper anticipation of wants on the part of the purchasing department. The concern may be pursuing a policy of hand-to-mouth buying on material in constant demand, thus involving high overhead charges for frequent ordering, and incidentally losing the advantages in price obtainable from bulk-ordering. Frequently, even where anticipated impending changes in market prices dictate a policy of hand-to-mouth buying, it will be found that too narrow an interpretation is being placed on the policy, and that the prospective saving is more than offset by hindrances to smooth production.

Storage methods also must be investigated, to see that efficient stock records are maintained, with maximum and minimum limits to prevent unexpected shortages, and to ensure economic ordering. Close attention should be paid to the location and system of identifying parts to ensure that they do not get lost in the store room, and the system of requisition and delivery of material to workmen must be examined with a critical eye.

The plant and equipment of the factory should be overhauled to ascertain whether the most efficient layouts are being used, and the machines kept in good repair and adjusted for the utmost efficiency in operation. In this connexion, arrangements for the supply and inspection of tools, jigs, and auxiliary supplies must also be examined. Finally, the method of production planning should be studied to ensure at least that there is enough scheduling done for another job to be ready for the workman before he has finished the job in hand.

Having examined the plant and equipment, and the general factory methods, the various processes themselves should be studied to see, firstly, whether they are really necessary, and whether satisfactory arrangements are made for the supply of bills of material, assembly diagrams, and route sheets. It must also be appreciated that a degree of standardization must be achieved before any critical study is made of individual processes. The object of such a study is to determine whether the existing method is the most suitable and profitable for the performance of the process. A decision on this score can be reached only after a careful study of the operation itself.

Methods Employed. The usual method employed for the study of operation on a time basis involves first of all the analysis of the operation as a whole into a series of elements. The operation is then watched by an observer, who notes down, over a reasonably long period, the time taken for each element. In examining these figures, attention should be paid to any special circumstances affecting the operation, such as the degree of skill on the part of the operator, and the time of day at which the operation was performed. The various times for the same, or alternative elements of the operation, should then be compared, and improved combinations tested experimentally to see whether they are practicable, or whether apparently useless motion can be eliminated without increasing the time for other elements. Attention should also be paid to the degree of subdivision of work, bearing in mind the fact that the subdivision of work means that skilled and unskilled operations can be separated, and that workmen can obtain greater speed on a simple operation than on one more complex, but that, at the same time, subdivision of work involves more effort in co-ordination, and renders the factory less flexible to deal with changes in demand.

Having obtained actual figures for the time taken for each element of an operation over a reasonable period of time, there are several methods available for the establishment of standard times for the operation as a whole, to be used as a basis for rate setting. In the first case, average times may be worked out for each element and taken as representative standard times. Alternatively, figures may be selected to form an ideal series composed of the shortest recorded time for each element (after eliminating abnormal times) and an overall percentage allowance made to cover inevitable delays due to interruption, and to allow for rest by the operator. Typical percentages employed are 10 per cent on machine time where the operator merely watches and regulates the process, and 30 per cent or more on handling time where the operator is actively engaged in the process.

A more suitable method of establishing normal times as a basis for rate setting is the study of the times taken for each element according to their frequency of occurrence. A chart can be prepared showing the number of times the operation was performed in, say, seven seconds, the number of times in eight seconds, and so on. Such a chart would indicate clearly the mode time, or time usually taken

to perform the operation, which, of course, would be established as the standard time. Incidentally, it should be noted that a wide range of times for the same element indicates that the particular operator is not used to the operation, or has not formed regular habits of work.

Standard Times Book. Although in the initial stages of the introduction of time and motion study it may be necessary, when determining a price, for an individual study to be made for each job, as times goes by it is usually found that a set of records can be built up which reduce to a minimum the need for individual study. The most significant progress along this line has been made in the engineering industry, and a considerable volume of data has been published, comprising the results of previous time studies. Similarly, for most kinds of machine tool work the time for manipulating the machine, and for chucking and removing the piece, is likely to remain constant for each element, provided the size and shape of the piece are within reasonably close limits. The time for making the cut itself is the variable, but often this can be calculated where the feed of the table and the speed of the cutter are known. Thus, tables are available, for instance, by which it is possible to determine the time standard for setting up a milling machine and for milling, say, a hexagon on the end of bolts, screws, or shafts. It is to be expected that more and more data of this kind will be published now that the lead has been given and as individual firms realize the benefits to be obtained from mutual interchange of the results of their studies in this direction.

CHAPTER XI

QUALITY CONTROL

THE objective control of quality is forced on manufacturing enterprise by two separate sets of circumstances. On the one hand, competitive pressure imposes a need for the maintenance of a certain standard of quality of product; on the other, the technical processes of manufacture impose their own requirements of quality that cannot be departed from without prejudicing the general economy of production.

Commercial Quality Standards. Quality has been described as that which makes a thing what it is. The characteristics by which it is judged vary widely. In a food product, for instance, the characteristics by which its quality is measured might be purity, flavour, smell, colour; a radio set would be judged by its tone, selectivity, and finish. Manufacturers have gone to considerable expense to associate their products in the minds of the public with certain standards of quality, and though it is not always practicable to maintain exactly the standard, considerable inspection costs are willingly shouldered to avoid any noticeable departure. The commercial significance of a certain accepted quality standard is illustrated by the fact that many concerns, finding themselves prevented by circumstances arising from the war from maintaining the quality of their branded products at the pre-war level, rather than debase that quality standard, have removed the particular line from the market and replaced it with a substitute under a different name. In some instances, the war-time product was openly advertised as a temporary substitute for the previous brand. In many others, however, the unannounced substitutes gave rise to considerable comment why these previously unheard-of products were obtainable while the "real thing" had vanished from the market.

Technical Quality Standards. Apart from standards of quality commercially associated with certain products, the development of manufacturing technique has introduced a technical need for certain standards of quality. Many industries incorporate the feature of divorcing assembly operations from machining. This means a need for interchangeable parts so that, when assembled, any part taken

at random from any batch may equally well answer the requirement of a correct fit. This automatically introduces a need for rapid and reliable inspection of machined parts to avoid costly hold-ups at later stages. Originally, this type of inspection was confined to the weeding-out of unsuitable parts before they were passed to the assembly operation, but later it was realized that such inspection could also with advantage be of a preventive nature. Obviously, if a particular machine is turning out faulty parts, it is better, if possible, to correct the fault before the complete batch has been run through. Similarly, if the fault can be discovered at an early stage of manufacture, the expense of subsequent abortive operations on that part can be avoided.

It is not the object of inspection to ensure perfection, nor yet fundamentally to obtain the specific measurement of any particular characteristic. Inspection standards must be expressed as permissible variations between upper and lower limits, and the purpose of inspection is to determine whether the product falls within these limits. In the mechanical world it is recognized that not only is perfection unattainable, but it is expensive to approach. An engineering design represents ideal conditions which cannot materialize in actual production. Machine tools, in removing material from the part they are cutting, are themselves reduced in size through loss of material at their cutting faces. True, the differences between subsequent parts may be infinitesimal, but the "growth" of the parts machined cannot be allowed to continue unchecked without re-setting the machine if the parts are required accurate within close limits. Temperature, too, has great influence on the question of accurate machining work. If a machine has been standing overnight, and is re-started when cold, considerable variation may be found between the first parts produced and those turned off the same setting later in the morning when the shop and equipment have warmed up. Furthermore, even the best machine tools can never themselves be perfect; bearings must have some degree of play; moving parts always vibrate; it is impossible to guarantee that the machine is set absolutely level. Finally, there are the imperfections introduced by the human element, and associated with the physical characteristics of the machine operator. All this is apart from imperfections arising from the fact that measurement itself can never reach perfection.

Manufacturing Limits. In consequence, although an engineering design may specify certain basic, or nominal dimensions, economy of production calls for the adoption by the designer of the widest possible tolerances consistent with good technical results. These tolerances represent the allowable variation in size between the limits of the maximum and minimum sizes permissible. These limits, besides taking account of the quality desired, must also take into consideration—

1. The effect of variations in the dimensions of any other mating parts.
2. The effect of wear on the parts after they have been in service.
3. A consideration of the nature of the manufacturing equipment, and the relative difficulty of manufacturing the various parts concerned.
4. The effects of errors accumulated from process to process where a part requires more than one machining operation.

These limits and tolerances may be incorporated on working drawings, and in quantity production may be physically interpreted as “go” and “not go” gauges, thereby reducing inspection measurement to a simple question of yes or no.

Size is not the only physical property of materials that is capable of measurement. Weight, electrical resistance, hardness, elasticity, viscosity, moisture-absorption per unit of time, density, all these, and many others, can, in appropriate circumstances, be established as inspection standards or permissible variations between upper and lower limits. So far as raw materials are concerned, considerable progress has already been made in the establishment of standard specifications. These are now widely used and represent a movement that is likely to go considerably further.

Inspection Duties. The position which the inspection function is to occupy in the organization structure of any particular company will depend on the size of the undertaking and the importance of quality in the product. Where quality is not of prime importance, the inspection force may consist of only a few people responsible to an individual in the organization, just high enough to represent impartial authority. At the other extreme, where quality is of prime importance, the inspection department may comprise a substantial proportion of the total number of employees, and the chief inspector may be found on a level footing with the works manager himself.

Similarly, the duties of the inspector may range all the way up to the stage where they include—

1. Inspection of raw materials and other purchased supplies.
2. Inspection and technical control of all processes as processes.
3. Inspection of actual production in all departments.
4. Inspection and technical control of all tools and equipment, including measuring devices.
5. Certification of volume of output from all manufacturing processes.
6. Supervision of salvage work.

Fundamentally, these amount to the assurance that production facilities can give the desired quality of product, and that these standards are, in fact, maintained in practice. Inspection does not, however, create quality, since, actually, the inspection department does no productive work on the goods. Its function is to weed out sub-standard work, and to draw the attention of the operating executive to the need for corrective action to restore the quality standards.

When and Where to Inspect. The problems of inspection, as distinct from the establishment of inspection standards, are to decide—

1. Where to inspect.
2. When to inspect.
3. How to inspect.
4. How much to inspect.

Thus, inspection may take place at the machines themselves, or in viewing rooms separated from actual production. Floor inspection avoids the cost of transporting materials from production to the inspection cages, and usually enables a quicker inspection service to be provided. Sometimes the product is so bulky that it is impracticable for inspection to be carried out except on the production site. Similarly, if progressive assembly is practised, with subsequent operations linked together by moving belt or other methods of mechanical handling, it is out of the question to run the product off into separate viewing rooms just because a quality check is called for at certain interim stages of assembly. On the other hand, a separate viewing room provides a situation much more conducive to accurate and rapid inspection than that provided by a production station. Inspection conditions are better, the proper instruments

can be provided, and there is less possibility of the inspector being influenced by the worker or the foreman.

The problem of when to inspect is intimately tied up with the nature of the product and the technique of manufacture employed. No general rule can be given about whether inspection should be carried out after each individual operation in the process or only at the final stage of completion. Generally speaking, however, a compromise between the two extremes is called for. It is, for instance, desirable to have an inspection stage before any operation that would conceal any defects not discovered before that stage. Usually it is desirable for inspection to take place where material is transferred from one production department to another, so as to localize the responsibility for any defective work. Another cardinal point in the determination of inspection stages is that the later in the process that a defect is discovered, the more costly becomes the rejection. Obviously, inspection should be placed primarily at the most likely sources of variation and before processes where failure would be costly, either because of the cost of the work about to be done, or because of the possible effect of failures in causing expensive machine breakdowns. Another aspect of this same problem that must be solved with reference to the same principles is whether stage inspection should be carried out only when the whole batch has passed through the process. For example, it is often desirable to have inspection pass the first part off to prove a machine set-up instead of waiting for the whole batch to be run off, while some operations may call for continuous inspection throughout the process. The aim should be to obtain the most effective possible control of quality consistent with a minimum of cost.

Inspection Methods. The modern attitude towards inspection is that the inspection processes should be regarded as an integral part of the cycle of manufacture, and that just as much forethought and planning should be devoted to them as to any of the productive operations themselves. The results of this attitude are reflected in the fact that a remarkable selection of mechanical and automatic inspecting devices is now available to help eliminate the "human element" and generally speed-up and improve inspections. Moreover, the application of the principles of motion study has resulted in the development of inspection techniques that can keep pace with the most rapid production processes.

Except on diversified production, micrometers are almost universally replaced by "go and not go" gauges. There are available indicating gauges that enable relatively unskilled labour to inspect parts to limits that, a few years ago, would have been thought impracticable, and the whole process of inspection has been speeded-up by the wider realization that its function is to answer "yes or no" the question whether the particular part falls within the limits of the inspection standard, and not to provide an absolute measure of dimensional accuracy or any other characteristic.

Sample Inspection. Although modern inspection methods have made it a practical proposition to carry out 100 per cent inspection, it is not always an economic proposition to go to this expense. This applies particularly to machine production where a very high degree of accuracy is not vitally important, or where the quality of production is controlled more by the machine than by the operator. Thus, the output from an automatic screw machine is more likely to be of a consistent quality than is the product from a hand-operated centre lathe. In these cases it is often justifiable to reduce the cost and amount of inspection by selecting a few parts at random from any particular batch and to consider them as representative of the quality of the whole batch.

It will be obvious that with any plan of sample inspection some defects will be passed that would not have got through a thorough 100 per cent inspection. Generally speaking, however, sample inspection schemes do not give due weight to the significance of this feature. It is recognized that, so far as possible, the samples to be inspected must be selected at random, so as to be representative of the batch, but usually the size of the sample selected is based purely on past judgment and experience. There is, however, no need for sample inspection to be so haphazard as this, and considerable progress has been made by a few leading firms specializing on automatic machine production, towards establishing by statistical methods the correct size sample to inspect, consistent with certain degrees of risk of passing inferior work. There is already available considerable literature dealing with this application of the laws of probability, and any detailed discussion of this aspect is outside the scope of this work.

Statistical Control of Quality. Apart from this use of statistical methods to associate a scale of probability with the sensitivity of a

sampling procedure, in certain classes of industry striking progress is being made in the development of statistical techniques for the control of quality, as distinct from the mere measurement of quality.

It has already been indicated that perfection is unattainable in repetition work, and that there will always be inherent variations in measurable characteristics. The fact that such variability must exist is conceded in the establishment of tolerances separating the upper and lower limits within which a product will be regarded as satisfactory from the technical viewpoint. These limits are not controlled directly by the variability of the process so much as by the demands imposed by the use of the part. The concept of statistical quality control, however, is fundamentally one of establishing a different set of *control limits* for the process determining the range in which variability is likely to occur if this variability is arising only from chance causes inherent in the process itself and the equipment on which it is performed. It is argued that if the actual degree of variability experienced is kept under observation, with particular reference to these new control limits, the earliest possible warning will be obtained of any new source of variation calling for preventive action, and that this warning will enable corrective action to be taken before the new cause of variation has had time to develop to any extent.

Towards this end special control charts, similar to that illustrated in Fig. 49, are used to provide a continuous record of the quality of the product while production is going on. These control charts are established by adopting a tentative standard level of control for use in future operations (usually on the basis of past experience) and setting control limits above and below the standard level. These control limits are determined with reference to the number of observations to be taken each time the product is sampled, in such a way that variations due to chance causes inherent in the process itself should fall within the two limits. The values obtained from inspecting the samples are then plotted on the chart as soon as they are obtained, and immediately a plotted point falls outside the two control limits it is regarded as an indication of the presence of a disturbing cause other than purely chance variation. Immediate action is therefore taken to identify, and if possible eliminate, the disturbing feature. As time goes on, quality is brought nearer and nearer to a state of control through a repetition of this procedure and

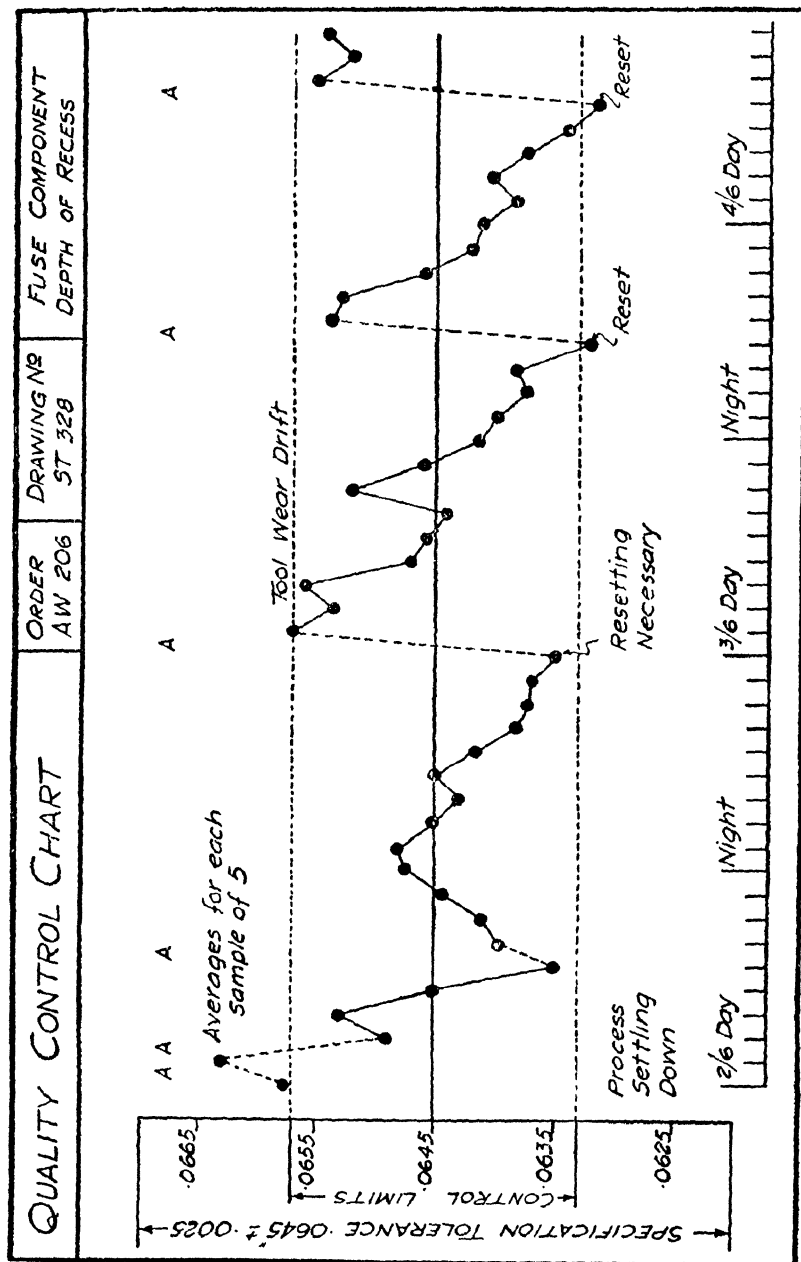


FIG. 49. STATISTICAL QUALITY CONTROL CHART

through the steps taken to prevent recurrences of trouble, and the control limits themselves are revised in the light of the fresh data required.

The reader who is interested in the subject of statistical control of quality, and requires further information on the underlying principles, may with advantage be referred to *Quality Control in Production*, by H. Rissik,¹ and publication 660 R of the British Standards Institution—*Quality Control Charts*, by B. P. Dudding and W. J. Jennett. This publication is a revision of the original B.S. 600, by E. S. Pearson, which deals comprehensively with the application of statistical methods to industrial standardization and quality control.

Quality control has also been actively sponsored by the Ministry of Supply, who have set up an advisory service on Statistical Method and Quality Control to encourage and advise on the use of statistical methods of inspection. The accumulated knowledge and experience gained by this branch of the Ministry in the direct introduction of quality control in engineering firms has now been made available to the general public in a publication, *A First Guide to Quality Control for Engineers*. This handbook has been compiled by Dr. E. H. Sealy, of the Ministry, and ably meets its object of providing a downright working guide for the man who, having decided that quality control is worth trying, wants to experiment with it on his own shop floor.

These statistical methods of quality control can be of enormous value if correctly applied in circumstances suited to their use. Unfortunately, however, the system has been rather "oversold," and dressed up with an easy optimism suggesting that it is all very simple and can be applied without knowing very much about it. True, the actual recordings can be made by semi-skilled patrol viewers, provided there is one individual behind the system familiar with the concept of likelihood of occurrence associated with statistical probability. But this frame of mind easily leads to the collection of a large volume of records, the bulk of which are probably obsolete before they are filed. There are many situations in machine shop practice where, apart from any question of statistical control of quality, the practice of patrol inspection while a job is in process offers advantages over inspection after the run has been completed. Great care should be taken not to confuse these advantages with those to be obtained directly from the new concept.

¹ Pitman (*in the Press*).

The proponents of quality control argue that the statistical technique will change the rôle of inspection from that of detective to constable, and will bring about a situation where this causes the inspector to be judged, not by the amount of material he rejects, but by the amount of help he gives the production engineer to maintain rejections at a low level. In practice, however, this objective can be reached without the aid of statistical quality control.

Only when the possibilities in this direction have been explored can a realistic approach be made to the question of statistical quality control. Such an investigation would show, for instance, that where products are constantly changing, the operating cost of establishing and maintaining quality control records can rarely be justified by the economics of the advantages to be expected. Seldom, in such circumstances, can the records be of assistance in future orders, where a change of design usually renders previous dimensions obsolete, and an equivalent service can be given by a co-operative patrol inspection.

On the other hand, undoubtedly, where a concern has a large volume of repetition work, or long runs of particular products, statistical quality control offers the possibility of rewards far outweighing the costs of the system. In these circumstances, actual experience with the system has already shown reductions in scrap, rectifiable rejects, and even the amount of final inspection, sufficient to repay many times the increased overhead cost involved.

CHAPTER XII

COSTS AND GENERAL CONTROL

It is only comparatively recently that industrial management has come to realize that the use of costing should not be confined to price fixing but rather to the provision of data which will direct attention to where inefficiencies are occurring, and so assist in the more effective operation of a productive unit. Fundamentally, prices are determined by the interplay of supply and demand, and should be established as the result of research into market conditions. The purpose of costing should be to indicate the extent to which the particular concern finds itself out of line with the general competitive set-up, and to indicate the direction to be followed by any corrective action that may be necessary. In the absence of adequate information on market conditions, costs can legitimately be used in practice to regulate selling prices. But this does not, or should not, mean a simple, straightforward process of arithmetic.

Costing Aims. The significance of the costing angle in business administration varies widely in individual circumstances, but in broad terms its aims may be said to be—

1. The regulation of selling prices—so far as the conditions of supply and demand permit.
2. The introduction in the framing of estimates and tenders of a sufficient degree of accuracy to avoid losses from unduly low quotations, or lost business from unnecessarily high quotations.
3. The establishment of which branches or groups of products do, or do not pay, and whether any article is costing more to produce than it would cost to buy.
4. The establishment of standards against which actual results can be compared to indicate waste of material and inefficient workmanship and management.
5. The determination of the degree of importance of each element of cost, or stage of process, with particular reference to the scope for economy.

The Practice of Costing. Usually the normal accounts of any concern reveal in total the revenue that has been earned in deliveries to customers, and the total costs that have been involved in the

provision of labour, materials, and service, to achieve those results. As a general rule they do not, however, indicate the relative profitability of individual lines, and costing methods in use have commonly grown out of the desire to establish whether any particular product is being made at a profit or at a loss. This involves a process of recording and analysing actual costs incurred.

In most instances it will be desired to establish these costs on the basis of individual shop orders, but in certain circumstances, where, for example, flow production of a standard product is carried out, it may be desirable to focus attention on the costs of carrying out individual operations. But whether the situation calls for job order costs, process costs, or some modification of these two types, the fundamental principle remains the same.

Allocation of Overheads. It has already been indicated in the earlier chapters that it is usual for shop stationery to be provided that will enable all issues of materials direct to production to be associated (usually through works order numbers quoted on material requisitions) directly with certain products or processes. Similarly, arrangements are made to enable direct labour to be analysed in a like manner (usually through works tickets). The materials and labour directly employed in the manufacture of any product do not usually, however, account for more than two-thirds of the total costs of running a business, and frequently do not amount to as much as 50 per cent of the total. The problem naturally arises, how to divide up the remainder of the costs and expenses product by product, or process by process, so as to arrive at an accurate figure for total costs.

The combination of the direct material used in the manufacture of a product and the labour employed directly in fabrication is commonly known as prime cost. The remaining expenses are variously referred to as overheads, burden, or expense, and comprise all items of expense pertaining to the running of the business, other than the wages and material directly chargeable to productive work, viz.—

1. Indirect or general non-productive labour (not directly employed on a particular process or product.)
2. Indirect or general expense materials not directly associated with specific products or orders.
3. Other general expenses.

The combination of these three may conveniently be regrouped into—

- (a) Factory expenses
- (b) General expenses
- (c) Administration expenses
- (d) Selling expenses

giving a step-by-step build-up from prime cost to total cost as shown in Fig. 50.

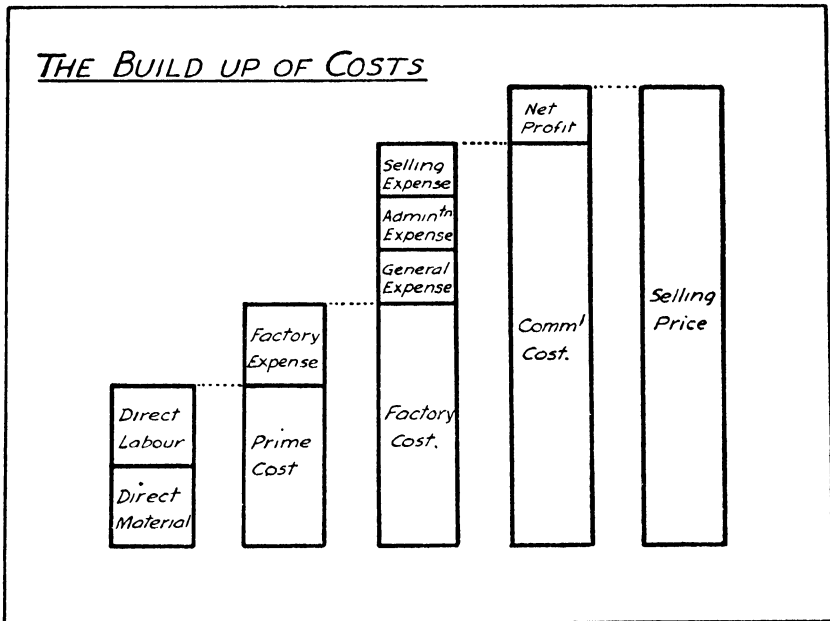


FIG. 50. COST BUILD-UP

It should be realized that up to the present stage of discussion the problem of distribution of overhead expense is being treated from the purely historical point of view. The position is taken as being one where it has been established that for a specific period of time an established grand total expense has been incurred in doing a certain grand total of business, and it is required to find some basis for the allocation of this expense between individual shop orders or processes. The simplest and most convenient method that suggests itself is to express the amount of burden to be distributed as a percentage relationship to the amount of direct labour

charged to production. Where there is reasonable uniformity between processes and labour costs this method is the most practical and most accurate available, but in practice this method is often used in circumstances that do not justify its application.

The question of the method, or combination of methods, to be used for distributing burden is vital if really accurate costs are to be obtained; it is also one to which no universal answer can be given that will satisfy the requirements of all factories. Fortunately, however, it can be answered by the application of common sense to the specific problems of the particular concern. Fundamentally, the system must give the nearest possible approach to an accurate representation of the true state of affairs, without involving in itself an unjustifiable expenditure on clerical costs out of proportion to the value of the information obtained.

Blanket Rate Recovery. The implications of the adoption of a blanket rate of overhead expense based on direct labour costs are that an article which costs 10s. in direct labour to produce would carry double the overheads of an article that costs 5s. Included in this overhead figure might be all the costs incurred in running the business. The costs of receiving, handling, and storing materials, for instance, are included, and in certain circumstances, ten shillings' worth of labour spent in fabricating one ounce of brass may be carrying just the same charge for these elements as ten shillings' worth of labour spent in cutting and welding half a ton of structural steel. To overcome this difficulty, some concerns remove from their total overhead figure those expenses which are more directly associable with material costs than with labour costs, and use two separate blanket rates to absorb burden, one as a percentage on labour, the other as a percentage on material.

Following a similar line of argument, general administrative overhead is often separated from factory overhead for separate application. In this way a factory cost figure is arrived at by combining material and labour costs with factory expense (say on a direct labour basis) and then allocating general expense on the basis of this total factory cost figure.

Overhead as Service Charge. Another school of thought on distributing burden centres round the conception of overhead expense as a service charge to be covered on an hourly basis. In such a system an hourly overhead rate is used instead of a percentage

to labour costs, sometimes as a blanket rate for the factory as a whole, and sometimes as a separate departmental rate for different shops. This mental attitude towards overhead expense automatically introduces the question whether overhead distribution can properly be considered on a purely historical basis. Is overhead expense to be considered on the basis that certain expenditure was involved in doing a certain amount of business? Or is the attitude to be that certain expenses are normally incurred to make it possible to do a certain normal amount of business? Modern cost accounting methods are tending strongly towards the direction that overhead expense should properly be regarded as a cost of preparedness to do business. Total annual burden and annual production are adjusted up or down to arrive at a theoretical normal. In this way, fluctuations in business activity reflect themselves, not in fluctuating costs, but in surpluses or deficits in the recovery of overhead expense. Profits and losses arising from volume activity are thus divorced from costs for separate consideration. In this connexion, the establishment of the "theoretical normal" is often a moot point. Is the normal the maximum potential capacity allowing only for ordinary operating interruptions? Or is it the maximum probable capacity, allowing for the general experience of a certain proportion of unused capacity due to insufficient sales demand. Is a normal to be established individually for each department; is some arbitrary level to be selected for the business as a whole; or is normal capacity for each separate department to be established with reference to the normal capacity of related departments? In certain circumstances the establishment of the theoretical normal may justifiably constitute one of the most scientific and delicate tasks of cost accounting, and the results achieved may more than repay the expenses involved. In other circumstances it may amount to little more than a question of playing with figures for the cost accountant's personal satisfaction.

Machine-hour Rates. Usually, the tangible expression of this attitude towards overheads is the establishment of machine-hour rates, or operational man-hour rates, for overhead costing. Such rates represent a recognition of the great differences in type and cost of equipment in the various departments in any factory, and an appreciation of the fact that certain operations are inherently more expensive to provide for than are others.

In some instances a calculation is made for each machine (or group of similar machines) in the factory, of—

- (a) The hours that machine will normally be engaged in a year.
- (b) The expenses that may properly be allocated to that machine.

The result may be expressed as an inclusive hourly rate, covering direct labour and overheads; as an exclusive burden rate, not covering direct labour, but including all items of factory expense; or as a supplementary rate to be used in conjunction with certain blanket rates to arrive at a total. Initially, the common practice was for the establishment of machine-hour rates covering all elements of factory expense, but this practice should not blindly be adopted without careful consideration. There are many cases where it would be highly desirable to operate supplementary machine-hour rates, including the supply of power for the machine, normal repair and maintenance charges, depreciation of the particular machine, interest on capital investment (where interest is considered an element of cost). These expenses are directly applicable to the particular machine and should be charged to product cost on the basis of the extent to which the facilities incorporated in the machine are employed in the production of the product. There are a few more isolated examples where the rent of the floor space occupied may with advantage be incorporated in the machine-hour rate. But before elaborate calculations are put in hand to incorporate the remaining elements of factory cost in the rate, some evidence should be demanded of the advantages that will be obtained as distinct from the use of a blanket or departmental rate to cover these particular elements of cost.

Predictive Costs. It will be appreciated that one of the results of allocating overheads on the basis of a certain normal volume of business is that the expense charged to production in a particular period will not necessarily agree with the total of actual expenditure. In a busy period, increased activity will result in a surplus recovery of overheads; a slack period would mean a deficit in the account. The significance of this state of affairs is that costs are not allowed to be influenced by considerations of abnormalities in the volume of activity. The profit or loss from high capacity sales, or subnormal activity, are removed from the calculation and thrown into relief for separate consideration. Cost information is of practical value only in so far that it offers an indication of what may be expected

in the future and in so far that it draws attention to any unsatisfactory elements in the cost situation that may call for remedial action. Each time a manufacturer quotes a price for future business on the basis of past costs he is virtually taking a gamble that the particular cost figure can be achieved again in the future.

The gradual realization of this fact has led to a movement away from the old-fashioned, retrospective approach to cost accounting towards the basis of predetermined costs, or, to use the more commonly employed description, standard costs. Primarily, standard cost methods are intended to meet the demand for predictive costs, and were developed as the outcome of criticisms of retrospective cost methods. To be successful, they must be associated with the standardization of product design, operating policies, and production and clerical routines. In effect, you cannot have a standard cost system until you have standards.

Cost Standards. In the earlier chapters, explanations have been given of the engineering work involved in preparation for production of a particular product. Usually, this engineering analysis determines a standard quantity of material to be incorporated in the manufacture of the article. The standard may be expressed on a raw material list, a part sheet, part drawing, standard layout chart, or similar compilation of technical data. The cost accountant's concern is to establish a standard price which can be associated with this standard of quantity to obtain a material cost standard. Generally this involves the establishment of price standards for all raw materials at an estimated normal level.

In a similar way, labour cost standards are also products of two factors, time standards and rate standards. The determination of the time factor is an engineering function. At one extreme, expert time and motion study engineers may be employed for this purpose. At the opposite extreme, time standards may be based on an analysis of records of past performance. The question of rate standards will be governed mainly by the type of wage payment plan that is employed.

An indication has already been given of the methods followed for the establishment of overhead standards. Virtually, these amount to the compilation for each production centre of a schedule of normal expenses for a normal year of activity. This gives the required information for the incorporation of standard overheads

in standard costs on whatever basis is employed for expense allocation.

Control through Standards. So far, the discussion has been confined to the mechanics of the establishment of costs standards. It must be appreciated, however, that standard costing is much more than a question of arithmetical refinement in costing. Although this practice satisfies the requirements of predictive cost, it also provides historical records of considerable practical value in assisting the management of an enterprise. The established standards provide a uniform base against which actual results may be compared to provide pointers to any necessity for corrective action. The full advantages that have been recognized in practice to follow from the adoption of standard costs include the following—

1. They stimulate efforts towards the standardization of products, methods, and processes.
2. They focus attention on variations from established standards of cost and of expense, and provide a means for the analysis of such variations as to causes.
3. By simplifying procedure they reduce the cost of operation of the costing system itself, and provide information with greater promptness.
4. By eliminating extraneous circumstances they provide common units of comparison for costs. This facilitates the determination of the rate and direction of cost trends, and offers a more stable and accurate basis for establishing selling prices.
5. They provide objectives for all branches of the business and facilitate more effective control by concentrating on exceptions from standards.

From the control point of view, the essential feature of a standard cost system is the establishment of standards against which actual results can be compared. The actual cost of providing raw materials can be compared against standard prices to establish the profit or loss in actual purchasing. Actual figures for raw material consumption against standard quantities will point to any shop waste in excess of that planned, and similar lessons can be learned from the economy of direct labour usage. The major benefits in this direction from standard costs, however, lie in the improved control of overhead expenses.

Expense Control. The preparation of a schedule of normal overhead expenses amounts, in fact, to the initiation of budget control

of overhead cost. In the broadest sense, there is no basic difference between standard costs and budgets. The overhead expense schedule can be broken down into convenient groups for control purposes and actual expenses, period by period, can be compared with the appropriate portion of the total for, say, the year. So long as activity is round about normal, this provides a reliable yardstick, and departures from the standard can be taken as indications of the necessity for corrective action. Trouble is experienced, however, when the volume of activity does depart appreciably from the normal standard, and in these circumstances the yardstick needs correction to allow the proper comparisons to be made. This trouble arises from the fact that the individual items of overhead expense do not all fluctuate directly in proportion to changes in the volume of activity.

Flexible Standards. Overhead expense may properly be regarded as comprising one group of items that remain constant with changes in the level of activity; another that fluctuates directly and proportionately with changes in activity; and a third that will increase with increases in activity, but not at the same rate. The significance of this is that if a certain expense standard has been established on the basis of a given normal volume of activity, then changes in the volume of activity will call for the establishment of a different standard of comparison. For instance, if business increases by 25 per cent, then it is logical to expect expenses to increase, but not by as much as 25 per cent. Similarly, a reduction in activity would not be accompanied by a corresponding percentage reduction in overheads, owing to the inclusion of certain fixed elements that do not fluctuate with activity. From a proper consideration of the characteristics of the various elements of expense it is possible to establish a system of flexible standards that enables the proper comparisons to be made for any volume of activity. To avoid any confusion, however, it should be clearly understood that the purpose behind the establishment of these flexible standards is purely one of expense control, and not one of cost adjustment. Overhead is charged to sales on the basis of the normal standard, and if business volume departs from normal there is a corresponding over- or under-recovery of expense. The flexible standard enables a true assessment to be reached of how far this over- or under-recovery is the result to be expected from purely volume considerations, and how far it may be

due to inefficiency in operating most economically at the actual volume experienced.

Budgetary Control. It will be appreciated that these comparisons of actual results against standards may often amount to a matter of shutting the stable door after the horse has gone. The determination of operating variances from standards certainly focuses attention upon causes of business losses, such as use of unnecessarily expensive material; labour inefficiency; illegitimate use of highly rated labour; poor workmanship; purchasing at the wrong time, or at the wrong price; excessive departmental expenditure; and insufficient sales volume. But in all cases the information is brought to light for remedial action some time after the trouble has occurred, and the necessity for promptness of action may not always allow the necessary consideration to be given to the fullest implications of the steps taken.

Standard costs are of considerable assistance to business management, but experience indicates that, if optimum results are to be achieved, their incorporation should be associated with a system of budgetary control. The budget idea in business implies the thought of forecasting the future and laying co-ordinated plans for the business that will yield the best possible results in view of the impending situation. Essentially, it is a question of foresight as distinct from wisdom after the event. Budgetary control involves setting up the vital figures of business in anticipation of future operations and establishing a co-ordinated plan of action in advance. The budget represents a goal for all branches of the business and provides a method of control that permits remedial action before it is too late. Budgetary control is not a substitute for management, but undoubtedly it is one of the most valuable management tools ever developed.

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