THE BOOK WAS DRENCHED

PAGES MISSING WITHIN THE BOOK ONLY

UNIVERSAL
LIBRARY

OU_160369

UNIVERSAL
LIBRARY

OSMANIA UNIVERSITY LIBRARY

Call No. 338 W25T Accession No. 22625

Author Ward, C. A

Title Those raw materials 1941

This book should be returned on or before the date last marked below

THOSE RAW MATERIALS

THOSE
RAW MATERIALS

An Introduction
to the
Study of Raw Materials

by
C. A. WARD, A.M.I.E.E.

LONDON
George Allen & Unwin Ltd
1941

ALL RIGHTS RESERVED

PRINTED IN GREAT BRITAIN
in 12-Point Baskerville Type
BY UNWIN BROTHERS LIMITED
WOKING

Dedicated to E. D.

PREFACE

THIS book is the outcome of a study extending over a period of some five to six years. It is concerned in the first place with the preparation and uses of raw materials. A further section deals with the occurrence of the latter, with special reference to minerals, and also includes a brief review of the world production of coal and petroleum in the years immediately preceding the War.

Formerly, a work of this description might well have been regarded as only of interest to the purely technical public, but such no longer applies in these days where there is a constantly growing demand, on the part of a far wider section of the population, for general knowledge, and an increasing desire to fathom the mysteries of industry.

That there is such a thirst for general knowledge has been acknowledged not only by publishers of cheap serial works covering technical and economic subjects, but also by our great newspapers. Two notable instances that may be mentioned in this connection are the Supplements on Gold and Silver, published by *The Times* some years ago, which dealt in a most comprehensive way both with the economic questions connected with these metals and with the technical problems relating to their production.[1]

The primary object I have had in view, in preparing this book, has been to give a general outline of the subject of raw materials, that might serve as a background for a more detailed study of the question. For this reason, I have confined myself,

[1] See Bibliography.

in a large measure, to general considerations and have endeavoured to bring into relief fundamentals such as factors governing the use of the materials and principles underlying the preparatory treatments.

For a more detailed study of individual raw materials, an extensive and varied literature is available. The latter ranges from short monographs, to monumental works such as *The Science of Petroleum*, with its four volumes containing contributions on every aspect of the subject, by authorities on the particular question, or reference works of a more specialised nature, such as the exhaustive survey dealing with the properties of rubber (*Rubber—Its Physical and Chemical Properties*), published by the Research Association of the British Rubber Manufacturers. A selected list from the literature of raw materials is given in the Bibliography.

Even a cursory review of a subject so vast as that of raw materials is a rather formidable task, which I could not have achieved without the assistance of the many who have given me the advantage of their advice and expert knowledge. I am specially indebted to the producers of raw materials who have afforded me the opportunity of visiting their plant, and to the manufacturers who have furnished me with information regarding the preparation of their particular materials. I also wish to acknowledge the help I have received from the Development Associations connected with the various raw material industries, from officials of Dominion and Colonial Departments, and from academical institutions. Lastly, I have to express my indebtedness to the Imperial Institute—that great centre of information on all matters relating to the raw materials of the Empire—for the assistance given to me, through

answering my many queries, during the past few years.

In conclusion, I would just say that if this book can give to the reader, be it only a mere fraction of the interest I have derived in working on it, I shall feel well rewarded for my labours. At the same time, it is my earnest hope that this short survey may prove a useful contribution, modest as it may be, towards what Lord Stamp has called the mobilisation of knowledge, and be thereby of some service to the country.

C. A. WARD

LONDON
January 1941

CONTENTS

Chapter — Page

Preface 9

PART ONE

RAW MATERIALS AND THEIR USES

I. Introductory 19

II. On Coal, Petroleum and Metals 23
- Coal and Petroleum
- Ferrous Metals and their Alloys
- Non-Ferrous Metals—I
- Non-Ferrous Metals—II

III. More about Metals 41
- Alloys of Non-Ferrous Metals—I
- Alloys of Non-Ferrous Metals—II
- Alloys of Non-Ferrous Metals—III
- Noble Metals

IV. Raw Materials of the Builder and the Potter 57
- Stone and Clay
- Ceramic Materials and Products
- Glass

V. Range of Products of the Chemical Industries 69
- Chemical Products and Chemical Elements
- Inorganic Chemical Compounds
- Organic Chemical Compounds

VI. Some Special Fields of Application of Chemical Products 86
- Dyestuffs and Explosives
- Synthetic Materials—I
- Synthetic Materials—II

Chapter Page

VII. Raw Materials of the Textile Industries and of the Leather Trade 99
Fibres—I
Fibres—II
Hides and Skins

VIII. A few other fundamental Raw Materials of Vegetable and Animal Origin 112
Rubber and Resins
Vegetable and Animal Fats and Oils—I
Vegetable and Animal Fats and Oils—II

IX. The Raw Material with the most varied Uses 129
Timber
Wood Pulp and Paper—I
Wood Pulp and Paper—II

PART TWO

OCCURRENCE OF RAW MATERIALS

With Special Notes on Coal and Petroleum

I. Nature of Raw Materials 145

II. Mineral Deposits and Methods of Extraction 150
Occurrence of Ores
Working of Stratified Mineral Deposits
Working of Ore Bodies and other Unstratified Mineral Deposits

III. Coalfields and Oilfields 162
Origin and Formation of Coal and Petroleum
Geological and Geographical Distribution of Coal and Petroleum

IV. The Production of Coal and Petroleum 172
World's Coal Supplies
World's Petroleum Supplies—I
World's Petroleum Supplies—II

PART THREE

PREPARATION OF RAW MATERIALS

Chapter		Page
I.	Scope of Preparation of Raw Materials	193
II.	Preparatory Operations applicable to Minerals in general	198
	Mechanical Preparation of Minerals	
	Hand-sorting and Washing	
	Crushing—I	
	Crushing—II	
	Screening	
III.	Processes associated with the Preparation of Ores prior to Metallurgical Treatment	216
	Classification	
	Concentration of Ores	
	Flotation and Magnetic Separation	
	De-watering	
IV.	Metallurgical Treatments as applied in the final Preparation of Metals	234
	Hydro-metallurgy	
	Roasting	
	Smelting	
V.	Metallurgical Treatments as applied in the final Preparation of Metals (concluded)	245
	Fire-refining—I	
	Fire-refining—II	
	Fire-refining—III	
	Electro-metallurgy	
VI.	From Crude Petroleum to Refined Oil Products	261
	Principal Mineral Oil Products and their Preparation—I	
	Principal Mineral Oil Products and their Preparation—II	
	Refining of Mineral Oil Products—I	
	Refining of Mineral Oil Products—II	

Chapter — Page

VII. Treatment of Coal for the Preparation of Coal Derivatives and Oil 276
- Coal Carbonisation—I
- Coal Carbonisation—II
- Coal Hydrogenation

VIII. About Fibres and their Preparation 288
- Natural Fibres and their Preparation—I
- Natural Fibres and their Preparation—II
- Natural Fibres and their Preparation—III

IX. Special Preparatory Treatment required by the individual types of Fibre 301
- Wool—I
- Wool—II
- Cotton
- Silk

X. Special Preparatory Treatment required by the individual types of Fibre (concluded) 319
- Stem Fibres—I
- Stem Fibres—II
- Leaf Fibres
- Mineral Fibres with special reference to Asbestos Fibre

XI. Preparing the Raw Materials of the Leather Trade 334
- Hides and Skins—I
- Hides and Skins—II

XII. A few other basic Raw Materials and their Preparation 343
- Rubber and Resins
- Vegetable and Animal Oils and Fats
- Wood

Bibliography 357

Indexes 367

PART ONE

RAW MATERIALS AND THEIR USES

CHAPTER I

Introductory

Products and more products

From mines, quarries, farms and plantations, the raw materials continuously flow to the mills, factories, works and building yards of the vast machine of production. From there, they emerge again converted into products of countless shapes—some doomed to finish sooner or later on the scrap heap, once their period of usefulness is completed, others destined to endure as permanent records of the labours and activities of mankind.

Products and more products. Such seems to be the urge of modern civilisation. Every year ushers in some new article, some new device, some new appliance or some new constructional achievement. From year to year the process continues, so much so that it is no longer possible to keep count of these creations of man's inventive genius and ingenuity.

Essential needs and non-essential requirements

Yet, every single article is intended to meet some human need or desire. What are these multitudinous wants of humanity? They come under two categories: essential needs and non-essential requirements. The line of demarcation between the two is, however, constantly shifting. The luxuries of one age become the necessities of the following. The results of labour, researches and inventions of one generation are taken as a matter of course by the next generation, and industry hastens to make them available to all.

There are, nevertheless, certain fundamental wants, imposed by nature for the preservation of mankind, that have always existed and would subsist even if some cataclysm were to wipe out the whole of our civilisation; these are food, articles of wear, shelter, tools for shaping materials, and weapons.

Under primitive conditions of life, where man has to be entirely self-sufficient, the individual himself has to attend to all these wants. Under the present order of things, however, tools and weapons no longer come within the scope of the needs of the private individual: manufacturing is done for him by industry, and defence is the province of the State. Thus, the need for tools has been transferred to industry, and that for weapons, to the State: tools have become the manufacturing equipments, and weapons, the vast national armaments of to-day.

Industries providing for the primary needs of mankind

The branch of industry that is mainly responsible for the supply of manufacturing equipments and armaments is the engineering industry. The latter thus holds a key position in our modern world. As regards the needs of the individual, they are catered for by whole groups of manufacturing industries, each sharing to some degree in the task of satisfying the particular want.

In the case of foodstuff,[1] the group consists of the ten or more different trades responsible for the supply of such products as bread and cakes, biscuits, cocoa and sugar confectionery, preserved food, bacon and sausages, etc. Closely allied to the food trade is the drink trade with its branches covering brewing and malting, spirit distilling, spirit recti-

[1] Only manufactured products are referred to here.

fying, etc. Another trade that is somewhat akin to these is the tobacco trade.

The articles of wear necessary for men and women under our civilised conditions are supplied by a group comprising the tailoring, dressmaking and millinery trades, the hosiery trade, the boot and shoe trade, the hat and cap trade, the glove trade, the fur trade and certain minor trades.

Housing needs are met by the building trade, while the other home requirements are satisfied by such trades as the furnishing and upholstery trades, the hollow-ware trade, the cutlery trade, the china and earthenware trade and the glass trade, for instance.

Other industries catering for human wants

To these primary wants must be added the needs that have arisen with civilisation. Reading and writing requirements come under this category. These needs have led to the growth of such trades as the paper and board trade, the printing, book-binding and engraving trades, the publishing trade, the manufactured stationery trade, the ink and gum trade, and the pen and pencil trade.

Other trades that have likewise developed in the course of time are the watch and clock trade, the soap, candle and perfumery trades, the sport requisites trade, and the games and toys trades, while luxury trades are represented by the jewellery trade, in particular.

Then, there are the industries whose purpose is to supply heating and lighting, and those providing the means of transport. In the latter field, the carriage, cart and wagon industry, and the ship-building industry have been supplemented by the locomotive industry, the motor vehicle and cycle

industries, and the aircraft industry. The two principal representatives of the heating and lighting group are the gas and the electric supply industries; the match industry also belongs to this group.

Finally, it is necessary to include in the enumeration public works contractors, who build roads, erect bridges, construct docks, etc., and departments of public services that deal with the construction of railways, telegraph lines, water supply systems, etc.

Industries yielding the raw materials

The raw materials required by all these manufacturing and constructional industries and trades reach the latter through definite channels. Thus, the foodstuff manufacturing trades, for instance, receive their raw materials through the milling industry, the sugar industry, the cocoa industry, the meat industry, etc. As regards the other manufacturing industries, their main channels of supply are the coal and carbonisation industries, the petroleum industry, the iron and steel industry, the non-ferrous metal industries, the stone industry, the clay industries, the chemical industries, the textile industries, the leather industry, the rubber and resin industries, the seed and oil industry, and the timber industry.

In the following chapters, it is proposed to consider successively the raw materials yielded by each of these individual industries or group of industries, and to describe briefly their principal uses. Foodstuffs will be left out of this survey, so that the first materials to be dealt with will be those supplied by the coal, petroleum and metal industries.

CHAPTER II

On Coal, Petroleum and Metals

Coal and Petroleum

Importance of coal

Coal surpasses all other raw materials in importance, owing to its varied uses. By carbonisation,[1] it yields a large number of valuable products; by combustion, it generates heat. In the latter field of application, it holds the foremost place, due to its high calorific power[2] and relative cheapness.

Coal as source of energy

As heat represents energy, coal is at the same time one of the principal sources of energy. Energy in the form of heat is converted into mechanical power through the intermediary of steam, the first stage of the conversion being the generation of steam under pressure in the boiler, and the second stage, the expansion of the steam in the engine or turbine. In industry, the mechanical power supplied by engine or turbine is usually further transformed into electric energy in an electric generator, for the purpose of distribution. With modern boiler and turbine plant, heat can be converted into motive power on an enormous scale. The only other natural form of energy that lends itself to utilisation on such a scale is water power.

Although fuel oil, Diesel oil and petrol also play

[1] Carbonisation is a distillation process.

[2] The calorific power of a fuel is a quantity representing the heat evolved by the combustion of a unit of fuel.

a very important part as sources of energy in their particular fields of application, it is upon coal that industry as a whole has to rely for the bulk of its motive power, in the absence of hydraulic resources.

Coal in metallurgy

In blast furnaces, coal provides the heat for smelting. In the case of this application, coal is previously converted into coke by distillation (carbonisation) at a high temperature. The coke is introduced together with the iron ore and limestone into the blast furnace, the air required for the combustion being supplied through tuyeres at the base.

Coal as source of supply of chemical products

By carbonisation, coal is separated into various gaseous, liquid and solid products. The nature of these products and the proportion in which they occur depends upon the temperature of the process. Thus, with so-called low temperature carbonisation, the final solid residue is semi-coke, while with high temperature carbonisation, it is coke; semi-coke is a smokeless fuel used for domestic purposes.

The principal liquid products are tar, ammonia and benzol. Tar provides the basic substances from which synthetic dyes are derived; it also yields creosote, carbolic acid and pitch, the latter being the final residue of distillation. Ammonia is largely converted into sulphate of ammonia, which is a fertiliser. Benzol serves for the production of motor spirit.

The coal gas resulting from the carbonisation process is a mixture of gases and volatilised liquids. The principal gases entering into its composition are methane and hydrogen. Coal gas is used as an

industrial fuel and, in a purified form, for domestic purposes (town gas).

Petroleum products

Petroleum (mineral oil), like coal, is a composite substance from which a great variety of products can be derived. The most important of these products are gasoline, fuel oils and lubricating oils. Gasoline represents the lightest fraction of the crude oil; it is the principal motor fuel. Fuel oil is an oil capable of being burnt, but free from volatile constituents. The oils used as fuel oils are mainly residual oils;[1] this also applies to Diesel fuel oils. In the latter case, however, the residual oils have to be carefully selected to meet the requirements of Diesel engines. Heavy crude oils may themselves be marketed as fuel oils, when unsuitable for any other purpose. It is only for higher grade products such as domestic fuel oils and Diesel fuel oils for aeroplanes, that distillate oils are utilised.

Lubricating oils cover a large group of products ranging from light motor oils to heavy cylinder oils. Other petroleum products include kerosene, paraffin wax, petroleum jelly[2] and asphalt. All these are materials contributed by the petroleum industry.

Ferrous Metals and their Alloys

Iron and steel industry as channel of supply of raw materials

The raw materials that enter the machine of production through the iron and steel industry

[1] Residual oil is the product left over after the removal of the lighter fractions of the crude oil.

[2] A well-known brand of petroleum jelly is the product sold under the name of "vaseline," this designation being an abbreviation for "vaseline" petroleum jelly.

comprise on the one hand iron, and on the other hand the various alloying elements that are used for giving particular qualities to this metal. These alloying elements include carbon, chromium, manganese, silicon, vanadium, molybdenum, titanium, nickel and cobalt.

Iron is used in three main forms: pig iron, wrought iron and steel. From a chemical point of view, the main difference between these products resides in their carbon content and the form in which this alloying element occurs (graphitic carbon or combined carbon).

Pig iron—the crude product

Pig iron is the crude product obtained through the smelting of iron ore in blast furnaces. It is rich in carbon,[1] the latter being present both in graphitic and in combined form. A certain proportion of the pig iron output is used for making iron castings, but most of it is converted directly into steel in Bessemer converters or open hearth furnaces. A small part is utilised for the production of wrought iron in puddling furnaces. Each application requires a particular type of pig iron.

Ferro-alloys and their use for the production of alloy steels

Apart from ordinary pig iron, various so-called ferro-alloys are produced, where the iron is associated with a more or less high percentage of particular alloying elements. Thus, spiegeleisen and ferro-manganese are alloys of iron and manganese —the former, with about 15 to 20 per cent of manganese, and the latter, with as much as 70 to 80 per cent of this element. Ferro-alloys further include

[1] Pig iron contains 3 to 4 per cent of carbon; the carbon comes from the coke used for smelting.

ferro-silicon, ferro-chromium, ferro-vanadium and ferro-titanium. These ferro-alloys are obtained by smelting the ores in blast furnaces or electric furnaces.[1] Such ferro-alloys are used for introducing alloying elements into the molten steel.

Wrought iron now largely displaced by steel

Wrought iron is an iron with a very low carbon content[2] obtained by refining pig iron. The particular process used for its manufacture gives it a fibrous texture, which distinguishes it from low carbon steel. Wrought iron is rolled into bars of various shapes (rounds, squares, flats, angles, tees, channels, etc.); its range of applications is, however, rather limited at the present day, owing to its having been largely displaced by steel in many directions, notably in the field of structural material.[3] Special grades of wrought iron are used for making ships' chains and cables, draw-gear, hooks and couplings for railway rolling stock, etc., while hurdles and fences are built of a lower grade metal.

Steel and its suitability for structural work

Steel too is obtained by refining pig iron. Like wrought iron, it has a very low carbon content, but differs from that type of iron both as regards texture and properties, this being due to the process of manufacture. The larger proportion of the steel output is mild steel,[4] which is a product cheaper

[1] Spiegeleisen, ferro-manganese and ferro-silicon are blast furnace products. The other ferro-alloys are made mainly in electric furnaces.

[2] The carbon content of wrought iron may be as low as ·05 per cent, in the case of the purest product.

[3] All large size structural material is made of steel.

[4] Mild steel has a carbon content of ·15 to ·25 per cent. Softer steels contain less carbon, and harder steels, more.

than wrought iron and specially suited for making large size structural material.

Wide range of steel products

The field of applications of steel covers practically every branch of engineering. Steel is the metal universally used for structural work. For use as structural material, steel is rolled into a great variety of sections; these comprise ordinary sections such as round, square, flat, half-round, angle, convex, zed, tee, oval, channel, bulb flat, bulb angle and bulb channel sections, and special sections such as column profiles, troughing profiles and H sections, the latter being the sections utilised for girders, stanchions, joists, beams and pillars.

The range of steel manufactures further includes plates for shipbuilding, boiler making and other constructional work, sheet for the production of galvanised sheet and tin-plate,[1] and rails. Tubes and pipes, and wire are other all-important products, while shafts, axles, wheel centres and also guns are made of steel forgings. Steel is furthermore utilised in the form of castings for machine parts, etc.

Largest proportion of steel produced represented by carbon steel

The bulk of the steel produced is carbon steel, that is to say, steel where carbon alone controls the physical characteristics of the metal. As a rule, carbon steel also contains manganese and other elements such as silicon, sulphur and phosphorus, but not in sufficient quantities to affect the properties

[1] Galvanised sheet is sheet steel with a zinc coating; it is used in the corrugated form for roofing. Tin-plate is steel plate or sheet coated with tin; the largest users of this product are the motor car industry and the canning industry.

of the products. When alloying elements other than carbon are used for influencing the properties of the metal, the steel is known as an alloy steel.

Importance of nickel steels and nickel-chromium steels

The alloy steels with the widest range of applications are nickel steels and nickel-chromium steels. Nickel steels have the ductility of carbon steels and possess at the same time greater strength. These steels are easy to roll and to forge; they are specially suited for structural purposes and are also utilised for boiler plates, ore skips, etc. Nickel steel forgings are used for ship shafts, turbine rotors, etc.

Nickel-chromium steels are particularly useful alloy steels, as they have the best characteristics of nickel steels and, in addition, great hardness; they can be further improved by adding such alloying elements as molybdenum. The motor vehicle and aircraft industries are large consumers of these steels.

Other alloy steels with valuable properties

Manganese steels are used where great toughness is required. Products made of such steels include jaws of stone crushers, rails, etc. Copper steels have corrosion-resisting properties; they are specially suited for exposed structures such as transmission towers, for instance.

Special applications of certain classes of alloy steels

Stainless steels, high-speed steels and electrical steels are other important classes of alloy steels. Stainless steels comprise certain chromium- and chromium-nickel steels with acid resisting properties;[1]

[1] Typical stainless steels are the chromium steel with 13 per cent chromium, and the chromium-nickel steel with 18 per cent chromium and 8 per cent nickel. A wider range of resistance to corrosion is obtainable with the latter class of steels.

they have a wide field of applications in the engineering, chemical and aircraft industries, and are also used for cutlery and other domestic articles.

High-speed steels are special steels for making cutters, drills, etc., of machine tools; they are characterised by great hardness. In these steels, tungsten is the principal alloying element, chromium and vanadium being usually also present. Electrical steels are silicon steels with high magnetic permeability utilised for the cores of transformers and the poles of electric machines.[1]

Vast range of materials with iron as basic constituent

This enumeration of alloy steels is necessarily very incomplete; it should nevertheless suffice to give some idea of the vast range of materials that are produced with iron as basic constituent. There now remains to deal with the various other metals of industry.

Non-Ferrous Metals—I

Copper and its uses in electrical manufacture

The principal non-ferrous metals are copper, tin, zinc (spelter), lead, aluminium, magnesium and nickel; each of these metals serves in turn as base for a number of alloys. Copper owes its great importance to the property it possesses of being a very good conductor of electricity. It is thus, in the very first place, the raw material of the electrical industry, which is by far the largest consumer of this metal. For electrical purposes, copper has to be extremely pure.

[1] Cores and poles are built up of superimposed layers of steel sheet.

Copper for pipes

Another valuable property of copper is its high resistance to corrosion. This property is due to the natural protective coating that forms on the copper, when the latter is exposed to air or water, and shields it against corrosive agents. Owing to this resistance to corrosion, copper is widely used for water piping, specially where water is soft and liable to cause heavy rusting of iron pipes. The protective coating that forms in the interior of the piping takes the shape of an oxidised film.

Copper in building construction

The protective coating that occurs when copper is exposed to the atmosphere also consists, in the very first place, of an oxidised film. The latter is, however, transformed after a time into green "patina,"[1] through the action of the impurities in the air. The patina may be a basic sulphate, chloride or carbonate, according to the nature of the impurities responsible for its formation. In view of the great durability conferred to the metal by this protective coating, copper is suitable for outside work on buildings; thus, copper sheet is used for roofing, gutters, etc.

Further uses of copper

In addition to resistance to corrosion, copper also possesses high thermal conductivity. The combination of these two properties renders the metal specially suited for equipments of the chemical industry. Copper is utilised there for tanks, pans, tubing, etc., while evaporators, distilling columns, condensers, etc., are made of this material.

[1] Green patina must not be confused with verdigris that forms only in the presence of acetic acid.

Finally, the ductility and tenacity of copper make it a very valuable material for many parts of machinery. It is extensively used in the motor vehicle industry; the shipbuilding industry too ranks among the largest copper consumers. Furthermore, copper is utilised, in the construction of locomotives, for fire-boxes, fire-box side-stays and small tubes;[1] in this case, however, a small amount of arsenic is added, in order to give toughness to the metal.

Tin and its application as a protective coating

Tin affords a great contrast with copper; it is a soft and malleable metal with insufficient strength for ordinary manufacturing purposes. The particular attributes which make tin a material of such immense importance are its brilliant lustre, that is hardly affected by the atmosphere, and its pronounced acid resisting properties.[2] In view of these qualities, tin is an ideal medium for use as a coating on other metals, for the purpose of improving their appearance or protecting them against corrosion.

Mild steel sheet coated with tin is known as tin-plate; it is a most useful material, which combines the good mechanical properties of steel with the special qualities of tin. Owing to the pliability of the latter and the strength with which it adheres to the underlying metal, it is possible to work tin-plate into any shape, without risk of detaching the coating. Tin-plate is used in enormous quantities for the manufacture of cans for the canning industry.

Tinning is also applied in the case of copper, when direct contact between the metal and some other substance has to be avoided, owing to the

[1] It is the general British practice to make the fire-boxes of copper. In the United States, steel is widely used for the purpose.

[2] Tin is resistant to a number of distinctly acid media.

detrimental effect that would otherwise result for the one or the other. Thus, copper vessels for the treatment of milk are tinned, as contact with copper would affect the flavour of the milk. Electric copper wire too is given a coating of tin, when it is to be insulated with rubber compound, this being necessary for preventing the contamination of the copper by the sulphur of the insulation.[1] On the other hand, a large number of small metallic articles such as lighting fixtures, buckles, buttons, etc., are tinned mainly for decorative purposes.

Tin manufactures

The range of products made of tin alone is limited not only by the physical properties of the metal, but also by its relatively high cost. The softness and ductility of tin render it suitable for rolling into very thin sheet, known as tin foil; this material is used for wrapping foodstuff and sweetmeat, for electrical condensers, etc. Tin is also made into tubing for conveying fluids such as milk and beer. Collapsible tubes represent another application. A further use of tin is for the manufacture of pewter utensils. Pewter such as produced to-day consists nearly entirely of tin, a small amount of antimony and copper being added to the latter, in order to strengthen the metal.[2]

Zinc and its use as protective coating

Zinc (spelter), like tin, is used as coating on iron and steel for protective purposes. The method of applying this coating most widely resorted to is to

[1] Sulphur affects the electrical properties of copper.

[2] Pewter was originally an alloy of tin and lead; the latter metal is no longer used in pewter, owing to the risk of its contaminating food.

immerse the object in the molten metal (hot-dipping), as in the case of tinning, such application of zinc being known by the general term of galvanising.[1] The principal type of product treated by galvanising is steel sheet.

The coating imparted to the steel sheet by galvanising is characterised by its hardness and its relative high resistance to abrasion. It also possesses considerable durability, owing to the formation of an insoluble film of oxide and carbonate on the surface of the zinc, through the action of atmospheric agents (oxygen, carbon dioxide and moisture of air), which prevents any further oxidation of the metal. This outer film is, however, rapidly destroyed by acid fumes. When such fumes are present, bituminous paint can be applied as a protection.

Galvanised sheet, either flat or corrugated, is used for roofing and siding of buildings; flat sheet is further utilised for water tanks, etc. Two other important classes of products treated by galvanising are pipes and wire; galvanised wire is employed for fencing, for instance. Galvanising is further applied to fabricated hardware, nuts and bolts, nails, etc. Any pressing or stamping is usually done before galvanising, in order to avoid damage to the zinc coating.

Rolled zinc

Zinc is also rolled into sheet, strip and plate. In these forms, it has numerous applications. Thus, in building construction, zinc sheet is used externally

[1] Apart from hot-dip galvanising, there are other methods of applying a zinc coating. In electro-galvanising, the zinc is deposited through electrolytic action, while, with Sherardising, the object to be coated is heated at a certain temperature in contact with zinc powder. Zinc can furthermore be sprayed, in which case the coating can also be applied to non-metallic materials.

for roof covering and is suitable for protecting window sills and for copings. Internally, it serves for kitchen fittings such as drain boards. Another use in buildings is for air ducts of conditioning plant. Thin zinc sheet is employed as lining to render wooden packing-cases air-tight. In the electrical industry, rolled zinc is utilised in the manufacture of dry batteries, and in the printing trade, for engraving, addressing and lithographic plates. The shipbuilding industry is another large consumer of rolled zinc. Zinc oxide is a zinc compound which is used as a base for paint.

NON-FERROUS METALS—II

Lead and its use in building construction

Lead is another metal that is applied to many purposes in building construction, owing to its durability. When exposed to atmospheric influences, it acquires like zinc an insoluble outer film which acts as protection to the metal itself. Furthermore, it has acid resisting properties that make it a very valuable material for equipments in the chemical industries.

In building construction, lead is used externally in sheet form for protecting exposed surfaces of cornices, chimneys, offsets, parapets, etc.[1] This material is specially suited for the purpose, as it combines impermeability with tractability, and can be adapted to practically any shape. Lead is further utilised for gutters and rainwater pipes, as well as for roofing.

In the interior of buildings, lead is the plumber's metal. It is used for wastes, vents and piping to lavatory basins, as well as for tanks; in the latter

[1] These protective coverings are known as weatherings and flashings.

case, lead generally only serves as a lining to a wooden casing, that takes the weight of the water.

Lead water supply pipes

In regard to the use of lead pipes for the supply of water for domestic purposes, it may be mentioned that occasionally waters are found which tend to take into solution a certain amount of lead from the service pipes. Most natural waters, however, contain dissolved mineral salts (carbonates and sulphates) which reduce this solvent action to very minute proportions and soon entirely arrest it, through the formation of a protective coating on the inner surface of the pipe. In the case of waters which have an exceptionally low content of such natural salts, the usual remedial treatment adopted consists in supplying carbonate filters at the source.

Other applications of lead

Lead is also utilised in many other directions. In the chemical industries, it is used for vats, etc., to hold sulphuric acid, very pure metal (chemical lead) being employed for this purpose. In the electrical industries, it serves for sheathing cables, as well as for the manufacture of plates for accumulators, while in the armament industries too it has numerous applications. A special use of lead is as protection against X-rays, in the medical field and in engineering shops.[1] In the sphere of metallurgy, an interesting development is the adding of minute quantities of lead, in the production of certain types of steel; this confers to the metal a remarkable degree of machineability.

[1] X-rays are being used increasingly for the inspection of engineering parts.

Red lead and white lead

Red lead and white lead are two important lead compounds used as bases for paint, the former being an oxide, and the latter, a carbonate. The chief value of white lead in paint is the fact that, when applied with linseed oil, a lead compound (lead linoleate) is formed, which possesses great elasticity and thus enables the paint film to expand and contract without cracking.

Aluminium and its properties

Lead is the heaviest of the common base metals.[1] Aluminium is amongst the lightest.[2] In spite of its lightness, aluminium has good mechanical properties, while the oxide film it acquires immediately any part of its surface is exposed to the air protects it effectively against further oxidation. Such a film can also be produced artificially by an electrolytic process known as anodising; by this means, a coating of any desired hardness can be obtained.

Aluminium is resistant to most organic acids, to a great number of organic substances and to certain inorganic acids such as concentrated nitric acid and dilute sulphuric acid; the resistance to corrosion is specially pronounced in the case of anodised aluminium, which is, in particular, unattacked by sea air. Other valuable characteristics of aluminium are its high thermal conductivity and good electrical properties.

Uses of aluminium

In view of its many qualities, aluminium has applications in a number of manufacturing indus-

[1] Base metals are metals that become oxidised when heated in air, while noble metals are metals that are not liable to oxidation under these conditions. The principal noble metals are gold, silver and platinum.

[2] Magnesium is lighter than aluminium.

tries. The motor vehicle and aircraft industries are very large consumers of this metal. As, however, aluminium is used there mainly in the form of alloys, this particular field will be dealt with later on. The electrical industry is another large user of aluminium. This metal presents, in certain cases, advantages over copper, for current conductors, in view of its lightness.[1] Thus, aluminium is used in place of copper for rotor windings of large turbo-generators, in order to reduce the weight of the rotating masses and, consequently, the centrifugal stresses. It is, on the other hand, resorted to for busbars of outdoor substations, while stranded aluminium cable, with steel core for additional strength, has been adopted on an extensive scale for high tension overhead transmission lines.

Further applications of aluminium

Aluminium also has its uses in textile mills, where its immunity from rust is a valuable feature, in view of the moist atmosphere of these installations. The lightness of the material renders it suitable for such moving parts as shuttles and bobbins. Trays, covers and guards are other components which are made of this metal. In the chemical industries, aluminium can be used for vats, pans and tanks for many processes, owing to its acid resisting properties. Furthermore, its high thermal conductivity suits it for stills, heating coils, etc. In the rubber industry, aluminium plays an important part due to its resistance to sulphur and other ingredients of rubber.

Containers for food or drink are other forms in

[1] The specific weight of aluminium is about one-third of that of copper. The difference in weight between copper conductors and aluminium conductors is, however, not quite so great, as the latter have to be given a larger section, due to the lower conductivity of aluminium.

which aluminium is utilised; these range from cooking utensils to brewery equipments. Aluminium, like tin, is made into foil for packing tea, chocolate and sweets. Finally, in building construction, it serves for panels, copings, window frames, etc. As powder, aluminium is used for giving protective or decorative coatings to other metals, the coating being applied as paint or sprayed on.

Magnesium and its characteristics

Magnesium is a lighter metal than aluminium, its specific weight being only about two-thirds of that of the latter. When exposed to the atmosphere, it acquires too a thin superficial film that tends to arrest corrosion. This film does not, however, possess the permanency of that of aluminium, so that a special protective coating is necessary, when the material is to be subjected to severe corrosive influences. Pure magnesium is a relatively soft metal which is not sufficiently strong in that state for engineering purposes. In view of this, it has to be alloyed with other elements, in order to fit it for industrial use. Magnesium alloys will be referred to at a later stage.

Nickel and its uses

Nickel serves more especially as an alloying element; it is, however, also applied to many uses in the pure state. Nickel possesses hardness and strength, and is highly resistant to air and water, as well as to aqueous solutions of certain acids and alkalies. Its resistance to corrosion makes it a very valuable material for the chemical industries, where it is used either as protective coating on steel, or independently. Thus, tanks and tank cars for the storage and transport of phenol are constructed of

nickel-clad steel, while equipments such as kettles, stills, etc., are made of pure metal.

On the other hand, nickel plating is resorted to for decorative purposes, in the case of numerous iron and brass articles, and as an undercoating for chromium plating in motor car construction. Finally, considerable quantities of rolled nickel and nickel wire are required by the radio industry for the manufacture of valves.

The alloys of nickel, as well as those of the various other non-ferrous metals, will be dealt with in the following chapter.

CHAPTER III

More About Metals

Alloys of Non-Ferrous Metals—I

Immense variety of alloys

Copper, tin, zinc, lead, aluminium, magnesium and nickel are all used very extensively in alloyed form; in fact, many of the alloys of these metals are of greater importance than the base material itself. The metallurgical industry produces an immense variety of such alloys, each with its special characteristics and fields of application. Some, like bronze and brass, have been known from the earliest ages; others are materials evolved to meet particular requirements of present-day engineering, and marketed by the makers under different trade names. The majority of these alloys are casting alloys.[1] There are, however, also alloys suitable for rolling into sheet or other forms, and even for forging.

Copper-tin alloys or bronzes

Copper alloys include some of the most useful materials of industry. The principal alloying elements are tin, zinc, lead, aluminium and silicon. Copper-tin alloys are known as bronzes. As, however, this term is also applied to certain copper alloys other than copper-tin alloys, it is customary

[1] Casting is one of the most important manufacturing processes. There are three main methods of casting, namely, sand casting, gravity casting and die casting. With the first method, sand moulds are used, while with the other two, metallic moulds are utilised, the molten metal being introduced by gravity in the case of gravity casting, and under pressure in the case of die casting.

to refer to the latter as true bronzes. The tin content of these alloys ranges from about 4 per cent to about 33 per cent.

Wrought bronzes

The alloying of tin with copper increases the hardness of the copper, but reduces its ductility. In view of this, only the alloys with a low tin content can be worked under the hammer. Such copper-tin alloys are known as wrought bronzes. They can be made into sheet, rods and wire, and are used extensively in engineering in one or the other of these forms, owing to their springiness and corrosion resisting properties. Wrought phosphor-bronze is obtained by treating wrought bronze with phosphorus.[1] This bronze possesses great toughness; it is suitable for such parts as piston rods, propeller blades, etc.

Casting bronzes

Casting bronzes are copper-tin alloys with a higher tin content than wrought bronzes. They embrace a large variety of bronzes and include gun metal,[2] in particular. Such bronzes usually also contain a small amount of zinc and lead. Cast phosphor-bronze, like wrought phosphor-bronze, is produced by treating the bronze with phosphorus; it is characterised by its great hardness. Casting bronzes are used for steam and water fittings, gears, bearings, etc.

[1] In practice, rich phosphor-copper or phosphor-tin is used for the purpose in the place of phosphorus itself, as these materials are safer to handle. Phosphorus being a very powerful reducing agent causes in the very first place the reduction of the cuprous oxide in the metal; phosphor-bronze is thus primarily a deoxidised bronze and may only contain traces of phosphorus.

[2] Gun metal is no longer used for guns; in this field, it has been superseded by steel.

Other copper-tin alloys

Bell metal is a copper-tin alloy which contains a still higher percentage of tin; it is used, as its name implies, for the casting of bells. The alloy with the highest tin content is speculum metal. This metal is capable of being brightly polished and resists tarnish; it serves for making telescope reflectors and mirrors.

Copper-zinc alloys or brasses

Copper-zinc alloys are known as brasses; they have a zinc content up to about 50 per cent, and often include in their composition other metals such as tin, lead and aluminium, while manganese is added in certain cases to increase the hardness of the material. Brasses possess very good casting properties.

The ductility of copper is far less affected by zinc than by tin, so that brasses even with a relatively high zinc content still retain that property. The most ductile brass is cartridge brass that contains about 30 per cent of zinc. Muntz metal is a copper-zinc alloy with a zinc content above the latter figure; it possesses a great resistance to corrosion.

Many uses of brass

Brasses are extensively used for sand casting and die casting; they are also utilised in the form of forgings. The more ductile brasses are rolled into sheet, made into tubes and drawn into wire. A great variety of component parts are made of brass, both in heavy and light engineering work. These parts range from condenser tubes of steam plants, to clock gears and screws. In motor vehicle construction, use is made of brass for radiator tubing, chromium-plated pressings such as lamp bodies and reflectors,

and stampings such as control levers and small brackets. On the other hand, brass serves for the manufacture of hardware.

Further copper-zinc alloys

Copper-zinc alloys containing manganese are termed manganese "bronzes," although they are actually brasses; other alloying elements that may enter into their composition are iron, tin, nickel and aluminium. Manganese bronzes have a very high tensile strength. Such alloys are utilised for valve spindles, pump rods, propeller shafts, ship propellers, etc.

Copper-lead alloys

Copper-lead alloys contain up to 50 per cent lead; they generally include tin as a further alloying element. These alloys are used for bearings.

Copper-aluminium alloys or aluminium bronzes

Copper-aluminium alloys are given the name of aluminium bronzes; they comprise a number of alloys which vary considerably as regards tensile strength and ductility. The aluminium content may be up to about 15 per cent; iron is added to neutralise the brittleness imparted to copper by aluminium. The harder aluminium bronzes are used for propellers, ball bearings, gears, etc.

Copper-silicon alloys or silicon bronzes

Silicon, like phosphorus, has the effect of reducing the cuprous oxide in the copper and of increasing thereby the strength of the latter. Copper-silicon alloys are known as silicon bronzes. The silicon content does not as a rule exceed 5 per cent and is more often very much less; silicon bronzes may also

contain tin. These alloys possess great tenacity, good electrical conductivity and high resistance to corrosion. The main purpose to which they are applied is for making telegraph and telephone wires.

Alloys of Non-Ferrous Metals—II

Tin alloys

Tin alloys, lead alloys and zinc alloys are mainly casting alloys. In the case of tin alloys, the principal alloying elements are lead, antimony and copper. Tin-lead-antimony alloys and tin-lead-antimony-copper alloys are used for die casting; antimony and copper give greater strength to the tin, while lead reduces the cost of the material. These alloys are utilised for rubbing parts of explosion engines, while their excellent casting qualities make them specially suitable for use where thin sections are required.

Tin-antimony alloys and tin-antimony-copper alloys cover numerous alloys known as Britannia metal; the latter serve for making silver-plated hollow-ware, for instance. Tin-antimony-copper alloys further include white metal (Babbitt metals) for lining bearings. As regards tin-lead alloys, they are low melting point alloys which are utilised as solders. Solders range from electricians' solders with a low lead content, to plumbers' solders, where the lead is predominant, which come under the category of lead base alloys.

Lead base alloys

The chief alloying elements in lead base alloys are antimony and tin; the latter impart hardness to the lead, while antimony has the further effect of giving anti-friction properties to the material.

Lead-antimony-tin alloys include a great number of so-called anti-friction metals, and also type metals for printing, which are the most important representatives of this group of alloys.

Zinc alloys

Zinc alloys are the alloys most extensively used for die casting; they are particularly suited for this purpose, owing to their relatively low melting point. As impurities greatly affect the properties of these alloys, the zinc used for their manufacture must be of high purity.

The principal metals with which zinc is alloyed are aluminium and copper. Zinc alloys possess good mechanical properties; they have many applications in the construction of motor vehicles and machines, and serve for the manufacture of countless parts such as typewriter frames, clock cases, door handles, etc. Zinc castings take any kind of finish (electroplating, paint, enamel, etc.).

Aluminium alloys

Aluminium alloys and magnesium alloys represent the light alloys. Aluminium alloys are available in the form of castings, sheets, forgings and structural shapes, with a wide range of mechanical properties. These alloys combine the light weight and resistance to corrosion of aluminium with increased strength and hardness.

The casting alloys include ordinary casting alloys which are not heat-treatable, and heat-treatable alloys. The ordinary casting alloys comprise aluminium-zinc alloys, aluminium-copper alloys and aluminium-silicon alloys; they have a tensile strength up to about that of grey cast-iron.

The heat-treatable casting alloys are materials

where aluminium is alloyed with such metals as copper, nickel and magnesium; as cast and heat-treated, they are considerably stronger than ordinary casting alloys.

The alloys for forging or rolling comprise also non-heat-treatable and heat-treatable alloys. The latter include alloys which contain manganese, in addition to copper and magnesium; they are the strongest of all aluminium alloys and have a tensile strength that may reach that of structural steel. Duralumin is one of the types of alloys coming under this category.

Applications of aluminium alloys

The most important field of application of aluminium alloys is in aircraft construction. Aluminium alloys are used there mainly in the form of thin sheets, which are given such shapes as to ensure maximum strength with minimum weight. These sheets are usually anodised,[1] in order to increase their resistance to corrosion, and provided with a protective coating of paint. Aluminium alloys are also utilised in the form of castings and forgings, for component parts of internal combustion engines, and in rolled sections, for structural members.

Magnesium alloys

Magnesium alloys are the lightest of all alloys; they comprise groups of alloys made by different manufacturers and known under trade names such as Dowmetal, Electron alloys, etc. Dowmetals are mostly magnesium-aluminium-manganese alloys; some of them also contain zinc. Electron alloys vary

[1] Anodising is an electrolytic treatment whereby aluminium can be given a more resistant film of aluminium oxide than that produced merely by exposure to air.

considerably in composition; the alloying elements used for their production include aluminium, zinc, manganese, copper and silicon.

Apart from their extreme lightness, magnesium alloys possess the characteristic of being easy to machine. The oxide film that forms on the surface of the metal affords a certain degree of protection against corrosion. As a rule, however, a protective coating is applied, in order to ensure more effective resistance to corrosive action; it may be in the form of a chromate deposit or merely of paint.

Uses of magnesium alloys

Magnesium alloys are available for sand casting, die casting, forging, and for rolling into bars, rods and sheets; heat treatment is resorted to in certain cases for increasing the tensile strength of the material. These alloys are used for crank cases of internal combustion engines, both in the motor vehicle and aircraft industry. In aircraft construction, they are further utilised for landing wheels, instrument housings, etc., while motor vehicle bodies can be built of sheets and structural sections of these alloys. Magnesium alloys are specially suited for rotating parts of textile machines, fans, blowers, etc. Household appliances, such as vacuum cleaners, for instance, represent another field of application.

Alloys of Non-Ferrous Metals—III

Valuable properties of nickel alloys

There still remains to deal with nickel alloys. In view of the valuable properties conferred to alloys by nickel, even when it is present only in small quantities, it is proposed to make a brief survey of the whole range of alloys where nickel plays a

definite part in determining the characteristics of the material. For the purpose of this review, alloys will be divided into non-ferrous and ferrous alloys.

Non-ferrous nickel alloys

The principal non-ferrous nickel alloys are nickel-copper alloys, nickel-copper-zinc alloys and nickel-chromium alloys. Nickel-copper alloys include in the first place cupro-nickel alloys with a nickel content ranging from a few per cents to about 40 per cent; their field of application covers condenser tubes, locomotive tubes, hardware, bullet jackets, etc. Nickel-copper alloys with a high percentage of nickel up to 80 per cent are suitable for electric resistance wire and utilised in this form for industrial furnaces and such household appliances as toasters, electric irons, etc.

Monel metal

The most important nickel-copper alloy is, however, Monel metal, which contains 67 per cent nickel; it is available as a casting alloy, and in the form of rolled rods and bars, wire and sheet. This material is characterised by its toughness and resistance to abrasion, by its strength at high temperatures and by its high resistance to corrosion, which renders it invaluable for a great number of applications.

Uses of Monel metal

Monel metal is used in the chemical industries for filter cloth, for autoclaves for the manufacture of dyestuffs, etc., in the tin-plate industry for pickling crates, in the gas industry for centrifugal baskets for drying sulphate of ammonia, in the coal mining industry for screens, and in the textile industries for

dyeing plant. It is further utilised in building construction for specially exposed external parts, and internally for sinks, etc. In power plants, Monel metal is often adopted for such parts as stop valves, valve seats, valve spindles, drain cocks, etc. Finally, owing to its immunity from sea water corrosion, it is widely employed in seaplane construction, for floats, petrol tanks, etc.

Nickel silvers

Nickel-copper-zinc alloys are represented by nickel silvers, which contain 7 to 30 per cent nickel. These alloys are used both in wrought form and as castings. They closely resemble silver in appearance: hence, their name. Nickel silvers are utilised for silver-plated spoons, forks, tea-pots and dishes, for sink fittings, for watch cases and for motor car parts such as door handles, screws, etc.; military badges too are made of this material.

Nickel-chromium alloys

Nickel-chromium alloys with a high nickel content are characterised by their resistance to corrosive agents, their strength at high temperatures and their high electrical resistivity. Inconel which is a nickel-chromium alloy containing 80 per cent of nickel is used for food handling equipments, in particular; in aircraft, it is often adopted for parts subjected to hot gases, such as exhaust manifolds of aeroplane engines. Inconel is further utilised as a protective cladding bonded to a steel base, in distilleries, breweries, etc.

Another application of nickel-chromium alloys with a high nickel content is in the manufacture of heating resistances for industrial electric furnaces, as well as for household appliances such as toasters, electric irons, etc.

Alloying of nickel with iron

As regards ferrous alloys, they cover in the very first place nickel steels and nickel-chromium steels; these highly important steels have been referred to when dealing with the principal alloy steels. Nickel steels contain up to about 7 per cent nickel, while chromium-nickel steels, which include stainless steels, have a nickel content ranging from about 7 per cent to 35 per cent.

Apart from these alloy steels, there are other important nickel-iron and nickel-iron-chromium alloys. Thus, nickel-chromium-iron alloys comprise a whole range of heat-resisting alloys with a nickel content up to about 80 per cent. The alloys richest in nickel possess a high resistance to corrosion even at high temperatures and, for this reason, have many applications in the chemical, steel and enamelling industries, for instance.

Nickel-iron alloys too include groups of alloys with very valuable properties. Invar type alloys are nickel-iron alloys with 35 to 45 per cent nickel, which have a very low coefficient of expansion; they serve for making measuring tapes and certain instruments. Permalloys are nickel-iron alloys, where the nickel content may be as much as about 80 per cent; they are characterised by their high permeability which suits them for various electrical purposes.

Nickel cast-irons

Nickel is also alloyed with cast-iron, with a view to improving the qualities of this material. Nickel cast-irons are employed in the construction of Diesel engines, pumps, air compressors, etc. Ni-Tensyl is a nickel cast-iron with a tensile strength intermediate between that of cast-steel and that of ordinary cast-

iron; it is utilised for gears, turbine castings, etc. Ni-Hard is a nickel cast-iron which resists abrasion; it is resorted to for crusher rollers, crusher jaws, etc. Ni-Resist is a nickel cast-iron that is resistant to corrosion and also possesses stiffness and strength; it is used for textile machines, for paper making machines and in oil refineries, and further serves for the manufacture of household equipments such as pans, stove parts, etc.

Vast choice of materials afforded by alloys

Although the foregoing survey has necessarily been of a very cursory nature, it should nevertheless give some idea of the immense variety of constructional materials afforded by metals and their alloys. At the present day, there are many thousand different alloys available for engineering purposes, and their number is constantly increasing from year to year. Thus, the manufacturer has a very extensive range of products from which to choose the materials best suited to his particular requirements.

Noble Metals

Characteristic of noble metals

The foregoing sections have been concerned with base metals and their alloys. It is now proposed to deal very briefly with noble metals. These metals are characterised by the fact that they do not oxidise when heated in air; they include, as principal representatives, gold, silver[1] and platinum.

Gold and its properties

Gold, apart from possessing the characteristic common to all noble metals, has furthermore the

[1] Silver, when in the molten state, absorbs oxygen.

property of being immune from corrosion by any single acid; it is, however, dissolved by certain solution of salts, mixtures of acids, etc., but it is easily precipitated from the latter, in the metallic state.

This quality of durability, the beautiful colour of the metal and the fact that the latter does not tarnish, have made gold a highly valued material, while its relative scarcity guards it against depreciation. As a result, gold has come to be regarded as the standard of value, par excellence, and the most convenient medium for the storing of wealth.

Gold in the field of finance

The earlier connection of gold with monetary systems has been mainly as coinage. In more recent times, gold stocks have been used as Central Bank reserves and backing of currencies, in conjunction with or independently of Gold Standard systems, and as means for the settlement of international balances and the operation of Exchange Equalisation Accounts. It is mainly due to gold being the accepted medium for carrying out these different functions that it holds a position of such importance.

Gold in industry

The industrial uses of gold are very limited. The principal application is in jewellery and plate. A small amount of gold is also utilised in the optical trade, for dentistry, for nibs, etc. Gold is very malleable and ductile, so that it can be rolled into thin sheet, which can further be reduced to gold leaf, by beating. Gold leaf serves for gilding purposes, while gold sheet is used with a backing of base metal such as bronze, for the manufacture of numerous articles. The material obtained by rolling

the gold sheet with its backing of base metal is known as rolled gold.

Alloying elements introduced into gold

Owing to its softness, gold cannot be utilised for manufacturing purposes, in the pure state. The principal alloying element used for hardening it is copper; this metal may at the same time be added with a view to cheapening the material. Copper when present in any considerable proportion has, however, the effect of giving gold a red colouring. In view of this, it is necessary in such a case to introduce other alloying elements such as zinc, for restoring the colour of the metal. The fineness of gold is expressed in carats. The highest carat number is 24, which corresponds to pure gold. The ratio between the carat number of a sample and the number 24 gives the proportion in which pure gold occurs in the sample.

Silver and its abandonment as a monetary standard

Silver too is a metal that has been closely associated with monetary systems. In fact, in the past, it has played an even more important part than gold, in this particular field. Now, however, it has fallen from its place of eminence. China, the last important country to use silver as a monetary standard, went off silver in 1935, and except in the United States and India silver has not figured in recent times to any large extent in reserves for the backing of national currencies.

Silver coins merely token coins

At the present day, silver lacks the essential qualification required of a universal standard of value. As a result of the abandonment of the Silver

Standard by the countries where this Standard was formerly in operation, large stocks of silver have become available, while the supplies are being constantly augmented not only by the production of the silver mines, but also by that of base metal industries, where silver is yielded as a by-product. Silver is still used, it is true, for coins, but the latter are merely token coins, as their metal value is far below their face value, owing to the large proportion of alloying elements they contain.[1]

Silver for plate

The principal application of silver in industry is in the production of plate. Silver is, however, too soft for use in this connection, in the pure state; it is usually hardened by the addition of copper. In British Standard Silver, the proportion of pure silver amounts to 92.5 per cent, the balance consisting of copper or other base metals; such silver can be guaranteed by hall marking. The articles made of silver include dishes, trays, spoons, forks, tankards, etc.

Other applications of silver

Owing to its resistance to oxidation at high temperatures and to attack by organic acids, silver has many applications in the chemical industries, in the food industries and even in the engineering industry. It is used for stills and condensers for the manufacture of fine chemicals and for equipments for the preparation of food. In the electrical industry, silver serves for fuse wires and for the plating of contacts.

[1] Silver coin in this country only contains 50 per cent of silver; the remaining part consists mainly of copper, with a small amount of nickel and zinc.

Use of silver salts in photography

Certain silver salts possess the property of being highly sensitive to light and are utilised for photographic purposes. Silver bromide, in particular, is consumed in large quantities in the production of films.

Platinum and its properties

Platinum is a soft and malleable metal; it is hardened by adding iridium, which belongs to the same group of metals.[1] Platinum is very resistant to oxidation at high temperatures and to attack by acids. It is used for certain parts of laboratory equipments, for contacts of magnetos and for surgical instruments. In jewellery, it serves for mounting precious stones.

Survey of metals concluded

With this brief reference to gold, silver and platinum, the survey of metals and their uses must be brought to a close. Another all-important class of materials will now be dealt with—the class represented by stone and clay, which in spite of the multitudinous applications of metals still remain the fundamental raw materials of mankind.

[1] This group comprises platinum, osmium, iridium, ruthenium, rhodium and palladium.

Clays can be roughly divided into common clay, fireclays and pottery clays. Common clay includes a great variety of clays and clayey materials ranging from plastic clays to marls, loams and shales,[1] which are used with or without admixture of other ingredients (sand, chalk, limestone, etc.) for such products as building bricks, roofing tiles and chimney pots.

Fireclays

Fireclays are clays capable of withstanding a very high temperature without fusing. As a rule, a certain amount of non-plastic material such as burned clay (grog) is added in a powdered condition, in order to prevent too great shrinkage in drying. Fireclays are utilised for glazed bricks and sanitary appliances, for instance; another application is in the manufacture of refractory bricks. Although refractory bricks do not in themselves constitute a class of clay products, being largely made of other materials, it may nevertheless be convenient to deal with them briefly here.

Refractory bricks

Refractory bricks serve for the brickwork of furnaces, kilns, coke ovens, gas retort settings, etc. In most of these applications, the bricks are subjected not only to very high temperatures, but also to corrosive action, which necessitates the choice of a material as resistant as possible to the particular chemical agents.

There are many varieties of refractory bricks. These different types of bricks are classified accor-

[1] Marl is a mixture of clay and chalk, and loam, a sandy clay, while shale is clay that has been hardened and laminated through the forces of compression of overlying strata.

ding to their chemical properties under three main heads, namely, acid, basic and neutral bricks. Fireclay bricks and silica bricks come under the first category, magnesia bricks and bauxite bricks, under the second, and chromite bricks and carborundum bricks, under the third.

Raw materials of refractory bricks

Silica is a natural oxide of silicon; it occurs in massive form in quartzites, sandstones and ganister. Bauxite, chromite and magnesite, from which magnesia (magnesium oxide) is derived by calcination, also occur in nature. Carborundum (silicon carbide) is obtained by heating a mixture of sand and coke in an electric furnace.

For the production of the bricks, the materials have to be crushed and mixed with a binding substance (bond); the two principal bonds used are lime and clay. Refractory bricks are made into a number of standard shapes, with which the different elements of the brickwork are built up.

Pottery clays

The clays described as pottery clays are those used for making fine pottery; they include white-burning clays such as china clays and ball clays, in particular. China clays and kaolins are clays which are very resistant to heat; they are, however, only feebly plastic. Ball clays, on the other hand, are highly plastic, but do not burn as white as china clays. As regards clays utilised for coarse pottery, they do not form a class of their own, as practically any kind of clay can be applied to the latter purpose.

Pottery and its composition

Pottery consists of a clay body, in which non-plastic materials are incorporated in a finely ground

state; the body may or may not be covered with a glaze. The non-plastic materials added to the clay come under different categories. They may be so-called opening materials for reducing the plasticity of the clay paste and limiting shrinkage in burning, fluxes for lowering the temperature of hardening and vitrification, or substances indispensable for obtaining the desired chemical composition.

Opening materials include in the very first place silicious materials such as quartz and flint, which play a very important part in ceramics in many connections. Grog is another opening material. Fluxes comprise such substances as felspar, Cornish stone, chalk, lime, magnesia, potash, soda and bone ash.[1]

Glazes

Glazes are vitreous coatings which partly combine with the bodies and render the latter impervious to liquids and gases; they are somewhat akin to glass and consist of a mixture of silicates or of silicates and borates. The fluxes utilised to regulate their fusibility include lead compounds, potash, soda, lime, borax, etc. Glazes are generally grouped according to the nature of the flux, being divided into lead glazes, alkaline glazes and boracic glazes.

Forms of pottery

The principal forms of pottery are porcelains, earthenware and stoneware. Porcelains have a vitrified impermeable body, which is characterised by its translucency. The body is normally white, but may be coloured with metallic oxides, for decorative purposes; it is usually glazed.

[1] Bone ash is phosphate of lime.

Hard porcelains

Porcelains comprise hard porcelains and soft porcelains.[1] The fundamental materials used for the body of hard porcelains are china clay, silicious material in the form of quartz, and alkaline fluxes such as felspar;[2] it is often necessary to mix several china clays, in order to obtain the correct composition. The glazes most widely employed for these porcelains are felspathic glazes. Hard porcelains serve for table-ware and decorative ware, for electrical insulators, etc.

Soft porcelains

The most important variety of soft porcelain is bone china (English porcelain). The body of bone china varies considerably as regards its composition. It is generally formed of china clay, with bone ash and Cornish stone as fluxes. Other materials that are sometimes added are flint and ball clay, the purpose of the latter being to increase the plasticity of the material. Various lead glazes and leadless glazes are utilised for this porcelain. Bone china is less costly than hard porcelain and easier to decorate; it is mainly used for table-ware.

Earthenware and its raw materials

Earthenware is a clayware with a more or less porous body, which thus requires glazing, if it is to be rendered impervious. It is divided into coarse and fine earthenware. Coarse earthenware is made of unprepared natural clay and generally has a coloured body. Fine earthenware is made of white-burning clay.

[1] The terms "hard" and "soft" refer to the degree of firing, hard porcelain being a porcelain fired at a very high temperature.

[2] A small amount of calcareous fluxes such as chalk is sometimes added.

There are many varieties of fine earthenware; these are grouped under the heading of felspathic earthenware or calcareous earthenware, according to the nature of the principal flux. English earthenware is a felspathic earthenware. Its body is composed of ball clay, china clay and flint, with Cornish stone[1] as flux. The proportion of these different constituents, as well as the type of glaze vary from one maker of pottery to another.

Uses of earthenware

Fine earthenware is used for domestic wares such as plates, cups, dishes, basins, bowls, etc. Coarse earthenware serves for articles ranging from culinary wares to flower-pots, which are made of red-burning clays.

Stoneware

Stoneware, like porcelain, has a vitrified body. The body of stoneware differs, however, from that of porcelain in that it is opaque and usually coarser in texture; it is of a buff or light grey colour. Stoneware too is divided into coarse and fine stoneware. The difference between the two resides mainly in the purity of the material used.

The clays utilised for the production of stoneware are clays that vitrify over a suitable range of temperature, without losing their shape; a certain amount of grog has to be added to the clay. Stoneware can also be made of artificial mixtures consisting of ball clay, china clay, flint and Cornish stone, for instance. Various glazes are employed for stoneware, including salt glaze. Stoneware is used for culinary ware, for jars and bottles, and in the chemical industries, in particular.

[1] Cornish stone is a felspathic mineral.

GLASS

Fundamental constituents of glass

Glass comes under a category of its own. It consists essentially of a mixture of silicates in solid solution, formed by the union of silica and basic oxides.[1] The nature of these oxides and the proportion in which they are present varies according to the kind of glass. The principal basic oxides used in the manufacture of glass are oxides of sodium, potassium, calcium, barium, lead, aluminium, zinc and magnesium. Oxides of sodium and potassium have always to be accompanied by other basic oxides, otherwise the glass lacks stability and resistance. The mixture of raw materials used for making a given glass is known as the batch.

Batch materials for plate glass

The materials required for producing a glass are firstly silica, and secondly the basic oxides necessary for the particular glass, or compounds capable of yielding these oxides through reaction during fusion. The principal constituents of plate glass, for instance, are, apart from silica, oxides of sodium and calcium. The silica is provided by quartzose sand.[2] The oxide of sodium is supplied by soda ash or salt-cake, and the oxide of calcium, by limestone.

Batch materials for crystal glass

In the case of crystal glass, the chief basic oxides are oxides of potassium and lead. Oxide of lead is

[1] Certain glasses also contain borates formed by the union of boric oxide and basic oxides. Silica (oxide of silicon) and boric oxide are acidic oxides.

[2] Quartzose sand is sand derived from quartz; the latter mineral is crystalline silica.

provided by red lead or litharge, and oxide of potassium, by potash. When the glass must also contain oxides of aluminium and magnesium, the oxide of aluminium may be derived from calcined alumina or china clay, and the oxide of magnesium, from calcined magnesia, magnesite or dolomite.

Nature of batch materials

With the exception of quartzose sand, limestone, china clay, magnesite and dolomite, which are found in nature, these batch materials are products of the metallurgical or chemical industries. Several of the natural materials contribute more than one constituent of glass. China clay, for example, gives silica, as well as aluminium oxide, and dolomite, oxides of magnesium and calcium. On the other hand, certain raw materials not only yield necessary basic oxides, but also act as fluxes; this is the case for the sodium and potassium compounds, in particular. Waste glass (cullet) is another important ingredient in glass making.

Special agents used in glass making

Batches may further include in their composition other materials serving for special purposes: oxidising agents for counteracting the reducing influence of furnace gases, decolorisers for neutralising the colouring due to iron compounds contained as impurities in the batch materials,[1] colouring agents for coloured glass, etc. Sodium nitrate (Chile saltpetre) and potassium nitrate come under the category of oxidising agents. Manganese dioxide is one

[1] Iron compounds in the batch materials cause the formation of ferric and ferrous silicates in the glass. Ferric silicate imparts to the glass a yellowish colouring, and ferrous silicate, a greenish tint.

of the chief decolorisers.[1] As regards colouring agents, they comprise various metallic oxides such as nickel oxide, cobalt oxide, copper oxide, etc., and also manganese dioxide.

Process of chemical manufacture

In the manufacture of glass, the final product is obtained as a result of the re-distribution of the elements or groups of elements yielded by the batch materials, through the action of heat. This phenomenon of re-distribution that characterises all chemical reactions is the means by which substances ranging from the most complex compounds to single elements are produced by the chemical industries.

The manner in which individual materials react together depends upon the chemical properties of the latter. In certain cases, the reaction may take place spontaneously, while in other cases the application of such external agents as heat or pressure may be necessary. A re-distribution of elements is also possible through the medium of electric current, the process in question being known as electrolysis. The principal classes of chemical products and the corresponding raw materials will be reviewed in the following chapter.

[1] Manganese dioxide has the dual effect of oxidising the ferrous silicate to ferric silicate, and of producing the necessary complementary colour for neutralising the colouring.

CHAPTER V

Range of Products of the Chemical Industries

Chemical Products and Chemical Elements

Grouping of chemical products according to uses

The products of the chemical industries can be divided into eight principal groups, according to their uses. A first group includes products for processing purposes such as bleaching, dyeing, calico printing, mercerising of cotton yarn, sizing, fireproofing, impregnating of wood, tanning, vulcanising of rubber and pickling of metals. A second class comprises stains, paints, varnishes and enamels, a third, products of general use such as soap, soda, disinfectants and glues, and a fourth, industrial materials such as celluloid. The other four groups cover explosives, fuels and oils, fertilisers, and drugs and medicinal products, respectively.

Chemical products used by nearly every industry

From the above enumeration, it can be seen that practically every single industry is dependent to some extent upon the chemical industries. This is more especially the case for the agricultural industry, the textile industries, the leather industry, the rubber industry, the ceramic industries, the glass industry, the industries engaged in the manufacture of wood pulp and paper, the gold mining industry and the photographic trade, while the brewing trade, the aerated mineral water trade and even

the confectionery trade are consumers of certain chemical products.

Chemical products and their properties

The uses to which a chemical product can be applied necessarily depend upon the chemical or physical properties of the latter; these properties in turn are governed by the composition of the material, which may consist of a single element, of a single compound, or of a mixture of compounds.

Chemical elements

There are some ninety chemical elements; these are divided into non-metallic and metallic elements. The former include such elements as hydrogen, chlorine, iodine, oxygen, sulphur, nitrogen, phosphorus, arsenic, carbon, silicon and boron; the latter comprise potassium, sodium, calcium, barium, magnesium, zinc, copper, iron, chromium, manganese, aluminium, nickel, antimony and cobalt, in particular.

Metallic elements

The metallic elements iron, copper, tin, zinc, lead and aluminium are the principal manufacturing materials of the engineering industry; their individual uses have been described in the chapters on ferrous and non-ferrous metals. Chromium, manganese, nickel, cobalt and the non-metal silicon are valuable alloying elements, which have also been referred to in the same chapters. As regards sodium, potassium and calcium, these are elements from which are derived some of the most important chemical compounds; the latter will be considered at a later stage.

Non-metallic elements

The non-metallic elements are chiefly used for the production of chemical compounds. A certain number, however, also have applications in the isolated state. Thus, chlorine is employed for treating drinking water, when there is a danger of its being infected; another use of chlorine is for bleaching wood pulp. Iodine is a well-known disinfectant. Phosphorus (red phosphorus) serves for the manufacture of matches. Hydrogen, oxygen and nitrogen are elements that not only enter into the composition of countless compounds, but also play an important part as individual elements; in view of this, special reference will be made to them here.

Hydrogen

Hydrogen is used in industry for the hydrogenation of coal, for the hardening of oils and for the production of synthetic ammonia, in particular. In all these processes, which entail the direct combination of hydrogen with other substances, catalysts[1] are necessary. Hydrogen is produced on a large scale for hydrogenation purposes, by the water-gas catalytic process, by the steam-iron process and by the electrolysis of water. With the water-gas catalytic process, hydrogen is evolved through the reaction of water-gas[2] and steam in the presence of a catalyst, the resultant product being a gas mixture containing mainly hydrogen and carbon dioxide, which latter is subsequently removed. With the steam-iron process, hydrogen is obtained by causing

[1] Catalysts are substances that promote reactions, without actually taking part in them.

[2] Water-gas is a gas-mixture consisting chiefly of carbon monoxide and hydrogen, which is produced when steam is passed over incandescent coke.

steam to pass over heated iron; the oxygen of the water then combines with the iron, while the hydrogen is liberated. In the case of the electrolysis of water, hydrogen and oxygen are produced at the same time.

Nitrogen

Nitrogen is used in large quantities for the production of synthetic ammonia and other nitrogen compounds. The main source of supply of nitrogen is the air, where nitrogen represents nearly 80 per cent of the volume; the other principal constituent of air is oxygen. Nitrogen can be extracted from the air by liquefaction of the latter, followed by fractional distillation. It can also be isolated by removing the oxygen from the air by hot coke, for instance. When both nitrogen and hydrogen are required, as in the manufacture of synthetic ammonia, these two gases can be obtained together, in the correct proportion, from a suitable mixture of producer gas and water-gas. The combination of nitrogen and hydrogen for the production of synthetic ammonia necessitates a very high pressure and the use of catalysts.

Oxygen

The principal industrial application of oxygen is in connection with oxy-acetylene welding and metal cutting; in the process in question, a flame with a very high temperature is obtained through the combustion of a mixture of oxygen and acetylene. Oxygen is also utilised for medical and other purposes. Most of the oxygen used in industry is derived from liquid air.

Inorganic Chemical Compounds

Structure of chemical compounds

Compounds are characterised by the number of atoms of the different elements entering into the composition of their molecules and by the grouping of the atoms. Atoms of different elements unite together in a certain ratio expressed by their valency.[1] Carbon compounds form a special group of their own and are known as organic compounds. The other compounds come under the category of inorganic compounds;[2] the latter will be considered in the first place.

Classes of inorganic compounds

Before dealing with inorganic compounds individually, it is proposed to make a brief reference to their classification. The three principal classes of products, from the point of view of chemical properties, are acids, bases and salts. Acids and bases are characterised by the fact that, when dissolved in water, they conduct electricity, but in their case the passage of electric current is accompanied by a transfer of matter (electrolytic process); this is due to there being a splitting up of a certain proportion of the molecules into positively charged and negatively charged particles (ions). Aqueous solutions of salts, as well as certain fused salts, also possess similar properties.

Acids give rise to hydrogen ions, and bases, to

[1] An atom of hydrogen can only combine with a single atom of another element; it is said to be monovalent. If the atom of an element unites with two atoms of hydrogen, it is di-valent, and so on.

[2] Simple carbon compounds such as oxides and sulphides are usually grouped with the inorganic compounds.

hydroxyl[1] ions. Acids are therefore substances that always contain hydrogen in their composition, and usually oxygen too; they may be derived from non-metallic oxides, through the combination of the latter with water. Bases, on the other hand, always include a hydroxyl group; most metallic oxides form bases, when combining with water.[2] Salts are neutral substances, such as result from the neutralisation of an acid by a base, for instance; water is then formed at the same time.

Sulphuric acid and other important acids

The most important of all acids is sulphuric acid. It is obtained through the combination of sulphur trioxide with water, the sulphur trioxide being itself derived from sulphur dioxide by oxidation. Sulphur dioxide can be produced by roasting such minerals as iron pyrites (iron sulphide) and zinc blende (zinc sulphide).

Sulphuric acid serves for the production of fertilisers such as sulphate of ammonia and superphosphate. It is used in the manufacture of explosives, dyes, artificial silk, soap, etc. A further application of sulphuric acid is for removing rust, etc., from the surface of metal, the process in question being known as pickling.

Hydrochloric acid (muriatic acid) is employed likewise for pickling. It is also utilised in connection with the production of dyes and in the artificial silk industry. Hydrochloric acid consists of hydrogen chloride dissolved in water; hydrogen chloride is a gas that can be produced through the action

[1] A hydroxl is a group of atoms consisting of one atom of hydrogen and one atom of oxygen.

[2] The higher oxides of manganese and chromium, however, yield acids.

of sulphuric acid on common salt (sodium chloride).

Nitric acid and boric acid are other inorganic acids. The former is a strong oxidising agent, while the latter is characterised by its antiseptic properties.

Caustic soda and sodium salts

Two of the strongest bases are caustic soda (sodium hydroxide) and caustic potash (potassium hydroxide); these products are known as alkalis. Caustic soda is used in the manufacture of soap, artificial silk, dyes, paper, etc., as well as for the refining of oil and reclaiming of rubber. Caustic soda can be obtained through the reaction of soda ash (sodium carbonate) with slaked lime (calcium hydroxide), and by the electrolysis of brine. The latter process gives chlorine and hydrogen as by-products.

Salts of sodium play a very important part in chemical manufacture; they include common salt (sodium chloride), soda ash (sodium carbonate) and salt-cake (sodium sulphate). Common salt or brine is the principal raw material for the production of other sodium compounds. Sodium carbonate is used in the soap industry as well as in the glass industry, and is consumed in large quantities by the textile industries. It is prepared by the so-called ammonia-soda process, the materials required for the purpose being brine, ammonia and limestone; the ammonia is recoverable.

Sodium sulphate is employed in the production of wood pulp, in particular. It can be manufactured by heating salt with sulphuric acid, the other product yielded by the reaction being hydrogen sulphide. The list of useful salts of sodium further includes acetate, bicarbonate, bichromate, chlorate,

cyanide, hyposulphite, nitrate, nitrite, phosphate, prussiate, silicate and sulphide of sodium.

Caustic potash and salts of potassium

Caustic potash (potassium hydroxide) is produced in a similar way to caustic soda by the reaction of potassium carbonate (potash) with slaked lime, or by the electrolysis of potassium chloride.

The salts of potassium are represented in the first place by potassium chloride, potassium sulphate and potassium carbonate. Potassium chloride is found in nature, usually mixed with other salts; it is the principal raw material for the manufacture of potassium compounds. Potassium sulphate can be derived from potassium chloride through the action of sulphuric acid; it is a valuable fertiliser.

Potassium carbonate (potash) is utilised for making soft soap and certain glasses. It can be manufactured from potassium sulphate, the other materials required in this connection being limestone and coal. Bichromate, chlorate, muriate, nitrate and permanganate of potassium are other potassium salts, all with their particular uses.

Slaked lime and salts of calcium

Slaked lime (calcium hydroxide) also comes under the category of a strong base, while ammonia, dissolved in water, forms a certain amount of ammonium hydroxide and is very basic too. Slaked lime has already been referred to as a material used in the manufacture of caustic soda; it is obtained by calcining limestone and subjecting the resulting calcium oxide (quicklime) to the action of water.

The salts of calcium include such products as superphosphate of lime and chloride of lime (bleaching powder), while calcium carbide is another very

important calcium compound. Superphosphate of lime is one of the foremost fertilisers; it is produced by treating phosphate rock with sulphuric acid. Bleaching powder, as its name implies, serves for bleaching fabrics, etc.; it is obtained through the absorption of chlorine by lime. Calcium carbide is used in the manufacture of munitions; it is obtained by heating lime and coal or coke together in an electric furnace.

Ammonia and ammonium salts

Ammonia is a compound consisting of nitrogen and hydrogen. It is extensively used in organic chemistry and is further employed for metallurgical processes.[1] Another application is in connection with the production of ice. Ammonia is a by-product of the gas industry and is also made synthetically through the direct combination of nitrogen and hydrogen. The salts derived from ammonia include ammonium chloride (sal ammoniac), ammonium sulphate (sulphate of ammonia) and ammonium carbonate (sal volatile).

Sal ammoniac is utilised in soldering, in electric cells, etc.; it is obtained through the reaction of ammonia with hydrochloric acid. Sulphate of ammonia is one of the principal fertilisers; it is produced by passing ammonia gas through sulphuric acid. Sal volatile is used in wool scouring, etc.; it is obtained by heating sulphate of ammonia and chalk together.

Lead compounds

Lead has a number of very useful compounds. White lead, for instance, is a lead carbonate which

[1] Steel can be given considerable surface hardness by treatment in ammonia gas at a high temperature.

is used as a base for paint,[1] while lead nitrate is a product employed in calico printing and dyeing. White lead is obtained from lead via lead acetate, through the action of acetic acid and carbon dioxide. Lead nitrate is produced by dissolving lead or oxide of lead in nitric acid.

Litharge and red lead are other important lead compounds. Both are oxides of lead; red lead is the higher oxide of the two. The oxidising agent is air. Litharge is utilised in the production of certain glasses. Red lead serves for the manufacture of protective paint for coating iron and steel structures.

Organic Chemical Compounds

Classification of organic compounds

It is now proposed to make a brief survey of organic compounds. Owing to the fact that carbon atoms can link up with other carbon atoms, the number of carbon compounds is practically unlimited. In view of this, all that can be done is to give a few particulars regarding the most important classes of compounds.

Organic compounds are divided into open chain compounds and cyclic compounds, according to the arrangement of the carbon atoms in the molecules. In the case of the former compounds, the carbon atoms form an open chain, while with the latter compounds they constitute one or more rings. The rings may be composed of atoms of the same element (iso-cyclic compounds) or of different elements (hetero-cyclic compounds).

[1] The other main ingredients of the paint are linseed oil and turpentine or white spirit, which act as binder and thinner, respectively.

Hydrocarbons

The compounds containing carbon and hydrogen alone are known as hydrocarbons. They hold a very special position, as all other organic compounds can be regarded as derived from them, through the substitution of one or more atoms of hydrogen by different elements or groups of atoms. Hydrocarbons are found in petroleum and are evolved by the distillation of coal, wood and other carbonaceous materials; they are also produced synthetically. There are a number of series of hydrocarbons, each corresponding to a particular type formula.

These series of hydrocarbons comprise, on the one hand, series of open chain (acyclic) hydrocarbons, and on the other hand, series of cyclic hydrocarbons. The former, which are further known as aliphatic series, include the paraffin, olefine, diolefine, and acetylene series, while the latter cover the benzene, naphthene, naphthalene, and anthracene series, in particular; the benzene series is also given the name of aromatic series, due to the fragrant odour of certain derivatives of benzene.

Hydrocarbons of the paraffin series and some of their derivatives

Methane (marsh gas), the first member of the paraffin series, is the simplest of all hydrocarbons; its molecule consists of one carbon atom with four hydrogen atoms linked to it.[1] The successive members of the series are built up by replacing one hydrogen atom of the member immediately preceding it, by one carbon atom with three hydrogen atoms linked to it; from the fourth member onwards, this can be done either at the end of the chain (normal hydrocarbon) or at intermediate points

[1] Carbon is tetra-valent.

(isomeric hydrocarbons), in which case branched chains are obtained. By such substitutions, hydrocarbons are formed with two carbon atoms and six hydrogen atoms (ethane), three carbon atoms and eight hydrogen atoms (propane), four carbon atoms and ten hydrogen atoms (normal butane and isobutane), etc.

It follows from the above process of formation of the paraffin series that there is, in the case of each hydrocarbon, a whole group of atoms which passes unaltered into the next higher member, such groups or radicals being composed of the constituents of the hydrocarbon, less one hydrogen atom. These radicals of the hydrocarbons of the paraffin series are known as alkyls; they are named methyl, ethyl, propyl, butyl, etc., after the corresponding hydrocarbon. Any hydrocarbon can thus be said to consist of an alkyl group linked to one hydrogen atom.

Alcohols

The hydrocarbons of the paraffin series have an immense number of derivatives in the form of alcohols, aldehydes, ketones, acids, esters, ethers, etc. Alcohols are derived from hydrocarbons through the substitution of hydrogen atoms by hydroxyl groups, that is to say, groups consisting of one atom of oxygen and one atom of hydrogen. Alcohols with only one hydroxyl group are termed monohydric alcohols. The most important alcohols of this class are methyl alcohol (wood spirit) and ethyl alcohol (common alcohol).

Methyl alcohol[1] is a compound resulting from the substitution of one hydrogen atom in methane by a hydroxyl group. Ethyl alcohol is derived, in a

[1] The official name of methyl alcohol is methanol.

similar way, from ethane. Methyl alcohol is obtained by the distillation of wood,[1] and ethyl alcohol, by the fermentation of sugars contained in fruit or formed from starch in grain, etc. These alcohols are used in the chemical industries as solvents.

Methane and ethane, which are hydrocarbons with one and two carbon atoms, respectively, only have one monohydric alcohol derivative. In the case of hydrocarbons with three or more carbon atoms, however, the hydroxyl group may be introduced at different points of the carbon chain, with resultant formation of different alcohols (isomeric alcohols); these alcohols may come under the category of primary, secondary or tertiary alcohols.

A primary alcohol is obtained when the hydroxyl group is introduced at a terminal point of the carbon chain, where the carbon atom is linked to three hydrogen atoms, one of these being displaced. The group formed by the hydroxyl group, the carbon atom and the two remaining hydrogen atoms is the group characteristic of primary alcohols; the alkyl represented by the rest of the carbon chain and the hydrogen atoms linked to it constitutes the alcohol radical.

The alcohol resulting from the introduction of the hydroxyl group at an intermediate point of the carbon chain, where the carbon atom is linked to two hydrogen atoms, and from the displacement of one of the latter, is a secondary alcohol. Both methyl alcohol and ethyl alcohol come under the category of primary alcohols.

Aldehydes

Primary alcohols yield aldehydes on oxidation. Aldehydes are characterised by a group consisting

[1] Methyl alcohol is also produced synthetically.

of one carbon atom, one hydrogen atom and one oxygen atom. An important representative of this class of carbon compounds is formaldehyde, which is an aldehyde derived from methyl alcohol. This product is used in the manufacture of synthetic resins.

Ketones

Secondary alcohols yield ketones on oxidation. The molecule of these compounds incorporates a characteristic group composed of one carbon atom and one oxygen atom (carbonyl group), and alkyl groups, after which the ketones are named. Ketones are represented by di-methyl ketone (acetone) and methyl ethyl ketone, for instance; the former is derived from secondary propyl alcohol, and the latter, from secondary butyl alcohol. These two ketones both occur in crude wood spirit. Acetone is a valuable solvent.

Acids

Primary alcohols are converted by oxidation into aldehydes. Further oxidation results in the formation of acids, which are characterised by a group consisting of one carbon atom, two oxygen atoms and one hydrogen atom (carboxyl group). Acids containing only one carboxyl group are termed mono-carboxylic acids.

The mono-carboxylic acids derived from the hydrocarbons of the paraffin series are given the name of fatty acids, as the higher acids of the series are found in natural fats. The first two members of the series of fatty acids are formic acid and acetic acid, which are derivatives of methyl alcohol and ethyl alcohol, respectively. Formic acid is found in nature, in ants and in pine needles, for instance;

it is prepared from various carbon compounds. Acetic acid is a wood distillation product. Both these acids have their uses in chemical manufacture. The higher members of the series include palmitic acid, stearic acid, etc.

Acids containing more than one carboxyl group are called di-carboxylic acids, tri-carboxylic acids, etc., according to the number of carboxyl groups. If hydroxyl groups are also included in the acid, the prefixes hydroxy, di-hydroxy, tri-hydroxy, etc., are used, according to the number of hydroxyl groups. Thus, oxalic acid is a di-carboxylic acid, lactic acid, a hydroxy mono-carboxylic acid, tartaric acid, a di-hydroxy di-carboxylic acid, and citric acid, a hydroxy tri-carboxylic acid.

Esters

Acid derivatives include esters, salts and anhydrides. Esters are formed through the combination of acids with alcohols, water being produced in the process. The esters of fatty acids comprise such products as methyl acetate, ethyl acetate and butyl acetate, derived from acetic acid. Other useful esters are ethyl lactate and butyl lactate, and di-ethyl tartrate and di-methyl tartrate, which are derivatives of lactic acid and tartaric acid, respectively.

Salts

The simplest salts of organic acids are neutral salts produced by the neutralisation of acids by bases. Fatty acids, which are mono-carboxylic acids, only have such salts. Sodium acetate and lead acetate are neutral salts derived from acetic acid. Tartaric acid,[1] on the other hand, which is an acid

[1] Tartaric acid has four isomers. Only ordinary tartaric acid (dextro-tartaric acid) is referred to here.

with two carboxyl groups has a normal potassium salt and an acid potassium salt (cream of tartar), for instance. The latter substance is prepared from the deposits (lees) at the bottom of wine casks; it is a constituent of baking powders.

Anhydrides

Acid anhydrides are formed through the removal of the elements of water from acids. Acetic anhydride is a representative of this class of acid derivatives; it is used in the manufacture of artificial silk.

Ethers

Before passing to the very important class of carbon compounds known as carbohydrates, a brief reference may be made to ethers. The latter are oxides of alcohol radicals (alkyls); they consist of two alkyls united through an oxygen atom. The ethers with similar alkyls are termed simple ethers, and those with different alkyls, mixed ethers. Simple ethers are represented, for example, by di-ethyl ether (common ether), which is utilised as an anaesthetic.

Carbohydrates

Carbohydrates are carbon compounds containing on the one hand carbon, and on the other hand the two elements hydrogen and oxygen in the same proportion as in water; they include mono-saccharides (monoses), di-saccharides, tri-saccharides and poly-saccharides. Mono-saccharides comprise simple sugars such as glucose (grape sugar) and fructose (fruit sugar). Saccharose (cane sugar) and maltose (malt sugar) come under the category of di-saccharides. Poly-saccharides cover such substances as starch and cellulose.

Mono-saccharides are poly-hydric alcohols where

one carbon atom has been oxidised to an aldehyde group or a ketone group, these two classes of oxidation products being known as aldehyde alcohols (aldoses) and ketone alcohols (ketoses), respectively; a poly-hydric alcohol is an alcohol with several hydroxyl groups. Glucose and fructose are monosaccharides with six carbon atoms, derived from hexa-hydric alcohols; the former is an aldose, and the latter, a ketose.

CHAPTER VI

Some Special Fields of Application of Chemical Products

Dyestuffs and Explosives

Intermediates

In the preceding chapter, a brief survey has been made of some of the basic types of organic compounds. It is now proposed to consider, in the first place, the all-important group of chemical products used in the manufacture of synthetic dyestuffs and termed intermediates. These products, as their name implies, represent an intermediate stage in the building up of the dyestuff compounds from the primary materials.

Hydrocarbons of the aromatic series

The principal primary materials serving for the production of intermediates are benzene, naphthalene and anthracene, which are all coal-tar products. These compounds are cyclic hydrocarbons, that is to say, hydrocarbons where the carbon atoms form a ring or a system of rings.

Benzene and its derivatives

Benzene is a cyclic hydrocarbon with a single ring composed of six carbon atoms, each with a hydrogen atom linked to it. Naphthalene has two interlinked benzene rings, with two carbon atoms common to both rings; in this case, the total number of carbon atoms is ten, and of hydrogen atoms, eight. Anthracene has three interlinked benzene rings, with

fourteen carbon atoms and ten hydrogen atoms in all.

From the benzene ring, with its six carbon atoms, each with one hydrogen atom linked to it, countless intermediates are built up, through the replacement of one or more hydrogen atoms by another element or by a group of atoms. The substitution group may be a nitro-group, a sulphonic group, an amino-group, an alkyl group, a hydroxyl group, a carboxyl group, an aldehyde group or a cyanogen group, for instance, while a halogen such as chlorine may also be introduced.

Nitro-compounds and sulphonated compounds

The nitro-group consists of one nitrogen atom and two oxygen atoms; its introduction is termed nitration. The nitrating agent is nitric acid. Nitro-benzene is a product obtained by linking up one nitro-group to the benzene carbon ring; di-nitro-benzene is an intermediate with two nitro-groups. The sulphonic group, on the other hand, is composed of one sulphur atom, three oxygen atoms and one hydrogen atom. The incorporating of such a group is called sulphonation, the sulphonating agent being sulphuric acid.

Amino-compounds

Amino-compounds are of special importance. The amino-group comprises one nitrogen atom and two hydrogen atoms; it can be obtained by displacing the oxygen of a nitro-group by hydrogen, by means of a reducing agent. Amino-benzene, which is a product resulting from the linking up of an amino-group with one of the carbon atoms of the benzene carbon ring, is known as aniline.

Aniline is a substance from which an immense

number of intermediates are derived. Thus, sulphanilic acid is produced by linking up a sulphonic group to the carbon ring at a point of the latter separated by two carbon atoms from the point where the amino-group is located, while, by introducing a nitro-group, ortho-nitraniline or para-nitraniline are obtained, according to the position of the nitro-group in relation to the amino-group. On the other hand, aniline is converted into di-methylaniline by replacing the two hydrogen atoms of the amino-group by two methyl groups.

A few other benzene derivatives

The substitution of a hydrogen atom of the benzene nucleus by a hydroxyl group yields phenol which is the base of many intermediates. Benzoic acid is a derivative of benzene where one hydrogen atom is replaced by a carboxyl group. In benzaldehyde, the substitution group is the aldehyde group. When two hydrogen atoms of benzene are displaced by chlorine, ortho-dichlorbenzene or para-dichlorbenzene is produced, according to the relative position of the chlorine atoms along the carbon ring.

Naphthalene and some of its derivatives

Naphthalene is likewise the starting point of intermediates such as nitro-naphthalene and beta-naphthol, where the substitution groups are the nitro-group and the hydroxyl group, respectively. Amino-naphthol-sulphonic acid, which is a derivative of naphthalene, with one amino-group, one hydroxyl group and one sulphonic group linked to the naphthalene nucleus, has a number of isomeric forms including J acid and Gamma acid, while H acid is an amino-naphthol-disulphonic acid.

Explosives

These are but a few examples of intermediates used in the dyestuff industry. Another group of organic products of great importance is that represented by explosives such as nitro-glycerin, gun-cotton, picric acid and tri-nitrotoluene.

Nitro-glycerin is the name commonly given to glycerol tri-nitrate. It is derived from glycerol (tri-hydroxy propane) by replacing the hydrogen atoms of the three hydroxyl groups by nitro-groups. This substitution is brought about by treating glycerol with nitric acid mixed with sulphuric acid. The product resulting from the absorption of nitro-glycerin by diatomaceous earth[1] is known as dynamite.

Gun-cotton is a substance obtained by treating cotton with a mixture of nitric acid and sulphuric acid; it consists of cellulose nitrate (nitrocellulose), chiefly in the form of hexa-nitrate. Gun-cotton and nitro-glycerin are the two main constituents of cordite. Picric acid is a tri-nitrophenol, that is to say, a compound composed of a benzene nucleus where one hydrogen atom is replaced by a hydroxyl group and three other hydrogen atoms, by nitro-groups. Tri-nitrotoluene (T.N.T.) is a nitration product of toluene, the latter being the second member of the benzene series of hydrocarbons.

Other cellulose nitrate products

Cellulose nitrate products include, apart from gun-cotton, such substances as collodion and celluloid, which have a lower nitrogen content. Collodion is a solution of cellulose nitrate in a mixture of ether and alcohol. Celluloid is produced by mixing nitrocellulose, camphor and alcohol. Cellulose

[1] Diatomaceous earth is a residue of minute marine plants.

nitrates are further used for lacquers (cellulose lacquers).[1]

Synthetic Materials—I

Some typical classes of synthetic materials

Synthetic materials represent a very important category of chemical products, which includes synthetic resins, synthetic rubber, artificial silk and synthetic wool. The names resin, rubber, silk and wool are used here merely to indicate that the synthetic materials possess, to a greater or lesser degree, the physical properties usually associated with these natural products, without this implying similarity in chemical composition.

The synthetic materials in question, like the natural products they are intended to reproduce, are characterised by the fact that their molecules are made up of a very large number of atoms, the latter being linked together so as to form a chain or network. The atoms in the molecule of such synthetic materials can number as much as several thousands.

Polymerisation and condensation

The starting-point for the production of these synthetic materials may be compounds having molecules with only a small number of atoms. The large molecules are then built up from the smaller ones through the linking up of atoms of individual molecules, by polymerisation or condensation.

Polymerisation is the name given to the phe-

[1] For the production of lacquers, the cellulose nitrate is dissolved in a solvent and mixed with certain other ingredients (gums, plasticisers, pigments and diluents). Lacquers are also made with cellulose acetate.

nomenon whereby molecules of a substance link up together, with resultant formation of a new compound with multiple molecular weight. Condensation is the term applied to the case where molecules of the same substance or of different substances react together and form more complex molecules, usually with elimination of a simple product such as water, for instance. As a rule, polymerisation and condensation are brought about through the agency of a catalyst.

It is by such building-up processes that synthetic resins and synthetic rubber are produced. Artificial silk and synthetic wool, on the other hand, are made from natural substances which themselves have molecules with a large number of atoms, the basic material for their manufacture being cellulose, and casein, respectively. The chemical treatment to which these substances are subjected is then primarily intended to impart to them certain desired properties.

Synthetic resins

Synthetic resins include such condensation products as phenol-formaldehyde resins, furfural resins, urea-formaldehyde resin and glyptals, and polymerisation products such as coumarone resins and vinyl resins.

Phenol-formaldehyde resins comprise, as foremost representatives, the bakelite type resins. These resins are produced through the reaction of phenol and a solution of formaldehyde, in the presence of a catalyst. Phenol itself is a by-product of the coal tar industry,[1] while formaldehyde is obtained by the oxidation of synthetic methyl alcohol. Furfural resins are represented by phenol-

[1] Phenol (carbolic acid) is mono-hydroxy benzene.

furfural resins and acetone-furfural resins. Furfural (furfuraldehyde) is a product manufactured commercially from oat hulls and also from sawdust and wood shavings.

Urea-formaldehyde resins are made by causing the reaction of urea and formaldehyde. Urea is produced by heating carbon dioxide and ammonia under high pressure. Glyptals are condensation products of polyhydric alcohols and polybasic acids or anhydrides. Typical resins of this group are manufactured from glycerol and phthalic anhydride. Coumarone which is polymerised for the production of coumarone resins is a fraction contained in solvent naphtha coal-tar distillate. As regards vinyl resins, they are polymers of such compounds as vinyl acetate, vinyl chloride and chlorovinyl acetate;[1] these compounds can be derived from acetylene or ethylene.

Synthetic rubber

Rubber, like resins, is formed of long chain molecules. The parent substance of natural rubber is a hydrocarbon which belongs to the butadiene group and is known as isoprene (beta-methyl-butadiene). The repeated group of the chain molecule consists of two isoprene units.

This chain structure of the molecule, which represents the factor primarily responsible for the characteristic properties of natural rubber, is built up, in the synthetic products, by polymerisation. Thus, a whole range of synthetic rubbers are produced through the polymerisation of butadiene or butadiene derivatives. Butadiene can be obtained from various sources—notably from acetylene.

[1] Vinyl is the name of a radical which is characteristic of these compounds.

German Buna rubbers, for instance, come under the category of butadiene polymers or polymers of butadiene and other polymerisable substances.

A rubber-like material, with remarkable properties, is marketed under the name of Neoprene;[1] it is polymerised chloroprene. The latter substance is a chlorinated hydrocarbon derived from acetylene. Acetylene is first converted into monovinylacetylene by condensation, through the agency of a catalyst, after which the monovinylacetylene is treated with hydrochloric acid. Acetylene itself is produced by the reaction of water and calcium carbide.

SYNTHETIC MATERIALS—II

Artificial silks and their manufacture

Artificial silks such as manufactured to-day are all composed of cellulose or cellulose derivatives; they are made by dissolving the cellulose or cellulose derivative in a suitable solvent, and squirting the cellulose solution (spinning solution)[2] through small holes in a nozzle, so as to form fine jets, from which the cellulose material is precipitated in filament form.

If the solvent is volatile, the cellulose material in the jets precipitates in the air. Otherwise, the cellulose liquid has to be squirted into a coagulating bath (spinning bath), which eliminates the solvent holding the cellulosic material in solution and may,

[1] Neoprene is a product of the E.I. Du Pont de Nemours & Co., Inc., of Wilmington, Delaware, U.S.A.

[2] In artificial silk manufacture, the term "spinning" only refers to this ejection of liquid through the holes of a nozzle to form filaments. If the formation of filaments takes place in the air, the process is known as dry spinning, while wet spinning implies the use of a coagulating bath.

in the case of cellulose compounds, also decompose the latter. The bundle of filaments thus formed is drawn on to the winding contrivance and, on certain types of spinning machines, twisted at the same time, to a greater or lesser degree. In order to obtain the finished product, the thread has still to undergo washing, drying, doubling,[1] bleaching and dyeing.

Cellulose

Cellulose is the substance of which the cell structure of plants is built up. The two main sources of cellulose for the production of artificial silk are cotton, in the form of cotton linters[2] or spinning waste, and wood.

Cotton yields the purest cellulose. Crude cotton fibre may contain about 84 per cent of cellulose, the other constituents being water, wax and fat, protein and non-nitrogenous matter easy to extract, with a small mineral residue. The greater part of these impurities can be removed by chemical treatment. The latter includes boiling with a dilute solution of sodium carbonate or caustic soda, and bleaching. The chemical treatment of cotton linters has to be preceded by mechanical cleaning, for eliminating the dirt, dust and vegetable fragments mixed with the fibre in the cotton bales.

In wood, the cellulose is encrusted in a hard substance known as lignin, which it is necessary to dissolve, in order to liberate the cellulose, this being done by the sulphite process, when the cellulose is for artificial silk. In this process, the lignin is dissolved by boiling the wood, under

[1] Doubling is a twisting process.

[2] Cotton linters are the short cotton fibres that remain attached to the cotton seed after the first ginning process.

pressure, with a solution of calcium bisulphite. The dissolved lignin is subsequently removed by washing, and such parts as knots, etc., which are not disintegrated, are eliminated by mechanical means. The pulp is then bleached and made into sheets, in which form the cellulose is supplied to the artificial silk manufacturers.

Viscose silk

There are three main varieties of artificial silk: viscose silk, acetate silk and cuprammonium silk. In the case of viscose silk, the spinning solution consists of cellulose xanthate dissolved in dilute caustic soda, the liquid in question being known as viscose.[1] Viscose silk is generally made from wood cellulose. The cellulose is first converted into alkali-cellulose. For this purpose, the cellulose sheets are soaked in a solution of caustic soda, after which they are pressed, in order to expel the excess solution. The dry alkali-cellulose is then finely crushed and allowed to mature (ripen). Cellulose xanthate is produced by mixing the alkali-cellulose with carbon bisulphide.

The viscose obtained by dissolving the cellulose xanthate in dilute caustic soda is first allowed to ripen, and then filtered, after which it is squirted through the apertures of a nozzle into the spinning bath. The substances entering into the composition of the spinning baths most commonly used are sulphuric acid, metallic salts (sulphates of sodium and zinc) and glucose; ammonium sulphate may also be a constituent. Through the action of the bath, the cellulose xanthate of the viscose is coagulated and decomposed, with regeneration of cellulose.

[1] Viscose is not only used for the production of artificial silk; it also serves for making cellophane and wool substitutes.

Acetate silk

For acetate silk, the spinning solution consists of acetone-soluble cellulose acetates[1] dissolved in acetone or other suitable solvents. The first stage in the manufacture of acetate silk is the conversion of cellulose into cellulose tri-acetate through the action of acetic anhydride, the latter being mixed with acetic acid and with a catalyst such as sulphuric acid, for instance.

Cellulose tri-acetate changes into acetone-soluble acetate through hydrolysis.[2] Hydrolysis can be brought about through the agency of a mixture of acetic acid, water and sulphuric acid. The acetate obtained is precipitated, washed, dried and then dissolved in the solvent for the spinning solution. Spinning solutions with acetone as solvent can be spun in air, as acetone has a low boiling point and readily evaporates in a warm atmosphere, leaving the cellulose acetate to form the filament.

Cuprammonium silk

In the case of cuprammonium silk, the spinning solution consists of cellulose dissolved in ammoniacal copper oxide. The latter is produced by treating copper hydroxide, for instance, with ammonia. Copper hydroxide is formed by precipitating an aqueous copper sulphate solution with caustic soda. As a rule, the cellulose is introduced at this stage, being mixed with the copper hydroxide precipitate.

The cellulose-copper hydroxide paste is pressed

[1] There are several varieties of cellulose acetate. Cellulose tri-acetate represents the most highly acetylated product; it is, however, not soluble in acetone. The acetone-soluble acetates are less highly acetylated compounds.

[2] Hydrolysis is a reaction where a compound combines with the elements of water.

in a filter press and, after disintegration, dissolved in ammonia. Certain other substances such as glucose, etc., may be added for improving the spinning qualities of the liquid. The spinning solution is finally diluted with a mixture of water, ammonia and caustic soda, in order to obtain the proper cellulose content. Air bubbles and excess ammonia are removed through the action of vacuum.

For the spinning bath, use can be made of water, as ammonia is very soluble in the latter. The filaments obtained in this case are composed of cellulose, copper and alkali; they are very plastic, so that they can be easily stretched to a smaller diameter (stretch-spinning process). This first bath of water may be followed by a second bath of very dilute caustic soda. After this, the filaments are passed through a dilute solution of sulphuric acid, which combines with the copper to form copper sulphate, leaving pure cellulose.

Synthetic wool

Synthetic wool is represented in the very first place by the fibre marketed under the name of Lanital;[1] the latter is made from casein. Casein is a substance with various industrial uses,[2] obtained from milk;[3] its chemical composition is somewhat like that of natural wool, the elements composing it being

[1] Lanital is a product of the Soc. Nazionale Industria Applicazioni Viscosa of Milan. The brief outline of the process of manufacture of Lanital given here is based on the information contained in the issue of April–June, 1938, of *Snia Viscosa*, the Journal of that firm.

[2] Casein is used, for instance, for making glues, and for the production of mouldings.

[3] Milk contains in the first place proteins, with casein as chief representative; other constituents are fat, sugars, vitamins and mineral salts.

carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur.[1]

For the production of Lanital, the casein is precipitated from skim milk by means of a curdling agent, the mass obtained being pressed in a filter-press, in order to expel the whey from the casein. The latter is then washed, dried, ground and finally dissolved in a suitable solvent to form the spinning solution. The solution is allowed to mature, after which it is filtered. The spinning process is similar to that for artificial silk. The threads produced are cut, washed and dried, and manufactured into yarn in the same manner as wool.

Artificial silk itself can be used for producing wool-like fibre. Thus, various processes exist for imparting to the artificial silk filaments a wave or curl, such as possessed by natural wool fibre. This crimping of the filament may be brought about by mechanical or chemical treatment. The artificial silk filaments may also be cut into short pieces of definite length (staple fibre), for manufacture into yarn by the ordinary spinning processes.

The uses of synthetic fibres will be referred to when dealing with the raw materials of the textile industries, in general.

[1] Natural wool is composed of carbon, hydrogen, oxygen, nitrogen and sulphur.

CHAPTER VII

Raw Materials of the Textile Industries and of the Leather Trade

FIBRES—I

Fundamental fibres

The fundamental fibres of the textile industries are wool, silk, cotton and flax, to which must be added artificial silk. Each of these fibres has its special characteristics that govern its field of application, while the cost of the material is another all-important factor influencing its use.

Wool and its characteristics

Wool is a fibre with a scaly surface and natural waviness. It is characterised by its felting properties, its great elasticity and resiliency,[1] and its ability to hold a high percentage of water without feeling wet. Furthermore, it lends itself to the production of yarns incorporating a large number of air spaces, which prevent the flow of heat and thus act as a protection against heat or cold.

Uses of wool

All these different qualities render wool specially suitable for the manufacture of garments. Other users of wool, apart from the clothing industry, are the hosiery, blanket and carpet industries. Each of these industries requires wool with given characteristics. The widest range of wool is taken by the

[1] Wool fabric tends to return to its original shape after being stretched.

clothing industry, owing to the great variety of cloths produced, which range from fine cashmeres to heavy tweeds. The hosiery industry utilises the finer quality wools such as merino and down wools. The blanket industry is the principal consumer of skin wool, which it blends with fleece wool. As regards the carpet industry, its raw material consists of the coarsest wools.

Grading of yarn by weight

The yarn into which wool is spun for its various applications is classified in different ways. It is graded in the first place according to its weight. The measure used in this connection is the count. The count gives the number of hanks of 560 yards that go to the pound of yarn; it varies from 4's to 80's, in the case of the finest yarns.

Worsted yarn and woollen yarn

Another most important classification is one based on the structure of the yarn, the division being into woollen yarn and worsted yarn.[1] Worsted yarn is a yarn in which the wool fibres have been made to lie parallel by a combing process; the wool utilised for its manufacture is mainly finer grade wool of 3-in. to 8-in. staple. The types of wool that come under this category are merino and fine crossbred. Woollen yarn is a yarn where the wool fibres do not lie parallel, but are intermixed, so that in the woven fabric the weave can no longer be clearly detected. The wool used for this yarn is lower quality wool with large-scaled fibres, short wool rejected during the combing process (noils) and reconditioned wool (shoddy or mungo).

[1] Woollen yarn and worsted yarn correspond to entirely separate branches of the textile industries.

Warp and weft

A further division of yarn is into warp and weft. These designations indicate the function for which the yarn is suitable in the weaving process. Warp is the yarn stretched across the path of the shuttle; it is therefore subjected to greater strain than the weft, which is fed from the shuttle. In view of this, warp has to be stronger and is spun from wool with a greater length of staple, the latter being as a rule not less than three inches.

Apart from these main classifications of yarn, there are a number of subdivisions, each corresponding to the particular qualities of the wool.

Silk and its properties

Silk is the most costly of all fibres, but it is also the most beautiful one and possesses at the same time very valuable qualities from the point of view of textile manufacture. These properties of the silk fibre are its extreme fineness, its great strength in relation to its cross-section and its length. Silk is further characterised by its elasticity and durability. Like wool, it can absorb a considerable proportion of water without feeling wet.

The fineness of silk is expressed in denier counts. The denier represents a unit of weight equal to five centigrams and the count, the number of deniers that 450 metres of silk weigh.

Silk fabrics

Silk fabrics range from plain fabrics to chiffons and velvets; ribbons represent another class of silk manufacture. Silk is used in the very first place for dress goods. It further serves for draperies and is particularly suited for ornamental purposes. Apart from this, silk has various special applications; it is

utilised, for instance, for umbrella covers. In the field of aviation, its lightness combined with strength has led to its use for parachutes. Finally, the low electrical conductivity of silk fibre makes it a good electrical insulating material.

Cotton—the universal textile material

Cotton is the universal textile material. This fibre possesses a characteristic spiral twist which, when spinning, causes the individual fibres to cling together and permits of the production of a strong and even yarn. Cotton has greater strength than wool, but is less elastic. It is easy to clean and can be washed in boiling water without injury. Its ability to withstand a considerable amount of rough handling is another valuable property. Through the process of mercerisation,[1] cotton can be given a lustre approaching that of silk, while its strength and affinity for dyes are increased at the same time.

Classification of cotton

The fundamental classification of cotton fibre is according to its length (staple). The staple varies from $\frac{3}{8}$ in. and less, in the case of the coarsest Indian cotton, to $1\frac{3}{4}$ in. and more, for Sea Island cotton.[2] The bulk of American cotton is medium staple cotton of $\frac{7}{8}$ in to $1\frac{1}{8}$ in.; Egyptian cotton is a long staple cotton of $1\frac{1}{4}$ in. and more. Cotton fibre is furthermore divided into a number of grades

[1] This process consists in the immersion of yarn under tension in a solution of caustic soda.

[2] At the present day, Sea Island cotton comes mainly from the Bahama Islands. Up to about 1920, it was also grown on a large scale in the coastal plains of Georgia, South Carolina and Florida. During the following years, however, it was practically wiped out, owing, in a considerable measure, to the spread of the boll weevil.

depending upon the particular qualities of the cotton.

Cotton yarn

The fineness of yarn obtainable with any variety of cotton depends primarily upon the staple. The degree of fineness of yarn is measured in counts, which represent the number of hanks of 840 yards to the pound. Fine counts of 60's and more necessitate the use of long staple cotton such as Egyptian cotton, while short staple cotton, such as ordinary Indian cotton, can only be used for coarse counts below 24's. American cotton serves mostly for counts of 30's to 40's.

Cotton fabrics

American cotton is utilised for a very wide range of cloths, from plain calicoes to good twilled sheetings and canvas. Egyptian cotton is suitable for all purposes where strength and smoothness are required; it is extensively used for the manufacture of fine fabrics, underwear, lace and sewing cotton. Another application is for the cotton foundation of cycle and motor tyres. Indian cotton serves for cheaper cloths.

FIBRES—II

Flax and its characteristics

Flax is stronger than cotton; it is characterised by its tenacity and durability, and by the fineness of fibre obtainable. Flax fibre is soft and flexible, and has a silky lustre; it varies in length from about 1 ft. to 3 ft. and is built up of minute filaments cemented together. The textile manufactures made of flax are given the name of linen.

Linen products

The coarser fibre is used for making canvas, sail-cloth, tarpaulin, etc., while the finer fibre serves for the production of household linen such as table cloths, bed-sheeting, etc., articles of wear such as shirts and collars, linen thread and lace. The finest fabrics have the lustre of silk. Linen is cooler to the touch than cotton and readily gives up moisture. Owing to the latter property, it is specially suited as material for towels and handkerchiefs. In the industrial field, linen is used for aircraft fabrics.

Synthetic fibres and their properties

As a result of the improvement of the properties of synthetic fibres, the latter have assumed a more and more important place in textile manufacture. At the present day, synthetic fibres are produced with a dry strength exceeding that of cotton,[1] while new processes of manufacture have made it possible to obtain yarns with a soft and lustreless finish. The different kinds of fibre necessarily vary as regards physical and chemical properties. This applies, in particular, to their affinity for dyes. Thus, viscose silk and cuprammonium silk take direct cotton dyes, whereas cellulose acetate silk cannot be dyed with them.[2]

Uses of artificial silk

Artificial silk, either alone or in combination with natural fibres, is manufactured into the most varied fabrics for clothing and household requirements. These fabrics range from crepe to velvets

[1] Synthetic fibres lose strength when wetted.

[2] In view of these dyeing characteristics of cellulose acetate silk, it is possible to dye fabrics made of cellulose acetate fibre and cotton into two colours in one operation, by using a bath with a cotton dye and a dye which the acetate fibre alone will take.

and heavy brocades for decorative purposes. Artificial silk is used for underlinen, for women's wear such as frocks, knitted blouses and hosiery, for sheets and table-linen, for upholstery, etc.

Applications of synthetic wool

As regards the synthetic wool known as Lanital, it is made into a variety of clothing materials. The fabrics produced include both light and heavy cloths, suitable for men's suits and overcoats, and for women's wear. Lanital wool can also be used for knitted work.

Other important fibres

Wool, silk, cotton, flax and artificial silk represent the principal raw materials of clothing and household fabrics. Apart from these fibres, there are other important fibres which are used either for weaving purposes or for cordage. Jute, for instance, is utilised in large quantities in textile manufacture for the production of cheap woven goods. Ramie is another textile fibre with valuable properties. Common hemp, Manila hemp and sisal are, on the other hand, primarily cordage fibres.

Jute

Jute fibre possesses good spinning qualities. The strands of fibre yielded by the jute plant are from five to eight feet in length and capable of very fine subdivision. The fibre, however, lacks strength and durability, and is liable to deterioration, when in prolonged contact with water. This necessarily limits, to a certain degree, its field of application. The principal uses of jute fibre are for making hessians,[1]

[1] Hessian is the name given to a type of cloth mainly used for making into bags, such as serve for holding grain, potatoes, etc.

sacking, tarpaulin, curtains, carpets, rugs, matting and backing for linoleum and oil-cloth. In India, it is also utilised for cordage and sails.

Ramie

Ramie is a fibre remarkable for its length, great strength, durability and lustre. It is capable of being made to resemble wool or cotton, but lacks the elasticity of the former and the flexibility of the latter. Although ramie has a wide field of utility, as a fabric fibre, its use is restricted due to the costliness of the process required for its preparation.

Common hemp

Common hemp or true hemp is a strong and durable fibre; the best types of hemp are nearly white and have a good lustre. Hemp fibre serves more especially for making ropes, cables, twines and nets, but it is also utilised for sail-cloths and tarpaulins, and as warp for carpeting material. In Italy, hemp is used, mixed with other fibres, as substitute for flax and cotton, in clothing and other fabrics.

Manila hemp

Manila hemp is characterised by its high tensile strength, lightness and resistance to sea-water; these properties render it specially suitable for ship's ropes and cables. Manila hemp is further made into best grade binder twine and is spun into yarn for coarse weaving. Waste fibre is used in the manufacture of "manila" paper.

Sisal

Sisal comes under the category of a hard fibre. It is very strong and, in this respect, ranks next to

Manila hemp, but is less flexible than the latter; the fibres measure up to about four feet in length. Sisal serves mainly for binder twine and rope. It is, however, also used for making bags, rugs, carpets and matting, and even for footwear. In the United States, sisal fibre is utilised furthermore for upholstery purposes.

Further vegetable fibres

Vegetable fibres further include Sunn hemp, New Zealand hemp and Mauritius hemp. Sunn hemp is used as a substitute for common hemp; it is made into cordage and coarse textiles. The principal use of New Zealand hemp and Mauritius hemp is for the manufacture of cordage and twine; Mauritius hemp is also employed for making bags.

Asbestos

In conclusion, reference may be made to asbestos, which is a mineral fibre. Asbestos possesses the valuable property of being non-inflammable, while it also has heat insulating qualities. The longer fibre can be spun into yarn, which is woven into cloth for fire-proof clothing, theatre curtains, conveyor belts, brake lining, mattresses for boiler insulation, etc.; gaskets[1] and packings are other products made from asbestos fibre. In order to reinforce the asbestos yarn, fine metal wire can be spun together with the fibre.

As regards the shorter fibre, it is utilised mainly for asbestos-cement products such as tiles, pipes, flat or corrugated sheets, etc., which are manufactured in very large quantities. Millboard and paper are other forms into which asbestos is made.

[1] Gaskets are pieces of jointing material, cut to shape, for insertion between the faces of a joint.

Hides and Skins[1]

Hides and skins yielded as by-products

Hides and skins form the basic substance of leather; they are yielded in enormous quantities as by-products of the meat-packing, dairy and wool-growing industries, while slaughtered beasts of draught are a further source of supply. Apart from the general classification of leather raw stocks, according to the species of the animal, a further subdivision into mature and immature hides and skins is necessary, owing to the different qualities of these products.[2]

Classes of leather raw stocks

Leather raw stocks include in the very first place cattlehides and calfskins, sheepskins and lambskins, and goatskins and kidskins. Horsehides, buffalo hides and pigskins are minor classes of raw stocks. Hides and skins come not only from slaughtered beasts, but also from animals that have died from accidents or other causes (fallen hides and skins).

Cattlehides

The cattlehide class covers the hides of mature cattle of the bovine species (neat cattle). These hides constitute by far the most important category of leather raw stocks. Cattlehides necessarily vary considerably as regards size and thickness; they are usually cut longitudinally in two parts (sides), and split into an inner and outer layer,[3] except when

[1] The difference between hides and skins is merely one of size and weight.

[2] The terms "mature" and "immature" relate to the age of the animal.

[3] The inner layer is known as a split.

used for sole leather, belting or harness. Cattlehides have a relatively coarse grain.

Kips and calfskins

Hides of semi-mature cattle are known as kips; the latter form an intermediate class between cattlehides and calfskins. Calfskins themselves are skins of immature cattle. The qualities of these skins are greatly influenced by the diet upon which the animal has been fed before slaughtering. Skins of calves not yet weaned or artificially milk-fed are characterised by their fine grain.

Sheepskins and lambskins

Sheepskins differ considerably, according to the particular breed. In a general way, the better the wool, the poorer the skin. Thus, merinos which are noted for their fine and abundant wool yield skins lacking in smoothness and resistance, and much inferior to those of low-wooled sheep. As regards lambskins, they mostly come from animals not yet shorn, and give a better grade leather than the mature stock.

Goatskins and kidskins

Goatskins represent a more expensive variety of leather raw stock. The qualities of the skins are, in this case too, dependent upon the breed. Short-haired breeds of the tropical areas yield fine-grained skins, while the long-haired stock of the colder climates give coarse-grained products. Kidskins are skins of immature animals; they have specially valuable characteristics, being very fine-grained and supple.

Horsehides

Horsehides, buffalo hides and pigskins are leather raw stocks of considerably lesser importance. Horsehides have this peculiarity that they embody in their rear part two oval-shaped patches of entirely different structure to the rest of the hide. These patches that correspond to the two sides of the rump of the animal are formed of hard cartaliginous substance of practically non-porous nature. As regards the remaining portion of the hide, it has some similarity to the upper layer of cattlehide, but is more resistant.

Buffalo hides and pigskins

Buffalo hides represent a coarser type of hide. The utility of these hides is mainly due to the thickness and the great toughness of the latter. Pigskins possess the special quality of being relatively resistant to abrasion; they lack, however, tensile strength and are relatively porous. In view of this, heavy stuffing with grease is necessary, to render them impermeable to moisture.

Shoe leather

Hides and skins are used in the very first place for shoe leathers; the latter include sole leather and upper leather,[1] in particular. For sole leather, use is made of full thickness cattlehide, while the raw stocks employed for upper leather include split cattlehides, sheepskins and lambskins, and horsehides. Calfskins yield upper leather too, but for lighter shoes; certain grades of goatskins are also utilised for the purpose.[2]

[1] Upper leather is leather used for the pieces (uppers) forming the upper part of the shoe. Apart from sole leather and upper leather, there are stocks for linings, tongues, etc.

[2] The shoe leather made from goatskins is given the name of kid leather, although it comes from mature stock.

Glove leather

Glove leather constitutes another important class of leather. Lambskins, kidskins and pigskins go into leather for the finer gloves. For work-gloves, on the other hand, raw stocks such as split cattlehides or horsehides are employed.

Other leathers

Apart from shoe leather and glove leather, there are numerous other sorts of leather serving likewise for products for personal or household use. These leathers include bag and case leather, upholstery leather, fancy leather,[1] etc., and specialities such as chamois leather, clothing leather, strop leather, etc.

Strap leather and harness leather are leathers made from cattlehides; the latter are further used for saddle leather. For high-grade saddles, however, pigskins are utilised. As regards buffalo hides, they have only a rather limited field of application. In view of their toughness, they are specially suited for mechanical leather[2]; they also go into low-grade sole leather.

[1] One of the best-known varieties of fancy leather is morocco leather, which is made from goatskins.

[2] Mechanical leathers are leathers used in machinery.

CHAPTER VIII

A Few Other Fundamental Raw Materials of Vegetable and Animal Origin

Rubber and Resins

Raw Rubber

Rubber is obtained by coagulating the milky liquid (latex), exuded from the bark of rubber trees, where it occurs in the form of small globules in suspension. It is a tough material with elastic properties. In its raw state, however, it is very sensitive to temperature conditions,[1] is highly susceptible to oils, and remains permanently deformed to a greater or lesser extent after stretching, this permanent deformation being due to the plasticity of the material. For this reason, raw rubber as such has necessarily but a limited sphere of utility, which is mainly confined to the production of crêpe soles, adhesive and insulating tape and rubber cements, and to the preparation of the various rubber derivatives.

Vulcanised Rubber and its Properties

In the vulcanised state, on the other hand, rubber has an immense variety of uses. The ordinary method of vulcanisation is to heat the rubber with sulphur, to which other suitable ingredients (compounding ingredients) are added, according to the qualities required. Through the introduction of sulphur and compounding ingredients, rubber can

[1] Through the influence of cold, raw rubber becomes hard and stiff ("frozen").

be conferred the most valuable properties, while its sensitiveness to heat and oils is greatly reduced.

A pure rubber-sulphur mixture yields a product possessing high extensibility and compressibility, with ability to recover to a very large extent its shape after deformation, and having an ultimate tensile strength considerably greater than that of raw rubber. By the addition of certain compounding ingredients, the tensile strength can be very much increased, but at the expense of the deformability. The rubber can further be made to lose entirely its resilience and assume the toughness of leather, and by prolonged vulcanisation and use of a high proportion of sulphur can finally be converted into a material of great hardness, known as ebonite.

Owing to its being able to acquire such divers mechanical characteristics, vulcanised rubber can be applied to the most varied purposes, while its chemical resistance and its electrical insulating properties widen still further its field of application.

Uses of Rubber

The foremost application of rubber is for the manufacture of motor tyres and their inner tubes. In the case of tyres, rubber acts as flexible bonding for the cotton foundation; the tread of the tyre requires a very tough material, offering great resistance to cutting and abrasion. For inner tubes, on the other hand, a soft flexible material is necessary. Mechanical rubber goods further include a variety of other products ranging from washers to hose and belting, and from rubber road blocks to rubber springs and buffers for railway stock.

In the chemical industries, rubber is utilised not only for hose, but also for lining vats containing acids such as hydrochloric acid, for instance, while

in the electrical industry it plays an essential part as constituent of insulating compounds for wires and cables. Another important field of application of rubber is in connection with footwear; it is used there for making waterproof boots and shoes, and in the form of component parts such as heels and soles. A further use of rubber is for the proofing of fabrics.

Latex Rubber

Rubber products are also being made to an increasing extent directly from latex; in this case, the latex itself is mixed with the sulphur for vulcanisation and with the compounding ingredients. Thus, a whole range of articles such as toy balloons, gloves, surgical goods, etc., are produced by dipping into the latex suitably shaped formers, the film of latex adhering to the former being subsequently dried, and the dry product, vulcanised, unless vulcanised latex[1] has been used. Sponge rubber is another product which can be made directly from latex.

Synthetic Rubbers

Synthetic rubbers include such products as Neoprene made by the Du Pont Company in America, and the Buna rubbers produced in Germany. Neoprene, like natural rubber, is mixed with various ingredients and heat-treated (vulcanised), in order to make it into a tough elastic material; it cannot, however, be vulcanised to the same degree of hardness as natural rubber. A further difference between this synthetic rubber and the natural product is that sulphur is not

[1] Vulcanisation can be carried out before the dipping process, while the rubber is still in globules in the latex.

required for the vulcanisation of Neoprene, although it can be added as a compounding ingredient.

Neoprene compounds are very stable, have a high resistance to oils, are practically unaffected by sunlight and do not lose their resilience at high temperatures. Neoprene also resists a number of chemicals. In view of its special qualities, this synthetic material has many applications, in spite of its higher price as compared with natural rubber. Thus, it is utilised for oil and fuel hose, for conveyor belts, for gaskets, for the covering of electric cables liable to trail in oil, etc.

Buna rubbers comprise a large range of synthetic rubbers. Buna S is the raw material used for motor tyres; it has a very high resistance to abrasion and, in this respect, is superior to natural rubber. This synthetic rubber is manufactured on a very large scale in Germany.

Resins and their uses

Resins are substances secreted by plants; an exception is shellac, which is the product of an insect. These substances are fusible, emit a smoky flame when burning and are insoluble in water. Resinous substances include, apart from true resins, mixtures of resins with other constituents such as essential oils,[1] gums,[2] etc.; balsams and gum resins come under this category. Commercial resins comprise not only resins of recent formation, but also fossil resins, such as copals, etc., which are found in the ground.

[1] Essential oils are more or less volatile, aromatic oils that occur in plants and give them their distinctive odour. Turpentine is an instance of an essential oil.

[2] Gums are also substances exuded by plants. True gums differ, however, from true resins in that they are soluble in water.

Resins or "gums"[1] are of great importance as basic constituents of varnishes. There are two main classes of varnishes: oil varnishes and spirit varnishes or lacquers. For the manufacture of oil varnishes, the resins or "gums" are dissolved in a drying oil such as linseed oil, and mixed with a volatile thinner such as turpentine, a preliminary heat treatment (gum running) being necessary, in order to render the resins soluble in linseed oil. When the varnish is applied, the thinner evaporates, leaving a sticky film, which hardens as the oil oxidises.

In the case of spirit varnishes, the resin is dissolved in a volatile solvent such as alcohol, that evaporates on application of the varnish. Varnishes are also made with cellulosic materials as basic constituents; the cellulosic materials used are nitrocellulose or celluloid. Most of these varnishes or lacquers also include resins in their composition Apart from serving as raw materials for varnishes, resins have various other industrial applications, while many resinous substances are utilised for medicinal and pharmaceutical purposes.

Rosin

Rosin is the cheapest resin. It is derived from the natural resins (oleo-resins) secreted by various species of pine trees, turpentine being yielded as second product. By subjecting these oleo-resins to steam distillation, the turpentine is volatilised, leaving rosin as residue. Rosin is used in the manufacture of paper size, in varnishes, more especially in combination with other resins,[2] for soap, for

[1] The term "gum" is used commercially in place of "resin," although the designation is technically incorrect.

[2] Apart from rosin-China wood oil varnishes, only poor quality varnishes are obtainable with rosin as base.

printing ink, etc. Turpentine is utilised as a thinner in the paint and varnish trade.

Shellac

Shellac is the most important spirit varnish resin. It gives a tough film capable of being highly polished. Furthermore, it possesses water-proofing qualities and electrical insulating properties; in view of this, it is widely used for protective coatings and as insulating varnish for electrical machines. Shellac is also used for high-grade sealing wax, while it further serves for stiffening hats. The most important application of shellac is, however, in the manufacture of gramophone records.

Synthetic resins

Synthetic resins are used both for moulding purposes and for varnishes. Resins utilised for moulding come under two categories; thermo-setting resins and thermo-plastic resins. In the case of the thermo-setting type, the resins are converted by heat into infusible and insoluble products, and lose entirely their plasticity. With the thermo-plastic type, on the other hand, the resins retain their plastic properties.

The most important moulding resins are phenol-formaldehyde resins of the bakelite type, and urea-formaldehyde resins, which are thermo-setting. These resins are made into moulding powders, the latter being produced by mixing the resins with a filler such as wood meal, asbestos, etc., and pigments. The moulding is done under high pressure, in heated steel moulds.

These moulding powders serve for making products of every description, ranging from motor car accessories, telephone equipments and parts of radio

sets, to tooth-brush handles, knitting needles and spectacle frames. Phenol-formaldehyde resins are utilised chiefly for dark-coloured articles, and urea-formaldehyde resins, for light-coloured objects.

Vinyl resins are other resins employed for moulding purposes; they belong to the thermo-plastic type. Both small and large objects are moulded from resins of this group. Glyptals comprise thermo-setting and thermo-plastic resins. An application of the thermo-setting type is as cement in laminated mica material for electrical insulation. Furfural resins too possess moulding properties.

Synthetic resins also serve, in the same manner as natural resins, for the manufacture of varnishes and lacquers. In this connection, they are used either alone or modified with other resins, for instance. Phenol-formaldehyde resins, urea resins, vinyl resins, glyptals and coumarone resins are some of the principal synthetic resins utilised by the varnish industry.

Vegetable and Animal Fats and Oils—I

Principal classes of oil

There are three principal classes of oils: mineral oils, fatty or fixed oils, and essential oils. In the following, it is proposed to deal with fatty or fixed oils, which are products derived from the vegetable and animal kingdoms. Essential oils which are other oils of vegetable origin, have not been included within the scope of these remarks; a brief reference has been made to them in the section on natural resins.

CHAPTER IX

The Raw Material with the most Varied Uses

Timber

Wide range of applications of timber

Timber is the raw material with the widest field of applications. Although it may no longer have so extensive a range of uses in building as in olden times, it is still the principal material for carcassing, flooring, windows and doors. In furniture making, it remains supreme. On ships, timber has no doubt been largely displaced by steel for structural parts, but it is, as before, indispensable for decking, ceilings, etc.; furthermore, it is extensively utilised for decorative purposes.

In railway construction, timber is used for sleepers, and in the building of rolling stock, for the superstructure of coaches and frames of wagons. In mines, timber is utilised for pitprops. In harbour work, it serves for piling and for wharfing timbers. It is employed for cooperage, for wheelwright work, for packing-cases and for countless other purposes.

Great choice of woods

There are over three thousand varieties of wood in commercial use. These different kinds of wood come under two main categories: softwoods and hardwoods. Softwoods are easy to work. They comprise the woods of the conifer family; pines, firs, larches, spruces, cedars, etc. As regards hardwoods, they include an immense number of

woods: European woods such as ash, beech, chestnut, elm and oak,[1] North American woods such as maple and hickory, tropical woods such as teak, mahogany, ebony, rosewood and sandalwood, Australian woods such as karri and jarrah, etc.

Some common softwoods

Softwoods constitute the principal woods of the building trade. The wood most commonly used for the purpose is that derived from the Northern pine (*Pinus sylvestris*). This tree abounds in Northern and Central Europe, from where the wood is shipped as redwood; similar timber found in this country is given the name of Scots pine. When in the form of planks, deals, battens, boards, etc., this wood is defined as red deal.[2]

Another very important wood is that yielded by the European spruce (*Picea excelsa*). The main source of supply of this wood is Northern Europe, from where it is shipped as whitewood; Eastern Canadian spruce is a similar timber from Canada. European spruce is given the name of white deal, when in the sawn state. White deal is also used in building, but is less resistant to weather than red deal.

Other kinds of softwoods

Larch is a most valuable timber, owing to its great durability; it is, however, one of the more expensive softwoods. This timber is used for barns and outhouse buildings, for mining timbers, for scaffolding, for piles and wharfing timbers, flooring, etc. Pitch pine is another very durable wood suitable for piling.

[1] Oak is widely distributed over the Northern Hemisphere.

[2] The term "yellow deal" is also used.

Douglas fir and Western red cedar are two types of Canadian softwoods extensively used in this country. Douglas fir is a tree that grows to a great height. Its wood possesses considerable strength and is specially suitable for heavy structural work. It is employed for bridge timbers, wharfing timbers and piles, for ship masts and hatch covers, for railway sleepers, etc. Douglas fir is also utilised for flooring, doors, stair-work, etc., as well as for certain classes of furniture (cupboards, etc.).

Western red cedar is a very durable wood, while the aromatic oil it contains renders it to a large extent immune from attack by insects. It is particularly suited for parts exposed to the weather, such as roofing shingles,[1] weather boards, window sills, transmission poles, etc. Inside buildings, it is used for panelling, mouldings, etc. Cabinet making and pattern making, for instance, are other purposes to which it is applied.

Two important hardwoods

One of the most important hardwoods is oak; the latter comprises a very large number of species. In view of its great strength, toughness and durability, it is specially suitable for structural parts such as roofs of large buildings, for instance; other uses in building construction include flooring, panelling, etc.

Although oak has lost its place of pre-eminence in shipbuilding, since the advent of steel ships, it still has many applications in this particular field, while it is employed to a certain extent in barge building. Oak is utilised for railway wagon frames; wheelwright work is another of its numerous applications. Oak is furthermore one of the chief

[1] Shingles are wood tiles.

woods for furniture making. Other woods extensively used in this connection are mahoganies and walnuts; both these woods, as well as certain oaks, are utilised as veneers.

Teak is another hardwood, which is very valuable for constructional purposes. This wood too possesses great durability and strength, and has furthermore heat-resisting qualities. A special characteristic of teak is the presence in its structure of an oil which prevents the rusting of iron or steel placed in contact with the wood. Teak is used in large quantities in shipbuilding and naval work; it is also used in railway coach-building. In building construction, it serves for doors, window frames, balustrades, etc.

Further types of hardwoods

Ash, beech, sweet chestnut and elm are hardwoods which each have their particular applications. Ash is used for coach bodies, in aircraft construction and for wheelwright work. Beech is employed for chairs and tool handles, for instance. Sweet chestnut is very suitable for carved work and is often utilised in combination with oak; cleft chestnut fencing is also a noted product. One of the characteristics of elm is the durability of the latter under water, which suits this wood for piles, wharf construction, sea groynes, etc.; elm also serves for wagon building, wheelwright work, etc.

Maple is a wood particularly suitable for flooring, owing to its tough texture. Hickory is characterised by its great springiness; it serves for sport requisites,[1] tool handles, and in some countries, for wheelwright work. Karri and jarrah are both very useful

[1] Hickory was the wood used for golf clubs, before the introduction of steel shafts.

CHAPTER I

Nature of Raw Materials

Vegetable raw materials

Raw materials come under three headings: mineral, vegetable and animal raw materials. Vegetable and animal raw materials are products of the living world, so that their supplies are continually being renewed by nature. Each plant is in itself a chemical factory that draws from the soil and the atmosphere the various materials required for its growth, and transforms them into the compounds that constitute its substance.[1] The organism of every type of plant is adapted to certain climatic conditions, which are necessary for its proper working.

Influence of climate and soil on production

Climate and soil are thus factors that play a very important part in connection with the production of vegetable raw materials. Cotton is an instance of a plant that prospers under conditions differing very considerably; it is grown within the wide belt comprised between the latitudes of 40° North and

[1] The materials assimilated are carbon dioxide and oxygen from the atmosphere, and salts from the soil. A portion of the water absorbed by the plant is also assimilated; it combines with the carbon dioxide and forms carbohydrates.

The chemical elements introduced into the plant by the salts include non-metals such as hydrogen, oxygen, nitrogen, sulphur and phosphorus, and metals such as potassium, calcium, magnesium and iron.

30° South.[1] Rubber, on the other hand, needs an equable tropical temperature and a well distributed and high rainfall, but can thrive on a large range of soils.

Control of production by man

Within these limits of climate and soil, production can to a great extent be controlled by man. Contingencies such as excessive rain or drought, or insect pests are, however, factors that have always to be reckoned with. The time that a plant takes to reach the productive stage varies considerably according to the botanical species. Cotton, for instance, is a plant that is sown yearly; its acreage can thus be increased or decreased after every season. Rubber trees come into bearing after five or six years. An increase in rubber production necessitates therefore a period of years. As regards timber, the time it requires to reach maturity varies from some twelve years, in the case of willows, to more than a century, for oak.

Animal raw materials

For animals, climatic conditions and even soil are no less important. Some breeds of sheep can prosper on the rough grazings of the mountainside, while others need the richer grass of the plain; each breed yields wool with special characteristics. Supplies can here too be regulated in a large measure by man, although there is always the possibility of such disturbing factors as drought and disease. Animal raw materials may be either primary products or by-products. Hides and skins, for instance, are usually by-products, while the primary product is meat.

[1] Cotton includes a great variety of species.

Mineral raw materials

As regards minerals, they are the constituents of the rocks that form the crust of the earth.[1] Certain rocks consist of a single mineral, in a more or less pure condition; this is the case for marble, quartz, felspar and mica, for instance. Most rocks, however, are an aggregate of several minerals. Rocks such as granite,[2] sandstone, shales, slates and limestone, which constitute a great part of the crust of the earth, come under this category.

Composition of minerals

The mineral itself may consist of one or more chemical elements (non-metals or metals). In view of the wide applications of metals, metallic constituents of rock are of special importance. The metal may be in combination with a single other element such as oxygen (oxide) or sulphur (sulphide); it may, on the other hand, be associated with a group of elements consisting, for instance, of carbon and oxygen (carbonate) or silicon and oxygen (silicate). Metals very rarely occur in the pure state. Metal-bearing rocks, where the concentration of metal is sufficient to permit of its economical extraction, are known as ores,[3] the minerals accompanying the metallic substance being the gangue.

Sedimentary rocks

Rocks are grouped in two principal classes: sedimentary rocks and igneous rocks. Sedimentary rocks are mainly the result of the process of denudation

[1] In geology, the term rock also includes clay, sand, gravel, etc.

[2] Granite is an aggregate of quartz, felspar and mica.

[3] The term "ore" is furthermore only applied to rocks yielding useful or precious metals.

that has been going on at the surface of the earth ever since the latter was subjected to the action of water.[1] These rocks consist of a conglomeration of materials that have been detached from pre-existing rock and deposited on the beds of rivers, lakes and seas. This is the origin of sandstone, clay and shale, in particular.

Other sedimentary rocks have been formed through the accumulation of organic remains (vegetable matter, etc.). The most important representative of this class of rock is coal. Finally, deposits have also come into existence through chemical precipitation or evaporation. Salt is an instance of such deposits.

Owing to the movements of the earth, these beds of sedimentary rock have been subjected to great disturbances; in many cases, they have been lifted high up above their original level and crumpled into folds, often intersected by cracks and fissures.

Igneous rocks

Igneous rocks are the result of the cooling down of a molten mass. This molten mass may have solidified within the stratified structure of the sedimentary rocks, in deep-seated cavities that may have very large dimensions (bosses), in cracks or fissures (dykes) or between two beds of rock (sills). It may, on the other hand, have reached the surface through vents and formed lava deposits. Some of the principal constituents of igneous rocks are quartz, felspar and iron oxides.

[1] Water first appeared on the earth when the crust of the latter became sufficiently cool to permit of the condensation of the surrounding water vapours.

Geological age of rocks

As a result of the study of the fossilised remains of fauna[1] and flora found in sedimentary deposits, it has been possible to identify rock formations with particular eras and periods. The eras into which the geological time[2] has been divided, in this connection, are the Archaean or Pre-Cambrian era, covering the remotest ages, followed by the Palaeozoic or Primary era, the Mesozoic or Secondary era and the Cainozoic or Tertiary era, reaching up to recent times.

The principal subdivisions[3] of the three latter eras are the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods, for the Palaeozoic era, the Triassic, Jurassic and Cretaceous periods, for the Mesozoic era, and the Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Recent periods, for the Tertiary era.

The rocks originating from these respective eras and periods are described accordingly, by the name of the particular era or period. Thus, Jurassic rocks, for instance, are rocks of the Jurassic period, while Tertiary deposits are deposits of the Tertiary eras. Cambrian rocks are the oldest rocks containing fossils.

[1] In the oldest sedimentary deposits, the fossils are confined to marine organisms.

[2] Geological time must be envisaged in terms of millions of years.

[3] These subdivisions are enumerated in order of decreasing antiquity.

CHAPTER II

Mineral Deposits and Methods of Extraction

Occurrence of Ores

Ore deposits

Ore deposits, with the exception of iron ore deposits, do not form any substantial part of the crust of the earth. It is true that certain metals are common constituents of rock,[1] but the metal concentration is, in most cases, quite insufficient to bring the rock within the category of an ore; as a rule, it is only when the metal is of a very valuable nature that it pays to work rocks having no more than a small metal content. Furthermore, some metallic compounds do not lend themselves to the economical extraction of the metal and, for this reason, are not regarded as ores; thus, although aluminium is the most widely distributed metal, its source of supply is mainly confined to one mineral, namely, bauxite.

Primary ore deposits

In their primary state, ore deposits may occur in the form of veins[2] or as masses, permeated to a greater or lesser degree with metal. A large part of the ore deposits are of igneous origin. The metallic constituents of the molten mass may have solidified within the latter in a more or less segregated con-

[1] Metals, other than aluminium and iron, that are extensively found in more or less minute quantities in igneous rocks, include magnesium, titanium, barium, manganese, nickel and chromium.

[2] Veins are sheet-like formations.

dition or they may have escaped, as highly heated metal vapours under great pressure, by way of cracks and fissures, far into the sedimentary rocks where the metal has been deposited in the form of veins. Other ore deposits are due to percolation of water containing minerals in solution through the rock.[1]

Iron ores hold a special position, owing to their being important constituents of the crust of the earth. They occur both in the form of igneous masses and of sedimentary beds.

Secondary ore deposits

Apart from these primary ore deposits, there are also secondary deposits resulting from the disintegration of the former through atmospheric agents (rain, etc.). The materials thus detached have often been carried considerable distances by streams and rivers, and have settled in the beds of the latter or on their banks, as alluvial deposits; these deposits usually consist of sand or gravel, with which the particles of metal are mixed. Gold, tin and platinum are metals that are found in such secondary deposits.

Tracing of ore deposits from geological features

The solid rock of the crust of the earth is in large part concealed from view by a layer of earth, stones, etc., with a covering of vegetation serving as protection against denudation. It is, as a rule, only in accidents of the ground (precipitous cliffs, rifts, erosions, etc.) or in regions where vegetation cannot subsist due to rigorous climatic conditions or lack of water that the rock formation is exposed to any considerable extent and reveals the presence of any

[1] This penetration may take place through the porous mass of disintegrated rock, and through fractures and other interstices.

ore deposits. Otherwise, the only external evidence of such deposits is that which may be furnished by fragments of rock detached from outcrops[1] at some time or another and scattered about by the forces of nature.

The identification of the deposit may even so not always be easy, as exposed minerals may present a very different appearance from that of the material underground, especially in damp climates, due to atmospheric weathering.

Locating of ore bodies by geophysical measurements

The study of the geological features of the country can necessarily only give definite information regarding deposits actually reaching the surface, although inference may be drawn, as to the possible presence of ore deposits at some depth below, from the occurrence of certain rocks which are known often to form the matrix of metallic veins.[2]

Prospectors have, however, at their disposal various means for detecting ore bodies even at considerable depths. For the location of magnetic ores such as magnetite, use can be made of different types of instrument embodying a magnetic needle. When prospecting for non-ferrous metals, several electrical methods can be resorted to. These are based either on the effect of ore bodies on a current sent through the earth or on the fact that certain ore bodies (sulphides) have earth currents flowing through them, due to chemical action. Another method makes use of a torsion balance which is influenced by the different densities of minerals. With seismic methods, an explosion wave is pro-

[1] Outcrops are exposed portions of a bed, seam or vein.

[2] Granite, schist and quartz are rocks that often contain metallic veins.

pagated through the rocks, and its distortion by the underground formation, observed.

Determination of boundaries of ore bodies

The information obtained by such methods regarding the presence of ores, as well as the deductions from observations at the surface, must necessarily be verified by means of bore-holes[1] or exploratory workings. By these means alone is it possible to ascertain definitely the boundaries of the ore bodies. Furthermore, an assay of samples is indispensable, in order to get some indication of the metal content of the deposit.

Working of Stratified Mineral Deposits

Factors governing choice of method of working deposits

The methods used for working mineral deposits vary from place to place. They depend in the very first instance upon whether the deposit is stratified or unstratified, and upon whether the latter is close to the surface or at a certain depth. Apart from these primary factors, there are a number of other considerations that influence the choice of the method of working: steepness and thickness of the bed, seam or vein, condition of rock surrounding the deposit, freedom from or presence of water, etc. Furthermore, local custom and practice play an important part.

[1] These are usually made with drills having a cylindrical bit set with diamonds (diamond drills), attached to a tubular rod that can be extended as the hole reaches deeper into the rock. As the drill cuts annular holes, it is possible to bring to the surface cores of the material traversed.

Minerals occurring in stratified formation

Minerals encountered in stratified formation include coal, limestone, gypsum, slate, shales, clay, potassium salts, phosphate rock and salt, for instance. Certain iron ores occur likewise as stratified deposits, while tin, gold and platinum are found to a considerable extent in alluvial deposits.

Working of surface deposits of hard materials

When the mineral bed is near the surface and of the consistence of hard rock, the material is got by quarrying. Large limestone deposits are worked in this way in Derbyshire, for example, and in other parts of Great Britain. Ironstone too is obtained in open excavation in Lincolnshire. If the quarry face is of sufficient length and height, tunnels can be driven into the rock, terminating in headings branching off on either side, where the blasting charges are placed;[1] in this manner, a large width of wall can be broken down. Otherwise, powder holes are drilled into the rock usually downwards, beginning at the top of the quarry face. The overburden[2] is removed, as a rule, by steam or electric shovels or by excavators.

Working of surface deposits of soft materials

When the deposit consists of soft or finely divided material such as clay, sand, gravel, etc., use can be made of bucket excavators. Another method that is also resorted to is hydraulicing. With this method, water under natural pressure or artificial pressure is used for washing down the material, which is led along in the form of a muddy mixture to tanks or

[1] With this method, sections of the quarry have to remain idle, while the tunnels are driven.

[2] Earth and other material covering the deposit

sluices. Such a method is utilised in china-clay pits, for instance, the pure clay being then obtained from settling tanks. Hydraulicing is also one of the methods used for working tin-bearing alluvial deposits; in this case, the ore is separated from the accompanying material in sluices.

Underground mining and means of access to the working districts

The working of stratified deposits close to the surface is in most cases a fairly simple proposition. When, however, it is a question of getting the minerals from deposits that pitch at a greater or lesser inclination from the surface into the crust of the earth, or lie at a certain depth, the problem is a very different one. It is then necessary to provide suitable means of access to the districts underground where it is proposed to work the seam or bed, and at the same time ensure proper ventilation.

In the case of outcropping stratified deposits dipping into a hill, for instance, the means of access may be in the form of drifts,[1] tunnels or slopes driven into the hillside, from which branch off roadways leading to the various working districts. When, on the other hand, the deposits are at a certain depth, shafts have to be sunk to the level of the seam or bed, and roadways provided there, from the shafts to the working districts, for the use of the men, for haulage and for ventilation. Furthermore, provision has to be made in every case for the drainage of water, while measures have to be taken to prevent the falling in of the overlying rock along the roadways and at the working faces.

[1] Drifts are passages started at the outcrop and driven in the deposit itself.

Working systems and stowing methods

Whether the excavated space (goaf) is filled in again or not with packing material (stone, debris, etc.) to take the pressure from above depends upon the method of working. In the case of coal working systems where the coal is got by driving passages in the seam, at right angles to each other, so as to form pillars which are subsequently removed (bord and pillar working), the overlying rock is usually allowed to subside.[1] When, however, the coal seam is worked in long continuous faces in a direction away from the shaft (longwall advancing), pack-walls are required on either side of the roadways through the intervening goaf.[2]

This partial or complete filling in of the excavated space in mines, which is known as stowing, is specially important in the case of deep mines, where the overlying strata exert huge pressures. Stowing may be done either by hand or hydraulically. In the latter case, sand or other finely divided material, mixed with water, is sent down the mine from the outside through a pipe and led into wooden frames erected at the points where stowing is required. Should no suitable material be available for stowing, pillars of sufficient dimensions can be left standing to support the roof.

Stratified minerals obtained from deep-seated beds

Underground mining has to be resorted to for the extraction of a number of stratified minerals, due to their occurring usually in more or less deep-seated beds. Coal is by far the most important of these and it is to a large extent on the systems evolved

[1] Reference is made more especially to the British practice.

[2] When the deposit is worked towards the shaft (longwall retreating), the goaf can be left behind without stowing.

for coal mining that have been modelled the methods for the working of other stratified deposits such as those of ironstone, oil shale and potassium salts. There are no doubt many stratified minerals, such as limestone and slate, that are mainly got by open excavation from surface deposits, but even in their case underground mining has occasionally to be adopted.

Salt deposits

A stratified mineral that belongs to a class of its own is salt. Apart from being mined in the usual way, it can also be extracted in solution, owing to its high degree of solubility. Thus, in a certain district of Yorkshire, where there are important salt deposits, water is fed through pipes into the beds and the salt is pumped out in the form of brine.

Working of Ore Bodies and other Unstratified Mineral Deposits

Minerals occurring as unstratified deposits

Unstratified deposits represent a mode of occurrence characteristic of such minerals as pyrites, magnesite, feldspar, mica and asbestos, and of the majority of ores.[1] In view of the predominant part played by metals, ore deposits will be dealt with in the very first place.

Various shapes of ore bodies

Ore bodies assume most varied shapes. They occur in sheet-like formation (veins or lodes), as lense-shaped deposits or merely as irregular masses,

[1] Certain iron ores occur in stratified rock formation, while tin, gold and platinum are found to a large extent in alluvial deposits.

sometimes of very large dimensions. The veins themselves differ greatly as to thickness and may lie at any inclination from the vertical to the horizontal; they are encountered both singly and in association, often interlinked together. Ore lenses too pitch at any angle, while they may also overlap to a greater or lesser extent.

Working of ore bodies near surface in open pit

Large ore bodies situated near the surface can be mined in open pit. In this case, excavation takes place in steps (benches). The blasting of the individual benches is done by the usual quarrying methods, the charge being placed either in powder holes or in headings at the end of short tunnels driven into the face of the deposits.

Combined open excavation and underground work

Sometimes open excavation is combined with underground work. This is the case with the milling method, where haulageways starting from a shaft or from the hillside are driven through the deposit directly under the open excavation and linked up with the latter by passages through which the broken ore is extracted. Below the haulageways of this upper level are others at lower levels, which are used successively, as the surface working gets deeper and cuts into the haulageways of a level.

Underground mining of ore bodies

The applications of open pit working are necessarily limited and in the greater number of cases a shaft has to be sunk, and underground mining resorted to. In the case of ore bodies extending in depth (large masses or veins with a steep gradient), the deposit is opened up by running through the

ore body, at different levels, haulageways and by connecting up the latter by passages driven upwards (raises) or downwards (winzes). These raises or winzes form the points of attack for the excavation work.

By working from these different points, a succession of chambers (stopes) are created which eventually reach from level to level. A small width of deposit (pillar) is, however, usually retained at the top to serve as floor for the upper level. At the bottom too, a sufficient thickness may be left to form a roof over the haulageway. Another arrangement is merely to keep clear a passage for the latter through the broken ore by timbering or, in the case of narrow veins, to build a roof of boards from wall to wall. The broken ore is drawn from the stopes through chutes arranged at intervals along the haulageways.

Forms of stopes

In the case of veins of moderate thickness, the stopes occupy the whole cross-section of the deposit and are limited by the walls of the latter. There is then only one haulageway per level, and the stopes along its length constitute more or less narrow chambers with the inclination of the vein. In large ore bodies, on the other hand, the stopes are usually in the form of high vertical cavities, which are distributed along several haulageways and separated by pillars; these pillars are subsequently removed.

Underhand stoping and overhand stoping

When excavating the stopes in the block of deposit between levels, work may proceed from the top downwards (underhand stoping) or more usually from the bottom upwards (overhand stoping). The

working faces may be advanced in a direction more or less parallel to the levels, or diagonally to the raises or winzes. Progress may even occasionally be parallel to the latter. In the case of high vertical stopes, a certain number of sublevels may be provided between the haulage levels, and work carried on at these different points. The ore is usually broken by drilling and blasting. Caving[1] is another method resorted to; drilling and blasting are, however, required in this case for starting the caving.

Methods of supporting walls of stope

At the same time as the working face advances, it is generally necessary to provide supports for the walls and possibly for the top (back) of the stope. In narrow stopes, stulls and props[2] may be utilised for supporting the walls. When the width of vein is too great for the use of stulls or props, timbering has to take the form of a wooden framework (square sets). This framework serves also for carrying the working platforms.

The most effective method of support is, however, by waste filling, the waste being brought from the level above. Passages for manways and ore chutes, from the working space to the haulage level below, are kept clear through the waste filling by means of timber frames.

Shrinkage stoping

Another method of working is to leave the broken ore to accumulate in the stope and only remove a sufficient amount to allow the necessary working space for the miners (shrinkage stoping). The broken

[1] Subsidence through the action of the weight of the masses.

[2] Props are set normal to the walls, while stulls are placed at a certain angle.

ore is then removed at a later stage. All these various systems can be modified and combined at will to meet the particular conditions encountered.

Methods of working veins with low angle of inclination

In the case of the methods of stoping referred to, the ore passes from the stope to the haulage level below by gravity. When, however, the inclination of the vein is not sufficient to permit of this,[1] the cars have to be brought up to the working face. The methods of working resorted to then are somewhat similar to those used for the mining of coal seams.

Mining of other unstratified deposits

The varied conditions encountered in connection with ore deposits have given rise there to so wide a range of mining systems that the latter include most of the methods used for mining other unstratified minerals. Some of these minerals are, like certain ores, met near the surface. Thus, asbestos for example is obtained in greater part from open-cast workings. Mica, on the other hand, is worked both in open cuttings and in underground mines.

[1] In the case of veins with a low angle of inclination, the action of gravity can be assisted by providing wooden or metal chutes, which latter have necessarily a much lesser friction resistance than the floor of the stope.

CHAPTER III

Coalfields and Oilfields

Origin and Formation of Coal and Petroleum

Origin of coal

Coal is a material with a very complex chemical composition. It is the result of the gradual transformation of vegetable debris through the action of such natural processes as fermentation, maceration, compression and heat. The parent substance of coal is thus represented by the organic compounds (celluloses, lignins, proteins, fats, waxes, resins, etc.) that formed the original vegetable matter, the elements contained in these compounds being carbon, hydrogen and oxygen, and in certain of them, nitrogen and sulphur too.[1]

Process of coalification

In all the various phases of the maturing process, these elements are found again, but in different proportions. Thus, in peat, lignite and brown coals, that correspond to the earlier stages of transformation, the proportion of carbon is relatively low, while in bituminous coals and anthracite, which are the mature products, carbon constitutes a very high percentage. This is due to the chemical changes that most of the original compounds undergo in the process of coalification, and in the course of which

[1] Cellulose, lignins, fats, waxes and resins are compounds of carbon, hydrogen and oxygen, while proteins also contain nitrogen and sulphur.

new compounds are formed, with elimination of oxygen. There are, however, certain plant products, such as waxes, that subsist in the coal in a more or less unaltered condition.

Gases and mineral impurities in coal

Coal always contains, apart from this organic substance, a certain amount of moisture, while gases may be trapped (occluded) in its structure.[1] Furthermore, mineral impurities are present to a greater or lesser degree; these impurities which may be in the form of pyrites, clay or shale, for instance, yield the ash left over after the combustion of the coal.

Origin of petroleum

Petroleum, like coal, is a product of the living world. It owes its origin to organic matter, incorporated in clay or other argillaceous beds, when the latter were being deposited in the shallow waters of estuaries or deltas of the age. From these beds, the oil has passed into adjoining strata of sands and porous rocks, and eventually migrated to its final location, through the action of natural agencies such as gravity, capillarity, compression due to earth movements, etc., other influences in this migration being the water (usually salt water)[2] accompanying the oil, and the gas (natural gas) that is also evolved from the organic matter and generally present in oilfields.

Petroleum composed of hydrocarbons

Petroleum consists of compounds of carbon and hydrogen (hydrocarbons), accompanied by a small

[1] The principal gas found in bituminous coal is methane (fire-damp).

[2] The deep-seated water is regarded as sea water that has been retained in the porous strata.

proportion of impurities, in the case of the crude product; these impurities may be in the form of oxidised matter or of compounds containing sulphur or nitrogen. There are an immense number of hydrocarbons, which differ one from the other by the number of atoms of carbon and hydrogen in the molecule, or by the arrangement of the atoms in the latter. The fact that there are such a multitude of compounds of carbon and hydrogen is due to certain characteristics of carbon.

Types of hydrocarbons

Carbon is quadrivalent, that is to say, atoms of this element link up with four atoms of hydrogen.[1] The carbon atom can, however, also join up with other carbon atoms, instead of with hydrogen atoms; in such a case, there may be one link between carbon atoms (saturated compounds) or several links (unsaturated compounds).[2] These linked up carbon atoms may form an open chain (open chain compounds),[3] or constitute a closed chain (closed chain, ring or cyclic compounds). The hydrocarbon with the simplest structure is that where one atom of carbon is combined with four atoms of hydrogen; the hydrocarbon in question is known as methane.

Hydrocarbon series occurring in petroleum

A number of hydrocarbon series have been identified in crude oil; they include paraffins, olefines,

[1] An element is known as monovalent, bivalent, trivalent or quadrivalent, according to whether the atom of this element combines with one, two, three or four atoms of hydrogen. This characteristic of an element is its valency.

[2] Unsaturated compounds differ from saturated compounds in the manner in which they react: unsaturated compounds can combine directly with other materials, while with saturated compounds such a reaction necessitates the displacement of hydrogen.

[3] The chain may be straight or branched.

diolefines, aromatics and naphthenes. The hydrocarbons of the first three series are open chain compounds, and those of the two last series, closed chain compounds. Paraffins and naphthenes are saturated hydrocarbons, while olefines, diolefines and aromatics are unsaturated.

Classification of crude oils

Paraffins and naphthenes are the predominant series and serve for the classification of crude oils, the latter being described as paraffin base, naphthene (asphalt) base or mixed base oils, according to their content of hydrocarbons of these series.[1] Each hydrocarbon series has a corresponding type formula, which expresses the relation between the number of carbon atoms and hydrogen atoms in the molecule of the compound of the particular series.[2]

Oil-bearing strata

Oil is found chiefly in sands, sandstones, porous limestones, conglomerates and grits. The most important of these, as reservoir rocks, are sands and limestones. The oil-bearing strata are usually confined between impervious beds of clay or shale, which prevent the oil from escaping and thus permit

[1] Paraffin base oils leave as residue paraffin wax, and naphthene (asphalt) base oils, asphalt.

[2] The type formula is a formula where the number of atoms of carbon and hydrogen is expressed as a function of a quantity n, which can be given any value. The type formula of the paraffin series, for instance, is C_nH_{2n+2}; thus, in the molecule of the compounds of this series, the number of hydrogen atoms is equal to twice the number of carbon atoms plus two.

As the type formula is only concerned with the number of atoms, compounds with a different internal structure may have the same type formula. This is, in particular, the case for the naphthene and olefine series, which both have as type formula C_nH_{2n}.

of its accumulation; these beds of clay or shale, rendered compact and impermeable by compression, may have been the sediments that originally held the oil-yielding substances.

Due to oil having a lesser density than water, it tends to rise above the latter, when the two are in association in the porous strata. Thus, in the case of folded strata, the oil is more often found, with the gas, at the crest of the upward folds (anticlines), while the water is located below. The sealing of strata by faults, intrusions of igneous rocks, etc., may, however, alter this distribution. If the oil-bearing strata are in communication with the surface, the presence of oil may be revealed by seapages.[1]

Drilling for oil

Drilling for oil is generally done by means of rotary drills; the drill is attached to a line of pipes which is extended as the hole deepens, muddy water[2] being forced down this hollow stem and through apertures in the bit, to clear the bottom of the hole. The water charged with broken material returns to the surface along the outer side of the pipe. In order to prevent the caving of the walls, a tubular casing is inserted into the hole.

Initial production and settled production of oil wells

When oil is struck, the gas pressure or hydrostatic pressure may cause it to rise to the surface, and even, in certain cases, to spout up with great force in the form of "gushers." This initial stage corresponds to maximum production. As, however, the

[1] Leakages of oil.

[2] Muddy water is used as it has not got the same disintegrating action on the walls of the hole as clear water.

gas pressure becomes exhausted, the yield of the well gradually declines, until after a certain period settled production is reached. The well may then still be flowing or it may have to be pumped.

Oil shales

Oil shales are argillaceous rocks containing oil-yielding substances, derived from the organic matter originally incorporated in the sedimentary deposit and retained in the latter. Some of these oil shales are mined for the extraction of oil, which is then obtained by a distillation process. Oil is produced commercially from the oil shales of the West and Mid-Lothian areas of Scotland, for instance.

Geological and Geographical Distribution of Coal and Petroleum

Coal deposits and their age

The coals of the various coalfields of the world differ very considerably as regards their age. On the one hand, there are immature coals (lignites and brown coals) of the younger rock formations and, on the other hand, mature coals of the older formations.

Lignites are mainly confined to formations of the Tertiary era. Brown coals are found in formations of the Tertiary era and also of the end of the Mesozoic era. Mature coals occur in formations of the Palaeozoic era, the Mesozoic era and the beginning of the Tertiary era, the most valuable deposits being of the Carboniferous period of the Palaeozoic era.[1]

[1] The vegetation of the Carboniferous period was specially luxuriant.

Palaeozoic coals

Coals of the Carboniferous period of the Palaeozoic era occur in North America, Europe and Asia. The vast deposits of Pennsylvania, in eastern North America, the coalfields of Great Britain, Northern France, Belgium and the Ruhr, in western Europe, and the great coal basins of Moscow, the Donetz and the Urals, in Russia, belong to the Carboniferous period, while coal of that age is also found in Poland and Bohemia, in central Europe.

In other parts of the world, Palaeozoic coals are represented mainly by deposits of the Permo-Carboniferous period. In New South Wales, there are rich coalfields of that period, while China has very extensive deposits. South Africa and India also have coal of the Permo-Carboniferous.

Mesozoic coals

Coals of the Mesozoic era are found more especially in North America, Europe and Asia. The Mesozoic coals of North America are chiefly of the Cretaceous period; important deposits of that period occur in British Columbia, Alberta, and in the Northern Plains of the United States, where they are closely associated with Tertiary coals.

In Europe, the deposits are principally in the central and south-eastern areas. Thus, Poland, Jugo-Slavia and Bulgaria are all countries possessing coal of the Mesozoic era. Coals of that age are also found in Sweden, as well as in France and Spain. In Asia, the deposits are located mostly in the central part of the continent and in Southern China.

Tertiary coals

Coal occurs in Tertiary rock formations in all the continents. In North America, the Tertiary deposits

consist mainly of lignites; they are found over large areas in the Great Northern Plains of the United States and in the neighbourhood of the Gulf of Mexico. The deposits of South America are located mainly in the northern part of the continent.[1]

In Europe, the coals of the Tertiary era are principally brown coals and lignites; there are, however, in certain regions, deposits of sub-bituminous coals of that age.[2] Tertiary coals are found in most countries of Central and Southern Europe. Germany has very large supplies, while Russia has considerable deposits in the southern part of her territory.

Tertiary coals occur in many parts of Asia. Thus, Japan has important deposits of bituminous coals of the Miocene, and lignites of the Pliocene. Extensive reserves of Miocene coals exist in Northern Siberia too, while Asia Minor is another region where Tertiary deposits are encountered.

Coals of the Tertiary era figure very prominently in the coal resources of Oceania. There are large deposits of that age in Victoria, as well as in New Zealand. Tertiary coals are also found in many islands of the East Indies.

Petroleum and its age

Petroleum is found in rocks of nearly all ages from the Ordovician period of the Palaeozoic era to the Pleistocene period of the Tertiary era. By far the largest proportion of the oilfields of the world belong to the Cretaceo-Tertiary age.

[1] Tertiary coals occur in Venezuela, Colombia, Ecuador and Peru, in particular.

[2] Deposits of sub-bituminous coals of the Tertiary era are found in Germany and Spitzbergen.

Location of oilfields

As oil-yielding sediments are mainly marine sediments, deposited in relatively shallow water, there is necessarily a close relationship between their location and that of the coastlines of the seas of the times when the deposits were formed. These coastlines have varied very considerably from age to age, as the sea advanced or retreated, and continents changed their shape, as a result of the upheavals of the crust of the earth.

The most favourable conditions for the accumulation of oil-yielding deposits of great thickness have been those afforded by the sea basins occupying the more or less shallow depressions corresponding to zones of weakness of the earth crust (geosynclines), where the sea floor was gradually sinking, as the sediments were being deposited.

Subsequent earth movements have caused these deposits to be squeezed between the harder masses of the globe, with the result that the strata have become highly folded and mountain ranges have come into being. Many of the most important oilfields of the world are associated with such geosynclinal zones.

Palaeozoic oils

Oils of the Palaeozoic era are found principally in the United States. The oilfields of the Appalachian Plateau and those over the greater part of the Interior Plains are of that age. Palaeozoic oils also occur in Canada.

Cretaceo-Tertiary oils

Most of the other oilfields of the world are of the Cretaceo-Tertiary age. In the United States, the Rocky Mountain fields are chiefly of the Cretaceous

period, while the Gulf Coast fields belong mainly to the Tertiary era. In the Pacific Coast fields, oil is yielded by Cretaceous and Tertiary formations.

In Mexico, the oil is derived principally from Cretaceous deposits. The oilfields of Trinidad and also those of Venezuela, Colombia, Ecuador, Peru and Argentina, all belong to one part or another of the Cretaceo-Tertiary age. This also applies to the fields of Roumania, Galicia, France, Germany and Italy, and to those of Russia, Iran, Iraq and Egypt. In Burma and the East Indies, the oil is associated with Tertiary formations, which are also the source of oil in Japan.

CHAPTER IV

The Production of Coal and Petroleum

WORLD'S COAL SUPPLIES[1]

World's production of coal and lignites

The largest coal producers are the United States, Great Britain, Germany and Russia. Next in importance come France, Poland, Japan, Belgium, India, China, the Union of South Africa and Holland. Australia, Canada, Manchuria, Spain, Turkey and Chile are smaller producers.

In 1938, that is to say, in the last pre-War year, the average monthly world production of coal was in the neighbourhood of 90 million tons; four-fifths of this total were contributed by the first group of countries referred to, the figure for the United States being about 29 million tons, and that for Russia, about 11 million tons. The corresponding figures for 1937 were about 100 million, 37 million and 10 million tons, respectively.

The average monthly coal production of the countries of the second group, during 1937 and 1938, ranged from about 4 million tons, in the case of France, to about 1 million tons, for Holland. For lignites, the average monthly world output amounted to about 20 million tons in 1938 and about 19 million tons in 1937. Germany was responsible for the greater part of the total, the balance

[1] The production figures are based on those given in the *Monthly Bulletin of Statistics* of the League of Nations, and the export and import percentages, on those contained in the publication of the International Labour Office entitled *The World Coal-Mining Industry*.

being made up by Hungary, Jugo-Slavia, Canada, Roumania and Bulgaria.

The United States as foremost coal producing country

The United States are by far the most important coal producing country of the world, as shown by the production figures for 1938 and 1937, for instance, that averaged about 29 million tons and 37 million tons per month, respectively. The State of the Union that contributes the largest share of the output is Pennsylvania; not only does Pennsylvania rank as largest producer of bituminous coal, but it also supplies most of the anthracite of the country. The next most important coal producing States are West Virginia, Illinois and Kentucky.

The bulk of the coal production of the United States is consumed in the country. In the years preceding the War, the proportion of the output exported amounted only to about 3 per cent. This percentage small as it may be represents nevertheless a very considerable tonnage, in view of the high level of the coal production, so that the United States are even so amongst the largest coal exporters.

Leading position of Great Britain as coal exporter

The principal coalfields of Great Britain are those of South Wales, in the south, those of Yorkshire, of North Derbyshire and Nottinghamshire, of South Derbyshire, Leicestershire, Cannock Chase and Warwickshire, and of Lancashire, Cheshire and North Staffordshire, in the centre, and those of Durham, Northumberland and Scotland, in the north.[1]

The average monthly production of the country

[1] Other coalfields are those of Cumberland, North Wales, South Staffordshire, Shropshire, Bristol, Forest of Dean, Somerset and Kent.

was about 19 million tons in 1938 and about 20 million tons in 1937. Some of the coals produced possess specially valuable characteristics. Thus, the steam coals[1] and anthracites of South Wales have a world-wide reputation, while the Durham coalfields are noted for their gas and coking coals. Great Britain holds first place as exporter of coal; about 20 per cent of the coal production was being exported before the War.[2]

Germany also an important coal exporting country

The chief coal producing areas in Germany are the Ruhr, the Aachen district and the Saar, in the west, West Upper Silesia and West Lower Silesia, in the east, and Saxony. Lignites are mined in the Lower Rhineland, in Central Germany and east of the Elbe. The average monthly production of coal alone was about 15 million tons, during 1937 and 1938; in the case of lignites, the figures were about 16 million tons for 1938 and about 15 million tons for the preceding year. Germany too exported about 20 per cent of her coal production, which placed her second as coal exporter.

Coal production of Russia (U.S.S.R.)

The most important coal mining region in Russia is the Donetz basin, where both bituminous coal and anthracites are found. Coal is also mined extensively in the Urals. Russia's coal production, which averaged about 11 million tons and 10 million tons per month in 1938 and 1937, respectively, makes that country rank among the largest coal producers; her coal exports are, however, relatively small and

[1] These coals are smokeless semi-bituminous coals.

[2] Bunker loadings, which are reckoned here as exports, represent a considerable proportion of Great Britain's coal export trade.

in the years preceding the War only represented 1 to 2 per cent of her output.

Other coal exporting countries

Apart from the three great coal producing and exporting countries—Great Britain, Germany and the United States—there are certain other countries which, although comparatively small coal producers, are nevertheless of considerable importance as coal exporters, owing to the large proportion of their output that they export. Thus, Holland exported before the War more than 50 per cent of her production, while for Poland and Belgium the figures were about 30 per cent and 25 per cent, respectively. The list of coal exporting countries further includes a large number of smaller coal producers.[1]

Coal importing countries

Even though countries may themselves produce coal, they nearly all have to import a certain amount, either to supplement their home supplies or to make good their deficiencies in particular grades. France, for instance, was a very large importer of coal in pre-War years, her coal imports being greatly in excess of what she exported. In the case of several countries, the coal imports more or less balance coal exports. Holland, in particular, is in this position; prior to the War, she both imported and exported coal on a considerable scale. On the other hand, such countries as Argentina, Denmark, Switzerland, Norway, Greece, Sweden and Italy have to rely entirely or nearly entirely on imported coal to meet their domestic requirements, owing to the absence or scarcity of home supplies.

[1] Most coal producing countries export some proportion of their output.

WORLD'S PETROLEUM SUPPLIES[1]—I

Principal oil producing countries

By far the largest oil producing country is the United States; its average monthly production was in 1938 about 101 million barrels, representing more than 60 per cent of the total world production, which averaged in that year about 165 million barrels per month. The next most important producers are Russia (U.S.S.R.) and Venezuela; for these countries, the corresponding figures were about 17¼ and 15¾ million barrels, respectively. Then follow Iran, the Dutch East Indies, Roumania, Mexico, Iraq, Colombia, Trinidad, Argentina, Peru, India and Burma, Bahrein, Sarawak and Brunei, and Canada,[2] whose average monthly production in 1938 ranged from about 6½ million barrels for Iran to about 580,000 barrels for Canada. Finally, there are a number of smaller producers including Germany, Poland, Egypt, Saudi Arabia, Japan, and Ecuador.

Oil production of the United States

At the end of 1939, there were over 370,000 wells[3] in active production in the United States; the total oil output during that year averaged about 105 million barrels per month, as compared with about 101 million barrels in 1938. The average yield of the individual wells ranged from less than half a barrel a day, for certain of the older fields, to 40

[1] The production figures are given in barrels of 42 U.S. gallons and based on the revised data as published in the *Petroleum World* of January 1941.

[2] These countries are enumerated in order of importance, on the basis of the 1938 production figures.

[3] The number of active wells on December 31, 1939, was 372,468 (see *The Oil and Gas Journal* of January 25, 1940, page 78).

barrels and more, for some of the newer fields; the average for all oilfields was about 9¼ barrels. The wells include flowing wells and pumping wells, but mostly belong to the latter class.

All grades of oil are produced in the United States. Thus, light paraffin base oil is found in Pennsylvania, while heavy asphaltic base oil is typical of certain parts of the Californian oilfields.[1] In the Mid-Continent oilfields, on the other hand, the oil comes mainly under the category of mixed base oil. The oil occurs in limestone, sandstone and sand. It is found at levels varying according to the oilfields. Some of the deepest wells are in the Gulf Coast region, where production is obtained in several fields from depths of 10,000 to 13,000 feet.

The State of the Union with the largest production is Texas. Next comes California, followed by Oklahoma, Louisiana, Illinois, Kansas and New Mexico. The other principal oil producing States are Michigan, Wyoming, Arkansas, Pennsylvania, Montana, West Virginia, New York and Ohio. The oil industry originated in Pennsylvania in 1859, when drilling was applied for the first time to the extraction of oil. From there, oilfield development spread to the other parts of the country.

Oil in Canada

In Canada too, oil has been produced since far back in the nineteenth century, but only on a relatively limited scale. In 1867, the prolific Petrolia and Oil Springs fields were discovered, these fields being situated in the region at the south-western extremity of the Province of Ontario,

[1] In former times, heavy asphaltic base oil was the predominant type of crude in the Californian fields. In more recent times, however, large quantities of lighter oils have also been found there.

between Lake Huron and Lake Erie, which up to recent times has been the principal producing area. During the last few years, however, important oilfield developments have taken place in the Province of Alberta, notably in the Turner Valley, where some ninety wells had been brought into production by the end of 1939. The opening up of these oilfields has greatly altered the oil position in Canada and led to a large increase of the Canadian production, which averaged about 580,000 barrels per month in 1938 and about 650,000 barrels per month in 1939.

Mexican oilfields

The chief oilfields of Mexico are in the Tampico-Tuxpan area of the Gulf Coast. The northern section of this area contains a large group of oilfields, of which one of the most important is the Panuco field. The southern section includes the famous stretch of oilfields known, for its richness, as the "Faja de Oro" (Golden Lane); further south is the recently opened-up and highly productive Poza Rica field. Apart from these oil districts, there is another oil producing area lower down the coast, in the region of the Isthmus of Tehuantepec.

The oil-bearing strata are, in the greater part of the oilfields, at a depth ranging from about 1,600 feet to about 2,900 feet; shallow oil-bearing strata are met in a few individual cases. In the Tampico-Tuxpan fields, the oil occurs in porous limestone, often under a high hydrostatic pressure exerted by the underlying water, which appears when all the oil has been expelled. Some remarkably high initial yields have been obtained, figures of as much as 50,000 barrels per day being on record. Commercial production was commenced in 1901. The output

rose to a maximum in 1921, when the average monthly yield of the Mexican oilfields was about 16 million barrels. Since then, production has fallen off very considerably. In 1938, the average monthly output was about 3,200,000 barrels and, in 1939, about 3,300,000 barrels. The Mexican crudes are mostly mixed base oils.

Oilfield development in Venezuela

The principal oilfields of Venezuela are in the western part of the country, in the Basin of Lake Maracaibo; the latter is the remains of a branch of the sea that covered for a time the whole area. On the eastern side of Lake Maracaibo are the rich fields of Mene Grande and La Rosa, with the El Mene field further north; the Lagunillas oilfield is another field in this area. In the western portion of the Maracaibo Basin are situated the fields of La Concepcion, Las Cruces and Las Paz. Oil is also found in Eastern Venezuela, in that part of the Orinoco Basin opposite the Island of Trinidad; the Quiriquire field is one of the most important oilfields of this region. Rapid progress has been made, in recent years, in the development of the fields of Eastern Venezuela.

The Venezuelan crudes are mostly heavy crudes. In the case of the Mene Grande field, a heavy and a lighter crude are obtained from different formations. The oil occurs chiefly in fine loose sand. In the Venezuelan oilfields too, very high initial outputs have been attained. Thus, one well in the La Rosa field is estimated to have yielded more than 100,000 barrels per day, before it finally sanded up. The oil-bearing strata are at a depth varying from about 800 feet in certain parts of the El Mene field to over 4,000 feet in the Las Cruces field.

The accession of Venezuela to the ranks of oil-producing countries was of relatively recent date. Oil was produced there, for the first time, on a commercial scale, in 1917. The expansion of the oil industry has, however, been so great that Venezuela now occupies third place among the oil producers of the world, with its average monthly output of about $15\frac{3}{4}$ million barrels in 1938 and of about 17 million barrels in 1939.

Trinidad and its oil production

The Island of Trinidad, that lies off the coast of Venezuela, is specially noted for its asphalt deposits, which are among the largest in the world. In the south-western part, not far from Brighton, is the famous Asphalt Lake of La Brea, which covers nearly 130 acres and has been known from the early days of the history of the Island.

Drilling for oil was started towards the end of last century, but it was not until 1909 that commercial production was reached. The main oil-producing region is in the south-western portion of the Island, between Brighton in the north and Palo Seco in the south. The oilfields in this region include the Brighton, Vessigny, Point Fortin, Parrylands, Fyzabad, Los Bajos and Palo Seco fields. To the east of these are the fields of Barrackpore and Tabaquite; another oilfield is the Guayaguayare field, which is situated in the south-eastern extremity of the Island. The depth of the oil-bearing strata varies from a few hundred feet to some 7,000 feet. The oil occurs in sand that is in some cases loose and in others, more or less consolidated.

The oils produced in Trinidad range from the heavy asphaltic crudes of the region of the Asphalt Lake of La Brea, to the light density paraffin base

oil of the Tabaquite field. The average monthly production of Trinidad was about 1,500,000 barrels in 1938 and about 1,600,000 barrels in 1939.

Oilfields of Colombia

The main oil producing area of Colombia is the upper part of the Magdalena Valley, where various fields have been opened up. These include the important Infantas field; the oil obtained there is of a paraffinous nature. The La Cira field is another oilfield more recently developed. The oil occurs in sandstone and limestone; the oil-bearing strata vary in depth from about 600 feet to about 2,200 feet. Commercial production was started in 1919. In 1938, the average monthly output of the country was about 1,800,000 barrels; in 1939, the production increased to about 1,850,000 barrels.

Other oil producing countries of South America

Peru is another important oil producing country of South America, while Ecuador that adjoins it, to the north, is a smaller producer. The chief oilfields of Peru are in the coastal area, at the northern extremity of the country; in this region are situated the Negritos, Lobitos and Zorritos fields. The oil obtained there is mixed base crude; it is found in sand, sandy shales and sandstone, at a depth of 400 feet to 3,000 feet and more. A further oil-bearing region is the Amazonas territory, where a rich oilfield has been developed not far from the Brazilian border.

Oil has been produced in Peru on a commercial scale since 1896. The average monthly production was in 1938 about 1,300,000 barrels and, in 1939, about 1,100,000 barrels. The principal oilfields of Ecuador are in the region of the Peninsula of Santa

Elena, where the oil occurs at a depth of about 600 to 2,400 feet; most of the production comes from the Ancon field. The average monthly output of Ecuador was about 190,000 barrels both in 1938 and in 1939.

Argentina is a large oil producer; its average monthly output was about 1,400,000 barrels in 1938 and about 1,500,000 barrels in 1939. The most important oilfield is situated in the Territory of Chubut, in the southern part of the country, near the town of Commodoro Rivadavia on the Gulf of St. George. The other producing oilfields of Argentina are along the Andes in the Territory of Neuquen and the Province of Mendoza, and at the north-western extremity of the country, in the Province of Salta, near the border of Bolivia. The oils produced are mostly mixed base oils; they occur in loose sand, clayey sand and sandstone. In the Commodoro Rivadavia field, the oil-bearing strata are met at a depth down to about 2,500 feet. Commercial production was started in Argentina in 1908.

World's Petroleum Supplies—II

Russian oilfields

In the Eastern Hemisphere, the country which is by far the largest oil producer is Russia (U.S.S.R.), with its average monthly production amounting to about 17¼ million barrels in 1938 and to about 18 million barrels in 1939. The richest oilfields of the U.S.S.R. are in the region of the Aspheron Peninsula, on the European side of the Caspian Sea, near the south-eastern extremity of the Caucasus Mountains.

The oil industry of this area dates as far back as the sixties of last century. The centre of the industry is Baku, which is near the base of the Peninsula, on the south coast of the latter; it is connected by a pipe line with Batum on the Black Sea. Baku is surrounded by a whole belt of oilfields, including the Balakhany-Romany-Sabunchi and Surakhany fields to the north-east, the Binagady field nearly due north, and the Bibi-Eibat field to the south-west, in the immediate vicinity of the city; the Lok-Batan, Puta and Kara-Chukkur fields are other oilfields of the Baku district. Further east, towards the end of the Peninsula, is the Kali field, while oil is also produced in the Island of Artem, that lies off the coast in this neighbourhood.

In the Aspheron region, the oil is mostly found in loose or consolidated sand, where it is often accompanied by much gas. Oil sands are met at a number of different levels, which may vary in depth from a few hundred feet, in the case of the higher strata, to some 5,000 feet and more, for the deepest strata, in certain areas. Some of the fields of this region yield asphaltic base crude, and others, paraffin base crude, while in several cases the former type of oil is obtained from one level, and the latter, from another, in the same field.

The other principal oilfields of the Caucasus are those of Grozni and Maikop, on the northern side of that range, the former being towards the Caspian Sea end, and the latter, at the Black Sea extremity. The most important oil producing areas outside the Caucasus are the Volga-Ural region, whose rich oil resources are now being extensively developed, the Emba region to the north-east of the Caspian Sea, the Turkomenian region down the eastern coast of the Caspian, the Ferghana Valley at the foot of

the Turkestan Mountains in Central Asia, and the Island of Sakhalin[1] off the coast of Eastern Siberia.

Roumania and its oil production

Oil has been produced commercially in Roumania since about 1860. The chief oil producing area is the foothill region on the south-eastern flanks of the Carpathian Mountains, to the north of Bucarest, where in the course of years numerous oilfields have been located and opened up. The first oilfield to be developed on a large scale was the Bustenari field, which was responsible for the bulk of the production in the earlier days of the Roumanian oil industry, another important oilfield of that period being the Campina field.

The oilfields in production at the present day include the Gura Ocnitu, Moreni, Baicoi, Tintea, Boldesti and Ceptura fields; the largest producer in recent times has been the Moreni field. The principal oil refining centre is Ploesti, which is connected by pipe lines with the chief oilfields. Trunk pipe lines link up the oil district with Constanza on the Black Sea and Giurgiu on the Danube. The average monthly oil production of Roumania was about 4,000,000 barrels in 1938 and about 3,800,000 barrels in 1939.

The oil occurs chiefly in loose sand. The depth of the oil-bearing strata varies from a few hundred feet to 3,000 feet and more. In most cases, the oil sands are closely associated with saliferous beds, this being a special feature of the Roumanian oilfields.

[1] The northern part of the Island of Sakhalin is Russian; it possesses considerable oil resources, which are exploited both by Russian and Japanese interests. The southern part of the island belongs to Japan.

Both paraffin base and asphaltic base oils are produced. Thus, certain fields yield a rich paraffinous oil, while others give a light density asphaltic oil; heavy asphaltic crude is also met. Even in the same oilfield, the oils obtained at different points may vary considerably.

Other oil producing countries of Europe

Poland is another European country that possesses considerable oil resources. The oil producing region is on the north-eastern flanks of the Carpathians. The most important field is that of Boryslaw-Tustanowice, to the south-west of Lvov, where rich paraffinous oil is produced. The oil is contained in sandstone. The oil-bearing strata lie at a depth varying from about 2,600 feet to about 6,500 feet.

Oilfield development was started on a commercial scale in this part of Europe in 1874. The highest production level was reached in 1909, when the average monthly output figure for the whole of the oilfields of the region rose to about $1\frac{1}{4}$ million barrels; the bulk of the oil came from the Boryslaw-Tustanowice field. Since then, production has decreased very considerably; the average monthly production was about 320,000 barrels in 1938, and about 325,000 barrels in 1939.

Oil is also found in Germany. The two principal oil producing areas are those of Nienhagen and of Oelheim-Eddesse, in the neighbourhood of Hanover, the former being to the north-east of that city, and the latter, to the east of it. The oil occurs in sandstone and limestone at several levels down to about 3,000 feet. The main oil horizons yield a light oil. The average monthly oil production of Germany reached a figure of about 360,000 barrels in 1938 and of about 440,000 barrels in 1939.

Egypt and Saudi Arabia as oil producers

In Egypt, there are oil occurrences near the mouth of the Gulf of Suez, at the northern extremity of the Red Sea. The chief producing field has, for a long time, been the Hurghada field on the west coast at the entrance of the Gulf, opposite the island of Gefatin. The oil obtained there is mixed base crude. It is found in sand and shale, the oil-bearing strata being reached at a depth of 1,600 to 2,000 feet. Quite recently, however, a rich field has been opened up at Ras Gharib between Hurghada and Suez. As a result of this new development, the Egyptian oil production has increased from an average monthly figure of about 130,000 barrels in 1938 to about 380,000 barrels in 1939. Saudi Arabia is another country that has joined the ranks of oil producers. From an average monthly figure of about 40,000 barrels for 1938, its production rose to about 330,000 barrels in 1939.

Oil production of Iran

The three principal oilfields of Iran are the Masjid-i-Suleiman and Haft Kel fields in the south-western part of the country, to the north of the Persian Gulf, and the Naft-i-Shah field further north, on the boundary of Iraq. The oils obtained are mixed base oils with a high paraffinous content. The oil-bearing rocks are limestones, where the oil occurs under considerable pressure due to accompanying gas. The wells in the Masjid-i-Suleiman field vary in depth from about 1,500 feet to over 5,000 feet; the oil from this area is conveyed by pipe line to Abadan, which is situated on the Shatt-al-Arab,[1] some forty miles upstream from the

[1] The Shatt-al-Arab is a river resulting from the union of the Tigris and the Euphrates.

mouth of the river in the Persian Gulf. The average monthly production of Iran was about 6,500,000 barrels in 1938 and 1939. Oilfield development was started on a commercial scale in 1912.

Oilfields of Iraq

Oil is found in Iraq over considerable areas, in the basins of the Tigris and the Euphrates. Although the presence of oil has long been known, due to the existence of extensive oil seepages, it was not until 1927 that commercial exploitation of the oilfields was commenced. At the present day, Iraq ranks among the leading producers of the world, with an average monthly output amounting to about 2,700,000 barrels in 1938 and to about 2,550,000 barrels in 1939. The main oilfield is the Kirkuk field, which is to the south-east of Mosul; the oil occurs in porous limestone. A pipe line has been built to connect the oil producing area with the Mediterranean coast, one terminal being Haifa in Palestine and the other, Tripoli in Syria.

Bahrein as oil producing centre

The Island of Bahrein, which lies off the west coast of the Persian Gulf, is another important oil producing centre. The oil industry is here also of quite recent date, commercial production being started only in 1934. The average monthly output of the Island was about 690,000 barrels in 1938 and about 630,000 barrels in 1939.

Other oil producing regions of Asia

In India, oil is found in the Punjab, as well as in Eastern Bengal and Assam. The oilfields from which production is obtained in the Punjab are the Dhulian field and the Khaur field, near Attock, at the

northern extremity of the province; the oil district is linked up by a pipe line with Rawalpindi.

Burma is a further region with important oil resources. Oil is obtained at many points along the Irrawaddy River. One of the principal oilfields is the Yenangyoung oilfield, which is situated some 350 miles up the river; the Singu field, a little further north, is another important oilfield. The oil producing area is connected by a pipe line with Rangoon, at the mouth of the Irrawaddy. India and Burma had together an average monthly production of about 850,000 barrels in 1938 and 1939.

Japan is also an oil producing country. Oil is found in the Islands of Formosa, Honshiu and Hokkaido. The principal fields of Honshiu are those of Nishiyama, Higashiyama, Niitsu and Akita. A great variety of crudes are obtained from these fields. In 1938 and 1939, the average monthly output figure was in the neighbourhood of 200,000 barrels.

Oilfields of the Dutch East Indies

The Dutch East Indies with their average monthly production of about 4,600,000 barrels in 1938 and of about 5,200,000 barrels in 1939 represent one of the most important oil producing regions of the world. Sumatra provides the largest share of the total output. Dutch Borneo comes next, followed by Java. In Sumatra, there is a northern and southern oil district; the main seat of the oil industry of the northern district is Pangkalan Brandan, while Pladjoe and S. Gerong are the chief oil centres of the southern district. The oil producing area of Java is in the east-central part of the Island, the main oil centre being Tjepoe. The principal oilfields of Dutch Borneo are on its

eastern side, being situated in the Balik Papan region and on the Island of Tarakan, further north, off the coast. Most of the oils obtained are light. Some of the crudes are waxy crudes, while others contain no paraffin at all. Commercial production was started in 1893.

Oil in Sarawak and Brunei

Oil is also produced on a considerable scale in the north-western part of Borneo. The oil producing region embraces the coastal district at the northern extremity of the State of Sarawak and the adjoining area of the neighbouring British Protectorate of Brunei. The principal oilfields are those of Miri in Sarawak and Seria in Brunei. Commercial production was obtained in Sarawak in 1913, and in Brunei, in 1932. The average monthly output for Sarawak and Brunei was about 590,000 barrels in 1938 and 1939, Brunei being the larger producer of the two.

PART THREE

PREPARATION OF RAW MATERIALS

CHAPTER I

Scope of Preparation of Raw Materials

Preparation of raw materials indispensable

The raw materials such as yielded by nature can only be used for manufacturing or constructional purposes after they have undergone preparation. The work entailed for this conversion of the crude material into the final commercial product may include mechanical operations, chemical treatment or a combination of the two, as with metals, for instance. The material has thus to go through a number of stages in the course of its preparation, during which it increases gradually in value, as it passes from one stage to the next.

Preliminary preparation done by producer

There is, as a rule, a certain minimum preparation which is indispensable before a material is marketable even in the crude state. Such operations as may be required in this connection have necessarily to be carried out by the producer himself. As regards the other operations during which the material is converted from the crude to the final form, they may be dealt with elsewhere in the producing country or in the consuming country, this being a matter governed by economical factors as well as by national policy. The natural tendency is, however, to push the preparation of a raw material to as advanced a stage as warranted on economical grounds, in the producing country, in order to retain there the largest possible share of the wealth created by the product.

Final preparation in producing or consuming country

When the conditions are favourable, the whole of the preparation of the raw material may be carried out in the producing country. This is the case for tin in British Malaya, which is exported in greater part in the form of refined metal. Copper too is refined before export in such producing countries as the United States and Canada; other producers such as Chile, for instance, ship copper matte or blister, which correspond to intermediate stages of preparation. This tendency to export wholly or semi-prepared materials rather than the crude product also applies to other classes of raw materials. Thus, timber intended for the manufacture of paper is generally made into pulp before being shipped to the consuming country. There are, on the other hand, certain raw materials which for technical reasons must be treated on the spot. Latex, for instance, if not used as such, is invariably converted into rubber sheet or crepe in the factories on the rubber estates.

Minerals

The scope of the preparation of mineral raw materials varies very considerably, according to the nature of the latter and the purpose to which they are to be applied. The blocks of material detached from the rock formations have in the first place to be reduced to suitable size for handling or for use. If the material is for constructional purposes (road-making, building, etc.), this may represent the whole of the preparation.

When, however, a particular mineral is required, some process of sorting is necessary to eliminate other minerals associated with it in the rock, should such be present. In the case of ores, where the

material required (metallic compound) is disseminated through the mass, the foreign matter can only be partially eliminated by mechanical means; the result is then merely a concentration of the ore.

The final removal of the foreign matter (gangue) accompanying the metallic compound, and the isolation of the metal from the compound itself has to be done by chemical means (metallurgical processes).

Mineral oils

In the case of mineral oils, the task is to split up the crude product (crude petroleum), which is a composite substance consisting of an immense number of hydrocarbons, into individual groups of hydrocarbons, each covering a particular range of boiling points. The separation of these fractions by distillation constitutes the fundamental process in the preparation of mineral oils.

Fibre

With fibre, a more or less lengthy preliminary preparation is needed for the purpose of freeing the fibrous material from all accompanying foreign matter. In the case of seed fibre, this means in the first place the detaching of the seed from the fibre, and with leaf and stem fibres, the removal of the tissue or incrusting substance in which the fibres are embedded. After the cleaning has been completed and the individual strands have been separated, the fibre is formed into a continuous band and finally into a loose thread, slightly twisted or otherwise consolidated, which spinning will transform into firm finished yarn.

Leather

For the conversion of hides or skins into leather, it is necessary on the one hand to remove the hair or wool, as well as the whole of the epidermis, and, on the other hand, to eliminate all flesh or fat that has remained attached on the carcase side. Once the true skin has been isolated in this way, it is brought to its permanent state of leather through treatment with a tanning agent, after having undergone such preliminary preparation as may be required.

Rubber and resins

Rubber is prepared by subjecting the milky liquid (latex), yielded by the rubber trees, to the action of a coagulant. The coagulum thus obtained is pressed between rollers into the form of sheet or crepe. Special precautions are necessary for preventing subsequent mould formation. For resins, the principal preparatory operations are cleaning and grading. The cleaning of the pieces of resin may be done by washing or by purely mechanical means. Lac is a resinous substance that undergoes a more lengthy preparation, this product being converted in greater part into the form of flakes (shellac) for marketing. The treatment comprises here, apart from the initial cleaning, such operations as melting, straining, stretching out into sheet and breaking up of the latter. In the case of rosin, the accompanying oil (turpentine) has to be separated.

Vegetable and animal fats and oils

Vegetable fats and oils are obtained from seeds or fruits, mainly by expression. This may be preceded by the separation of the hull from the kernel (decortication), the crushing of the material, or the

heating of the latter to increase the fluidity of the oil. Animal fats and oils are contained chiefly in the cellular structure of the fatty tissue. A partial breakdown of the walls of the cells can be brought about by allowing the tissue to decompose, while the escape of the oil can be facilitated by heating. Both animal and vegetable oils require treatment for the removal of the foreign matter they may contain.

Wood

Wood may be used for constructional purposes or for the manufacture of pulp. In the former case, the logs are first sawn up into planks, boards, battens, etc., which are in turn re-sawn to the desired dimensions and planed. As, however, the wood in its natural state is saturated with water, drying is necessary, as a preliminary measure, if subsequent shrinkage is to be avoided. The wood may furthermore be impregnated with a preservative, with a view to preventing attack by fungi or insects. Timber for wood pulp has to be sawn up too and reduced to suitable size for the pulp-making process.

CHAPTER II

Preparatory Operations Applicable to Minerals in General

Mechanical Preparation of Minerals

Fundamental purposes of mechanical preparation

The mechanical preparatory processes can be grouped under seven main headings, namely, hand-sorting, washing, crushing, screening, classification, concentration and de-watering. These processes represent the various means available for achieving the three fundamental purposes of mechanical preparation, which are subdivision of material, grading of product by size, and separation of foreign matter. The first of these functions is fulfilled by crushing, the second, by screening and classification, and the third, by hand-sorting, washing and concentration; de-watering is merely a subsidiary process.

Subdivision and grading by size as a rule essential

Subdivision of material and grading by size are essential requirements in the case of most minerals. Metal ores have to be reduced to suitable size for smelting. Minerals for chemical manufacture have usually to be converted into powder, while materials for constructional purposes, such as roadstone, have to be broken up and screened. Sizing is also required in the case of coal, for marketing reasons.

Conditions demanding mechanical separation of foreign matter

The question of the mechanical separation of foreign matter arises whenever the mineral is mixed with materials which either cannot be tolerated or must not represent more than a certain percentage in the product. Thus, coal derived from poorer seams may contain stone, that has to be eliminated by washing. Phosphate rock that occurs to a large extent in the form of pebbles or nodules embedded in sand or clay has also to be freed from these materials by a washing process.

Removal of gangue not necessary before smelting high-grade ores

Ores, on the other hand, where the metal is always accompanied by gangue, can be smelted without previous mechanical separation of the latter, as long as the gangue does not represent more than a certain percentage varying according to the metal; the gangue is then removed solely during the subsequent chemical processes.

Some metals, and classes of ore treated.

Nickel, chromium, antimony and aluminium are metals which are extracted in greater part from ores of sufficiently high grade not to require any mechanical separation of gangue beyond that obtainable with hand-picking. Iron is another metal derived largely from high-grade ores. As regards copper, it is also produced to a certain extent from high-grade ores, but much of this metal comes from low-grade ores. Other metals obtained from low-grade ores are zinc, lead and tin. Such ores may have a metallic content of only a few per cents, while in the case of tin ore from

lode deposits, the figure often does not exceed very much 1 per cent. Gold and silver, in view of their value, can be extracted from ores with a very low metallic content.

Far-reaching removal of gangue required before smelting low-grade ores

With low-grade ores intended for smelting, a far-reaching removal of gangue is necessary, in order to enrich the mineral. If the foreign matter is in the form of sand or clay, it may be removed merely by a washing process; tin ores from alluvial deposits are treated in this way. Otherwise, the separation of gangue necessitates the crushing of ore. This crushing is required not only for permitting of the removal of the gangue, but also for uncovering the metallic particles, so as to facilitate their fusion. In view of this, the ore may have to be crushed to sand or slime, if the fineness and dispersion of the metallic particles demand it. As the final grinding is done wet, the usual form of the product is pulp. Such pulp is then treated by one of the concentration methods, with a view to eliminating as large a proportion of the gangue as possible.

Mechanical preparation of ores for leaching or amalgamation

When the ore is to be extracted by leaching, crushing is also required. In this case, however, the subdivision of the material is merely intended to enable the leaching solution to reach the metal. With many copper ores treated by this process, coarse or medium crushing is sufficient for the purpose; gold and silver ores, on the other hand, have generally to be reduced to a fine state. For

amalgamation, which is another process used for the extraction of gold and silver, the ore must likewise be finely subdivided, as the metallic particles have to be free, in order to enable them to combine with the mercury. When leaching or amalgamation is resorted to, the process is carried out at the mill, where the ore undergoes mechanical preparation.

Location of mills for ore dressing

The mill containing the equipment for the mechanical preparation or dressing of ore is usually located in the neighbourhood of the mine, when there is an adequate supply of water available and suitable space for the disposal of tailing. If these conditions do not obtain, it may be necessary to choose a site some distance off and to convey the ore there by trucks or by ropeway, for instance. The plant for breaking up the ore may be set apart in a separate building, in order to keep the dust and vibrations away from the actual mill where the grinders and concentrating machines are installed. Storage bins to ensure a constant supply of ore to the mill are an essential part of the installation.

HAND-SORTING AND WASHING

Separation of materials by hand

Hand-sorting or hand-picking, as the term implies, consists in separating materials by hand. This operation which can only be applied to large-size materials is resorted to for picking out pieces of high-grade ore or for removing waste, as the case may be. The sorting is done on tables, trays,

belts, etc. Hand-picking is sometimes preceded by the breaking of the material with hammers (cobbing).

Separation of materials in current of water

Washing is also a process for the removal of foreign matter; it is, however, only applicable to small-size materials, which must as a rule be previously screened, in order that the pieces should be of fairly uniform dimensions. The separation takes place in a current of water, as a result of the difference in density between the mineral in question and the waste, the heavier material going to the bottom. In some cases, the waste is heavier than the mineral, as with coal, while in other cases, the foreign matter is lighter than the valuable content, as with ores.

Washing in descending current of water

The current of water can be in the form of a stream flowing down a slightly inclined channel. Sluices represent the simplest washers of this type. They are channels with low transversal strips (riffles) along the bottom, that serve to retain the lower layer of heavier material; the latter is subsequently removed, while the lighter material is discharged at the lower end of the sluice with the water.

Various designs of washers have been produced where both waste and mineral are discharged continuously. One of these appliances is built in the form of a trough, open at both ends, at the bottom of which are shallow scrapers attached to an endless belt; the scrapers push the lower layer up to the head of the trough and discharge it there, while the lighter material leaves with the

water at the lower end. Such equipments are used for washing coal, for instance.[1]

In the case of another design, the trough is replaced by a revolving cylinder. The displacement of the lower layer against the stream of water is caused here by a spiral thread fitted to the inner wall of the cylinder and extending along its whole length.

Washing in ascending current of water

Washing can also take place in an ascending current of water in a vertical tube. The water must then rise in the tube with a velocity lesser than the ultimate falling velocity of the heavier material, but greater than the ultimate falling velocity of the lighter material. Under these conditions, the fall of the lighter material is hindered, so that the latter is discharged over the top of the tube with the overflowing water, while the heavier material drops to the bottom of the washer. The equipments usually consist of a battery of washers.

Sand flotation

Sand flotation is a method of coal washing which is based on the principle that water with sand in suspension acts as a liquid of higher density, capable of floating materials even with the density of coal. The washing device is in the form of an inverted cone into which water charged with sand is being continually pumped, the sand being kept in suspension by means of agitators. The material that is fed into the washer is separated into clean coal that overflows at the top with the mixture of water and sand, and into foreign matter that

[1] Coal being the lighter material is discharged with the water at the lower end of the trough.

drops to the bottom. The sand clinging to the coal is removed by draining and spraying with clear water, and used again.

Jigs

Jigs represent another type of washing equipment. With this plant, water is made to move up and down through a sieve supporting the material to be washed. This motion of the water causes a stratification of the material, the pieces with a lesser density being raised to the top. The jig consists essentially of a box divided into two compartments communicating together. One compartment is fitted with the piston for giving the impulses to the water, while the other is for the sieve. In the case of this method, materials need not be sized before treatment.

Washing of ores

Washing is applied furthermore to the cleaning of certain ores where the metalliferous content is mixed with materials such as clay, sand, etc., that can be disintegrated by water. A great variety of appliances have been devised for the purpose. The plant may be in the form of a revolving perforated cylinder (trommel) in which high-pressure water jets play on the material. Another type of washer is built as a sloping trough accommodating a revolving longitudinal shaft (log) fitted with oblique blades along its surface, that force the material up the incline against the stream of water. A further washing appliance consists of a shallow circular tank where the material is stirred by means of paddles attached to arms carried by a central revolving shaft. These are but a few of the countless designs evolved for washing equipments.

CRUSHING—I

Different stages in crushing

Although washing plays a very important part in the preparation of minerals, the principal operation is, in most cases, the crushing of the material. Crushing can be divided into three stages: coarse crushing, intermediate crushing and fine crushing or grinding. The equipments used for these different classes of work can be classified accordingly, under the headings of coarse crushers, intermediate crushers and fine crushers or grinders. Coarse crushers deal with the minerals as extracted from the mine or quarry. Fine crushers supply a product of the fineness required for chemical manufacture, concentration of ore, etc. Intermediate crushers bridge over the gap between these two classes of machines, that is to say, they reduce the material discharged by the coarse crushers to the size needed for the feed of the grinders.

Jaw crushers

The two main types of machines used for coarse crushing are jaw crushers and cone crushers. The jaw crusher has a very wide range of applications. The largest jaw crushers can deal with lumps up to several feet in diameter, while the smallest machines can be designed for crushing relatively small-size materials. The appliance consists essentially of two jaws with plane or corrugated surfaces facing each other, one being fixed and vertical, and the other being hinged and at a steep inclination towards the lower edge of the opposite jaw, so that a wedge-shaped chamber is formed between the two. The material is crushed as a result

of the reciprocating motion given to the hinged jaw (swing-jaw), towards and away from the fixed jaw; the amplitude of the motion is the throw.

The width of the discharge opening between the lower edges of the jaw plates, when the swing-jaw is in its outermost position, is the setting of the crusher. The setting may range from 10″ and more, in the case of the largest equipments, to 2″ and under, with the smallest machines; the width of the feed opening between the upper edges of the jaw plates varies accordingly. A crusher has usually a minimum and a maximum setting. The average reduction ratio of jaw crushers is about 9, for the minimum setting, and about 5, for the maximum setting.[1]

Cone crushers

The cone crusher consists of an upright cone revolving eccentrically about a vertical axis, inside a ring of concave jaws converging downwards. The material is fed into the wedge-shaped annular space between these two crushing surfaces, where it is broken up. The setting of the crusher is represented by the maximum distance between base of cone and ring of jaws; it can be adjusted between certain limits. The average reduction ratio with this plant is about 6.

Cone crushers serve not only for coarse crushing; they are also extensively used in a modified form for intermediate crushing. The other principal types of intermediate crushers are disc crushers, rolls and stamps.

[1] The reduction ratio is the ratio between the size of the largest lumps that the crusher will take and the size of the largest product discharged by it.

Disc crushers

In the case of disc crushers, the material is crushed in the cavity comprised between a concave disc driven off the shaft of the machine and a second disc arranged close up to it. This second disc is not driven independently, but receives its rotating motion from the first disc, as a result of the wedging effect of the material between the two crushing surfaces, so that both rotate in the same direction and at about the same speed.

The crushing effect is obtained by causing the distance between the rims of the discs to vary during the rotation. This is done either by setting the second disc at a slight angle in relation to the first disc, as in the horizontal disc crusher, or by giving it a rocking motion by means of an eccentric, as in the vertical disc crusher. The material is fed into the crushing chamber through a central hole in the first disc; it is driven outwardly towards the rim by the centrifugal force and, after it has broken up, escapes through the gap between the two discs. The maximum distance between the disc rims is the setting of the crusher.

Rolls

Rolls constitute one of the simplest forms of crushers. The crushing is done here between two parallel horizontal rollers at the same level, set more or less close together. The rollers revolve in opposition to each other in such a way as to cause a downward motion of the material caught between the two crushing surfaces. A spring device is usually provided whereby one of the rollers can yield in the event of pieces of unbreakable material reaching the crusher. Of the two types of intermediate crushers described, rolls are the more

suitable for dealing with smaller materials, while disc crushers lend themselves better for the treatment of coarser ones. There are, however, special types of rolls which actually come within the category of coarse crushers. These equipments have rollers with surfaces studded with teeth; they serve for the coarse crushing of friable materials such as coal.

CRUSHING—II

Stamps

The most common type of stamp is the gravity stamp. In this appliance, the material is crushed through the impact of a falling weight. The fall of the weight takes place in a box having at its base a die on to which the material is fed. The crushed material is discharged through a screen on the side of the box. The weight itself is attached to a stem on which acts the lifting and release device (tappet). An equipment usually consists of a battery of stamps. Other types of stamps are steam stamps and pneumatic stamps. Stamps operate wet, that is to say, water is added to the material to be crushed.

Stamps permit of a very large size-reduction; thus, it is possible to reduce 3″ material to slime in one operation. Although such plant can be used for fine crushing, it is usually more economical to resort to other types of machines for the final grinding. For this reason, stamps are generally classed as intermediate crushers. Stamp units only have a very small capacity, as compared with the other types of crushers described.

Cylinder mills

Fine crushers or grinders comprise a very great variety of equipments. These can be roughly

grouped into cylinder mills, ring-roller type mills, grinding pans and beater type mills.

Cylinder mills represent the type of plant most widely used for the treatment of ores. In these mills, the material is crushed between loose balls, rods or pebbles, in a container with circular cross-section mounted in a horizontal position, the crushing bodies being constantly kept in motion through the slow rotation of the container. The mills are known as ball mills, rod mills or pebble mills, according to the nature of the crushing bodies.

In the simplest form of mill, the container is cylindrical. The material is fed at one end, through a hollow trunion, and discharged at the other end.[1] Ball mills which are charged with heavy metal balls can deal with a fairly coarse feed, while rod mills are not generally used for material of more than medium size. Both these types of mills have relatively short containers. Pebble mills, on the other hand, serve for grinding much finer material; they have lighter crushing bodies and a container of considerable length—hence, the name of tube mills.

Closed-circuit working with cylinder mills

A method frequently resorted to with these mills is closed-circuit working. In this case, the rate of feed is higher than would permit of the complete crushing of the material in one pass.[2] In view of this, the material leaving the mill comprises finished product and oversize, which latter is separated by

[1] There are also certain mills where the discharge takes place through perforations in the shell of the cylinder.

[2] The term "pass" refers to the travel of the material through the mill. When the complete crushing takes place in one pass, this is known as open-circuit working.

a sizing device and fed back into the mill for further treatment.

Ball mills and pebble mills can also be built with conical container, this design being extensively utilised at the present day. The mills can work dry or wet. In the latter case, the product is in the form of pulp more or less dilute.

Ring-roller mills

Ring-roller mills are machines embodying one or several rollers running along a die ring, the material being crushed between roller and ring. Edge runners and pendulum mills are instances of such grinding machines. In edge runners, the rollers are vertical and run on the upper surface of the horizontal die ring; they are arranged at the end of arms that radiate from a central vertical revolving shaft.

In the case of pendulum mills, the rollers are horizontal and run along the inner surface of the die ring; this ring is arranged inside a low cylindrical container and fitted tightly against the wall at the bottom of the latter. The rollers are suspended by their stems to a frame carried by a central vertical revolving shaft;[1] they are forced against the die ring by the centrifugal force. The product escapes through screens above the die ring.

Grinding pans

In grinding pans, the two crushing elements have flat surfaces. One is in the form of a wide annular die ring accommodated in a circular pan. The other consists of heavy shoes held in a ring, each

[1] There is also a design with single roller. In this case, the roller is suspended by its stem to a central point above the die ring, from where it is rotated.

covering an equal section of the die and forming together a similar annular surface, which is either continuous or interrupted by gaps between the shoes. The ring of shoes is rotated by a central vertical shaft through the intermediary of arms.

Beater type mills

With beater type mills, the material is broken down through coming into contact with beaters attached to a shaft or disc revolving at a high speed in the grinding chamber. The beaters may be in the form of swing-hammers or flails attached to a shaft; they may be in the shape of propeller blades or they may consist of pins, fitted in concentric rows, in the opposing surfaces of two discs. Beater type mills are used more especially for softer minerals such as clay and chalk, and for fibrous materials such as asbestos.

SCREENING

Division by size usually necessary before crushing

In order to ensure the economical operation of crushers, crushing is usually preceded by the removal from the material of such portions as do not require reduction and would only take up room unnecessarily in the crusher. This division of the material according to size, which comes under the heading of sizing, is still more important in connection with washing. For the latter process, there must be an actual limitation of dimensions, as the pieces of material must be fairly uniform in size, if separation by density is to be possible. Sizing is further necessary for the division of materials into grades for marketing purposes, as in the case of coal.

Bar type screens

Sizing is done invariably by means of screens, except when it is the case of very fine material. The product that passes through the screen is termed undersize, and that which is retained, oversize. The simplest form of screen consists of parallel bars arranged at a slope or, for certain purposes, horizontally.[1] Such screens are, as a rule, fixed, in which case they are known as grizzlies. There is, however, also a type with moving bars, utilised for the screening of coal. The bars are then free at one end; at the other end, they are linked up with the operating mechanism through the intermediary of two transversal supports to which the bars are connected alternately. The operating mechanism is such as to cause these two systems of bars to move in opposition, the motion of the one being forwards and upwards, when that of the other is backwards and downwards. The reciprocating motion is produced by eccentrics, while the rising and falling motion is due to the mode of suspension.

Use of punched plate or woven wire for screening

Bar type screens only limit the size of material in one direction. Their field of application is mainly confined to preliminary coarse screening. For most purposes, screens are used having surfaces of punched plate or woven wire. The size of the product that passes through a given woven wire cloth is determined by its mesh, which represents the number of apertures per linear inch. Granular material is known as sand, while impalpable powder is given the name of slime.

The screening surface may be flat or cylindrical.

[1] Horizontal grizzlies are used on the top of ore bins.

Flat screens may be fixed, in which case they have to be set at a suitable angle to ensure the natural flow of the load. Screens are, however, usually fitted with a mechanism that keeps them constantly in motion. This movement of the screen may itself cause the progress of the load, as with shaking screens, which can thus be arranged more or less horizontally. The motion may, on the other hand, simply serve for stirring the material, as with vibrating screens and revolving screens, so that the latter have to be mounted in an inclined position, in order to enable the gravity to come into play.

Shaking screens

Both shaking screens and vibrating screens are in the form of trays. In the case of shaking screens, the frame of the screen is itself in motion. The screening surface is given a forward and backward movement, combined with an upward and downward motion. Owing to the screen dropping sharply at the beginning of the backward stroke, the load is made to advance in successive jumps along the screening surface. The reciprocating motion is produced by eccentrics, while the rising and dropping movement results from the mode of suspension.

Vibrating screens

With the vibrating screens, the frame of the screen is generally fixed. The screening surface is set in motion through vibrations generated by some device attached to the frame; the movement is therefore very rapid and of short amplitude. The vibrating devices are of various designs. The source of vibrations may, for instance, be a shaft revolving eccentrically at a high speed. An electro-magnet

acting on an armature has also been used for the purpose.

There is a further type of vibrating screen where both frame and screening surface are in motion. In the case of the equipments in question, the frame is carried by two elliptical springs; it is depressed and released, in quick succession, by cams with teeth, the return motion of the frame being limited by bumpers.

Revolving screens

Revolving screens (trommels) represent a class of screen very widely used. The cylindrical screening surface may be carried by a central shaft, by means of arms, or it may be supported externally on rollers.[1] Cylindrical screens have to be set at a slope, so as to ensure the progress of the material fed into them. The screen can, however, also be made conical, in which case the axis can be horizontal, as the load will flow naturally towards the larger diameter. Trommels can be built with two or three sections giving different sizes of products, in which case the fine particles are separated first. An arrangement more generally used for the same purpose consists in disposing three trommels, for instance, in series in such a way that the separation begins with that of the coarser product.

Screens for pulp

Revolving screens can also be designed for screening pulp. Owing to the shortness of these screens, they can be mounted overhung at the end of the horizontal driving shaft. There are several designs of such overhung screens. One of the simplest equipments consists of a squirrel cage

[1] The latter design is used more especially for stone and coal.

frame carrying the woven wire cloth. The surface of the latter is not cylindrical, but is depressed between the bars, so as to form channel-shaped corrugations. The pulp is fed on to the top of the slowly revolving screen; it is held for a short distance in the corrugations and, during the time, is subjected to water sprays that force the fine particles through the screen into the interior, where they are collected in a channel. The oversize is carried along on the screening surface and drops below.

Belt screens

Another appliance working on somewhat similar lines is the belt screen. In the case of this equipment, the screening surface is in the form of an endless belt stretched between two horizontal rollers at the same level. The pulp is fed on to the upper span of the belt and the fine particles that pass through it are led away through a channel arranged in the space between the two spans. Water jets play on the material, as in the case of the screen previously described. The sizing device which is, however, more generally used for pulp is the water classifier.

CHAPTER III

Processes Associated with the Preparation of Ores Prior to Metallurgical Treatment

---

Classification

Classification and classifiers

Classification serves for the sorting of fine material; it causes the separation of the particles, according to their weight. Classifiers include water classifiers and air classifiers, for the treatment of the product of wet grinding and dry grinding, respectively.

Principle of water classification

With water classifiers, the product is subjected to the action of a current of water, the lighter particles being carried along in the stream of water, while the heavier ones are deposited in a pocket or in some other suitably shaped receptacle placed across its path.

The sorting of the material is thus according to the weight of particles. When all particles have the same density, their size necessarily varies with their weight, so that under these conditions sorting according to weight also means sorting according to size. When, on the other hand, the pulp is made up of materials of different densities, the product that settles in the pocket of the classifier includes as many different sizes of particles as there are materials of different density.

Applications of water classification

Water classification is used for the treatment of crushed ore. In this case, the product drawn from the pocket of the classifier comprises larger particles of lighter material (gangue) and smaller particles of heavier material (metallic grains). The ratio between the average sizes of the two materials is known as the settling ratio. Larger and smaller particles can be sorted out subsequently on concentrating tables.

An important application of water classification is for sand-slime separation, this operation being necessary when the sand in the discharge of grinding mills has to be returned to the mill for re-grinding (closed-circuit working). Water classification is also resorted to for dividing sands into various grades preparatory to concentration.

Surface classifiers and their design

There exist a great variety of water classifiers. These equipments can be grouped in two main categories: surface classifiers and hydraulic classifiers. In the case of the former appliances, the material is only subjected to the action of the water that enters with it into the classifier. The receptacle where the heavy particles settle may be a pocket shaped as a pyramid or a cone pointing downwards. The material that collects in the pocket (underflow product) is discharged through an opening at its base (spigot), while the fine material overflows with the water (overflow product). Two such pockets may be arranged in series, the overflow of one pocket serving as feed for the other one.

Mechanical classifiers

Another type of surface classifier is in the form of a trough set at a slope. At the lower extremity,

the trough has a vertical end wall over which the overflow takes place, while at the upper extremity the trough is open. The inclination of the trough is such that the floor of the latter is, at the upper end, out of the water, owing to its being higher than the level of the overflow. The sand deposited on the floor of the trough is forced towards the upper end, by means of rakes or other mechanical devices, and discharged there. Such classifiers are known as mechanical classifiers. The field of application of surface classifiers is mainly confined to sand-slime separation.

Hydraulic classifiers and their mode of working

In hydraulic classifiers, additional water is introduced at the bottom of the pocket of the classifier, through a so-called sorting tube or column. Part of this water rises through the pocket and carries upwards to the overflow any fine material that may have got entangled with the heavier particles. The other portion of the water drives the material deposited through the spigot discharge.

Free-settling and hindered-settling classifiers

Hydraulic classifiers are built as free-settling classifiers or as hindered-settling classifiers. In the former case, the sorting column has the same cross-section throughout its length, while in the latter case there is a constriction. The effect of this reduction in section is to increase at that point the velocity of the water rising through the sorting column; the velocity is thus greater there than above. As a result, certain particles will be able to fall to a level just above the constriction, but will be unable to pass through the latter. They will be held there in suspension in the manner of quick-

sand and will form a mixture acting as a fluid of greater density, thus causing a much higher settling ratio.

The principal use to which hydraulic classifiers are applied is for the division of sands into grades. For this reason, hydraulic classifiers usually have several pockets, disposed in series.

Principle of air classification

With air classifiers, the fine particles are transported by a current of air, created by a fan, to a collector where they are deposited, while the heavier particles either fail to be carried along, or fall out of the stream of air in a separator, according to the design of plant.

Fundamental types of air classifiers

Air classifiers can be divided into two main categories. In one class of equipments, the product is fed from the top on to a revolving disc and distributed by centrifugal force across the path of the air which rises around the disc, owing to the suction of the fan. The fine particles are taken along by the air; the heavier particles drop to the bottom of the classifier.

In the other class of air classifiers, the air is drawn direct from the discharge end of the grinding mill, the material being picked up by the air as a result of the draught caused by the fan. The stream of air then passes through a cyclonic separator, where it is given a whirling motion, so that the heavier particles are projected outwardly by the centrifugal force and discharged. The air leaves the separator through the centre, with the fine material, and is forced into a cyclonic collector working on the same principle as the former

device[1]; there, the fine material is deposited. The fan may be arranged either before or after the separator. These air classifiers, like water classifiers, are used in closed circuit with the grinding mills.

Concentration of Ores

Conversion of crushed ore into concentrate

Concentration is an operation that only applies to ores. It is carried out once the ore has been disintegrated by crushing, to such an extent as to expose the particles of metal or metallic compound. The purpose of concentration is to remove as large a proportion as possible of the gangue, in order to obtain a product where the metallic content represents a much higher percentage; such a product is known as a concentrate.

Factor governing choice of concentration method

The method of concentration used depends in the very first place upon the size of the material to be treated. The material may be relatively coarse, if the exposure of the metallic content has not necessitated too fine a reduction in size. It may on the other hand be extremely fine, when the dispersion of the metallic particles in the ore makes it necessary to grind the latter into a pulp, as is more usually the case.

Concentration in jigs or sluices

When the crushed material is coarse, or when the ore consists of fine particles mixed with gravelly material, as yielded by alluvial deposits, concen-

[1] The air is given a whirling motion by causing it to enter a chamber with a circular section, more or less tangentially.

tration can be obtained merely by washing the product by means of such appliances as jigs, or sluices, in the latter case; the principles upon which these washing appliances are based have been previously described. In the stratification that takes place in the washers, the gangue rises to the top, while the heavier metallic parts go to the bottom. In jigs, the latter product is discharged either through spouts above the level of the sieve, or through the sieve itself, according to the design of the jig.

Jigs generally provided with several cells

The jigs are usually built with several cells, in order to effect a more complete separation of the metallic parts. The first cells then yield the product with the highest metallic content. The material finally rejected is the tailing. Products whose metallic content is between that of the concentrate and that of the tailing are called middling. The metal contained in the middling can be recovered, after the product has been reground.

Strakes

The most primitive concentrating appliances for fine material are strakes; they work on the same principle as sluices. The strake consists likewise of a channel down which the material mixed with water is led; this channel is, however, shallower and the bottom instead of being riffled is covered with a blanket or other similar material, which retains the concentrate without interfering with the current of water carrying away the gangue. The blanket is subsequently removed and washed, in order to recover the concentrate.

Film concentration

When the material is in the form of finely ground pulp, film concentration can be resorted to. With this method, a thin film of pulp is fed on to a sloping surface (table). The heavier particles then settle near the feed, while the lighter ones travel lower down the slope. Automatic discharge of the products can be ensured by causing the displacement of the latter through the action of wash-water.

Revolving tables

An instance of such a machine for film concentration with automatic discharge is the revolving table. It comprises a revolving flat cone, with fixed central pulp and wash-water distributors. Pulp is fed on to one section of the cone, and wash-water, on to the remaining part. When the pulp drops on to the revolving cone from the fixed central distributor, the lighter particles start at once to travel down to the bottom, while the heavier parts are only set into motion when they come under the wash-water, after the cone has revolved through a certain angle. As a result, tailing, middling and concentrate are discharged separately along different sections of the periphery of the revolving cone. These revolving tables can be built with several decks.

Shaking tables and their action

In the case of the concentrating appliances referred to up to now, the particles are displaced merely by the pressure of the moving water. With shaking tables, a further factor comes into play in the form of impulses given to the particles in a transversal direction to their downward path. As a result of these transversal impulses, a sorting out

takes place laterally, so that the particles of different sizes or weights reach the lower edge of the table at different points along its length.

Design of shaking tables

Shaking tables consist of a plane surface, slightly inclined and usually riffled. The pulp is fed on to the table, at its upper edge, over a certain portion of its length, and wash-water, over the remaining section. The table is given a reciprocating motion, in its own plane, in a direction transversal to the natural downward path of the particles, by means of a mechanism embodying an eccentric. This motion is differential and such as to cause the displacement of the particles further and further across the stream of water, this being the direction of the forward stroke. In view of this, the velocity during the forward stroke is made to increase from a minimum at the beginning of the stroke to a maximum at the end. The momentum gained, in the process, by the particles, opposes their backward motion, when the table is sharply withdrawn under them, on the reversal of the motion of the latter. The abrupt withdrawal of the table is due to the velocity being maximum at the beginning of the backward stroke; the velocity then decreases to a minimum at the end of the stroke.

The depth of the riffles of the table depends upon the size of the material to be treated. It is greater for sand than for slime; in the latter case, a portion of the deck is left unriffled.

Vanners

Vanners represent another type of concentrating machine. They consist of an endless belt, usually of rubber, stretched between two horizontal pulleys,

one of which is at a lower level than the other, so that the belt slopes in the longitudinal direction. The upper surface of the belt fulfils the function of an inclined table. The pulp is fed on to the belt at a certain distance from the upper end and wash-water is sprayed a little higher up.

The frame supporting the pulleys and the belt is given an oscillating motion, which in this case serves merely to cause the stratification of the particles in the pulp. As the direction of travel of the upper belt surface is towards the top end, the heavier particles adhering to the belt are carried along up the slope and discharged over the head pulley. The lighter particles, on the other hand, are transported by the wash-water down the slope, and drop off at the bottom end.

Flotation and Magnetic Separation

Use of flotation confined to fine material

Apart from the various water concentration processes mentioned, there is a method based on an entirely different principle, namely, froth flotation. This method has assumed very great importance in recent times, as it permits of the treatment of many low-grade ores or residues of primary concentration, which could not be dealt with profitably by water concentration, due to the minuteness of the metallic particles, or were unsuitable for the latter process, owing to the heavy nature of the gangue. The use of flotation is confined to fine material, whereas water concentration is more especially suited for a granular product.

Ores lending themselves to treatment by flotation

The principal ores treated by flotation are the sulphide ores of copper, zinc and lead, as the latter possess to a high degree the property of being non-wetting, which is a necessary requirement for the application of the process. This property of base metal sulphides of being non-wetting is manifested by an affinity of their surfaces for air in preference to water. Thus, if particles of sulphide are brought into contact with air bubbles in water, they attach themselves to the latter and rise with them to the surface, while particles of gangue, which have the tendency to wet, drop to the bottom. This is the means whereby the metallic particles are separated from the gangue in flotation.

Necessary conditions for concentration by flotation

For concentration by flotation, it is necessary in the very first place to mix the ore pulp with a certain proportion of water, and to generate, in this diluted pulp, air bubbles which must be well distributed in the liquid. Secondly, the froth created by the bubbles, as they reach the surface, must possess a certain degree of coherence, in order to be able to carry the load of metallic particles. In view of this, the bubbles must be small, and the thin film lifted from the upper surface of the liquid to form the bubble envelope, into which the metallic particles are incorporated, must be sufficiently elastic not to break up of itself. These conditions are ensured by adding to the diluted pulp a so-called frothing agent, which gives a froth capable of supporting the metallic particles. One of the frothing agents most widely used is pine oil.

Agents to influence floatability

Further agents known as collecting agents are also introduced into the pulp for the purpose of increasing the floatability of the metallic particles. Fatty acids are extensively utilised in this connection. In addition to these collecting agents, there are a number of other agents which affect in one way or another the floatability of the minerals. Thus, some agents have the effect of rendering poorly floatable minerals capable of treatment by flotation, while others reduce the floatability of certain minerals. In view of this, it is possible in the case of complex ores to separate the various metals successively, by using suitable agents to cause a sufficient difference in their floatability.

Generation and diffusion of air bubbles

Various methods are adopted for the generation and diffusion of air bubbles in the pulp. In one class of flotation machines, use is made of a horizontal impeller, arranged at the lower part of the chamber into which the pulp is introduced, and driven by a vertical shaft. This impeller serves either both for drawing the air and mixing it with the pulp, or merely for the latter purpose, when the air is admitted under pressure.

Arrangements for the admission of air

The air may enter from above, through the action of the vortex created by the revolving impeller, as in the original agitation machine. At the present day, however, the arrangement most generally resorted to is that with air inlet below (sub-aeration type machine). In these machines, the air is admitted through nozzles at the bottom of the agitation chamber, either in a slightly com-

pressed state or at atmospheric pressure; in the latter case, the suction of the impeller is relied upon for the introduction of air.

Froth separation chamber

From the agitation chamber, where pulp and air are violently mixed together, the pulp passes into the froth separating chamber. There, relatively quiet conditions prevail, so that the bubbles with the metallic particles attached to them can rise to the surface and form a layer of froth, which is raked off and broken up by water sprays. Agitation chamber and froth separating chamber constitute a cell. A number of such cells may be arranged in series, the unfrothed pulp of one cell serving as feed for the next. These cells form together a flotation machine.

Further methods of aeration

In another type of equipment, the air is introduced into the pulp by forcing it through the porous bottom of the cell. This porous bottom may, for instance, consist of canvas held by wire netting. The cell is of considerable length and constitutes in itself a flotation machine. As the concentrate yielded by such a cell is usually not sufficiently clean, it is as a rule necessary to treat it again in a second cell. The first cell is then known as a rougher cell, and the second, as a cleaner cell. Aeration can further be produced by directing a stream of pulp into the body of pulp; the air is then entrained by the stream of pulp and forced by it into the pulp body.

Treatment of magnetic ores

The fact that certain iron minerals such as magnetite are strongly magnetic, while others such

as hematite can be given similar properties by roasting[1] makes it possible to separate these minerals from the gangue by magnetic means. The machines used for the purpose are called magnetic separators.[2] A number of types of magnetic separators have been evolved, which embody electro-magnets in one form or another. Machines are built both for dry and for wet magnetic separation.

Types of magnetic separators

One of the simplest types of magnetic separators is the pulley separator. It consists of an endless belt stretched between two horizontal pulleys. The head pulley, that is to say, the pulley towards which the upper span of the belt travels, accommodates in its interior a battery of electro-magnets arranged radially. The crushed ore is fed on to the upper span of the belt and carried by the latter over the head pulley. There, the non-magnetic material is thrown free into a chute. The magnetic material, on the other hand, is attracted by the magnets of the pulley and clings to the belt, until the belt section to which it adheres diverges from the pulley below and passes out of the range of the magnets. The magnetic material thus drops at this point.

[1] Roasting is a heating process, below the temperature of fusion of the material.

[2] Magnetic separators are used not only for concentrating iron ores, but also for eliminating iron particles in other ores, where their presence may unfavourably affect subsequent processes. Such particles may have been introduced by abrasion from the grinding mills. On the other hand, guard magnets are often fitted in front of crushers, above the conveyor belt feeding the latter, in order to keep back any pieces of iron or steel that may have found their way into the ore and are liable to damage the machines.

DE-WATERING

Product of concentration usually in the form of pulp

Water concentration, flotation and magnetic separation together account for most of the production of metal concentrates.[1] The concentrates yielded by these processes are, except in the case of dry magnetic separation, in the form of pulp. Such products must therefore be subjected to further treatment, in order to separate the solid concentrate from the water; this is known as de-watering.

Methods of de-watering

When the solid matter in the pulp is coarse, de-watering is a simple matter. The water can then be removed by draining, after which the product is dried. When, however, it is the case of dilute slime pulp, such as discharged by flotation machines, where the solid matter consists of fine particles in suspension, de-watering is a more lengthy process. The product must in the first place be converted into a thick pulp. A further separation of water necessitates filtration, while the remaining moisture is removed by drying.

Settling tanks

The slime pulp is thickened in settling tanks. The larger particles gradually find their way to the bottom through the action of gravity. The very minute particles in suspension in the water may, on the other hand, not settle at all, owing to their being

[1] Other methods such as pneumatic concentration and electrostatic concentration are of very little importance in connection with metal concentration. Pneumatic concentration has, however, special applications in the field of non-metalliferous minerals. It is used, for instance, for separating asbestos fibre from powdered rock.

in a so-called colloidal state. This colloidal state is due to the adsorption of ions by the particles, which phenomenon gives rise to electric charges at their surface. Under these conditions, the particles repel each other and thus remain dispersed.

Settlement of fine particles

In order to bring about the settlement of the particles, it is necessary to neutralise the electric charges. This is usually done by the addition of an agent (electrolyte) that supplies ions of opposite sign to those originally acquired by the particles. Once the particles are uncharged, they form aggregates, which latter act as larger particles and drop to the bottom. This aggregation of particles is termed flocculation.

Intermittent thickening process

The thickening process may be intermittent or continuous. In the former case, the thickener consists of a tank into which the slime pulp is fed at one end, an overflow being provided at the other end. Once the tank is full, the liquid flows more or less directly from the feed to the overflow. On its passage across the tank, it loses most of its particles of solid matter which drop to a lower level, so that clear water overflows. When, however, the liquid in the tank becomes too saturated with particles, the latter begin to reach the overflow. As soon as this occurs to an excessive extent, the feed is discontinued and the solid matter is allowed to settle at the bottom of the tank. When the settlement is complete, the water is drained off and the thick pulp is removed. An equipment may consist of a series of such tanks, which are filled and emptied in rotation.

Continuous thickening

With continuous thickening, the discharge takes place during the settling process itself. The simplest type of continuous thickener consists of a settling tank in the form of an inverted cone with concentrate outlet at the bottom, the discharge being here merely by gravity. Continuous discharge is, however, usually ensured by mechanical means. In one of the equipments most widely used, a system of rakes is arranged at the lower part of the settler, which is in the shape of a shallow circular tank. These rakes are attached to arms radiating from a slowly revolving vertical shaft suspended vertically; they are set in such a way as to force the deposited mass towards a central discharge opening.

Filtering and continuous drum type filters

As regards filtering, this is generally done by sucking air through a thin layer of pulp supported by a filter cloth. The process is made continuous by fitting the cloth on a revolving horizontal drum, for instance, on to which the pulp is continuously fed; the filtered product is scraped off automatically, before reaching again the feed point. Hollow spaces are provided under the cloth, in order to permit of the suction of air through the latter.

In such suction filters of the drum type, these spaces are created by keeping the filter cloth apart from the drum by longitudinal spacing strips. In this way, a number of longitudinal channels are formed under the filter cloth, all around the drum. As these channels are closed at either end, they each constitute an independent cell. These various cells can be connected either to a suction pump or to a compressed air supply by means of pipes, a suitable device being provided for ensuring the passage

between the pipe system of cells, on the drum, and that of the vacuum and compressed air outside the machine. The filter cloth is protected by wire netting.

Method of feeding pulp on to filter cloth

The lower part of the drum is immersed in a V-shaped trough into which the pulp is led. When a section of the revolving drum passes into the pulp tank, the cells under the filter cloth at this point are connected with the vacuum pump. Through the action of the vacuum, pulp is sucked against the filter cloth, where it remains as a coating when the section in question leaves again the pulp tank, after further rotation. As vacuum is maintained in the cells, during the travel outside the tank, air is drawn through the filter cloth and the layer of pulp. The conditions subsist up to a point a little before the return of the drum section into the pulp tank. At that point, a scraper is provided for detaching the filter cake from the cloth, this process being assisted by introducing compressed air into the cells under the cloth. The above applies, of course, to every section of the drum; there is thus a continual flow of filter cake over the scraper.

Continuous filters of the disc type

Continuous filters are also built of the disc type. In this case, the filter cloth forms the walls of the sectors of hollow vertical discs mounted on a revolving shaft. The spaces inside these sectors fulfil the same function as the cells of the drum type filter. The discs dip likewise into a tank containing the pulp, which is made to cling in a thin layer to the sectors by the vacuum inside the latter. The filter cake is subsequently removed by scrapers and

through the action of compressed air. In addition to suction filters, there are also pressure filters, such as filter presses. With these equipments, however, the process is intermittent.

Drying

The cake from the filters may be fed directly on to a dryer. A typical dryer used for flotation concentrate consists of a pan heated by a flue arranged under it. The concentrate is slowly moved from the feed end to the discharge end of the pan by means of rakes, which at the same time turn it over. In the case of coarse material, direct heating may be resorted to, the product being then dried by contact with the hot gases themselves, either in a vertical tower or in a slightly inclined cylinder.

CHAPTER IV

Metallurgical Treatments as Applied in the Final Preparation of Metals

---

HYDRO-METALLURGY

Separation of metal from gangue by chemical action

With ore dressing, the foreign matter is detached from the metal by mechanical force. In the processes now to be described, the factor that is responsible for the release of the metal is the chemical change of a temporary or permanent nature which takes place in the body of the material. The change may be brought about by subjecting the ore to the action of a solution capable of dissolving the metal (leaching), through the absorption of the metal by mercury (amalgamation), by applying heat in the presence of a reducing or oxidising agent (roasting, smelting and fire-refining) or by means of electric current (electrolysis).

Metallurgy and its divisions

All these processes come within the sphere of metallurgy, which is divided accordingly into three main sections: hydro-metallurgy including leaching and amalgamation, pyro-metallurgy embracing roasting, smelting and fire-refining, and electro-metallurgy covering electrolysis.

Leaching and choice of solvents

Leaching is resorted to more especially for the treatment of ores with a low metallic content. Its

chief application is for the extraction of gold, silver and copper. The choice of the solvent necessarily depends upon the metal or metallic compound to be treated; the nature of the gangue is also an influencing factor, as the material accompanying the metal must not be dissolved by the solution. Cyanide of potassium is the solvent universally used for gold and silver, the process being then known as cyanidation. Sulphuric acid is the principal solvent for copper; it is utilised for copper oxides and carbonates. Copper sulphate, into which form copper sulphide can be converted by roasting, is soluble in water.

Methods of leaching

In the case of sand or coarser material, the leaching solution is merely made to percolate through the mass; this is the more usual method. When, however, the ore is in the form of slime, it is necessary to mix the leaching solution with the ore. The mixing is generally done by means of some mechanical device provided in the leaching tank; the solution is sometimes introduced in the grinder.

With percolation, the progress of the solution through the material in the leaching vat may be upwards or downwards. In the former case, the circulation is ensured by a pump. The leaching plant normally consists of a series of vats. After the leaching solution has been circulated through the ore for a certain period, usually amounting to several days, it is drained off. The ore is then subjected to successive washing operations by means of solutions with decreasing degrees of concentration, finishing with barren water.

Precipitation of metal from leaching solution

The metal is recovered from the leaching solution by precipitation. Precipitation may be caused either by chemical reaction through the action of an agent such as zinc, as in the case of gold and silver in cyanide solutions, or by electrolysis; the latter method is that generally used for copper.

Amalgamation

Amalgamation is another process utilised for the extraction of gold and silver. The ore pulp is made to flow over silver-plated copper plates coated with mercury and set at a slope. On its passage over the plates, the pulp loses a certain proportion of the metal, through the latter coming into contact with the mercury, with which it combines and forms an amalgam. The amalgam is removed by scraping, after the plates have been cleaned up and heated. In order to separate the metal from the mercury, the amalgam is distilled in a retort;[1] there, the mercury is evaporated leaving a residue of sponge metal. Amalgamation is, as a rule, only used as a means for the preliminary separation of the metal, before cyanidation.

ROASTING

Successive stages in heating

In the case of the processes referred to, the chemical change takes place with little or no application of heat. In the processes to be dealt with

[1] Retorts are vessels in which materials to be distilled are heated; they are more generally cylindrical in shape and set in a horizontal or slightly inclined position. The vapours produced in the retort pass into a condenser, where they are cooled and condensed, the condensate being collected in a receiver.

now, heat is the principal factor responsible for the initiation of the chemical reaction. If heat is applied to an ore, its effect on the latter varies as the temperature increases. Up to 100° C., the action of the heat is merely to expel the moisture from the ore; this is the drying stage. Above 100° C., there is a decomposition of carbonates and a release of carbonic acid; this is the calcination stage. If the temperature is raised to red heat, sulphides can be oxidised if there is an excess of air, and oxides can be reduced[1] in the presence of a reducing agent; this is the roasting stage. If the temperature is still further increased, fusion takes place.

Roasting of metallic sulphides

Roasting is essentially a subsidiary process used for modifying the composition of the metallic compound in the ore, so as to render it more amenable to subsequent treatment. One of its principal objects is to remove sulphur from metallic sulphides. This is done by oxidation, and the operation is then an oxidising roast which entails an excess supply of air for providing the oxygen.[2] Copper sulphide ores to be smelted in reverberatory furnaces are usually subjected to an oxidising roast before smelting, in order to eliminate a certain proportion of the sulphur.[3] Iron sulphide (pyrite), on the other hand, is roasted with a view to obtaining the sulphur for the manufacture of sulphuric acid.

[1] Reducing denotes the removal of oxygen.

[2] The oxygen combines with the sulphur and forms sulphur dioxide.

[3] When copper sulphide ores are treated in blast-furnaces, roasting and smelting can be carried out there simultaneously.

Roasting of oxidised metallic compounds, and other applications

In the case of oxidised metallic compounds, roasting is used for removing oxygen. The operation then becomes a reducing roast, which requires the presence of a reducing agent such as carbon, nascent hydrogen[1] or a metallic sulphide. Roasting can also be utilised for transforming metallic sulphides into sulphates. Such a sulphating roast is resorted to for converting copper sulphide into sulphate for leaching. Another application of roasting is in connection with magnetic separation; roasting serves there for changing non-magnetic iron compounds into magnetic iron compounds. Thus, pyrite which is non-magnetic sulphide can be transformed into a magnetic sulphide or oxide, in this manner. Hematite that is a non-magnetic oxide can likewise be changed into a magnetic oxide.

Further uses of roasting

Roasting as a process preparatory to hydrometallurgical treatment can serve not only for rendering the metallic constituent of an ore soluble in a leaching solution, but also for making certain soluble minerals insoluble in it, in order that they should not be able to contaminate the product. Furthermore, it is possible by fractional roasting to destroy the floatability of particular sulphides in complex ores and thus separate the former from the floatable sulphide, during flotation. Such a process exists for the treatment of lead-iron-zinc sulphide ores. Fractional roasting is, however, a somewhat difficult operation, as chemical changes have to be

[1] Nascent hydrogen is hydrogen at the moment it is released as a result of a chemical reaction.

confined to particular metallic constituents of the ore.[1]

Conditions required for roasting

An all-important condition for good roasting is that the air should have proper access to all parts of the material. For this reason, the ore is usually crushed small before roasting. The interior of the mass can then be brought into contact with the air through stirring with some mechanical device. Another method resorted to is to force air through the charge. As the combining of oxygen with sulphur is accompanied by the production of heat, the latter may be sufficient to maintain the roasting process once started. It is, however, always necessary to heat the furnace before commencing the operation.

Continuous roasting

In large modern plants, the process is generally continuous, that is to say, no interruption of the operation is required for the removal of the roasted ore, as the latter is discharged automatically. A method adopted for achieving this object is to arrange a number of hearths one above the other in a cylindrical structure, with feed at the top, and to cause the charge to travel down from one hearth to the other, until it is finally discharged below. The progress of the charge is ensured by rakes provided at each level and carried by arms fitted to a central vertical revolving shaft. These rakes which are set at a suitable angle force the ore on the hearths towards openings communicating with the level below. The openings are alternately at the

[1] For fractional roasting, the metallic constituents of the ore must differ sufficiently as regards temperature at which they react.

centre and at the edge of the hearth, so that the movement of the charge is from the periphery to the centre of the hearth on one level, and from the centre to the periphery, on the next. The ore is roasted on the hearths and during its fall through the air.

Roasting on train of grates

In the case of another type of plant, roasting is done on a train of grates which travel on rollers, along a pair of tracks, in the manner of an endless conveyor. The ore is fed in a thin layer on to this grate conveyor, at one end, and carried to the other end, where it is discharged. Between these two points, the train of grates passes over a suction chamber which draws air through the layer of ore. The initial heating of ore is caused by some type of igniter, arranged immediately after the feed. This furnace is intended for the treatment of fine ore, which is converted into a porous cake (sinter) and thus rendered suitable for smelting in blast-furnaces.

SMELTING

Source of heat for smelting

With smelting, the heat required for raising the temperature of the material treated above melting point is supplied either through the combustion of fuel incorporated with it, as in blast-furnaces, or by a flame passing over it, as with reverberatory furnaces.

Blast-furnaces

Blast-furnaces are in the form of vertical shafts with circular or oblong section. The charge includes

here not only the ore, and the flux to help the fusion of the gangue, but also coke to serve as fuel; the material is fed at the top of the furnace, which is always kept fully charged. The air for the combustion of the coke is introduced through nozzles (tuyeres) near the base; the temperature is therefore highest there, and the ore and flux fuse together as soon as they reach the neighbourhood of that point. The molten mass passes into a crucible below, or is led by a spout into a settler,[1] where the separation of metallic content and slag takes place, by reason of their different densities. This type of furnace is not suitable for the treatment of fine material, owing to choking of air passages by the latter and losses through escaping dust.

Reverberatory furnaces

Reverberatory furnaces are built as long shallow hearths; the roof of the furnace is low and assists the action of the flame and of the combustion gases by refracting the heat on to the hearth. The powerful flame required is, in the present-day designs, obtained as a rule through the combustion of pulverised coal in burners,[2] the latter being arranged at one end and the flue, at the other end. The charge is fed through hoppers[3] in the roof at the end of the hearth adjoining the burners, and fuses as it comes into contact with the molten mass; the slag is drawn off at the opposite end, while the metallic content is tapped at different points along

[1] Settlers or fore-hearths are used in the case of copper blast-furnaces.

[2] The earlier designs of reverberatory furnaces were built for coal firing, the grate provided at the end of the hearth for the purpose being separated from the latter by a low wall (fire-bridge).

[3] Hoppers are bins with sloping sides, terminating in a small opening through which the material is delivered.

the sides. A characteristic of the reverberatory furnace is that smelting and settling take place there side by side.

Grades of ores suitable for smelting process

Smelting as a means for the extraction of a metal from its ore is applicable when the material treated has the necessary metallic content to make the process an economical proposition. Some ores have in their natural state a sufficient metallic content. Thus, most of the iron ores mined can be smelted direct, the process being carried out in blast-furnaces. With the majority of metals, however, concentration of ore is generally required. This is, in particular, the case for copper, lead and tin. Owing to the fineness of the concentrates, the latter cannot be smelted in blast-furnaces, unless they have previously been agglomerated into cake by sintering or in blocks by briquetting. Such a preparation is unnecessary when reverberatory furnaces are used.

Separation of gangue as primary purpose of smelting

The purpose of smelting is in the very first place to separate the gangue from the metallic content of the ore. As a rule, the gangue consists largely of silica and silicates, which are difficult to melt. For this reason, materials known as fluxes are added to the charge, which combine with the gangue and form a fusible product (slag). The material commonly used as flux for the smelting of iron ores is limestone.

Chemical changes in the metallic compounds

The high temperatures in the furnace cause not only reactions between the flux and the gangue, but

also chemical changes in the metallic compound or compounds yielding the metal. These compounds may be oxides, for instance, as with most iron ores, or complex sulphides, as with copper. In either case, a decomposition of the compounds takes place. Thus, the oxygen combined with the iron in the iron ores is eliminated through the influence of the reducing atmosphere of the blast-furnace,[1] with the release of metal, while the copper and iron sulphides in the copper ores lose a certain part of their sulphur and iron during the smelting process.

Metallic impurities of ores

Apart from compounds of the metal, there are usually other metallic constituents in the ore, occurring as impurities. These too undergo chemical changes. Owing to this, the molten mass necessarily includes, in addition to its two main constituents resulting from the release of the metal or metallic compound and the fusion of the earthy gangue, a certain number of other products. These associate with the one of the constituents in which they are soluble. Metallic sulphides dissolve in metallic sulphides, and metals in metals, while oxides are soluble in the slag.

Impurities associated with metal drawn off from furnace

In view of this, the metal drawn off from the furnace may not only be still combined with elements from the original compounds, but may also be associated with a number of metallic and other impurities absorbed during the smelting process. This occurs in copper smelting, in particular, where

[1] The reducing agent is carbon monoxide gas resulting from the combination of the oxygen of the air blast with the carbon of the coke.

the product obtained (copper matte) consists of copper, sulphur and iron from the original sulphides, accompanied by small amounts of other elements such as zinc, lead, bismuth, antimony, arsenic, silver and gold, for instance. With iron smelting, the metal produced (pig iron) contains as chief impurities carbon, silicon and manganese; phosphorus and sulphur are other common constituents. All these various foreign elements have to be removed to a greater or lesser degree by refining. The extent to which refining is pushed depends upon the degree of purity required for the metal.

CHAPTER V

Metallurgical Treatments as Applied in the Final Preparation of Metals (concluded)

FIRE-REFINING—I

Refining by oxidation of foreign elements

The elimination of the impurities accompanying the metal in the crude product can be brought about either by subjecting the latter, in the crude state, to the action of suitable agents in a furnace generally fire-heated[1] (fire-refining), or by electrolysis (electrolytic refining). In fire-refining, the fused metal is subjected to the influence of oxygen supplied by air or by oxides of the metal, as in steel-making by the open hearth process. By this means, such foreign elements as are more easily oxidised than the metal can be eliminated. The oxides produced form a slag that floats on the metal, or if volatile escape as gases.

Subsequent deoxidising of metal necessary

Owing to the metal also absorbing a certain amount of oxygen in the process, it has subsequently to be deoxidised by a reducing agent. Impurities are prevented from re-entering the metal, by removing the slag before the introduction of the reducing agent. This oxidising followed by reducing may be repeated at different stages.

[1] Furnaces are also built which are electrically heated, for special purposes.

Refining of pig iron in Bessemer converters

The types of furnaces used for fire-refining are converters and reverberatory furnaces. Converters vary in design according to the metal treated. The Bessemer converters for the refining of pig iron, with a view to the production of steel, consist of pear-shaped vessels carried by trunnions, about which they can be tilted for charging, or for pouring out the liquid steel. Air is introduced under pressure at the bottom of the converter and blown through the molten mass, where it oxidises first the silicon and the manganese, and then the carbon. The metal is kept in a state of fusion by the great heat produced by these reactions. Oxidation is very rapid with this type of furnace.

Acid process and basic process

Bessemer converters can be built for the acid or the basic process. For the acid process, the refractory lining of the converter is made of acid material. The acid slag yielded by the oxidation products[1] does not absorb phosphorus or sulphur, so that with this process the latter elements cannot be eliminated. For the basic process, the refractory lining is made of basic material. A basic slag is obtained here by causing the oxidation to take place in conjunction with a strong base such as lime, the slag produced being capable of absorbing phosphorus and to a small extent sulphur. As only a very small phosphorus content is permissible in the steel, high phosphorus pig iron has to be treated by the basic process.

Deoxidising and recarburising

The reducing agent most generally used for de-oxidising iron is manganese. Apart from this de-

[1] Silica is the principal acid-making constituent.

oxidiser, it is necessary to add carbon to recarburise the iron, owing to this essential constituent of steel having been removed in greater part during the oxidation process. Manganese and carbon may be supplied by a mixture of spiegel and pig iron[1] (spiegel mixture), introduced in the molten state, with the required content of deoxidiser and recarburiser. Ferro-manganese may also be used in place of spiegel. All these mixtures which can be varied at will, according to the grade of steel desired, contain silicon too. An important function of the latter is to prevent blow-holes in the metal, by attacking carbon monoxide gas.

Converters for treatment of copper matte

The converters used for treating copper matte are based on the same principle as Bessemer converters, but differ from the latter in design. They are generally in the shape of a horizontal cylinder, which is carried by rollers and can revolve about its axis. The air is admitted through a row of nozzles (tuyeres) along the length of the cylinder. In the normal working position, the spout through which the matte is charged, and the metal or slag poured out, is at the top, and the tuyeres are on one side below the level of the molten mass. When charging or emptying, the spout is tilted forward, and the tuyeres are raised above the bath of metal, by revolving the converter through a certain angle. Such converters are lined with basic refractory material, usually magnesite brick.

Conversion of copper matte into blister copper

As in the case of Bessemer converters, the heat

[1] Spiegel is a product of iron blast-furnaces, having a high manganese content.

produced by the oxidation of impurities is sufficient for keeping the metal in a molten state;[1] the impurities are here iron and sulphur, matte being mainly composed of copper and iron sulphides. During the first stage of the operation (slagging period), the sulphur of the iron sulphide and the iron itself are oxidised by the oxygen of the air blown in. The resulting products are sulphur dioxide gas and iron oxide. Silica has to be present for the iron oxide to combine with and form a slag; it is generally added to the charge in the form of siliceous ore. When all the iron has passed into the slag, the latter is poured out, leaving copper sulphide (white metal).[2] During the second stage, the sulphur of the copper sulphide is in turn oxidised and escapes in the form of sulphur dioxide. The remaining metal is known as blister copper.

Refining processes for blister copper

Blister copper is a raw copper that still contains a number of metallic impurities. In order to remove these impurities, the metal has to undergo further refining processes. In the case of electrolytic copper,[3] three such operations are required. The first takes place in a reverberatory furnace (anode furnace). The refined copper from this furnace is then cast into anode plates for the next operation which is the electrolytic process. The cathode copper yielded by this process has itself to undergo final treatment, once more in a reverberatory furnace.

[1] The converter has necessarily to be heated before starting the process.

[2] One or more further charges may be introduced and brought to the white metal state, before the following stage is proceeded with.

[3] Most copper is, at the present day, refined electrolytically.

FIRE-REFINING—II

Refining of pig iron in open hearth furnaces

Reverberatory furnaces such as used for refining purposes are built of various designs. An important representative of this class of furnaces is the open hearth furnace, which like the Bessemer converter is utilised for the refining of pig iron with a view to the production of steel. A special feature about the open hearth furnace is that it embodies the so-called regenerative principle, that is to say, the heat from the combustion gases instead of being lost is stored and used for pre-heating the air and gas entering the furnace.

Design of open hearth furnaces

The open hearth furnace consists of a long shallow hearth enclosed in a brick structure; the fuel used is generally gas.[1] The furnace can be fired from one end or the other of the hearth, as there are ports at both extremities, which can be used for the introduction of gas and air or for the escape of combustion gases, as required. For a given period, the firing is in one direction, after which the direction is reversed, so that the admission ports become the outlet ports, and vice-versa; this changing over is rendered possible by a system of flues and valves.

Storage of heat

The storage of heat takes place in chambers with brick checkerwork (regenerators), arranged below the level of the furnace and in the path of the flues leading to the ports. The combustion gases, as they

[1] The gas may be natural gas, coke oven gas or producer gas; pulverised coal and fuel oil are also utilised, in some installations.

leave the furnace at the end of the hearth, give up their heat to the regenerators corresponding to the ports at that end. When the direction of firing is reversed, and the ports which had been acting as outlet ports become the inlet ports, the regenerators give up their heat to the incoming gas and air.

Oxidation of impurities

The oxygen for the oxidation of the impurities of the pig iron is supplied by excess air admitted into the furnace and also by iron oxide ore introduced with the charge or at a later stage. The open hearth process (Siemens Martin process), like the Bessemer process, includes a basic and an acid process. With the basic process, the charge normally consists of pig iron, scrap, ore and limestone, as flux. Owing to the presence of lime, a basic slag is formed capable of absorbing the phosphorus of the pig iron, as well as the other impurities such as silicon and manganese.

Recarburising and introduction of other alloying elements

At the end of the refining process, the metal is drawn off through the tap hole at the bottom of the hearth and led into a ladle, where it is recarburised through the addition of spiegel mixture or ferro-manganese, for instance.[1] These recarburisers supply not only the necessary carbon, but also manganese. As regards other alloying elements, they are introduced either there or at an earlier stage, as the case may be. Alloying elements include such metals as nickel, copper, chromium, vanadium and molybdenum, and the non-metal silicon.

[1] As the slag floats on the top of the metal, it only reaches the tap hole when most of the metal has passed out, so that it can be collected separately.

Charge for open hearth process

With the acid open hearth process, the charge is made up of pig iron and scrap. Neither ore nor flux is introduced with the charge; ore is added at a later stage, as required. The slag is acid and does not absorb phosphorus; for this reason, the process is not suitable for the treatment of pig iron with a high phosphorus content. An acid lining is used here for the hearth, while a basic lining is required for the basic process.

Refining of pig iron in puddling furnaces

Another type of reverberatory furnace is the puddling furnace used for the refining of pig iron with a view to the production of wrought iron. The puddling furnace is usually coal-fired and of small dimensions. The hearth or puddle basin is arranged between the fire-place and the flue, and separated from either by a low wall extending across the furnace; it is provided with a built-up refractory lining, where iron oxide figures as principal constituent.

Fluxing material

This lining supplies a certain portion of the flux. Most of the flux, however, is yielded by the slag rich in oxides introduced into the furnace with the first charge. Through the action of this flux and of such further fluxing material as may be added at a later stage, the silicon, phosphorus and carbon of the pig iron are removed successively.[1] Stirring is a necessary operation during certain phases of the process; this stirring is done by means of heavy bars

[1] In the case of such elements as silicon and phosphorus, that pass into the slag, elimination is by oxidation and neutralisation. Carbon is removed in the form of carbon monoxide gas.

inserted through a hole in the door on the side of the furnace.

Final treatment of product of puddling furnace

At the end of the puddling process, the metal is in a pasty condition. It is removed from the furnace in the form of balls. These balls are passed through a squeezer where they are converted into suitable shape for rolling, and freed at the same time of a great part of the slag they contain.[1] The squeezed balls are then rolled into "muck bars." Finally, the muck bars are cut into short lengths and made up into piles, which are heated up to welding temperature and rolled, a further amount of slag being expelled in this way;[2] the product obtained is known as single-refined merchant bar. By repeating the operation, on somewhat similar lines, double-refined merchant bar is produced.

FIRE-REFINING—III

Reverberatory furnaces for refining blister copper

The reverberatory furnaces for the refining of blister copper, previous to the casting of the metal into anodes for the electrolytic process, differ from the usual design in that they have a somewhat deeper hearth. Furthermore, a special method is

[1] This work was originally done with the hammer. At the present day, squeezers have largely displaced the hammer in this particular field. The most common type of squeezer consists of a cylinder with corrugated surface, rotating inside a fixed cylinder of somewhat larger diameter, arranged eccentrically to it. The ball is introduced in the larger portion of the passage between the two cylinders, and made to travel, through the action of the inner rotating cylinder, to the narrower section, where it is discharged.

[2] A small amount of slag always remains incorporated in the metal; this is one of the characteristics of wrought iron.

adopted for the introduction of air, the latter being injected under pressure into the molten mass through cast-iron pipes. These pipes only have a short life, as they are gradually eaten away, and give up their iron to the slag.

Poling

Oxidation is continued until some of the copper is oxidised. When this is the case, it can be inferred that the oxidation of the impurities is complete, as these are more easily oxidised than the copper. The slag is then removed, and reducing begun. Reducing is done here by driving green wooden poles into the molten mass (poling). As the poles come into contact with the hot metal, a decomposition of the wood substance takes place, with violent generation of steam and production of carbon monoxide, hydrogen and hydrocarbons, which are responsible for the reducing effect.[1] At the same time, the great agitation set up in the molten mass, in the process, causes the expulsion of the sulphur dioxide gas dissolved in the metal. After the sulphur dioxide has been driven out, coke is very often scattered over the bath, as further reducing agent. When the necessary reduction has been achieved, the metal is cast into anode plates.

Reverberatory furnaces for refining cathode copper

The reverberatory furnaces for the refining of the cathode copper from the electrolytic process are, as a rule, considerably larger than the anode furnaces. The process is, however, very much the same. The oxidation is also caused by the injection of compressed air into the molten mass, and reduction, by

[1] Carbon monoxide and hydrogen are reducing agents, while the hydrocarbons yield carbon on being themselves dissociated.

poling, but in this case there is no sulphur dioxide to expel. A small amount of oxidised copper is left in the final refined copper, in order to give it the desired toughness. The presence of this oxidised copper is furthermore a guarantee that any remaining impurities are in the form of oxides, which are less harmful for the metal.

Refining of tin

The tin obtained from smelting contains various impurities such as lead, arsenic, antimony, iron, cadmium and copper. The usual method of refining the metal from these impurities is by liquation, followed by boiling or tossing.

Liquation

The purpose of liquation is to remove the impurities with a boiling point higher than that of tin.[1] The process is carried out in small inclined reverberatory furnaces, where the temperature is maintained just above the melting point of tin. As the metal melts, it runs out through a tap hole into kettles, while the dross, that still contains a certain amount of tin, remains in the furnace and undergoes further treatment at a higher temperature. The metal obtained from the initial heating (first-run tin) passes to the final refining stage, while the tin recovered from the dross is returned to the furnace with the next charge.

Boiling and tossing

Boiling and tossing are both operations having as object the oxidation of the impurities remaining in the tin after liquation, through bringing the different parts of the molten metal in contact with the air.

[1] Tin is a metal with a very low melting point.

In the case of boiling, a great agitation is produced in the molten mass by introducing green poles, as in copper poling; a similar effect can be obtained by making use of compressed air. With tossing, ladlefuls of molten metal are taken from the kettles and poured back into the latter, from a height. In either case, the dross is subsequently removed by skimming.

Extraction of metals in gaseous state by distillation

As long as the metal is separated in the liquid state, as in the smelting and fire-refining processes described, the charge can be heated directly by the burning gases. When, however, it is a question of extracting the metal in the gaseous state, indirect heating has to be resorted to. In this case, the charge is placed in a closed vessel (retort), which is itself subjected to a source of heat. This method of extraction (distillation), which is applicable to metals with a low boiling point,[1] necessitates the subsequent condensation of the metallic vapours in a condenser.

Zinc distillation

Distillation is, for instance, one of the methods utilised for the extraction of zinc.[2] The ore treated may be sulphide or carbonate ore; it has first to be roasted or calcined, in order to convert it into zinc oxide.[3] The retorts used for zinc distillation are of refractory material and generally of small dimensions; they may be in the form of cylinders three to five feet long, with an inner diameter of a few inches. A large number of such retorts are arranged in rows

[1] Metals with a low boiling point include mercury, cadmium, zinc and magnesium.

[2] Zinc is also extracted by electrolysis.

[3] Sulphide ore (blende) is roasted, while carbonate ore is calcined.

in a furnace, across the path of the flame; they are made to slope slightly from the centre of the furnace to the outside. The opening of the retort is at the latter end. The condenser is in the shape of a tubular piece also of refractory material, usually with a belly where the condensed metal can collect; it is fitted directly on to the retort and projects outside the furnace.

Charge of retort

The charge of the retort consists of zinc oxide and of coal, or coke and coal, as reducing agent. These materials are finely ground and mixed before charging. During the first stage of the process, the gaseous product issuing from the retort is mainly carbon monoxide resulting from the combination of the carbon of the reducing agent with the oxygen of the zinc oxide. After a while, the zinc begins to vaporise and condenses, as it enters the condenser; the metal is then removed from time to time.

ELECTRO-METALLURGY

Characteristic of electrolytes

The metal in the crude product can be isolated not only by heat treatments such as described, but also through the action of an electric current. The process in question is based upon a characteristic of certain current conducting substances known as electrolytes. This characteristic resides in the fact that the passage of current through these substances is accompanied by a transfer of matter.

Various categories of electrolytes

Electrolytes comprise fused salts that conduct without requiring admixture with any other

medium, and substances (salts, acids or bases) which conduct when dissolved in certain solvents, the most common solvent being water. These solutions are known as electrolytic solutions. The cause of the phenomenon is to be found in the electrical constitution of the atom. A digression on atomic structure is thus indispensable for a proper understanding of this process of electrolysis, as it is called.

Constituents of the atom and nature of ions

The atom of any element consists on the one hand of a nucleus with a net positive charge[1] provided by positive particles (protons),[2] which is unaffected by chemical changes, and on the other hand of negative particles (electrons) revolving in orbits about the nucleus. When the negative charge represented by the electrons of an atom is equal to the positive charge of the nucleus, the atom is in the neutral state. If, however, the atom loses one or more electrons, it becomes positively charged, while if it acquires additional electrons, it is negatively charged; such charged atoms or groups of atoms are known as ions. This loss or acquisition of electrons represents a change to a more stable grouping of electrons.[3]

[1] It is necessary to speak of "net" positive charge, as the nucleus may also contain negative particles, which neutralise an equal number of positive particles.

[2] Proton was the name originally given to the nucleus of the atom of hydrogen, which consists of a single positive particle and forms the only constituent of the ion of that element.

[3] This number of electrons which an atom or group of atoms loses or acquires on its conversion into an ion represents the valency of the element or radical in question. The valency governs the ratio in which elements or radicals unite; it indicates, in particular, the number of atoms of hydrogen that an atom of a given element or a group of atoms of a given radical will combine with or displace.

Ions in electrolyte displaced by electric current

In the solution of a salt, there is always a certain dissociation of the molecules of the latter into ions (ionisation) through the action of the solvent. If an electric current is sent through the solution by connecting the two poles of an electric supply to two conductors (electrodes) dipping into the solution, the passage of the current causes the displacement of the ions towards the electrodes. The positively charged ions (cations) move towards the electrode connected to the negative pole of the supply (cathode) and the negatively charged ions (anions) travel in the direction of the electrode corresponding to the positive pole of the supply (anode).

Reversion of ions to state of atoms on reaching electrodes

Once the ions reach the electrodes, they are neutralised and revert to the state of atoms or groups of atoms. The latter may either be deposited on the electrode or be precipitated to the bottom of the tank containing the electrolyte, or they may attack the electrode or the solution, according to the nature of the atom or group of atoms, and the composition of the electrode.

Electrolytic process as applied to the refining of copper

For the refining of metals, the electrolytes used are salts of the metal in solution. In the case of copper refining, for instance, use is made of an aqueous solution of copper sulphate and sulphuric acid. The anode is made of the copper to be refined, while the cathode consists of a sheet of refined copper. The copper sulphate is dissociated by the water into positive copper ions and negative sulphate ions. When the current is sent through the electrolyte, the positive copper ions travel to the cathode

and the copper is deposited on the latter. The negative sulphate ions go to the anode and attack the copper there, thus forming copper sulphate. This copper sulphate is in turn dissociated by the water, and the above cycle is repeated.

Anode copper to cathode copper

The refining thus consists in the conversion of the copper of the anode into copper sulphate, followed by the electrolysis of the latter with deposition of the metal on the cathode. Most of the impurities of the anode copper disappear in the process, as they are attacked and form salts, which are, however, in greater part insoluble, so that they then drop to the bottom of the electrolyser tank. Each tank accommodates a number of anode and cathode plates, which are arranged alternately. Processes also exist for the electrolytic refining of zinc, lead, nickel and tin.

Use of electrolytic method for the extraction of aluminium

Another very important application of the electrolytic method is in connection with the extraction of aluminium. This metal, like most other common metals, is produced by the reduction of an oxide. Aluminium oxide (alumina) cannot, however, be reduced by carbon monoxide, while reduction by carbon is not an economical proposition, owing to the very high temperature required.[1] For this reason, electrolysis is resorted to for the purpose. Alumina occurs in bauxite, mixed with various impurities,[2] which are eliminated by chemical means before the electrolytic process.

[1] There is this further difficulty that, at the very high temperatures required for reduction by carbon, aluminium is in the gaseous state, so that it mixes with the carbon monoxide produced in the process.

[2] The principal impurities are iron, silicon and titanium, in the form of oxides.

Composition of electrolyte and electrodes

The electrolyte consists here of alumina dissolved in fused cryolite (aluminium sodium fluoride). The electrodes are of carbon; a considerable amount of this carbon is consumed during the process by oxidation. The cathode is in the form of a thick lining covering the whole inner surface of the vat; it thus constitutes a sort of hearth, which holds the mass of molten material. The anodes are in the shape of blocks dipping into the electrolyte.

Dissociation of alumina into aluminium and oxygen

Through the passage of the current, the alumina is dissociated into aluminium and oxygen. The aluminium collects on the cathode at the bottom of the molten mass, from where it is drawn off through a tap hole. The oxygen rises along the anodes and combines with the carbon of the latter, thus forming carbon dioxide and monoxide. As the impurities contained in the alumina are not removed in the process, the material treated must be very pure. The heating effect of the current is sufficient to keep the electrolyte in the molten state.

Varied application of electric current in electro-metallurgy

Electric current thus serves several purposes in metallurgy. In copper refining, its function is purely electrolytic. In the reduction of alumina, it acts both as electrolytic and thermal agent, while in electric furnaces, it is used solely as heating medium. Electric furnaces are utilised to a considerable extent in iron and steel metallurgy. They permit of very high values of temperature and of an accurate control of the latter, while contamination by impurities from fuels is avoided.

CHAPTER VI

From Crude Petroleum to Refined Oil Products

Principal Mineral Oil Products and their Preparation—I

Light oils and heavy stocks

The various hydrocarbons entering into the composition of crude oil differ very considerably as regards boiling point. In view of this, it is possible to break up the crude oil by distillation, into fractions corresponding to different boiling ranges; this is known as fractional distillation. The hydrocarbons with low boiling point yield light oils and those with high boiling point, heavy stocks, while products with intermediate properties can be obtained in between. The light oils comprise gasoline (motor spirit), naphtha and kerosene (burning oil).

Topping

The proportion of light oils necessarily differs according to the nature of the crude oil. The removing of these light fractions of the crude constitutes what is known as topping or skimming. The oil left over after topping (reduced crude) may be disposed of as fuel oil or used, for instance, for the production of lubricant stock, if suitable for the latter purpose.

Cracked gasoline

The amount of light oils yielded by crude oils can be increased very considerably by cracking, that is to say, by decomposing heavy hydrocarbons

into light hydrocarbons through the action of high temperatures.[1] A very large part of the gasoline produced at the present day is manufactured in this way. Cracked gasoline is characterised by its anti-knock properties;[2] for this reason, it is blended into most high-grade motor spirits.

Lubricant stocks and lubricating oils

The crudes processed for lubricants are mainly paraffin base and mixed base oils, that is to say, wax-bearing oils. The lubricant stocks are derived from the oil, once the latter has been stripped of its volatile low boiling part; they comprise a light fraction (wax distillate) and a heavy fraction (cylinder stock). These products constitute the base materials for the manufacture of lubricating oils. The various operations required in this connection, which include in the very first place the removal of the wax, will be dealt with later on. Compounding (blending) of stocks is very often resorted to, in order to suit the oil to its various applications. The oils best suited for the preparation of lubricants are paraffin base oils.

[1] The cracking stock may be fuel oil, for instance.

[2] Certain fuels detonate violently in high compression engines; they are then said to knock. Thus, gasoline from paraffin base oils usually knocks, while gasoline from naphthene base oils is generally anti-knock. Knocking is very detrimental to the working of engines, so that anti-knock properties are very valuable. For rating the anti-knock properties of a fuel, use is made of a mixture of two reference fuels, of which one (normal heptane) has a very low anti-knock value, and the other (iso-octane), a high anti-knock value. The anti-knock tendency of the given fuel is then defined by the octane number, which is the volumetric percentage of iso-octane in a mixture of iso-octane and normal heptane, that possesses the same anti-knock characteristics as the fuel in question. In practice, cheaper reference fuels (gasoline with high knocking tendency and gasoline with low knocking tendency) are utilised, the mixtures being calibrated in terms of octanes.

Preparation of lubricating oils by solvent extraction

Lubricating oils can also be prepared from lubricant stock by solvent extraction. By this means, it is possible to separate the constituents of the oil by chemical classes. Thus, by using a selective solvent capable of dissolving naphthenic hydrocarbons, these compounds which have a low viscosity index can be removed in greater part from mixed base oils, leaving the high index paraffin hydrocarbons;[1] the solvents used in this connection include sulphur dioxide, phenol and nitro-benzene, for instance.[2]

Fractional distillation

After these few general remarks, a brief description may be given of the various operations, starting with fractional distillation which is the fundamental process in the preparation of oils. Fractional distillation entails firstly the heating of the liquid to the temperature required for the vaporisation of the fractions in question and secondly the separation of these fractions. The former function is fulfilled by the still and heat exchangers,[3] and the latter, by the fractionating tower.

Stills and heat exchangers

In modern installations, the stills are in the form of tube stills. With this design of still, the oil is

[1] With lubricating oils, it is very important that the oil should retain its viscosity at high temperatures. This viscosity-temperature relation is expressed by the viscosity index. A high index denotes an oil possessing to a very marked degree the property of retaining its viscosity at high temperatures, and a low index, an oil with the opposite characteristics. Paraffin base oils are high index oils.

[2] Another method is to use two solvents, that do not mix, one for the naphthenic hydrocarbons, and the other for the paraffinic hydrocarbons.

[3] When process steam is used, the latter is also a source of heat.

heated on its passage through the tubes; the process is thus continuous. Much of the heat communicated to the oil is recovered from the products of distillation in heat exchangers. There, these various products give up their heat to the oil on its way to the still; as a result, the products are cooled, while the temperature of the charge-stock is raised before it is fed into the still. A special characteristic about tube stills is that vapours and liquid remain in intimate contact up to the outlet of the still in the fractionating tower, vaporisation from this condition being known as flash-vaporisation.

Fractionating towers mostly built as bubble towers

Fractionating towers are mostly built as bubble towers; they consist of a high vertical cylinder divided into superimposed chambers by horizontal trays (plates), where the liquid can collect. The level of the liquid on each tray is limited by an overflow leading to an opening through which the liquid can drop on to the plate of the chamber below.

Main feature of bubble towers

The main feature of bubble towers is the arrangement for causing the vapours to pass through the liquid on the tray, on their way from the chamber below it to that above it. Such a result is achieved by providing a number of passages through the tray, terminating at their upper extremity above the surface of the liquid, in bells resting on the tray and having outlet openings below the surface of the liquid. As the only way the vapours can escape from the bells is through these submerged openings, they have to bubble through the liquid, in order to reach the space above. The plate on to which the

feed from the still is discharged is known as the feed plate; it is at a certain height above the bottom of the tower.

Mode of working of fractionating towers

In the fractionating tower, there are two flows: a flow of vapours rising from the feed plate up to the top of the tower, where the vapours representing the overhead product are led away, and a flow of cooling liquid (reflux) of similar composition as the vapours, descending from the top of the tower to the bottom. The cooling liquid used is condensed overhead product. The various chambers of the fractionating tower act as a succession of stills, each operating at a lower temperature than the other, from the feed plate to the top of the tower; thus, the highest boiling portion of the vapours rising from one tray is condensed as it comes into contact with the cooler liquid of the tray above, while the lowest boiling part of the latter liquid is evaporated by the heat communicated to it. This means that each tray contains a liquid with a different boiling range, and that different products can be drawn at intervals along the tower.[1] The product led away at the top of the tower (overhead product) being in the form of vapour has to be condensed externally in a condenser. The highest boiling fraction collects, on the other hand, at the bottom of the tower (bottoms product).

[1] As the various side-draw products contain a certain proportion of low boiling components, they each have to undergo further treatment for the removal of such material, steam stripping columns being used for the purpose. Steam stripping columns are built on the same principle as fractionating towers.

Principal Mineral Oil Products and their Preparation—II

Different methods of fractionation

In the case of low boiling fractions, fractionation can be carried out at atmospheric pressure (atmospheric fractionation). With high boiling fractions, ordinary atmospheric fractionation is no longer possible, as the high temperatures that would be required under these conditions would cause the decomposition of the hydrocarbons. In such a case, it is necessary either to introduce steam in the space where the fractionation is carried out (steam fractionation) or to reduce the pressure there (vacuum fractionation); the two methods may sometimes be combined together. High boiling bottoms products of atmospheric fractionating towers have invariably to be dealt with in this way for the separation of lubricant stock, for instance.

Cracking processes

Reference has been made to the cracking of heavy oils for the production of light oils by the decomposition of hydrocarbons. This decomposition can be brought about when the oil is either in a liquid condition or in a vapour state, or partly in a liquid condition and partly in a vapour state; the cracking processes are divided accordingly into liquid phase processes, vapour phase processes and mixed phase processes. The principal processes used at the present day come under the category of mixed phase processes.

Charge-stock decomposed in tube furnaces

The decomposition of the charge-stock takes place in the tube furnaces where the oil is heated and,

when a reaction chamber or soaking drum is provided, the reaction continues in the latter. Owing to the high temperature required for producing the decomposition, a high pressure has to be maintained in the heating tubes, in order to keep the oil, in greater part, in the liquid state.

Main component parts of cracking plant

The main component parts of the cracking plant are, apart from the heating tubes, the evaporator, where all the light constituents of the oil are vaporised and the heavy residue is removed, the fractionating tower, where the lighter fraction of the distillate is separated from the heavier fraction, and the condenser. When a reaction chamber or soaking drum is used,[1] it often also fulfils the function of the evaporator and replaces the latter. As customary with such installations, provision is made for the pre-heating of the charge-stock by the hot by-products of the process.

Applications of cracking

Cracking stocks were originally confined to heavy oils. At the present day, however, cracking is also applied to light oils, as cracked gasoline with its high anti-knock qualities is much more valuable than the straight-run product.[2] Cracking can also be used for the production of coke, in which case the cracking time has to be greatly increased. This lengthening of time is obtained through the use of reaction chambers or soaking drums, which serve at

[1] The reaction chamber or soaking drum permits of an increase of the capacity and yield of the plant; such a chamber or drum is furthermore indispensable, when coke is to be produced in the process.

[2] The charge-stock is then naphtha or gasoline with poor anti-knock qualities.

the same time for the accumulation of coke. Another application of cracking is for reducing the viscosity of heavy fuel oils. For this purpose, only a short cracking time is required; the equipment utilised is much simpler too. The stock that can be treated by a cracking process varies according to the latter. Some processes are only suitable for dealing with clean distillate, while others can be used for the decomposition of any charge-stock from naphtha to heavy residual oils.

Hydrogenation

Another interesting development somewhat related to cracking is hydrogenation. By this process, the nature of hydrocarbons is altered through decomposition and assimilation of hydrogen at high temperature and pressure, the hydrogen being introduced in the presence of a catalyst.[1]

Separation of oil constituents having similar boiling ranges

Although distillation is the fundamental method for the separation of the constituents of oil, there are cases where this process is no longer applicable, due to the constituents in question having more or less similar boiling ranges. Use has then to be made of some other characteristic for effecting the separation. An instance is afforded by the methods resorted to for the removal of wax from lubricant stock, which are based on the different behaviour of oil and wax at low temperatures.

Paraffin wax

Wax occurs in lubricant stock in crystalline form (paraffin wax) and in amorphous state (petrolatum).

[1] A catalyst is a foreign substance which has the effect of accelerating chemical reactions.

Paraffin wax is found in wax distillate, and petrolatum, in cylinder stock. The usual method of removing the paraffin wax is to chill the wax distillate, so as to cause the wax to congeal, and to pass it through a filter-press, where most of the oil is extracted. The residue of wax is then frozen into a cake and the latter is subsequently warmed slowly, so as to allow such oil as it still contains to drain off. Paraffin wax is used for such purposes as candle making. As regards the filtered oil (pressed distillate), it is the base material for the manufacture of light lubricating oil stock.

Petrolatum

In the case of petrolatum, the separation is generally effected in a centrifugal separator. Cooling is required with this process too, the cylinder stock treated being diluted in naphtha to the extent necessary to keep it in a non-viscous state under these lower temperature conditions. Through centrifuging, the cylinder stock is divided into brightstock and petrolatum. Petrolatum is the raw material from which petroleum jelly (vaseline) is obtained by refining. Brightstock is a heavy lubricating oil stock.

Refining of Mineral Oil Products—I

Origin of impurities in oil distillation products

The products yielded by fractional distillation necessarily contain a greater or lesser amount of impurities. These impurities are partly substances coming from the crude oil and partly compounds formed through the thermal decomposition that always occurs to a small degree during distillation.

Such undesirable constituents are still further increased when the stocks are subjected to actual cracking processes. As the qualities demanded of most oil products necessitate as far as possible freedom from impurities, more or less lengthy refining operations are usually required. It is only in the case of such products as fuel oils that refining may be entirely dispensed with.

Nature of impurities and refining processes

The impurities that have to be eliminated by the refining processes include unsaturated hydrocarbons,[1] that render the product chemically instable, resinous and asphaltic substances, that colour it, and sulphur compounds, that give it an unpleasant smell; further objectionable constituents are oxygenated compounds and nitrogen compounds. Refining is achieved primarily by chemical treatment. There are, however, also processes based on the adsorbent properties of such materials as clay, while solvents are used in certain cases.

Sulphuric acid as principal refining agent

Chemical refining consists in bringing the oil into contact with some agent that combines with the impurities, the resulting sludge being subsequently removed; the treatment is usually completed by the washing of the oil with water, in order to eliminate as far as possible all traces of the chemical. The most important refining agent is sulphuric acid. Under ordinary refining conditions, sulphuric acid

[1] The objectionable unsaturated hydrocarbons are, in so far as gasoline is concerned, those of the diolefine series, that tend to form gums in it. Olefines which also come under the category of unsaturated hydrocarbons are, on the other hand, useful constituents of gasoline, as they contribute to its anti-knock qualities.

does not attack paraffins or naphthenes to any appreciable degree, but it reacts to a greater or lesser extent with most other hydrocarbons and impurities. The factors governing the reactivity are the concentration of the acid, the temperature and the time of contact with the oil; these quantities have therefore to be fixed, in each particular case, according to the product treated and the constituents it is desired to remove.

Treatment with neutralising agent after acid process

Sulphuric acid is used in the very first place for improving the colour of oils. It serves furthermore for reducing the sulphur content of high-sulphur distillates, for removing the aromatics and unsaturated hydrocarbons in kerosene,[1] and for increasing the chemical stability of cracked distillates, in particular. After the acid process, the oil is treated with a neutralising agent, in order to extract any acid or acidic substances remaining in it.[2] A solution of caustic soda is commonly used for the purpose. Contacting with clay is also resorted to with lubricating oils.

Batch agitation

The oil may be dealt with in batches. In this case, oil and acid are pumped into large tanks (agitators), where they are mixed by means of compressed air or with a circulating pump, for instance. Batch agitation is the method generally used for the treatment of kerosene and lubricating oils. With kerosene, the same agitator can be utilised both for the acid process and the subsequent soda

[1] The object is to improve the burning qualities of the kerosene.

[2] Caustic soda is used not only as a neutralising agent after the acid process, but also as a refining agent independently of the latter.

treatment. With lubricating oils, on the other hand, separate agitators are required, as the soda treatment presents special difficulties here, owing to the formation of emulsions during the process. These difficulties in the neutralisation of lubricating oils can, however, be obviated by using clay as neutralising agent; the process is then one of adsorption. This type of treatment is referred to later on.

Continuous process

Instead of being applied to individual batches of oil, acid treatment can be carried out as a continuous process. In this case, the oil passes in a continuous flow through a series of tanks or apparatus, where mixing, separation of sludge, washing and neutralisation take place successively. This method of treatment is used for gasoline, in particular. The mixers utilised are based on various principles. In the orifice column, for instance, the mixing effect is obtained by forcing the oil and acid through orifices in plates arranged at intervals inside the column, while in mechanical mixers use is made of the action of revolving blades or other similar devices. The separation of sludge may take place in settling tanks or may be brought about by centrifugal means. As regards the wash-water, it is introduced in the wash-tanks through sprays below the surface of the oil, and withdrawn below.

Refining of Mineral Oil Products—II

Objectionable odoriferous sulphur compounds

The presence in the oil of certain sulphur compounds, known as mercaptans, which are not removed by the acid process and soda treatment,

necessitates further refining operations. Mercaptans are very objectionable impurities, as they give a sour smell to the oil; furthermore, if elementary sulphur occurs at the same time, be it merely in minute quantities, the product is rendered corrosive.

Sweetening process

In order to remove these odoriferous sulphur compounds, the oil is subjected to a so-called sweetening treatment. The two principal treatments used are the sodium plumbite treatment (doctor treatment) and the hypochlorite treatment. In the former case, the chemical agents are sulphur and an alkaline sodium plumbite solution, and in the latter case, sodium or calcium hypochlorite solutions. The sodium plumbite treatment eliminates most of the combined sulphur[1] and also the elementary sulphur; it is the sweetening process utilised in the case of cracked gasoline, for instance. The hypochlorite treatment, on the other hand, is only applied to non-cracked products.

Refining by adsorption

A further mode of refining, which is occasionally adopted in place of ordinary refining, but more often in conjunction with it, is one based on the property of certain materials such as fuller's earth, clays, bauxites, etc., of adsorbing impurities of the oil. The adsorption may take place in a column packed with adsorbent material in granular form, through which the oil is made to percolate. The adsorbent may, on the other hand, be mixed in a powdered condition with the oil, which is then

[1] There remain certain innocuous sulphur compounds resulting from the chemical reactions, that cannot be entirely eliminated, owing to their being more or less soluble in the oil.

heated and finally filtered (contact process). The treatment can also be carried out while the oil is still in the vapour state, before it is condensed. This method is applied to cracked distillate, in particular; in this case, the oil vapours are led through a tower filled with loosely packed adsorbent material. Adsorption is used for improving the colour of oils, for reducing the gum content, etc., while contacting with clay is resorted to for neutralising lubricating oils after the acid process.

Re-distillation

Refining operations further include re-distillation. By this means, it is possible to eliminate high-boiling substances produced at some stage or another and retained by the oil. Cracked gasoline, for instance, is usually subjected to steam distillation after the acid process. Distillation has to precede the sweetening treatment, as oil is liable to turn sour again, after the latter process, if subjected to high temperatures.[1]

Blending of gasolines

As it is generally not possible or not economical to prepare directly products capable of meeting the very divers requirements of industry, blending of stocks is extensively resorted to. Thus, most gasolines sold are blended products. The stocks used for blending are straight-run gasoline, cracked gasoline and natural gasoline;[2] the latter is a gasoline derived from natural gas. Through the admixture of natural

[1] This occurs as a result of the conversion of the non-odoriferous sulphur compounds that have remained dissolved in the oil, into sour smelling compounds, through the action of heat.

[2] Certain motor spirits are also produced by blending benzol and gasoline. Benzol is a light oil obtained as a by-product of coal.

gasoline of suitable composition,[1] the temperature at which the motor spirit ignites can be lowered to a greater or lesser degree. Cracked gasoline improves the anti-knock qualities of the product; detonation can also be lessened by adding a small quantity of tetraethyl lead.

Blending and compounding of lubricating oils

Lubricating oils have likewise to be blended, in order to obtain the desired characteristics as regards viscosity, specific gravity, etc., laid down in specifications. The products used for blending may be confined to different types of mineral oils. In some cases, however, fats or fatty oils of animal or vegetable origin are also mixed with the mineral oils, so as to give the lubricant certain qualities; the operation is then known as compounding. Fats and fatty oils that are utilised in this connection include animal products such as tallow, lard, neatsfoot oil[2] and sperm oil,[3] and vegetable oils such as olive, rape and castor oils. Greases are produced by converting mineral oils into a semi-solid state by means of a soap;[4] they also generally contain animal fat.

[1] Natural gasoline is a product with lower boiling range than regular gasoline. Its composition is varied to meet blending requirements, by removing a larger or smaller proportion of the lightest components of the raw product.

[2] Oil derived from hooves of cattle.

[3] Oil obtained from the sperm whale.

[4] Soaps are salts of fatty acids. The soaps used for the manufacture of greases are obtained by treating the fatty matter with lime or caustic soda. The greases are known accordingly as soda base, lime base or mixed base greases.

CHAPTER VII

Treatment of Coal for the Preparation of Coal Derivatives and Oil

Coal Carbonisation—I

Low temperature and high temperature carbonisation

If coal is heated at increasing temperatures, out of contact with air, its volatile constituents are gradually eliminated, the solid residue obtained approximating more and more the state of carbon; the process is known as carbonisation. The extent to which volatile components are removed necessarily depends, in the very first place, upon the final temperature. Thus, low temperature carbonisation yields a product (semi-coke) still containing a certain proportion of volatile matter, while high temperature carbonisation gives a residue (coke) consisting essentially of carbon;[1] there remains, however, always a small percentage of non-volatile mineral impurities.

Chemical decomposition

Carbonisation is not merely a process of distillation. Chemical decomposition sets in at an early stage and plays a more and more important part, as the temperature increases, while secondary reactions cause further transformations. It is only at relatively low temperatures that separation takes place unaccompanied by chemical change. Water,

[1] Low temperature carbonisation covers processes operating at temperatures not exceeding about 600° C., while high temperature carbonisation relates to systems where the temperature is generally above 900° C.

occluded gases and the oil present in the coal are expelled successively at this earlier stage.

Products of the chemical reactions

The first products of chemical reactions are water, carbon dioxide (carbonic acid) and sulphuretted hydrogen (hydrogen sulphide). Ammonia appears somewhat later on, while as a result of further decomposition gaseous, liquid and solid hydrocarbons,[1] hydrogen and carbon monoxide are evolved more or less abundantly. The gaseous hydrocarbons are represented by methane and ethylene, for instance, and the liquid hydrocarbons, by light oils such as benzene (benzol) and by tar. The latter is a product incorporating a whole range of hydrocarbons that may extend from benzene to heavy oils; its actual composition depends largely upon the temperature of carbonisation.[2] Naphthalene is a solid hydrocarbon that forms in the case of high temperature carbonisation.

Ultimate result of carbonisation

The ultimate result of carbonisation is thus the production of a residue (coke or semi-coke) and of a mixture of gases (hydrogen, methane, carbon monoxide, carbon dioxide, sulphuretted hydrogen, nitrogen, ammonia, etc.) and of vapours of liquids (benzol, tar, etc.) and even of solids (naphthalene), accompanied by a certain amount of moisture;[3]

[1] The terms "liquid" and "solid" refer to the condition of the substance at ordinary temperature and atmospheric pressure. During the carbonisation process, liquids and even solids are in the vapour state, if the temperature is above their boiling point.

[2] Tar contains, in addition to hydrocarbons, oxygenated compounds such as phenol (carbolic acid), cresol, etc., as well as sulphur and nitrogen compounds.

[3] Finely divided solids and drops of liquids may also be carried along in the gas stream.

this mixture constitutes crude coal gas. The benzol and tar content of the latter varies with the temperature of carbonisation, as well as with the type of coal.[1] Low temperature carbonisation gives the highest yield of these products. High temperature carbonisation, on the other hand, results in an increase of gases. The gases that predominate are hydrogen and methane; they represent the main combustible substances in the coal gas. The proportion in which these gases occur also depends upon the temperature of carbonisation. With increasing temperature, the proportion of hydrogen becomes larger, while that of methane decreases.

Retorts as used in gas-works

Carbonisation is carried out in retorts or carbonising chambers. In gas-works, coal is carbonised either in horizontal or in vertical retorts. The horizontal retorts consist of long pipes of refractory material, which are disposed in rows in a series of furnaces (settings). The vertical retorts are built as shafts of rectangular or elliptical section, widening towards the bottom in order to facilitate the downward motion of the coke. Such retorts can be arranged for continuous operation, in which case the coke is constantly discharged at the bottom, while fresh coal is introduced at the top.

Ovens for metallurgical coke and retorts for semi-coke

In the production of metallurgical coke, carbonisation generally takes place in high narrow ovens of rectangular shape, which are built in batteries and alternate with the heating flues. For the manu-

[1] Coals are classified as coking coals or gas coals, according to their suitability for the one or the other purpose. Blending of coals may sometimes be necessary, in order to obtain the desired qualities.

facture of semi-coke, various types of retorts are used. Thus, the Coalite retort[1] is a special cast-iron retort embodying a certain number of vertical tubes, increasing in diameter towards the bottom. These retorts are arranged singly in radiation chambers that alternate with the combustion chambers where the fuel is burnt; the burning gases do not therefore come into contact with the retort.

Methods of heating retorts and ovens

Retorts and ovens may be heated with coal gas from the carbonisation process itself, that has previously passed through the by-product recovery plant, with producer gas[2] or with blast-furnace gas; the choice is necessarily governed by the nature of the process and the local conditions. In gas-works, for instance, use is made of producer gas, the producer being built on to the retort settings. For coke ovens and semi-coke retorts, gas from the carbonisation process is generally used; coking plant in iron and steel works may, however, also be heated with blast-furnace gas.

Coal Carbonisation—II

By-products recovered

When the purpose of carbonisation is the production of metallurgical coke or semi-coke, both benzol and tar are recovered. In gas-works, on the other hand, it may be more profitable to leave the benzol in the gas, owing to its calorific and illuminating

[1] Coalite is a semi-coke produced by the Low Temperature Carbonisation Co. Ltd.; it is a smokeless domestic fuel.

[2] Such producer gas can be obtained by subjecting incandescent coke to the action of a mixture of air and steam.

properties; tar is, however, always removed, as it is an impurity that has to be eliminated from the gas. Tar or tar and benzol are extracted from the crude coal gas leaving the ovens or retorts, together with other by-products such as ammonia and naphthalene.[1]

Initial condensation of tar

The crude gas is first led by the ascension pipe rising from the top of the oven or retort to the collecting main (hydraulic main) of the battery. There, a preliminary cooling takes place, with condensation of part of the tar and of a certain amount of ammonia liquor.[2] More energetic cooling can be obtained by spraying the gas with ammonia liquor, at its entry into the collecting main; this liquor serves at the same time for flushing purposes.

Final removal of tar

Further condensation of tar is produced by passing the gas through coolers. Even so, this constituent is not entirely removed. There still remains a considerable amount of tar in the form of small particles in suspension in the gas. This tar is finally eliminated in a tar extractor or electro-static precipitator. In tar extractors, the particles of tar may be removed either through impact with surfaces against which the gases are made to impinge with great velocity, or by incorporation into tar and ammonia liquor injected under pressure through nozzles in the path of the gases in the form of spray.

[1] Ammonia is usually converted into sulphate of ammonia, which is sold as fertiliser, while naphthalene is used in the manufacture of dyes.

[2] Ammonia liquor is the name given to aqueous solutions of ammonia and ammonium salts. Such solutions form during the cooling of coal gas, owing to the presence of moisture and ammonia.

Electro-static precipitation

With electro-static precipitation, use is made of certain phenomena arising from the passage of electric current through gases. For a better understanding of what takes place, a brief reference may be made once more to the subject of the electrical constitution of atoms.

Effect of electric discharge on neutral particles in gas

As previously mentioned, the atom of any substance consists of a nucleus with a net positive charge, about which revolve in orbits particles of negative electricity (electrons). In the neutral state of atoms, the negative charge represented by the electrons is equal to the net positive charge of the nucleus. Electrons may, however, be detached from the atoms. This occurs, for instance, in gases in the path of an electric discharge produced between two electrodes. Such a discharge is nothing else than a stream of free electrons travelling at a high velocity.[1] These free electrons on colliding with gas atoms detach electrons from the latter, through the force of the impact. The electrons liberated in this way attach themselves to neutral particles in suspension in the gas, to which they communicate a negative charge, while the atoms deprived of part of their negative charge become positive ions.

Neutralisation and deposition of charged particles

In order to produce the discharge across the gas, a very great difference of potential is required between electrodes. This difference of potential is obtained by connecting the electrodes to the poles of a high tension supply, which for the purpose of

[1] Any electric current is a stream of electrons travelling at a greater or lesser velocity, according to the voltage.

electro-static precipitation must be unidirectional.[1] The particles in suspension in the gas, that have become negatively charged by the electrons, move then towards the positive electrode, where they are neutralised and settle.

Design of precipitators, and precipitation process

In practice, the positive pole of the high tension supply and the positive electrode are earthed, so that the connection between the two is through the earth. The positive electrode is in the form of a pipe through which the gas is led, a number of such pipes being arranged in parallel in a precipitator unit. The negative electrode is in the shape of a wire running along the centre of the pipe. The charged particles, represented here by droplets of tar, etc., collect on the inner wall of the pipe. The tar that thus accumulates on the inner surface of the pipe runs down the latter and drops to the bottom of the precipitator.

Composition of tar

The composition of tar varies according to the nature of the coal treated and the temperature of carbonisation. Tar yields oils, tar acids and such substances as pyridine, naphthalene, etc. The oils include benzol, creosote oil and heavy anthracene oil, and the tar acids, phenol (carbolic acid) and cresylic acid. The final residue of distillation is pitch. The amount of benzol that can be extracted from tar is small as compared with that obtainable from coal gas; it is thus from the latter source that most of the benzol is derived in coal carbonisation.

[1] This unidirectional supply is usually obtained by rectifying a high tension alternating supply.

Recovery of benzol

Benzol is recovered from the coal gas, after the gas has been freed of tar, ammonia[1] and naphthalene. The recovery takes place in scrubbers, where the gas is brought into contact with an absorbing oil (wash-oil) with a considerably higher boiling point than benzol.[2] The benzol is absorbed by the wash-oil and subsequently distilled from the latter.

Scrubbers

Scrubbers are built in the form of high towers. The lower part of the tower forms a reservoir for the benzolised wash-oil. The other portion is filled with wooden grids or hurdles. The wash-oil is introduced above through spray nozzles. On its way down the tower, it meets the grids and spreads over them, thus exposing a large surface to the gas passing upwards.

Motor benzol

By far the most important benzol product is motor benzol, which is a motor spirit possessing high anti-knock qualities; it is prepared by subjecting the crude benzol to fractional distillation and refining. The largest yield of benzol is obtained through low temperature carbonisation.

[1] Free ammonia is removed either by passing the gas through a hot solution of sulphuric acid in a separator, or by washing it with ammonia liquor and water in scrubbers; the product obtained is in the former case sulphate of ammonia, and in the latter case, ammonia liquor.

[2] The wash-oil may be a petroleum oil or a tar oil.

Coal Hydrogenation

Production of oil hydrocarbons from coal

In the case of the production of oil by coal carbonisation processes, the carbon and the hydrogen of the oil hydrocarbons are derived solely from the coal itself. With coal hydrogenation, additional hydrogen is supplied from an external source, while with purely synthetic methods the whole of the hydrogen is provided separately, so that the coal then merely contributes the carbon. The latter methods necessarily permit of a very high utilisation of the carbon content of the coal, for the production of oil, owing to the independent supply of hydrogen.

Practical realisation of coal hydrogenation

The idea of producing oil by the hydrogenation of coal was first conceived by Bergius, who started experiments in Germany before the 1914–18 War. The practical realisation of coal hydrogenation was, however, mainly the work of such great concerns as the I.G. Farbenindustrie in Germany, and the Imperial Chemical Industries Ltd. in this country, who applied their vast resources to the solution of the problem. The former built, in 1927, the first commercial hydrogenation plant, for the production of oil from brown coal, while the latter put into operation, in 1935, their huge plant for the treatment of bituminous coals. A factor that contributed very materially to the remarkable developments of recent years was the formation, in 1931, of the International Hydrogenation Patents Company for the pooling of the patent rights of the principal companies concerned with this particular field of investigation.

Destructive hydrogenation and the I.C.I. plant

Coal hydrogenation for the production of oil involves, in addition to the actual hydrogenation, the breaking up (cracking) of the larger hydrocarbon molecules; in view of this, it is referred to as destructive hydrogenation. The process used by the I.C.I. has been fully described by Mr. Kenneth Gordon, in the paper he read before the Institute of Fuel on November 22, 1935.[1] The following brief outline is based on the particulars and flow-sheets given there. The plant is designed not only for the hydrogenation of coal, but also for the treatment of low temperature tar and creosote.

Production of hydrogen for the process

The three fundamental parts of the installation are the plant for providing the hydrogen, the plant for preparing the coal and the hydrogenation units. The hydrogen is derived from water gas, which is a gas consisting mainly of hydrogen and carbon monoxide, produced through the interaction of steam and coke.[2] The carbon monoxide is converted into carbon dioxide, with further production of hydrogen, by treating the gas with steam in the presence of a catalyst. The resulting gas (catalysed water gas) is a mixture of hydrogen and carbon dioxide, with a small amount of carbon monoxide. The two latter constituents are then removed successively. The hydrogen purified from these accompanying gases is delivered under high pressure to the hydrogenation units.

[1] *Journal of the Institute of Fuel*, December, 1935.

[2] When steam is brought into contact with carbon at a high temperature, it is dissociated into hydrogen and oxygen. The hydrogen remains in the free state, while the oxygen oxidises partially the carbon, forming carbon monoxide.

Preparation of coal

As the coal to be hydrogenised must be as clean as possible, various operations are required for its preparation. These include extraction of gas and fine particles by pneumatic means, screening and washing. The coal is washed by the sand flotation process, in two stages. This treatment permits of the separation of the material with a too high ash content from the clean coal. Finally, the clean coal has to be converted into a paste for the hydrogenation process. This is done by passing the coal through mills, where it is ground and mixed with pasting oil;[1] a catalyst for promoting the hydrogenising and cracking reactions is also introduced at this stage. The coal paste is injected under high pressure into the stream of hydrogen.

Coal stalls

The hydrogenation units (stalls) comprise coal stalls, liquid phase stalls and vapour phase stalls.[2] The coal stalls are for the treatment of the coal paste. The mixture of coal paste and hydrogen passes first into the heat exchangers, then into the gas-fired preheater and finally into the converters, where the reactions take place. The hot products on leaving the converters are led in the first place to a catchpot in which the heavy residual oil (sludge) is separated, while the gases and vapours are conducted through the heat exchangers,[3] where they give up part of their heat, to the coolers. There, the

[1] The pasting oil consists of recycle oil and low temperature tar. Recycle oil is oil which, after leaving a hydrogenation unit, is returned for treatment; this is done in the case of heavy oils.

[2] Liquid phase stalls and vapour phase stalls are hydrogenation units for the treatment of liquids and vapours, respectively.

[3] In heat exchangers, there are two separate circulation systems, one for the heating medium and one for the medium heated.

vapours are condensed, the crude oil being collected in a catchpot.

Products yielded by the crude oil, and their treatment

The crude oil from the coal stalls is split up by distillation into petrol, middle oil and heavy oil. The petrol is led after refining to the petrol tank. The middle oil undergoes treatment in the vapour phase stalls, together with the creosote middle oil;[1] the oil yielded by these units is likewise distilled, in order to separate the petrol. As regards the heavy oil and the creosote heavy oil, they are treated in the liquid phase stalls.

Production of oil by purely synthetic method

In the case of the processes described, petrol is produced by the hydrogenation of coal and oils. Petrol can, however, also be obtained by hydrogenising other carbon compounds. Thus, in the Fischer-Tropsch process, the product treated is carbon monoxide. This process is a purely synthetic one, as the hydrogen is made to combine directly with the carbon, so as to form oil hydrocarbons. The reactions take place in the presence of a catalyst and without the assistance of pressure. The carbon monoxide and the hydrogen are obtained from coke and steam by the water gas process.

[1] The creosote oil to be hydrogenised is separated by distillation into middle oil and heavy oil.

CHAPTER VIII

About Fibres and their Preparation

Natural Fibres and their Preparation—I

Classes of fibres

From the point of view of preparation, natural fibres can be divided into two classes: free fibres and fibres that are embedded or encased in a more or less resistant substance. The former category comprises animal hairs (wool, etc.), silk, and vegetable fibres such as occur attached to seeds (cotton, etc.). The second class covers stem fibres (flax, common hemp, jute, etc.), leaf fibres (sisal, Mauritius hemp, Manila hemp, etc.) and mineral fibre (asbestos).

Stages in preparation

The preparation of most fibres includes two stages. Firstly, there is the preliminary preparation necessary before the raw product can be marketed, and secondly, the final preparation by the manufacturers, during which the fibre is converted into a suitable form for spinning. The following general considerations do not cover the case of silk, as this fibre requires a method of preparation of its own, seeing that it is in the form of a continuous thread, in its natural state.

Preliminary preparation

The scope of the preliminary preparation required by fibres depends upon the nature of the latter. With wool, the work is mainly confined to the

classing of the product. In the case of cotton, the seed has to be detached from the fibre. With stem fibres and leaf fibres, on the other hand, much more lengthy operations are involved, as it is necessary to isolate the fibre from its enclosing sheath of vegetable substance; the processes resorted to for the purpose will be described later on, when dealing with the different types of fibre individually.

Final preparation

The purpose of the further preparation carried out by the manufacturers is to open up and clean the fibre, to disentangle and straighten it, and to form it first into an untwisted rope (sliver) and then into a thread with a slight twist (roving) of sufficient strength for the actual spinning process, by drawing and twisting. A brief reference may be made to some of the machines used for these various operations.

Machinery for the opening and cleaning of fibre

The bulk of the impurities contained in cotton are removed in openers and scutchers, while wool for woollen manufacture is opened up in willows. Bale breakers and hopper feeders are auxiliary machines fulfilling important functions. The former serve for loosening the hard matted fibre from the highly compressed bales of cotton and jute; the latter are utilised in conjunction with other plant, for ensuring an even distribution of the fibre fed into them, an opening and cleaning effect being produced at the same time.

The fibre is conveyed from one machine to the other on moving frame-work platforms (lattices), working in the manner of an endless belt, on

travelling cloths, or in tubes where a current of air is set up by a fan.

Bale breakers

Bale breakers comprise in the very first place machines embodying crushing rollers between which the fibre is passed, the rollers being fluted or spiked. Such machines are used for opening up the blocks of fibre from jute bales, and represent the simplest form of bale breakers for dealing with the fibre slabs from the cotton bales.

Machinery with crushing rollers has, however, been largely displaced, for the treatment of cotton, by hopper bale breakers. With the latter type of plant, the cotton fed into the machine is seized by the spikes of an inclined lattice, that draw it out and carry it upwards. At the upper extremity of the lattice, the layer of cotton passes under a roller with teeth, which evens it out, by throwing back any excess fibre.

The cotton is stripped off the spikes of the lattice, at the beginning of the downward journey, by rollers with flaps, which throw it against an inclined grate, from where it drops usually on to a horizontal lattice, that carries it away from the machine.

Hopper feeder

Hopper feeders are built on very much the same lines as the machine just described, with inclined spiked lattice, evener roller and stripper roller; they embody, however, as additional feature a device for regulating the delivery of fibre, which emerges in the form of a sheet of more or less uniform thickness. An automatic arrangement may also be provided for maintaining constant the level of the cotton fed into the machine.

Openers and scutchers

Openers and scutchers are machines that all incorporate, as an essential part, one or more beaters in the form of revolving cylinders or frames, with teeth or blades. Porcupine openers, Crighton openers and exhaust openers are various types of openers which may be used in combination with each other. The small porcupine opener is a machine where the fibre after passing through two pairs of rollers is subjected to the action of a toothed cylinder rotating at a high speed. It is utilised as feeder for Crighton openers, for instance.

Crighton openers have a conical beater consisting of a number of bladed discs, mounted at intervals along a vertical shaft and increasing in diameter, from the bottom to the top disc. The fibre is fed at the lower part of the machine and drawn upwards past the blades of the beater, through the suction caused by a fan. As regards exhaust openers, a special feature of these machines is the powerful fan through the action of which the fibre is made to travel a considerable distance, along tubes, to the beaters. The fibre is delivered by the openers in the form of a compressed sheet (lap) made into a roll.

Scutchers are used for the further cleaning of cotton, after its passage through the openers. As a rule, four laps are superimposed (doubled) for this treatment, in order to obtain a more uniform product. The beaters consist here of two or three heavy blades, extending across the width of the machine, and carried by three or four sets of arms. Another type of scutching machine, with radial blades fitted to a set of arms, is utilised for separating the woody core from the flax fibre, after retting.

Willows

Willows or willeys include various types of machinery serving primarily for the treatment of wool. They comprise in the first place machines intended merely for shaking the wool, with a view to removing the dust and loosening the fibre. Such willeying machines are built, for instance, with one or two quick-running cylinders (swifts) provided with rows of pins, grates being incorporated in the lower part of the casing to permit of the escape of the dirt. In other machines, the shaking of fibre is produced by revolving fan-like wheels, while in a further type of plant rotating shafts with radiating rods are utilised.

The most important application of willeys is, however, for opening and blending wools in woollen manufacture. The machines used in this connection generally consist of a swift fitted with rows of teeth, working in conjunction with smaller rollers (workers), arranged along the upper part of its periphery. Teazers and tenter-hook willeys ("Fearnoughts") belong to this class of plant.

Natural Fibres and their Preparation—II

Machinery for disentangling and straightening

The machines referred to in the previous section are intended primarily for opening up and cleaning the fibre mass as a whole. The equipments now to be briefly described are for dealing with the fibres themselves more in detail, with a view to arranging them in a suitable order for spinning. For achieving this object, it is necessary in the very first place to comb out the agglomerations and entanglements of fibres, in order to isolate the latter, adhering foreign

matter being released at the same time. Furthermore, very short fibres have to be removed.

Some machines with combing action

Foremost among the machines serving for the purpose are cards or carding engines, which are used for cotton, in woollen manufacture, and for jute. Hackling machines also fulfil this combing function; they are, however, only suitable for the treatment of long fibre such as flax and hemp. Once the fibres have been isolated, they are formed into a band or sliver.

Combers are machines utilised in worsted manufacture and for best class cottons. In these machines, the fibres under the desired length are separated from the longer fibres, which are alone used for forming the sliver, and made to lie in parallel order; in this way, a much more even sliver and a stronger yarn are obtained.

Combination of doubling and drawing

Drawing machines represent another type of plant which plays a very important part in the preparation of the fibre. In these machines, it is possible by combining doubling with drawing to obtain a more regular resultant sliver. This sliver may either have the same thickness as the original superimposed slivers, or be attenuated, according to whether the draft merely compensates the doubling or preponderates. Another essential function of drawing is to straighten the fibre.

Consolidation of sliver by twisting

Drawing machinery includes such plant as drawing frames, fly-frames, drawing boxes and gill boxes;

the latter also have a combing effect. When the sliver is delivered by the drawing machine in an attenuated state, it is necessary to consolidate it. This can be done by giving it a slight twist, the latter being imparted by a flyer and bobbin system. This feature is embodied, for instance, in fly-frames. The twisted attenuated sliver is known as roving.

Cards

The central feature of cards or carding engines is the large revolving horizontal cylinder, clothed with wire teeth set more or less close together, which conveys the fibre from one point of the machine to another, and causes it to meet, as it travels round, other wire teeth that exert on it a combing action. The two principal types of cards are roller cards and revolving flat cards.

Characteristics of roller cards and revolving flat cards

In roller cards, the combing teeth are on rollers (workers) arranged along the periphery of the cylinder; cards of this description are used for wool and also for jute. In revolving flat cards, the combing teeth are carried by consecutive bars (flats) extending across the width of the machine, that form an endless belt surrounding nearly the whole upper half of the cylinder; this type of card is utilised for cotton. The clearance between wire clothing of cylinder and combing teeth is very small.

Combing action of cards

The opposing teeth travel in the same direction, but the peripheral speed of the combing teeth is lower—hence, the combing action. In the case of wool and cotton, the fibre fed into the machine is

first subjected to the cleaning action of a roller with saw teeth, from which it passes on to the cylinder. At the delivery end, the fibre is removed by a roller (doffer) with suitably inclined teeth.

Hackling machines

In hackling machines, the long fibre to be treated is made to hang, in the manner of a screen, from an upper supporting channel (head) extending the whole length of the machine. It is divided, for the purpose, into handfuls (pieces), which are securely clamped between the plates of individual holders, with suspension pins to engage the head. These holders with the fibre hanging from them are inserted at one end of the head and ejected at the other, after completion of the treatment of the fibre. The forward displacement of the holders, which takes place a short distance at the time, is combined with the upward movement of the head, which is given an up and down motion.

Hackling sheet

On the down motion of the head, the screen of fibre is lowered between horizontal rows of combs (hackles); the latter move in continuous succession in a downward direction and force their pins into the fibre. The supporting structure of these rows of hackles consists of horizontal bars uniting endless belts, running in vertical planes perpendicular to the fibre screen; supporting structure and hackles form together the hackling sheet. The hackles of the individual rows increase in fineness from the feed end to the discharge end of the machine, so that the fibre meets first the coarser and then the finer hackles, as its holder progresses along the head.

Use of spreader in conjunction with hackling machine

On the up motion of the head, the pins of the hackles comb out the fibre, which is finally lifted clear of them, as the head nears its upper position. Each time a holder is ejected at the end of the machine, the hackled fibre end hanging from it is clamped in another holder, and the original holder, removed, leaving free the uncombed end, which is subjected in turn to the hackling process. On modern machines, most of these operations are done automatically. After hackling, the fibre has still to be spread in a spreader, in order to make it form a continuous sliver. In many cases, hackler and spreader are combined in a single machine.

Natural Fibres and their Preparation—III

Combers as represented by the Noble comb

There are many different types of combers. The machine which is more especially used in this country, for worsted combing, is the Noble comb. In this machine, the combing device consists of a large horizontal ring (circle), with several concentric rows of pins fitted on the top of it, which works in conjunction with two small rings (circles) set eccentrically inside it, in the same plane, and provided likewise with rows of pins. These two small circles, which each only touch the large circle at one point, are arranged diametrically along the inner periphery of the latter. Both the large circle and the small circles revolve in the same direction.

Feeding the fibre on to the combing circles

The fibre to be combed is fed from a number of balls of sliver distributed along the outer periphery

of the large circle and carried by a creel revolving with the circle, each sliver being led through a separate feed box. At the moment a feed box reaches a position opposite the point of contact of the large circle with one of the small circles, the end of the corresponding sliver is laid across the two circles; at the same time, the fibre is dabbed into the pins of the two circles by a dabbing brush that descends into the latter.

Combing of the ends of the fibres

Due to the rotation of the circles, the pins of the large circle and those of the small circle, across which the fibre has been laid, move apart, with the result that the sliver is stretched out, the extremity of the fibres clinging to the large circle being combed, as the two portions of the sliver part, by the pins of the small circle, and the end of the fibres held in the small circle, by the pins of the large circle. This leaves a combed fibre fringe along the inner periphery of the large circle and along the outer periphery of the small circle.

Combing the remaining portion of the fibres

The two fibre fringes are seized by corresponding pairs of drawing rollers, mounted on the stationary part of the machine, which draw out the fibres from the pins of the respective circles and thus cause the combing out of the remaining portion of the fibre. These combed fibres are subsequently united into a sliver. The short fibres, on the other hand, are retained in the small circle, and removed at a further point of the periphery of the latter by stationary inclined knives fitted between the rows of pins of the circle.

Principle underlying drawing machines

Drawing machines are built on the principle of roller drafting, that is to say, the drawing effect is produced in this plant by subjecting the fibre to the action of successive pairs of rollers, each with a higher speed than the preceding one, the individual pairs of rollers being set with their centres a little wider apart than the length of the fibre. In most drawing machines, drawing is combined with doubling.

Drawing frames and fly-frames

In the case of machines for the treatment of short fibre such as cotton, the successive pairs of rollers can be set fairly close together. Two different types of machines are used for this fibre: drawing frames and fly-frames. The former serve mainly for levelling up purposes, several slivers being doubled and drawn out together to about the same thickness of sliver as the original ones. The actual attenuation of the sliver takes place in fly-frames, where the draft is made to preponderate over the doubling; the attenuation is followed there by twisting, through the intermediary of flyer and bobbin.

Gill boxes

Gill boxes and drawing boxes, which are machines for dealing with longer fibre, only have two pairs of rollers for their drawing device. As these pairs of rollers are a certain distance apart, intermediate supports are necessary for the fibre. In gill boxes, the intermediate supports take the form of combs or gills; the latter consist of pinned bars or fallers that travel along guides, in a constant succession, from the back rollers to the front rollers, the fallers being fed one after the other on to these guides

from a lower level, to which they drop again at the end of their forward journey.

Combing action of gill boxes

The forward displacement of the fallers and the return motion at the lower level are produced by rotating screw-spindles. As the fallers move faster than the rate at which the fibre leaves the back rollers, their pins have a combing effect on the fibre. Further combing, but in opposite direction, takes place as the front rollers are neared, owing to the fibre being drawn off at a higher speed than the rate of advance of the fallers.

The ordinary drawing box

In the ordinary drawing box, the intermediate supports are in the shape of rollers (carriers). Drawing boxes and gill boxes are both utilised in the preparation of wool for worsted manufacture. The ordinary drawing box can be used for the treatment of sliver in the untwisted or twisted state. Gill boxes, on the other hand, are unsuited for dealing with the twisted product, owing to the obstruction offered to the twist by the pins of the gills.

Form of product delivered by drawing machines

The fibre treated in drawing machines may be delivered as a sheet, as twistless sliver, or as twisted sliver, according to the type of delivery apparatus. In the case of twistless sliver, the product may be coiled in cans, or wound by friction on staves or bobbins revolving horizontally on rollers. Twisted sliver is wound on vertical bobbins; the twist is imparted to the sliver by a flyer working in conjunction with the bobbin. In the initial stage of

attenuation, the twisted sliver is known as slubbing; the finer twisted product is given the name of roving.

Flyer and bobbin system

Flyers consist of a frame fitted at the upper end of a vertical spindle. The frame has two arms arranged diametrically and directed downwards. Between these arms is the bobbin for taking the twisted sliver, the bobbin being mounted loose on the spindle. The sliver is led from the drawing rollers to the top of the flyer, down one of the arms and on to the bobbin; it is twisted through the rotation of the flyer, and delivered at a constant level. The distribution of the coils along the length of the bobbin is caused by giving the latter an upward and downward motion.

"Open" drawing and "cone" drawing

In the case of "open" drawing, the flyer alone is driven. The bobbin is dragged round by the sliver attached to it, but at a lower rate, owing to the retarding effect of a friction device. The rate of winding of the bobbin is governed by the difference in speed between flyer and bobbin.

In "cone" drawing, both the flyer and the bobbin are driven independently, in the same direction, but at different speeds. Owing to the drives being separate, the speed of the bobbin can be varied, as the coils on the bobbin increase in diameter. The method of winding may be with bobbin leading or with flyer leading. In the former case, the bobbin has a higher speed than the flyer and winds the slubbing or roving round itself. In the latter case, it is the flyer that winds it on the bobbin.

CHAPTER IX

Special Preparatory Treatment Required by the Individual Types of Fibre

---

WOOL—I

Importance of get-up

Wool is a fibre in the case of which the get-up is of great importance for the marketing of the product. The producer can, as a rule, secure a better price for his wool by classifying it in lots of different average qualities, provided such lots are sufficiently large, and by separating such wool as may detract from the value of the clip. The high reputation enjoyed by Australian wool must be ascribed in a large measure to the great attention paid in that country to this preparation of wool for the market.

Dividing into qualities

Division into qualities starts with the shearing operation. The wool from the belly of the sheep is first removed and set on one side, after which the rest of the wool is shorn in one piece, as a fleece. The fleeces are then transferred to the classing room, where they are spread out on tables and skirted.

Skirting consists in removing the parts of the fleece below the average quality of the latter and also pieces with burrs, stains or other defects. The extent to which the fleeces are skirted depends upon the regularity of the fleeces. If the fleeces themselves are lacking as regards uniformity of quality, as is

the case for crossbred wools, no advantage is gained by skirting the fleeces more than lightly.[1] On the other hand, very regular fleeces, such as merino fleeces, call for heavier skirting, as a higher average quality of fleece is obtained in this way. The fleeces once skirted are classed, bellies, skirtings and other pieces being dealt with separately.

Factors governing the classing of wool

The principal factors that govern the classing of wool are fineness, length and strength of fibre. Fineness, in particular, plays a very important part, as the commercial value of wool is based on it. Classing is usually done on the sheep station. Wool from small producers is, however, often classed by the brokers who bulk the wool from several farms, this being done in Australia, for instance. The farmer is thus given the benefit of a finer classification, which he could not carry out himself, owing to the small size of his clip.

Fleeces of the same class are packed together in bales, on which the description of the wool and the name of the station or farm are marked. Bellies, skirtings and other pieces are likewise classified and made up in lots.

Wool mostly marketed in greasy state

Washing or scouring of wool before marketing is practised to a certain extent in Australia, New Zealand and South Africa. The bulk of the wool, however, is sold in the greasy state, as most manufacturers prefer to do the scouring themselves, seeing that it is a very delicate operation, which has to be

[1] In Great Britain, fleeces are not skirted.

carried out with the greatest care; there is the further reason that wool in grease is less liable to injury during transport than scoured wool, and less liable to mildew.

Sorting at the mills

The ultimate purchasers of wool are on the one hand woollen manufacturers, and on the other hand, topmakers; the latter deal with the preparation of wool for the worsted industry. The first operation carried out when the bales are opened is the sorting of wool of the fleeces. This operation is simpler for merino fleeces than for crossbred fleeces, owing to the regularity in quality of wool of the former. Crossbred fleeces, which include several qualities of wool, have to be divided into a number of parts corresponding to the different qualities contained in the fleece. Special care is required in sorting wool for the worsted industry, as the wool for this class of manufacture has to be as far as possible uniform in length and fineness.

Impurities in wool

Wool in its natural state contains various kinds of impurities which have to be removed. The impurities come under two main categories: substances that have their origin in the fibre itself and extraneous matter which has collected in the fleece. Yolk or suint and wool fat belong to the former class,[1] and dust, sand, straw, twigs, etc., to the latter. The difference in character of these impurities necessitates different processes for their removal.

[1] For commercial purposes, the wool fat and the yolk proper are grouped together under the heading of "wool yolk."

Wool scouring

Yolk[1] and wool fat are removed by washing (scouring), dust and sand being expelled before this process, by willowing. The scouring system most generally used is the alkaline or emulsion system. With the process in question, use is made of water containing soap and an alkali such as soda or potash, which acts as emulsifying agent. Straw, twigs, etc., are eliminated by mechanical means, in the opening plant.

WOOL—II

Preparation for spinning

The scope of the preparation for spinning depends upon whether the wool is for the production of woollen yarn or worsted yarn. In the case of woollen yarn, the manufacturer does not desire the fibres to be in parallel order; on the contrary, he wishes them to lie in all directions, in order to increase the bulk of the thread and obtain a product with good felting properties.[2] Furthermore, neither great length, nor uniformity in length of the individual fibres are sought for. The preparation which wool has to undergo here is therefore much more limited in its scope than for worsted yarn, where parallel arrange-

[1] The yolk proper consists mainly of potassium carbonate and is soluble in water; it can therefore be removed previous to scouring by steeping in water, as practised on the Continent.

[2] Felting denotes here the interlocking of the fibres of neighbouring threads in a fabric, whereby the material is rendered more homogeneous, and the weave less clearly visible. This interlocking of the fibres projecting from the threads is due to the natural tendency of wool fibres to intertwine and cling together, which is a characteristic arising from their scale-like structure and the waves (crimps) along their length. Felting can be accentuated by the process known as milling.

ment and freedom from shorter fibres are necessary, with a view to obtaining a product of even character, strength and count.

Fibre used for woollen yarn

Woollen yarn can be made from all kinds of wools; it may furthermore incorporate cotton and even, in certain cases, other materials such as waste flax, prepared jute (artificial wool), etc. The wools utilised include new wool (mainly short staple wool), reconditioned wool from manufactured goods (shoddy and mungo) and short fibre rejected during the combing process in worsted manufacture (noils).

Blending

As a rule, woollen yarns are composed of different wools blended together. In view of this, one of the principal objects in the preparation of wool for woollen manufacture is to cause a thorough mixing of the individual fibres of the materials forming the blend. The necessary opening up of the wool and the redistribution of the fibres is commenced in such machines as teazers and fearnoughts, and continued in the cards, where the final separation of the individual fibres and mixing of the latter takes place.

Woollen carding and condensing

Carding is thus an operation of fundamental importance, all the more so as it is not followed here by any further levelling process before spinning. The carding equipment may comprise two or three cards. The first card is known as the scribbler; from there, the wool may pass into an intermediate card, the treatment being completed in the condenser card. The latter is provided with a special delivery

apparatus, where the thin film of carded wool is divided into a large number of ribbons, which are in turn rubbed (condensed) into threads, between rubbing leathers, and wound on bobbins ready for spinning.

Fibre utilised for worsted yarn

Worsted yarn, on the other hand, requires wool with special characteristics. Although this type of yarn is made more especially from the longer wools, length is not the only criterion as regards suitability of wool for its manufacture. A still more important factor is evenness and regularity of fibre. Thus, the highest counts of yarn[1] are made from fine merino, with very uniform but relatively short fibres.[2]

Combing

The basic process in the preparation of wool for worsted manufacture is combing. Through the removal of the fibres shorter than a given length, by the comber, a more uniform product is obtained, while impurities that preceding processes have failed to remove are eliminated at the same time, together with any defective fibres. The equalising and cleaning action is further accompanied by a straightening of the wool, which emerges from the machine in the shape of a continuous sliver (top). The combed wool is then passed through one or two gill boxes, where several slivers are doubled and drawn out; it is at this stage that blending is carried out in worsted manufacture. After this finishing process, the tops are wound into balls, in which form they are stored.

[1] The highest counts represent the finest yarns.

[2] Such merino wool may be of 3-in. to 4-in. staple.

Preparation for combing

Combing is preceded by a number of preparatory operations which are necessary for the opening out of the wool, the separation of the fibres and the final conversion of the latter into a sliver, where the fibres are sufficiently straightened out for treatment in the comber. This preparation which the wool undergoes after it has been scoured may be carried out in two different ways.

Worsted preparing and worsted carding

In the case of long wools,[1] use is made of a set of gill boxes, the process being known as "worsted preparing." Short wools, on the other hand, are treated in carding engines; this carding operation may be preceded by a preliminary opening up of the wool, in a willey. Once the natural wool formation has been broken up and converted into sliver formation, by such means, the wool is washed in a back-washing machine and straightened out in gilling plant, previous to being fed into the comber.

Worsted drawing

The final stage in the preparation for worsted spinning consists in reducing the combed tops, in successive operations, from thick sliver to roving of suitable fineness and evenness for the production of yarn of the desired count. This reduction and levelling is brought about by doubling and drawing out (drafting), in gill boxes or drawing boxes, the process in question being known as "worsted drawing."

[1] Long wools include lustre wools such as Lincoln and Leicester wools, and the longer crossbreds. Short wools comprise the shorter crossbreds and merino wools (Botany wools).

English drawing and French drawing

There are two systems of worsted drawing: the English system and the French system. In the case of the English system, a slight twist is imparted to the attenuated sliver, during the drawing. With the French system, no permanent twist is added; the attenuated sliver is consolidated here by rubbing. In view of the difference in treatment, the yarns spun from rovings produced by these respective systems each have their special characteristics.

COTTON

Preliminary preparation

Cotton is collected from the bolls of the cotton plant in the form of a fluffy ball representing the hairy covering of the seeds in the fibrous mass. The first necessary step in its preparation is thus to detach the fibres from the seeds, to which they cling more or less firmly. For this purpose, the cotton is passed through machines known as gins. By this means, the long hairs (lint) that constitute the cotton of commerce are separated. Ginning is usually preceded by the mechanical cleaning of the cotton, for the elimination of dust and dirt.

Ginning

Gins include roller gins and saw gins. In the saw gin, the cotton is fed on to a row of revolving circular saws, projecting through the slits of an inclined grate and mounted on a shaft behind it. The fibre on coming into contact with the saws is caught by the teeth and drawn by the latter through the grate, while the seed is unable to pass and torn off. Saw gins are also built with two rows of saws,

arranged one above the other. Once the cotton has been ginned, it is made into bales in baling presses, where the fibre is highly compressed, in order to reduce its bulk for reasons of transport.

Delinting

In the case of many varieties of cotton, the seed has, in addition to the covering of long hairs, a coat of short hairs (fuzz); this applies to most of the American upland cotton. These short hairs are not detached by the gin; they are subsequently removed from the cotton seed in machines known as delinters,[1] the fibres yielded by this second stripping process being called linters.[2]

Preparation by the manufacturers

Ginning is done for the cotton growers at the ginneries in the cotton producing areas. All the other preparatory processes are carried out by the manufacturers at the cotton mills. Owing to the high pressure applied in baling the fibre, the cotton arrives at the mills in a hard and matted state. In view of this, it is necessary in the very first place to break up and soften the matted fibre cakes in a bale breaker. Once the fibre has been loosened in this way, cotton from several bales is mixed in mixing chambers, in order to ensure greater uniformity in quality of the final product. Then follow the various operations for the opening up and cleaning of the cotton, and for its conversion from a fibrous mass

[1] Delinters are built on the same lines as saw gins; their saws are, however, set closer together.

[2] The fibres removed in the delinting process include, apart from the fuzz, the lint that has escaped the gin. These residual fibres, described as linters, constitute one of the sources of cellulose of the artificial silk industry; they are also used as filling material, for making cotton wool, for mixing with shoddy, etc.

into a sliver and finally into roving of the necessary fineness and evenness for the production of the particular yarn.

Opening and cleaning

For the purpose of opening up and cleaning the fibre, the cotton from the mixing chambers is passed through a series of machines, which differ according to the kind of cotton to be dealt with. The principal types of machinery used in this connection are the Crighton opener (single or double), the combined exhaust opener and scutcher, and the large cylinder opener (single or double); each of these has its special characteristics that determine its use.

The Crighton opener, while suited for the treatment of most classes of cotton, is particularly valuable for the cleaning of very dirty fibre. The combined exhaust opener and scutcher, on the other hand, is utilised for clean grades of cotton. The large cylinder openers are employed for Egyptian, Sea Island and good American cotton. The Crighton opener may be used in conjunction with a single or double scutcher, or with a combined opener and scutcher.

Feeding machinery

The cotton is usually fed into the opening plant through a hopper feeder. This machine not only ensures regularity of feed, but also opens up the fibre to a considerable extent. A small porcupine opener may be provided after the hopper feeder for preparing the cotton for the main opening plant. Such an auxiliary opener is used in connection with the Crighton opener and may also be employed with the combined exhaust opener and scutcher.

Lap formation

At the delivery end of the opening equipment, the emerging sheet of fibre is compressed and wound into a roll, by means of a lapping-up apparatus; this compressed sheet of fibre is called a lap. In this form, the cotton is fed into a scutcher, where it is subjected to further cleaning, while greater regularity of lap is obtained by superimposing several laps (usually four) for the treatment.

Carding and production of sliver

The final cleaning of the cotton takes place in carding engines. There, the individual fibres are separated and the dirt imprisoned between them is released; at the same time, faulty fibres are eliminated. The type of carding engine nearly exclusively used for cotton is the revolving flat card. Carding may be carried out in two stages, in which case the first machine is known as the breaker card, and the second, as the finisher card. The fibre emerges from the carding process in the form of a thin film, which is made to converge into a funnel. By this means, it is converted into a continuous rope or sliver, which is drawn between rollers and coiled into a can.

Treatment in drawing frame

After carding, the fibre undergoes treatment in a drawing frame, where several slivers are doubled and drawn out. The effect of this machine is to level the sliver and straighten out the fibres, the draft being chosen such as merely to compensate the doubling. In view of this, the sliver delivered differs little, as regards thickness, from the slivers fed into the drawing rollers.

Conversion of sliver into roving

The actual attenuation of the sliver takes place in fly-frames. In these machines too, several slivers are doubled and drawn out, but here the draft is made to preponderate. Furthermore, a slight twist is imparted to the sliver, in order to consolidate it in its attenuated state. This conversion of the sliver into a thread or roving of suitable fineness to meet the spinning requirements is carried out in stages. Thus, the fibre may be passed through three consecutive fly-frames, which are then known as the slubbing frame, the intermediate frame and the roving frame, respectively.

Combing

In the case of the finest yarns, where the fibres must not only lie parallel, but also be uniform in length and overlap evenly, the cotton has to undergo the further process of combing. This treatment is carried out after the carded fibre has been straightened out and levelled in a drawing frame. As the fibre has to be presented to the combing device in the shape of a lap, it is furthermore necessary to convert into that formation the slivers taken from the drawing frame.

This is usually done in a sliver-lap machine. There, a certain number of slivers are united into a sheet, which is consolidated through the action of rollers. Several such laps are then doubled and drawn out in a ribbon lap machine, in order to obtain a more regular lap for feeding into the comber. The cotton emerges from the comber itself in the shape of a sliver. After combing, the fibre is passed again through a drawing frame and subsequently fed into fly-frames, for conversion into roving.

Cotton waste

During the various preparatory operations, and also in the spinning process, a greater or lesser amount of cotton waste is produced. Openers, scutchers; cards, combers, fly-frames, etc., all contribute their quota. The best waste can be mixed with fresh cotton, after the necessary preliminary preparation, and used again in the manufacture of yarn by the ordinary cotton processes; otherwise, cotton waste is made into yarn on the condenser system or the coiler system. With the condenser system, the cotton passes directly from a condenser card to the spinning machine; no effort is made to parallelise the fibres, so that the latter lie in all directions in the yarn, with their ends projecting, thereby producing a woolly effect. A certain amount of cotton waste is also utilised for making wadding, as filling material, etc.

SILK

Reeled silk and spun silk

There are two forms of silk thread: reeled silk and spun silk. Reeled silk is the thread made directly from the long continuous strands unwound from the silk cocoons; these continuous strands are obtained from the middle portion of the cocoon. Spun silk, on the other hand, is a thread built up by the usual spinning processes from short lengths of fibre. This method of manufacture is applied mainly to silk unsuitable for reeling, due to the fibre being too short, entangled, broken or of poor quality.

Waste silk spinning

Such silk, which is known in a general way as silk waste, includes cocoons that have been pierced

by the moth or are otherwise defective, double cocoons, unreelable wild silks,[1] short fibre from the outer covering of the cocoon, residue from the inner parchment-like layer left over after reeling, etc. In addition to this, a large amount of reelable wild silk is worked up as waste, for the production of spun silk.

Preliminary treatment of silk cocoons

As silk cocoons may be kept for a considerable time, before the silk is reeled, it is necessary in the very first place to destroy the chrysalis they contain, or arrest its development, in order to prevent injury to the cocoon, such as would otherwise result on the emergence of the moth. Various methods are resorted to in this connection; dry heat, live steam and cold are some of the media used for the purpose. The further preparatory processes are carried out by the manufacturers.

Preparation for reeling

The first operation at the reeling mills is to sort the cocoons into grades and pick out the defective ones. After the grading has been carried out, there remains to prepare the cocoons for the reeling process. First of all, the hard external layer of silk gum (sericin) must be softened and removed; this can be done by "cooking" the cocoons in hot water. Then, the outer covering of short and tangled fibre (floss) must be detached. For this purpose, the cocoons immersed in scalding water are subjected to the action of a brush, which is generally worked mechanically. Once the floss has been finally cleaned off and the ends of the continuous strands have

[1] Apart from the cultivated mulberry silk worm, there are uncultivated or wild varieties, whose silk is also utilised. Some of the wild silks are reelable; others are only suitable for spinning.

been found, the cocoons can be unwound in the reeling machine.[1]

Degumming in the manufacture of spun silk

For spinning, a much more complete removal of gum is necessary than for reeling. Thus, silk waste to be spun has always to undergo a degumming process, even though it may be composed of silk that has already been degummed to a certain extent, in the preparation for reeling. The degumming process itself has to be preceded by the loosening and preliminary opening up of the compressed waste, as received by the spinner.

Fermentation and "discharging"

The two principal methods resorted to for degumming silk waste are fermentation and "discharging." In the former case, the process consists essentially in steeping the waste in hot water for a certain time, until the sericin begins to rot; washing followed by drying completes the treatment. With this method, a certain proportion of the sericin is left on the silk filaments. Silk that has been degummed by this process is known as "schappe." Waste from reeling is treated in this way in France and other Continental countries. With the second method, the waste is boiled in a soap solution, and subsequently washed and dried. In this case, the silk is entirely freed from sericin.

Preparation for spinning

In order to remove the brittleness imparted to the fibre by drying, the silk is subjected to a conditioning process, where it is allowed to absorb

[1] In the reeling machine, the filaments of several cocoons are unwound together and united to form a single thread.

moisture again. By this means, the fibre is rendered capable of withstanding the subsequent treatment it has to undergo. This treatment which has as purpose the conversion of the tangled mass of fibres into an even thread suitable for spinning includes such operations as beating and opening, filling, dressing, spreading and drawing.

Beating and forming a lap

Beating is primarily a cleaning process serving for the removal of chrysalis residues, dirt, etc. For this treatment, the silk is placed on a perforated revolving table, where it is subjected to the action of leather or rubber beaters. From the beating machine, the fibre passes to the opener. There, the fibre is gripped by feed rollers and presented to a revolving drum clothed with fine teeth, which draw it on to the drum and straighten it out at the same time. Once a sufficient layer of silk has accumulated on the drum, the machine is stopped. The layer is then cut open and stripped off in the form of a sheet (lap).

Cutting the lap into strips

After this, the fibre has to be cut, as a preliminary to combing (dressing). For the purpose of cutting the fibre, use is made of a filling machine. The main feature of this machine is a revolving drum, which is not only clothed with fine teeth, but has, in addition, rows of long straight pins, extending across the drum and spaced around the latter at intervals corresponding to the maximum length of fibre desired for the combing process. The building up of the layer of silk on the drum takes place as in the opener, and the drum is likewise brought to rest, when the teeth are full, for cutting the fibre.

In this case, however, the silk layer is split up into a number of strips of uniform length, by cutting across it along each row of pins.

Combing

In this form, the fibre is combed in the dressing frame. For holding the strips, use is made of wooden clamps (books), composed of two boards hinged together. These books grip the strip at one end, leaving the other end free for presenting to the combing device. Once one end of the strips has been combed, the other is treated in a similar way. There exist many designs of dressing frames. In one type, for instance, the combing device consists of a revolving drum clothed with teeth, the books being made to travel along a track surrounding the upper half of the drum, with their fringes of fibre in the path of the teeth.

Successive combing processes

The short fibres combed out by the teeth are removed from the latter in the form of a lap, which is in turn cut into shorter strips for combing. This second combing process itself yields as waste a lap of still shorter fibre. The cycle of operations is repeated several times, until the fibre residue is too short to be combed.

Forming a sliver

Now that the silk has been sorted out according to length, by these successive dressing processes, it is possible to build up a thread from fibre of more or less uniform length. As a first measure, the individual strips of combed fibre must be brought together, so as to form a lap. For this purpose, they are laid in suitable order on a travelling belt and

fed into a machine known as a spreader, which may take the form of a gill box, the lap being in turn condensed into a sliver, by causing it to converge into a funnel.

Drawing

The next stage of the preparation is in gill boxes. There, a number of slivers are doubled and drawn out, with a view to obtaining a more regular product, while any remaining impurities or short fibres are removed in the process. This is followed by treatment in a drawing box, where the sliver is finally attenuated and converted into a thread of the desired fineness for spinning; a slight twist is at the same time imparted to the thread, in order to consolidate it.

Carding of short waste

The fibres rejected during the last dressing process and too short for combing are treated in a carding engine and converted into thread for spinning in much the same way as in woollen manufacture. A characteristic of the yarns produced by this method is that the fibres composing them are no longer arranged in parallel order, but lie crossing each other in all directions.

CHAPTER X

Special Preparatory Treatment Required by the Individual Types of Fibre (concluded)

Stem Fibres—I

Preliminary preparation and its scope

Stem fibres and also leaf fibres require a more or less lengthy preliminary preparation, seeing that the fibre is here embedded in extraneous matter. In the case of stem fibres, which are represented by flax, common hemp and jute, in particular, the fibre occurs in an intermediate layer (bast) between the woody core of the stem and the outer covering of the latter; the individual fibres are grouped there in separate bundles extending longitudinally along the plant. The remaining section of the bast layer is occupied chiefly by gummy matter that links the fibre bundles together and binds them to the woody core and the outer covering. The extraction of the fibre thus necessitates, in the very first place, the loosening of the bast bundles from the parts of the stem to which they are attached.

Fibre bundles of stem loosened by retting

The loosening of the fibre bundles from the core and outer covering of the stem can be achieved by the process known as retting or rotting. Retting is a bio-chemical process where the substances enveloping the fibres are decomposed through the agency of micro-organisms, that do not, however, attack the cellulose fibres themselves. In the course

of the chemical changes that take place, the insoluble gummy matter is converted into soluble products which can be easily removed by washing, thus freeing the fibre.

Water retting and dew retting

This bio-chemical process is induced by steeping the uprooted plants or cut stems in water, or by exposing them to the action of dew, rain, etc. Under these conditions, the organisms that are responsible for the decomposition and are usually present on the plant become very active and multiply rapidly. Jute is retted in water, while in the case of flax and hemp, both water retting and dew retting are resorted to. The propagation of bacteria during the retting process is considerably influenced by the temperature and quality of the water.

Retting of flax

Flax is retted in ponds or in slowly moving rivers. The stalks are tied up in bundles and held immersed in the water by planks, stones or other means. In Belgium, flax is retted on a large scale in the river Lys, the flax being placed in wooden crates for the purpose. The retting of flax may also take place in tanks or vats, where the water can be maintained at the most favourable temperature. With this method of retting, it is also possible to add chemicals to the water, while in the case of certain processes bacteria are introduced. For dew retting, the flax is spread out over a field which has been recently cut, and exposed to atmospheric influences. The most suitable times of the year for dew retting are spring and autumn.

Drying of retted flax

Before retting, the flax is deseeded by drawing the stems through a comb (ripple) or by machinery. On completion of the retting process, the wet flax straw taken from the water is dried either in the open or artificially. In the former case, the flax is laid out in a thin layer over newly cut grass, for instance; another method is to set it up in cone-shaped stooks.[1] Artificial drying is carried out in drying installations, where the retted flax is placed in the path of currents of hot air, induced by fans.

Removal of woody core

After the retted flax has been dried, there still remains to remove the woody core (boon), from which the fibre bundles have become detached. In order to achieve this object, the flax is first subjected to a breaking or crushing process; by this means, the boon is broken up into small pieces, while the fibre itself is left intact. The fibre is then freed from the woody fragments by beating (scutching).

Breakers and scutching machines

Although breaking and scutching are still done by hand in certain flax growing districts,[2] the general practice is to resort to machinery. Breakers usually consist of pairs of fluted rollers, between which the flax is passed. The simplest form of scutching machine is composed of a vertical wheel fitted with blades, with a stock for holding the flax in the path of the latter, on the side of it.

[1] A stook is a pile of sheaves.

[2] Hand appliances are still used in certain parts of the Continent, where labour is cheap.

Automatic machinery

A number of scutching wheels may be mounted on the same shaft, a certain distance apart, each with its corresponding stock. In the most modern types of scutching machines, the treatment of the retted flax takes place entirely automatically. The raw fibre obtained is sorted according to quality, after which it is made up into bundles. Common hemp is dealt with in very much the same way as flax.

Unretted flax

Instead of retting the flax, the latter can be treated green in decorticating machines, where the stem substance is stripped off by mechanical devices. This method of preparation yields a fibre which has proved quite satisfactory for the production of heavy linen goods. Such unretted fibre is known as "green" fibre.

Retting of jute

Jute is a fibrous plant of India, that grows to a height of 10 to 12 feet, and even more. Once the plants have reached maturity, the stems are cut and made up into bundles for retting. Jute is retted in ponds or slow-moving streams, the bundles of stems being weighted with grass sods, for instance, in order to keep them submerged.

Stripping of fibre

The stripping of the fibre from the stem is usually done by hand, in the water. With a little skill, the fibre can be shaken off the stem, once the bottom part of the latter has been broken off, so as to give a bunch of fibre ends to grip. The fibre thus separated has still to be washed and dried, after

which it is made up into bundles. Jute intended for export is subsequently baled in baling presses, in order to reduce its bulk for transport.

STEM FIBRES—II

Preparation for spinning

At the mills or rope works, the flax, hemp or jute fibre undergoes the usual preparation for spinning, in the course of which the fibre, after having been finally opened up and cleaned, is formed into a continuous sliver and then drawn out into a thread with a slight twist (roving), such as can be spun into yarn, with the desired characteristics, for textile manufacture or cordage, as the case may be.

Loosening and softening of compressed jute

Apart from the fundamental processes required in this connection and applying to fibre in general, additional preparatory operations may be necessary for the particular fibre treated. This is, for instance, the case for jute, which in the baling process is pressed nearly into solid blocks. Such compressed fibre has first to be opened up by treatment between crushing rollers. Once the fibre has been loosened in this way, it is divided into bundles (stricks) of suitable size and weight, and treated in a softening machine consisting of a large number of pairs of fluted rollers between which the fibre passes successively, the mechanical action of the rollers being assisted by the application of oil and water to the fibre.[1]

[1] In the case of machine batching, which is the method usually resorted to, the lubrication takes place during the passage of the fibre through the softening machine. The oil and water may be applied in the form of an emulsion.

Cutting of fibre

Another preliminary operation that may be necessary is the cutting of the fibre. This is done, for instance, with flax, when it is desired to separate the inferior fibre of the root ends from the better quality fibre of the middle portion, in the manufacture of the finer yarns; the root ends of jute may also be cut off for similar reasons. On the other hand, the fibre may be cut or broken into shorter lengths, in order to facilitate handling, etc.

Hackling of flax or hemp

Even after scutching, the flax or hemp fibre may still have woody particles clinging to it, while the separation of the fibre strands may not be complete. These remaining impurities are removed, and the fibre agglomerations, opened up, by combing in a hackling machine, the fibre being at the same time straightened out and freed from short fibres (tow). For this operation, the fibre is divided into bunches (pieces), which are clamped, first at one end and then at the other, while the free portion is combed. Before the treatment in the hackling machine, the fibre is "roughed," that is to say, it is pulled through a coarse hackle (rougher), which consists of a plank with projecting steel pins.

Formation of sliver

After hackling, the bunches of fibre are laid lengthwise, with ends overlapping, on the feed sheet of a machine known as a spreader, which is provided with gills and drawing rollers. There, the fibre is drawn out, combed, straightened out and finally condensed into a sliver. Equipments are built, incorporating spreader and hackling machine,

where all the operations are carried out entirely automatically.

Carding of jute

As regards jute, it undergoes preparation in carding engines. In the carding machinery, the fibre is broken up into shorter lengths, thoroughly opened up and freed from foreign matter, and formed into a sliver. As a rule, the fibre is passed through two cards successively,[1] the first machine being known as the breaker card, and the second one, as the finisher card. Carding engines can be used both for long fibre and short fibre; thus, flax and hemp tows are treated in such plant. Hackling machines are only suitable for long fibre.

Drawing process

Once the flax, hemp or jute fibre has been converted into a sliver, the latter is repeatedly doubled and drawn out in drawing frames, in order to increase the regularity of the product. The two principal types of drawing frames used in this connection are spiral drawing frames and push-bar drawing frames; these machines both embody gills, but differ as regards the method resorted to for propelling the latter.

Spiral drawing frames

In the case of spiral drawing frames, the gill bars are propelled through being made to engage at their extremities the spiral thread of identical screw-spindles, revolving at the same speed and disposed in the desired direction of travel. An upper pair of

[1] In the case of poor quality jute, however, up to five cards may be utilised.

spindles serves for the forward motion, and a lower pair, for the return journey. On passing out from the upper spindles, when nearing the front drawing rollers, the successive bars are pushed down to the lower level by tappets, and on leaving the lower spindles, when approaching the rear retaining rollers, they are raised to the upper level by similar means.

Push-bar drawing frames

With push-bar drawing frames, the gill bars, after coming to the end of the upper slide track, are seized at their extremities by the teeth of revolving sprocket wheels, that convey them to the lower slide track, along which they travel with the gill pins inverted. The transfer from the lower slide track to the upper level is effected in a similar way. A special mechanism ensures that the gill pins leave and enter the fibre in a vertical direction. The displacement of the gill bars along the slide tracks is caused through the bars being pushed by those behind, as the latter are delivered by the pairs of sprocket wheels.

Drawing systems

In the case of flax fibre, use is made of spiral drawing frames. With ordinary yarns, three drawing frames are used in series, while for the finer yarns, the number of drawings is increased to four. With jute fibre, both push-bar and spiral drawing frames are employed. As a rule, there are two drawing frames per system, in which case a push-bar drawing frame may be utilised as first machine, and a spiral frame, as second. Three drawings are occasionally resorted to.

Conversion of sliver into roving

There still remains to pass the attenuated sliver through a roving frame, where the preparation for spinning is completed. The roving frame is a drawing frame which incorporates as additional feature a device for giving a slight twist to the thread. The roving frames used for flax and jute are mostly spiral roving frames, that is to say, machines with spiral mechanism for propelling the gill bars. The twist is imparted by a flyer which winds the roving on a bobbin.

Leaf Fibres

Some typical leaf fibres

The designation "leaf fibre" covers various types of fibre obtained from the leaves, leaf-sheaths or leaf stalks of certain plants. Typical fibres belonging to this group are those yielded by the sword-like leaves of sisal, Mauritius hemp and New Zealand hemp (Phormium tenax), and by the leaf-sheaths of Manila hemp.

Decortication of sisal

The fleshy tissue encasing the fibre is removed by a scraping process, the machines used for the purpose being known as decorticators. The decorticators utilised for the treatment of sisal leaves usually consist of revolving drums fitted with blunt blades, which strip off the flesh of the leaf presented to them, leaving the fibre exposed. In the latest types of equipments, the process is largely automatic.

Cleaning of fibre

The fibre is freed from the pulpy matter clinging to it by washing. This operation is carried out in

the decorticator, or in tanks after the decortication process.[1] The fibre is then hung out on wires or poles for drying. When artificial drying is resorted to, the fibre is first centrifuged or passed between squeezing rollers, in order to expel part of the water, after which it is finally dried in drying chambers. Drying is generally followed by brushing in hand-fed or automatic machines. There, the fibre is subjected to the action of beaters or brushes fitted on revolving drums. Once the brushing is completed, the fibre is graded and baled for shipment in baling presses.

Manila hemp fibre

The fibre derived from Manila hemp comes from the concentrically rolled leaf-sheaths, that form the stalks of the plant and represent the bases of the leaves. Once the stalks have reached maturity, they are cut a few inches above the ground. Strips are then pulled off from the outer fibre-yielding portion of the leaf-sheaths and subjected to a scraping process for separating the tissue from the fibre. The scraping is done by passing the strips through an implement, where they are pressed between the blunt edge of a knife and the surface of an underlying wooden block, the operation being repeated several times, until the fibre is entirely free from adhering matter. After this cleaning process, the fibre is dried, and finally made up into bundles and baled. The fibre can also be extracted by machinery, in which case use is made of decorticators similar to those employed for sisal.

[1] When centrifuges are used in the artificial drying of fibre, the washing process can be continued in these machines. In such a case, water is fed into the centrifuge during the first part of the centrifuging operation.

Preparation for spinning

Sisal, New Zealand hemp and Manila hemp are pre-eminently cordage fibres; they are used for the manufacture both of twine and rope. For the preparation of the fibre, the latter has to undergo two fundamental processes. The first of these is the hackling and spreading process, where the fibre is combed and converted into a continuous sliver; the second is the drawing process, whose object is to render the sliver more uniform and reduce it to a thread of the desired thinness for spinning.

Hackling and spreading

A typical machine used for converting the fibre into the form of a sliver is the Goods spreader. The latter is a horizontal machine with back rollers and front rollers, and two consecutive hackling sheets between the two. These hackling sheets each consist of gill bars connected together by endless chains, the speed of the second sheet being much higher than that of the first sheet. The fibre from the bales is spread lengthwise on the feed table behind the back rollers. It is combed a first time, as it is taken by the slow-running hackling sheet from the back rollers, and a second time, as it passes from the slow-running sheet to the fast-running sheet. A final combing takes place, as the fibre is drawn off the fast-running sheet by the front rollers. After leaving the front rollers, the fibre is condensed into a sliver. The fibre is usually treated in three such machines successively.

Drawing

After leaving the Goods machines, the sliver is passed over a series of drawing frames; the latter are usually heavy screw-gill machines. In these

drawing frames, a large number of slivers are doubled and drawn out. By this means, a greater regularity of product is secured, and the desired degree of attenuation for spinning, obtained.

Mineral Fibres with special reference to Asbestos Fibre

Types of mineral fibres

Fibres of mineral origin include asbestos fibre and mineral wool. Asbestos is the name given to various fibrous minerals that occur either concentrated in veins, where the fibres lie across the width (cross-fibre) or length-wise (slip-fibre), or distributed in the containing rock (mass fibre). The longer fibre, which in the case of cross-fibre type serpentine asbestos may measure up to three inches and more, is utilised for spinning. Mineral wool comprises rock wool, slag wool and glass wool; these are all manufactured products. Such fibre is mainly used as insulating material, for which purpose it is made up into blankets.

Crude asbestos

In the case of cross-fibre type asbestos, the fibre can be separated from the fragments of fibre-bearing rock, yielded by the blasting operation, either by cobbing or by milling. Cobbing consists merely in breaking away the rock adhering to the fibre by means of a hammer. Such fibre, which is still in its agglomerated (unfiberised) state, is known as crude asbestos. When crude is recovered, the pieces of rock containing crude are carefully sorted out by hand (hand-picked), the large blocks being blasted again. The sorted material is

then taken to the cobbing sheds, where it is dried before treatment. Crude asbestos always retains a certain amount of rock, which is removed at a later stage by the manufacturers.

Milled asbestos

With milling, the fibre is separated from the containing rock by crushing the latter by means of machinery, this being accompanied by the opening of the fibre. The actual milling process is preceded by the preliminary breaking up of the rock in a jaw crusher, for instance. Once the material has been reduced by this means to the desired size for the first milling operation, it is fed on to a picking belt, where the crude liberated can be recovered, and the foreign matter, removed. The rock is then passed to the dryers. These are usually built in the form of long slightly-inclined cylinders, through which circulates a current of hot air. The cylinders revolve on friction rollers and are fitted inside with longitudinal blades, so that the material, as it travels through the dryer, is continuously lifted and dropped in the path of the hot air. After drying, the rock is stored in bins ready for milling.

Milling carried out by stages

Milling is carried out by stages, in successive machines. In Canada, for example, use is made of such types of crushers as gyratory crushers or rolls, for the first stage; for the subsequent stages, machines are utilised in which the fibre is freed and opened through the action of beaters mounted on a horizontal shaft, revolving at a high speed in a cylindrical shell. After each crushing operation, the material is passed over a screen, through which the particles of rock drop, while the opened fibre

is lifted by air suction and led to a collector chamber.

Grading of crude asbestos

For the purpose of grading, asbestos is divided in the first place into crude asbestos and milled asbestos. Under the Canadian system of classification, the crude measuring over $\frac{3}{4}$ inch is graded as Crude No. 1, and that from $\frac{3}{4}$ to $\frac{3}{8}$ inch in length, as Crude No. 2; there are two further divisions for unsorted fibre and for crude not coming under the foregoing categories.

Grading of milled asbestos

In the case of milled asbestos too, the grading is primarily governed by considerations of length, the fibres being grouped together on the basis of ranges of fibre lengths suitable for a particular application. Thus, the longer fibres come under the textile and spinning group, while shingle fibre, paper fibre, etc., represent shorter fibres. This grading according to length is done by means of screens.

Preparation for spinning

The crude asbestos or milled asbestos used for the manufacture of yarn has to undergo, like all other fibres, certain fundamental operations, with a view to preparing it for spinning. As a first stage in the preparation, the fibre must be thoroughly opened up and freed from impurities, while the different varieties of fibre utilised for the yarn, and the cotton that may be added, must be intimately mixed together; furthermore, in the case of crude asbestos, crushing is necessary as a preliminary measure, for the fiberising of the material.

The final treatment of the fibre takes place in carding engines where the opening, cleaning and mixing is completed; at the same time, the fibre is formed there into a thin fleece, which is cut in the delivery apparatus into narrow strips, the latter being in turn condensed into threads suitable for spinning.

Rock wool and slag wool

In conclusion, a brief reference may be made to the manufacture of rock wool and slag wool. These products are obtained by subjecting a thin stream of molten rock or slag to a blast of steam or air. Such rock or slag must, in order to be suitable for the purpose, contain silica and lime in certain defined proportions, while alumina and magnesia are desirable constituents. Various rocks and mixtures of rocks (silica and limestone, for instance) are used for the production of rock wool.

CHAPTER XI

Preparing the Raw Materials of the Leather Trade

HIDES AND SKINS[1]—I

Nature of skin

Skin is composed of the skin proper or corium, from which leather is made, and of a very thin outer layer known as the epidermis. Furthermore, there is usually a protective covering of fibres (hairs, bristles, etc.); these fibres have their roots in bulbs which, although located in the corium, are surrounded by substance of the epidermis, continuous with the latter.

The skin proper

The skin proper or corium consists of an inner stratum of coarser structure, that represents the greater part of the thickness of the skin, and of a thin upper layer of finer texture, whose outer surface has a characteristic pattern called the grain, the latter term being also used to denote the upper layer itself. Between the epidermis and the corium, there is an extremely thin transparent membrane (the hyaline) that follows the surface of the grain and is retained in the leather. The skin is linked to the underlying muscular tissue or flesh through a layer of fatty tissue. The presence of this less cohesive layer directly under the skin greatly facilitates the stripping off (flaying).

[1] The distinction between hides and skins merely relates to size and weight.

Flaying

In order to be able to remove the hide or skin from the carcase, an initial slitting is generally required.[1] This slitting is done along the inner side of the legs or leg stumps, and down the centre line of the belly from the throat to the root of the tail, the object aimed at being to obtain a hide or skin as square as possible in shape. Light skins, such as those of sheep and goats, can be pulled off entirely by hand. The detaching of the skin is assisted by punching with the fist, while air is sometimes injected between skin and flesh. In the case of heavy hides, where the use of a knife is indispensable, the latter has to be worked with the greatest care, so as to avoid injury to the hide.

Curing

Once the hide or skin has been stripped off the carcase, decay through bacterial action is liable to set in rapidly. The decay starts in the epidermis and in the fatty tissue on the flesh side and, if not checked, gradually spreads to the interior. It is therefore necessary, for the preservation of the hides and skins during transport and storage, to subject them to a treatment capable of preventing or delaying the decay; this protective treatment is known as curing.

Air drying

The simplest method used in this connection is air drying. Decay is prevented here by removing from the hide or skin substance the moisture that would provide the suitable conditions for the development of the micro-organisms of putrefaction.

[1] In certain countries, goat skins are pulled off whole, without slitting.

It is essential, for the efficacity of this mode of protection, that the drying should be very thorough, as any moisture left in the interior may lead to decay starting there. Furthermore, drying must take place gradually, if defects are to be avoided. Air drying is resorted to in many hot countries, where other methods of preservation are not practicable or too costly, while the reduction in weight through the loss of moisture may be an important consideration from the point of view of transport.

Salting and brining

The most common means of preservation is, however, to treat the hides or skins with salt, use being made of the antiseptic properties of this chemical agent and of its power to absorb moisture. Before salting can be carried out, the dirt and blood on the pieces must be removed, so that the penetration of the salt should not be hindered. For the salting process, the hides or skins are laid hair down. The salt is applied on the upturned flesh side and the pieces are piled one over the other. The penetration of the salt is due to its dissolving in the natural moisture of the hide or skin substance. Salting can also be combined with brining. The hides or skins are then soaked in brine for a certain time, after which they are drained, piled and salted. Another method is to dry the hide or skin after salting.

Pickling

Pickling is a mode of preservation used when skins are shipped after having been de-haired or de-woolled, this treatment being applied to sheepskins and lambskins, in particular. Such pickled skins, which no longer have the covering of hair or

wool to protect them from injury, are generally packed wet in casks. In pickling, the skins are treated with a weak solution of an acid—usually sulphuric acid—to which salt is added, in order to neutralise the swelling caused by the acid. The acidity imparted to the skin renders the latter quite imputrescible. Pickling is also a process used before chrome tanning.

Preparation for tanning

Before the hides or skins can be tanned, they have to be subjected to various preparatory operations for the purpose of freeing the skin proper from extraneous matter and of rendering it capable of absorbing the tanning substance. Thus, the hair and also the whole of the epidermis have to be removed, while the flesh, fat, etc., on the underside, have likewise to be eliminated. As a rule, all this work is carried out by the tanner. An exception is the de-woolling of sheepskins and lambskins, which is done by dealers in hides and skins known as fellmongers, who thus carry out this part of the preparation. In most cases, however, hides and skins reach the tanner in the raw state, being more or less hardened by the curing process. In view of this, it is necessary in the very first place to soften them and make them regain, as far as possible, their natural consistency.

Soaking

In order to achieve this object, the hides or skins are soaked in water for a more or less lengthy period. The effect of the soaking is on the one hand to dissolve all soluble matter and on the other hand to restore to the hide or skin fibre its normal water content. In the case of salted hides or skins, the

treatment consists merely in immersing the pieces in cold water, which is renewed from time to time, superficial dirt being removed by mechanical means, if necessary; the water softens and plumps the hide or skin fibre, as it penetrates in the interior, and dissolves the salt. With dried hides, the absorption of water takes place much more slowly than with salted hides. For this reason, such hides are first subjected to a preliminary soaking, after which the soaking is accelerated through the use of chemical solutions or by mechanical treatment. The duration of the soaking process is necessarily limited by the fact that the curing processes applied to raw hides and skins merely arrest the development of the bacteria, without killing the latter, so that putrefaction is liable to start, as soon as the protection afforded by the treatments in question ceases.

Hides and Skins—II

Sweating

The first step in the actual preparation for tanning is to destroy the cohesion of the epidermic tissue, with a view to the removal of the hair and of the epidermis itself. Various processes are resorted to for the purpose. A very old method still used in certain cases, is that known as sweating. With sweating, the disaggregation of the epidermis is brought about by putrefactive action, which is induced by hanging the hides or skins in a closed room with a damp atmosphere, the temperature of the room being kept as constant as possible. A necessary precaution is that the decay should not be allowed to proceed too far, in order to avoid injury to the grain.

Liming

At the present day, however, the principal method used is that based on the action of lime. Liming not only serves as means of loosening the epidermis and the hair, but it also has the further effect of causing changes in the substance of the skin, that increase its power to combine with the tanning materials. The process consists simply in immersing the hides or skins in a solution of lime; the disintegration of the epidermis can be accelerated through the addition of sodium sulphide. Lime does not alter the hair to any extent, neither does very dilute sodium sulphide, but more concentrated sodium sulphide attacks it and may even entirely destroy it. A method resorted to in connection with the de-woolling of sheepskins and lambskins is to paint the flesh side with a strong solution of sodium sulphide thickened with lime. Once the wool has been loosened through the action of this paint, it is pulled; the de-woolled skins are then subjected to further liming.

Unhairing and fleshing

Unhairing and fleshing are both mechanical operations. For unhairing, the limed hide or skin is placed on a convex support and scraped with a curved double-handled knife with blunt edge; when, however, the hair has been decomposed through the action of sodium sulphide, washing may be sufficient for its elimination. For de-woolling, the wool is merely pulled off the treated skins. The flesh or fatty tissue adhering to the under-side of the skin is removed either with a knife or by machinery. In the former case, use is made of a double-handled knife with sharp edge. The fleshing machines utilised in the latter case embody a scrap-

ing and cutting tool, which may be in the form of a revolving cylinder with spiral blades arranged symmetrically on either side of the centre, the hide or skin being pressed against the blades by a supporting cylinder. For the removal of the epidermic residues, further mechanical treatment and washing are required.

De-liming

The skins now stripped of hair, epidermis and flesh, must be freed from lime, before they can pass to the tanning process. Only a partial removal of the lime is possible by washing in water, so that chemical treatment is necessary. De-liming can be done by neutralising the lime[1] with acids yielding soluble lime salts. Strong acids such as sulphuric acid and hydrochloric acid, though less suited than weaker acids, can be used with special precautions. As regards the weaker acids employed for de-liming purposes, they include boric acid and organic acids such as formic acid, lactic acid, acetic acid and butyric acid. In all cases, the acids are used diluted in a large quantity of water, skins and solution being kept in constant motion by an agitating device. A further class of de-liming agents comprises certain salts that react with lime. Ammonium chloride, for instance, belongs to this category; through reaction with lime, it gives calcium chloride, which is a very soluble product.[2]

Bating, puering and drenching

Apart from the treatments with acids or salts, there are other processes, specially applied to light

[1] The lime is in the form of slaked lime, which is an alkali.

[2] The second product of the reaction is ammonia.

skins, which not only serve for de-liming purposes, but also have the effect of rendering the leather softer to the touch or more supple, due to the changes they produce in the skin structure. Bating, puering and drenching are treatments that fulfil this dual function; they are all fermentative processes. With bating, as formerly practised, the skins were placed in a fermenting solution of pigeon or hen excrements, while with puering, dog dung was employed. The action of these solutions was due partly to the ammonium salts, etc., contained in the excrements, but more particularly to the accompanying ferments from the secretions of the glands of the animal organism. At the present day, the use of dung has been largely replaced by that of substances produced artificially, in which the necessary chemical compounds and ferments are incorporated.[1] In the case of drenching, the skins are treated with an infusion of bran, made with warm water, where fermentation is brought about through the action of bacteria, with resultant liberation of gases and formation of organic acids. The skins are finally freed from dirt, fat, etc., (scud) by mechanical means and by washing.

Pickling as a preliminary to tanning

The preparation for tanning may further include pickling. This treatment has already been referred to in connection with the preservation of hides and skins, for which purpose it is also used. It consists in causing the absorption of an acid by the skin, while preventing the swelling of the latter by adding a neutral salt (usually sodium chloride). Pickling is a process resorted to before chrome tanning.

[1] Only dog dung is still used to-day, to a small extent.

Leather

Once the hide or skin has undergone these various preparatory treatments, it can pass to the tanning process, where it is subjected to the action of further agents and converted into an imputrescible material, which is no longer liable to be swelled or otherwise altered under the influence of water; in this permanent state, it is known as leather.

CHAPTER XII

A Few Other Basic Raw Materials and Their Preparation

Rubber and Resins

Separation of rubber from latex

Rubber is derived from the milky substance known as latex, yielded by the rubber trees. It occurs there in the shape of small particles in suspension. These particles can be made to unite through the influence of a coagulating agent, the latex being thereby separated into a white coagulum and a watery liquid (serum). The coagulum itself contains, in its mass, a certain amount of serum, which is subsequently squeezed out during the rolling processes.

Smoked sheet and crepe

The two principal forms in which raw rubber is marketed are smoked sheet and pale crepe. Smoked sheet is thin translucent sheet with an amber colouring due to the smoke treatment. Smoking is resorted to as a preservative measure, in order to prevent mould growth due to the presence of serum residues, which can only be partially removed, as the structure of the coagulum is not opened up in the preparation of this rubber. Pale crepe is sheet with a rough or corrugated surface, produced in long lengths; its light colour is due to the addition of a chemical agent that prevents the natural oxidation and resultant darkening of the rubber, during drying. With crepe, the coagulum is

thoroughly broken down through the action of macerating rolls and, at the same time, freed from serum by washing in a stream of water.

Treatment of latex before coagulation process

The coagulation of the latex and the rolling of the coagulum is done at the factory on the rubber estate. There, the latex collected from the cups on the rubber trees is brought in buckets by the plantation workers; if distances are great, the latex may be transferred at some point into other receptacles for bulk transport by light railway, for instance. The latex as received at the factory usually contains a certain amount of impurities such as particles of bark shavings, etc., while premature coagulation may have taken place to some extent, with resultant formation of pieces of coagulated rubber; this can, however, be prevented by adding to the latex an anti-coagulant such as sodium sulphite. The first step in the preparation of latex for the coagulation process is to remove any lumps of coagulum that may have formed, after which the latex diluted with water is strained; by this means, the impurities as well as any small particles of coagulated rubber are eliminated.

Coagulating agents

Many acids can be used for the coagulation of the rubber. Acetic acid was formerly the principal coagulating agent employed, but has now been largely displaced by formic acid. In order to obtain a coagulum of uniform consistency, the latex is diluted to a certain dry rubber content; the usual standard in sheet preparation is 1½ lb. dry rubber per gallon, while for crepe the dilution is often only to 2 lbs. dry rubber per gallon. Sodium bisul-

phite is added as anti-oxidant, when the coagulated rubber is intended for crepe, with a view to ensuring the desired paleness of product.

Coagulation plant

On large estates, the coagulation is carried out in long tanks, which are divided up into a succession of narrow compartments once the coagulating agent has been mixed with the latex, through the insertion of partitions in vertical grooves in the longitudinal walls of the tanks. In this way, sheets or strips of coagulum are obtained, whose length and width are governed by the transversal dimensions of the tank and whose thickness depends upon the spacing of the partitions. With latex diluted to a dry rubber content of 1½ lb. per gallon, in the preparation of sheet, a distance of about 1½ inches between partitions is usually adopted; for crepe production, the partitions are set further apart or entirely omitted, in which case the coagulum is merely cut into pieces of suitable size for feeding into the creping machinery.

Preparation of sheet rubber

The coagulum is converted into sheet or crepe by rolling. For sheet, only light machinery is necessary. The rolling takes place in successive pairs of even-speed rolls with smooth surface, set increasingly close together, so as to obtain at the end of the treatment a thickness of sheet of about ⅛ inch. Finally, a pattern is impressed on the sheet by means of a marking machine with ribbed rollers. This pattern in relief facilitates the separation of sheets when in contact, and also gives a larger drying area.

Drying and smoking

The drying of the sheets is done in smoke-houses, which are generally two-storey buildings. The upper storey accommodates the racks on which the sheets are hung, these racks being distributed in separate chambers. The lower storey contains the furnaces, where heat and smoke are generated by slowly burning wood fuel. Single-storey smoke-houses are, however, also built; in this case, the furnaces are arranged below the floor. In order to permit of a better temperature control, heating with steam pipes, for instance, is sometimes resorted to, with independent smoking arrangements.

Production of crepe

For the production of crepe, heavy machinery is required, as it is a case here not only of rolling the coagulum, but also of breaking down its structure. Such a result is achieved by passing the coagulum between pairs of grooved rolls running at different speeds; the serum released in the course of this maceration process is constantly washed away with water. The rubber leaves these uneven-speed grooved rolls in the form of thick crepe. The latter is finally reduced to thin crepe in finishing machines, where it is subjected to the action of pairs of smooth rolls running at approximately even speed. The long strips of crepe thus obtained are then hung on racks to dry. Apart from first-grade crepe made from strained latex, lower grades of crepe are produced from lump rubber,[1] tree scrap,[2] etc.

[1] Lump rubber is rubber which has coagulated prematurely in the buckets, etc.

[2] Tree scrap is rubber that has coagulated naturally on the tapping cuts.

Preparation of resins

The resins of commerce include hard fossil resins, which are dug out of the soil, and soft resins, that are collected on the trees themselves. The hard fossil resins (fossilised Kauri gum, Congo copals, Angola copals, etc.) occur in smaller or larger pieces, which usually only require cleaning and grading. The method of cleaning varies with the particular product; it may consist in scraping with a knife, in washing, in steeping in dilute caustic soda or in sand-blasting. In the case of soft resins such as sandarac, damar, mastic, etc., the preparation is likewise mainly confined to cleaning and grading; a more lengthy preparatory treatment is, however, necessary for shellac, while rosin which is derived from pine oleo-resin has first to be isolated.

Shellac

Shellac is the most important form in which lac is marketed. Lac is a product secreted by a species of insects, which forms incrustations on the twigs where the insects attach themselves in swarms. The twigs with their incrustations are collected and the lac is removed by scraping with a knife, or by other means. In this crude state, the lac is known as stick-lac. The first step in the preparation is to eliminate adhering impurities by washing, after which the lac is converted into a more or less uniform granular material by crushing and sieving. Such granular lac is given the name of seed-lac. Further washing is required for removing the colouring matter (lac dye). The washed seed-lac is then dried and graded. Finally, various seed-lacs are blended together, in order to obtain shellac with the desired qualities; rosin or other ingredients

may also be introduced. The next stage of the preparation is the melting of the lac. For this purpose, the lac is placed in a long tubular bag, which is held in front of a fire and twisted. As the lac melts, it is squeezed out of the bag. The soft mass thus obtained is stretched into a thin sheet which, after hardening, is broken up into small pieces or flakes for marketing as shellac.

Rosin

Rosin is obtained as residue in the distillation of pine oleo-resin. As the resin contains a certain amount of solid impurities, which would contaminate the rosin, it is usually purified before the distillation process. The purification may be done by filtering followed by settling. This necessitates the melting of the resin; turpentine may furthermore be added to reduce the density of the liquid. Coarse impurities are retained in the sieves, while finer impurities as well as water are separated in the settling tanks. The rosin yielded by the distillation process is itself subjected to filtration, with a view to removing any remaining solid impurities.

Vegetable and Animal Oils and Fats

Methods of extraction

Vegetable fats and oils are derived mostly from seeds and fruits, while animal fats and oils are obtained from the fatty tissue of land and marine animals, and also from bones. Oil is extracted from seeds by expression or with the aid of a solvent. For animal oils, the process generally resorted to is that known as rendering; it consists essentially in

air, and then the cell walls begin to dry. This drying of the cell walls is what is known as seasoning.

Shrinkage of wood on drying

As a result of the withdrawal of moisture from the cell walls, the latter contract, so that a shrinkage of the wood takes place. The shrinkage is greatest in a direction tangential to the annual rings of the trunk; it is much less radially and occurs longitudinally only in the case of certain woods. The point where the cell walls begin to dry and the wood starts to shrink is called the fibre saturation point. The moisture content[1] corresponding to the fibre saturation point varies with the species, the average value being somewhat over 25 per cent, while the moisture content of the green timber may be some five times greater.

Moisture content and air humidity

If shrinkage is to be avoided in the manufactured timber, the moisture content of the wood has to be reduced to that corresponding to the air humidity of the place of use. Thus, in the case of wood for panelling near central heating radiators, the moisture content has to be reduced to a very low figure, while for window frames, for instance, a much higher moisture content is permissible. For rough carpentry, on the other hand, where drying can take place on site, wood can be employed with a moisture content only a few percents below fibre saturation point.

Methods of seasoning timber

The two principal methods of seasoning timber are air seasoning and kiln seasoning. With air

[1] The moisture content is the weight of water expressed as a percentage of the dry-weight of the wood.

seasoning, the drying of timber takes place under natural atmospheric conditions. In kilning, the timber is dried by artificial means, so that the process can be greatly accelerated; such artificial drying is indispensable when a very low moisture content is required. Kilning may be preceded by air seasoning, for the preliminary reduction of the moisture content of the timber.

Air seasoning

For air seasoning, the boards are piled in stacks in the open, the individual layers of the stacks being separated by spacing pieces so arranged as to provide ample passages for the circulation of air between the boards. The stacks are raised above the ground and surmounted by an inclined roof. The ends of the boards may be given a coating of waterproof paint, as a protective measure against the formation of end slits, by reason of the more rapid evaporation at these points.

Kiln seasoning

In the case of kilning, the timber is placed in a room heated with steam pipes, where it is piled in much the same manner as for air seasoning. The circulation of air is generally ensured by means of fans, while the desired degree of air humidity can be obtained through the introduction of steam. By varying the heating and the quantity of steam introduced, the conditions in the kiln can be so regulated that the timber is subjected first to damper air at a lower temperature and then to dryer air at a higher temperature.

Breaking down of the logs

The logs are converted into boards at the saw-mills, by means of circular saws, band saws or

reciprocating saws. Band saws may have teeth on one edge only or on the two edges; in the latter case, sawing can be done in both directions of displacement of the log. Reciprocating saws may have a single saw or incorporate several saws that are held in a frame and set at a given distance apart, so that the whole log is cut into boards in a single operation. The initial sawing of the logs is known as the breaking down of the logs. It is followed by re-sawing, with a view to obtaining products of the required shape and dimensions.

Decay in wood

Wood may be damaged by decay, unless special precautions are taken. The principal cause of decay in wood is the infection of the latter by fungi, which are liable to attack it, if the conditions are suitable for their development. The fungi penetrate the timber with their long threads and feed on the wood substance, which they disintegrate by means of the ferments they secrete. Some fungi, such as the dry-rot fungi, attack the cellulose of the wood alone, while others attack the lignin too. Essential requirements for the existence of fungi are moisture and presence of oxygen.

Attack by insects

Timber is also liable to be attacked by various insects. The commonest are the furniture beetle and the death-watch beetle. These beetles lay their eggs in cracks in the wood. The larvae hatched from the eggs work their way through the wood which they perforate with holes, leaving in the latter a more or less fine dust. Finally, they pupate and change into beetles, in which form the insects emerge from the wood.

Preservation of timber

In order to prevent the development of fungi or attack by insect pests, wood is treated with substances which are toxic to fungi or insects. A substance commonly used in this connection is creosote. For impregnation with creosote, the timber is placed in an air-tight cylinder, where vacuum is created, in order to extract the air from the wood cells. The creosote is then forced under pressure into the wood. Once the latter has been well saturated, the creosote is drained off. Various other agents are also utilised as preservatives.

BIBLIOGRAPHY

I. Locating and Working of Mineral Deposits

HADDOCK, M. H. The Location of Mineral Fields, 1926 (Crosby Lockwood & Son).

EVE, A. S., and KEYS, D. A. Applied Geophysics in the Search for Minerals, 1938 (Cambridge University Press).

BULMAN, H. F. The Working of Coal and other Stratified Minerals, 1927 (Ernest Benn Ltd.).

YOUNG, G. J. The Working of Unstratified Mineral Deposits, 1927 (Ernest Benn Ltd.).

CRANE, W. R. Ore Mining Methods, 1917 (John Wiley & Sons, Inc., New York).

II. Mechanical Preparation of Minerals

TAGGART, A. F. Handbook of Ore Dressing, 1927 (John Wiley & Sons, Inc., New York).

TRUSCOTT, S. J. A Textbook of Ore Dressing, 1923 (Macmillan & Co. Ltd.).

BLANC, E. C. Technologie des Concasseurs, Broyeurs et Tamiseurs, 1924 (Librairie Polytechnique Ch. Béranger, Paris and Liège).

GAUDIN, A. M. Flotation, 1932 (McGraw-Hill Book Co., Inc., New York and London).

III. Coal and Coal Products

BONE, W. A., and HIMUS, G. W. Coal: Its Constitution and Uses, 1936 (Longmans, Green & Co.).

LOUIS, H. The Preparation of Coal for the Market, 1928 (Methuen).

ARMSTRONG, J. Carbonisation: Technology and Engineering, 1929 (G. Griffin & Co., Ltd.).

WIGGINTON, R. Coal Carbonisation, 1929 (Ballière, Tindall & Cox).

ROBERTS, J., and JENKER, A. International Coal Carbonisation, 1934 (Pitman).

GLUUD, W. International Handbook of the By-product Coking Industry, English Edition by E. M. Myers, 1932 (Ernest Benn Ltd.).

MEADE, A. The New Modern Gas Works Practice, 3rd Edit., 1934 (Eyre & Spottiswoode).

DAVIDSON, W. B. Gas Manufacture, 1923 (Longmans, Green & Co.).

WARNES, A. R. Coal Tar Distillation and Working up of Coal Tar Products, 3rd Edit., 1923 (Ernest Benn Ltd.).

— The Coal Resources of the World: An Enquiry made upon the Initiative of the Executive Committee of the XIIth International Geological Congress, Canada, 1913, with the assistance of Geological Surveys and Mining Geologists of different Countries, 1913 (Morang & Co. Ltd., Toronto, Canada).

MOORE, E. S. Coal: Its Properties, Analysis, Classification, Geology, Extraction, Uses and Distribution, 1922 (John Wiley & Sons, Inc., New York).

GIBSON, W. Coal in Great Britain, 1927 (Edward Arnold & Co., London).

— The World Coal-mining Industry, 1938 (published by the International Labour Office).

IV. Petroleum and Petroleum Products

NELSON, W. L. Petroleum Refinery Engineering, 1936 (McGraw-Hill Book Co., Inc., New York and London).

BELL, H. S. American Petroleum Refining, 2nd Edit., 1930 (Constable & Co. Ltd.).

KALICHEVSKY, A., and STAGNER, B. A. Chemical Refining of Petroleum, 1933 (The Chemical Catalog Company, Inc., New York).

UREN, L. C. Petroleum Production Engineering, 2nd Edit. 1934 (McGraw-Hill Book Co., Inc., New York and London).

GURWITSCH, L., and MOORE, H. The Scientific Principles of Petroleum Technology, 2nd English Edition, 1932 (Chapman & Hall Ltd.).

DUNSTAN, A. E., and others, edited by. The Science of Petroleum, 1938 (Oxford University Press).

LILLEY, E. R. The Oil Industry, 1926 (Constable & Co. Ltd.).

GRUSE, W. A. Petroleum and its Products, 2nd Impression, 1928 (McGraw-Hill Book Co., Inc., New York and London).

EMMONS, W. H. Geology of Petroleum, 1921 (McGraw-Hill Book Co., Inc., New York and London).

THOMPSON, A. B. Oilfield Exploration and Development, 1925 (Crosby Lockwood & Son).

— Annual Reviews of Petroleum Technology. F. H. Garner, General Editor (published yearly by the Institute of Petroleum).

— Journal of the Institute of Petroleum: Abstracts (published yearly by the Institute of Petroleum).

V. Metals and their Preparation

LIDDELL, D. M., and DOAN, G. E. The Principles of Metallurgy, 1933 (McGraw-Hill Book Co., Inc., New York and London).

STOUGHTON, B. The Metallurgy of Iron and Steel, 3rd Edit., 1923 (McGraw-Hill Book Co., Inc., New York and London).

CAMP, J. M., and FRANCIS, C. B. The Making, Shaping and Treating of Steel, 4th Edit., 1923 (published by the Carnegie Steel Co.).

CLEAVES, H. E., and THOMPSON, J. G. The Metal—Iron, 1935 (McGraw-Hill Book Co., Inc., New York and London).

SKELTON, H. J. Economics of Iron and Steel, 2nd Edit., 1924 (Stevens & Sons Ltd., H. J. Skelton & Co. Ltd.).

ESCARD, J. L'Electrométallurgie du Fer et de ses Alliages, 1920 (Dunod, Editeur, Paris).

CRUMP, N. E. Copper, 1925 (William Rider & Son Ltd.).

ALTMAYER, M., and GUILLET, L. Métallurgie du Cuivre et Alliages de Cuivre, 1925 (Librairie J.-B. Baillière et Fils, Paris).

HOFMAN, H. O., revised by HAYWARD, C. R. Metallurgy of Copper, 2nd Edit., 1924 (McGraw-Hill Book Co.. Inc., New York and London).

HOFMAN, H. O. Metallurgy of Zinc and Cadmium, 1922 (McGraw-Hill Book Co., Inc., New York and London).

MANTELL, C. L. Tin: Its Mining, Production, Technology and Application, 1929 (The Chemical Catalog Company, Inc., New York).

EDWARDS, J. D., FRARY, F. C., and JEFFRIES, Z. The Aluminium Industry, 1930 (McGraw-Hill Book Co., Inc., New York and London).

— Aluminium. Supplement of the *Manchester Guardian* published on July 3, 1936.

HAUGHTON, J. L., and PRYTHERCH, W. E. Magnesium and its Alloys, 1937 (published by the Department of Scientific and Industrial Research).

VICKERS, C. Metals and their Alloys, 1923 (Henry Carey Baird & Co., Inc.).

WOLDMAN, N. E., and DORNBLATT, A. J. Engineering Alloys, 1936 (published by the American Society for Metals).

ROSE, T. K., and NEWMAN, W. A. C. The Metallurgy of Gold, 7th Edit., 1937 (Charles Griffin & Co. Ltd.).

DORR, J. V. N. Cyanidation and Concentration of Gold and Silver Ores, 1936 (McGraw-Hill Book Co., Inc., New York and London).

JULIAN, H. F., and SMART, E., revised by ALLEN, A. W. Cyaniding Gold and Silver Ores, 3rd Edit., 1921 (Charles Griffin & Co. Ltd.).

— Gold Number of *The Times*, published on June 20, 1933.

— Silver Number of *The Times*, published on February 20, 1934.

VI. Other Minerals and Mineral Products

WARNES, A. R. Building Stones: Their Properties, Decay and Preservation, 1926 (Ernest Benn Ltd.).

RICHARDSON, C. H. Building Stones and Clays, 1917 (The Syracuse University Book Store, Syracuse, N.Y.).

SEARLE, A. B. Limestone and its Products: Their Nature, Production and Uses, 1935 (Ernest Benn Ltd.).

The Clayworker's Handbook, 4th Edit., 1929 (Charles Griffin & Co. Ltd.).

An Encyclopaedia of the Ceramic Industries, 1929-30 (Ernest Benn Ltd.).

HODKIN, F. W., and COUSEN, A. A Textbook of Glass Technology, 1925 (Constable & Co. Ltd.).

SCHOLES, S. R. Modern Glass Practice, 1935 (Industrial Publications, Chicago).

HOWLING, G. E. Asbestos, 2nd Edit., 1937 (published by the Imperial Institute).

ROSS, J. G. Chrysotile Asbestos in Canada, 1931 (published by the Department of Mines, Canada).

VII. Chemistry and Chemical Manufacture

CHAMBERLAIN, J. S. A Textbook of Organic Chemistry, 1921 (George Routledge & Sons, Ltd.).

MORGAN, G. T., and PRATT, D. D. British Chemical Industry: Its Rise and Development, 1938 (Edward Arnold & Co.).

CURTIS, H. A. Fixed Nitrogen, 1932 (The Chemical Catalog Company, Inc., New York).

ELLIS, C. Hydrogenation of Organic Substances, 1930 (D. Van Nostrand Company, Inc., New York).

JONES, A. Cellulose Lacquers, Finishes and Cements, 1937 (Charles Griffin & Co. Ltd.).

VIII. Natural Fibres

PRIESTMAN, H. Principles of Woollen Spinning, 2nd Edit., 1924 (Longmans, Green & Co.).

Principles of Worsted Spinning, 2nd Edit., 1921 (Longmans, Green & Co.).

RADCLIFFE, J. W. The Manufacture of Woollen and Worsted Yarns, 2nd Edit., 1924 (Emmott & Co. Ltd.).

HIND, J. R. Worsted Carding and Combing, 1932 (Pitman).

BARKER, A. F. Woollen and Worsted Spinning, 1922 (Cassell & Co. Ltd.).

BROWN, H. B. Cotton, 2nd Edit., 1938 (McGraw-Hill Book Co., Inc., New York and London).

TAGGART, W. S. Cotton Spinning, 1920–21 (Macmillan & Co. Ltd.).

THORNLEY, T. Advanced Cotton Spinning, 3rd revised Edit., 1923 (Scott, Greenwood & Son).

CANSDALE, C. H. C. Cocoon Silk, 1937 (Pitman).

SCHOBER, J., translated by CUTHILL, R. Silk and the Silk Industry, 1930 (Constable & Co. Ltd.).

CARTER, H. R. Modern Flax, Hemp and Jute Spinning and Twisting, 2nd revised Edit., 1925 (Scott, Greenwood & Son).

LAZARKÉVITCH, N. A. Le Lin, 1925 (Gauthier-Villars & Cie, Paris).

WOODHOUSE, T., and KILGOUR, P. Jute and Jute Spinning, 2nd Edit., 1929 (Macmillan).

CHAUDHURY, N. C. Jute and Substitutes, 1933 (W. Newman & Co. Ltd., Calcutta).

WOODEHOUSE, T., and BRAND, A. A Century's Progress in Jute Manufacture, 1833–1933, 1934 (David Winter & Son, Dundee).

SMITH, H. H. Sisal, Production and Preparation, 1929 (John Bale, Sons, & Danielson).

HESS, K. P., edited by ANDREWS, B. R. Textile Fibers and their Uses, 1936 (J. B. Lippincott Company, Chicago and Philadelphia).

MATTHEWS, J. M. The Textile Fibers, 4th Edit., 1924 (John Wiley & Sons, Inc., New York).

IX. Artificial Silk

FOLTZER, J., translated by WOODHOUSE, T. Artificial Silk and its Manufacture, 4th Edit., 1928 (Pitman).

MORGAT, R. La Fabrication de la Soie Artificielle par le Procédé Viscose, 1930 (L'Edition Textile, 61, Avenue Jean-Jaurès, Paris).

DE LEEUW, H. Les Soies Artificielles: Technologie chimique et physique, 1932 (Librairie Polytechnique Ch. Béranger, Paris and Liège).

HOTTENROTH, V., translated by FYLEMAN, E. Artificial Silk, 1928 (Pitman).

X. Hides and Skins, and Leather Manufacture

ARNOLD, J. R. Hides and Skins, 1925 (A. W. Shaw Company, Chicago and New York).

— Hides and Skins, 1912 (published by the *Shoe and Leather Weekly*, Chicago).

PROCTER, H. R. The Principles of Leather Manufacture, 2nd Edit., 1922 (E. & F. N. Spon).

MEUNIER, L., and others. La Tannerie, 1936 (Gauthier-Villars, Paris).

FURLONG, J. R., edited by. The Preparation of Empire Hides and Skins, 1937 (published by the Imperial Institute).

XI. Rubber and Resins, natural and synthetic

LUFF, D. W. The Chemistry of Rubber, 1923 (Ernest Benn Ltd.).

BARRON, H. Modern Rubber Chemistry, 1937 (Hutchinson's Scientific and Technical Publications).

DAWSON, T. R., and PORRITT, B. D. Rubber: Physical and Chemical Properties, 1935 (published by the Research Association of British Rubber Manufacturers).

FLINT, C. F. The Chemistry and Technology of Rubber Latex, 1938 (Chapman & Hall Ltd.).

NAUNTON, W. J. S. Synthetic Rubber, 1937 (Macmillan & Co. Ltd.).

SCHOTZ, S. P. Synthetic Rubber, 1926 (Ernest Benn Ltd.).

BARRY, T. H., DRUMMOND, A. A., and MORRELL, R. S. The Chemistry of the Natural and Synthetic Resins, 1926 (Ernest Benn Ltd.).

BARRY, T. H. Natural Varnish Resins, 1932 (Ernest Benn Ltd.).

PARRY, E. J. Shellac, 1935 (Pitman).

MORRELL, R. S., and others. Synthetic Resins and Allied Plastics, 1937 (Oxford University Press).

XII. Vegetable and Animal Oils and Fats

CHALMERS, T. W. The Production and Treatment of Vegetable Oils, 1918 (Constable & Co. Ltd.).

LAUCKS, I. F. Commercial Oils, Vegetable and Animal, 1919 (Wiley & Sons, Inc., New York).

ANDÉS, L. E. Vegetable Fats and Oils, 4th English Edition by H. B. Stocks, 1925 (Scott, Greenwood & Son).

WRIGHT, C. R. A., revised by MITCHELL, C. A. Animal and Vegetable Fixed Oils, Fats, Butters and Waxes, 3rd Edit., 1921 (Charles Griffin & Co. Ltd.).

XIII. Wood and Wood Products

HOWARD, A. L. A Manual of the Timbers of the World: Their Characteristics and Uses, 1920 (Macmillan).

CROSS, C. F., and BEVAN, E. J. A Textbook of Paper Making, 5th Edit., 1936 (E. & F. N. Spon).

CLAPPERTON, R. H., and HENDERSON, W. Modern Paper Making, 1929 (Ernest Benn Ltd.).

SUTERMEISTER, E. Chemistry of Pulp and Paper Making, 2nd Edit., 1929 (John Wiley & Sons, Inc., New York).

XIV. Miscellaneous

MILLIKAN, R. A. Electrons (+ and −), Protons, Photons, Neutrons and Cosmic Rays, 1935 (Cambridge University Press).

FALKENHAGEN, H., translated by BELL, R. P. Electrolytes, 1934 (Clarendon Press).

DAVIES, C. W. The Conductivity of Solutions, 1930 (Chapman & Hall Ltd.).

NEWMAN, F. W. Electrolytic Conduction, 1930 (Chapman & Hall Ltd.).

A. SUBJECT INDEX

Air, liquid 72
Anaesthetics 84
Anions 258
Anode 258
Atoms 73, 90, 165 fn, 257, 281

Bast 319
Beetles—
  death-watch 355
  furniture 355
Blubber 127
Boll weevil 102 fn
Bones 348, 351
Boon 321
Bran 341
BRICKS—
  Building bricks 61
  Glazed bricks 61
  Refractory bricks, classification—
    Acid bricks 62
    Basic bricks 62
    Neutral bricks 62
  Refractory bricks, various—
    Bauxite bricks 62
    Carborundum bricks 62
    Chromite bricks 62
    Fireclay bricks 62
    Magnesia (Magnesite) bricks 62, 247
    Silica bricks 62

Calorific power 23, 23 fn
Camphor 89
Candles 126, 127
Carat number 54
Carbonisation—
  High temperature 24, 276, 276 fn, 277, 278
  Low temperature 24, 276, 276 fn, 278, 283
Carbonising chambers 278
Casein 91, 97, 97 fn, 98
Catalysts 71 fn, 96, 268 fn
Cathode 258
Cations 258
Cellophane 95 fn
Celluloid 89, 116
Cellulose 91, 93–97, 134, 134 fn, 135, 138, 162, 162 fn, 309 fn, 355
Cement 58, 59
  Portland 58
CHEMICAL CLASSIFICATION (excl. Hydrocarbons)—
  Acids 73, 74, 80, 83, 84, 257
    fatty 82, 83, 119, 127, 127 fn, 226, 351, 352
    organic 80, 82, 83
  Alcohols 80, 81, 83, 127 fn
    aldehyde (aldoses) 85
    iso-meric 81
    ketone (ketoses) 85
    monohydric 80
    primary 81
    secondary 81
    tertiary 81
  Aldehydes 80–82
  Alkalis 75, 97
  Anhydrides 83, 84
  Bases 73, 74, 83, 257
  Carbohydrates 84, 145 fn
  Compounds—
    cyclic 78
    hetero-cyclic 78
    iso-cyclic 78
    open chain 78
  Esters 80, 83
  Ethers 80, 84
    mixed 84
    simple 84
  Halogens 87
  Intermediates 86–88
  Ketones 80, 82
  Mono-saccharides (monoses) 84
  Salts 73, 74, 83, 257
  Soaps 275, 275 fn
  Sugars 84, 97 fn
CHEMICAL ELEMENTS, non-metallic—
  Arsenic 32, 70, 244
  Boron 70
  Carbon 26, 26 fn, 27, 27 fn, 28, 70, 78–88, 98, 98 fn, 119, 135, 147, 162, 162 fn, 163–165, 165 fn, 238, 244, 276, 284

CHEMICAL ELEMENTS, non-metallic—(*contd.*)—
Chlorine 70, 71, 75, 77, 87, 88, 139 fn
Hydrogen 24, 71, 71 fn, 72, 73, 73 fn, 74, 74 fn, 75, 77, 79, 80–84, 86–89, 98, 162, 162 fn, 163, 164, 164 fn, 165, 165 fn, 277, 278, 284, 285, 285 fn, 286, 287
nascent 238, 238 fn
Iodine 70, 71
Nitrogen 70–72, 77, 87, 98, 98 fn, 145 fn, 162, 162 fn, 164, 277
Oxygen 34, 70–72, 74, 74 fn, 80, 82, 84, 87, 98, 98 fn, 119, 120, 145 fn, 147, 163, 237, 237 fn, 239, 243, 285 fn
Phosphorus 28, 42, 42 fn, 70, 71, 98, 145 fn, 244
red 71
Silicon 26, 28, 41, 48, 70, 147, 244, 250
Sulphur 28, 33, 33 fn, 38, 70, 87, 98, 98 fn, 112, 113, 145 fn, 147, 162, 162 fn, 164, 237, 237 fn, 239, 243, 244, 277 fn
CHEMICAL PLANT—
Digesters 135, 351
Hydrogenation plant (I.C.I.) 285–287
Scrubbers 283, 283 fn
CHEMICAL PROCESSES, excl. Processing of Petroleum and Preparation of Fatty Oils—
Ammonia-soda process 75
Bleaching 71, 77, 94, 95, 139
Condensation 90, 91
Dyeing 78, 94, 104, 104 fn
Fischer-Tropsch process 287
Hydrogenation, coal 71, 284–287
Hydrolysis 96, 96 fn
Mercerising 102, 102 fn
Polymerisation 90–92, 121
Steam-iron process (hydrogen production) 71, 72
Tower absorption 137
Vulcanisation 112–114, 114 fn, 115
Water-gas catalytic process (hydrogen production) 71
CHEMICAL PRODUCTS, excl. Petroleum and Coar-Tar Products—
Acetic acid 31 fn, 78, 82, 83, 96, 340, 344
Acetic anhydride 84, 96
Acetone (di-methyl ketone) 82, 96
Alcohol, *see* Ethyl alcohol
Alkali-cellulose 95
Aluminium oxide 66, 67, 259
see also Alumina under "Minerals"
Amino-benzene 87
Amino-naphthol-disulphonic acid 88
Amino-naphthol-sulphonic acid 88
Ammonia 24, 75–77, 77 fn, 92, 96, 97, 277, 280, 283 fn
liquor 280, 280 fn, 283 fn
synthetic 71, 72
Ammoniacal copper oxide 96
Ammonium carbonate (sal volatile) 77
Ammonium chloride (sal ammoniac) 77, 340
Ammonium hydroxide 76
Ammonium sulphate (sulphate of ammonia) 24, 49, 74, 77, 95, 280 fn, 283 fn
Aniline 87
Barium oxide 66
Benzaldehyde 88
Benzoic acid 88
Beta-naphthol 88
Bleaching powder (chloride of lime) 76, 77, 139, 139 fn
Bone ash 63, 63 fn, 64
Borax 63
Boric acid 75, 340
Boric oxide 66 fn
Brine 75, 157
Butyl acetate 83
Butyl alcohol 82
Butyl lactate 83
Butyric acid 340
Calcium bisulphite (bisulphite of lime) 95, 136
Calcium carbide 59, 76, 93
Calcium carbonate 57, 58
Calcium chloride 139 fn, 340

CHEMICAL PRODUCTS (*contd.*)—
Calcium hydroxide, *see* slaked lime
Calcium hypochlorite 139 fn
Calcium oxide 66, 67
see also Lime
Calcium phosphate, *see* Phosphate of lime
Cane sugar, *see* Saccharose
Carbon bisulphide (carbon disulphide) 95, 350
Carbon dioxide (carbonic acid) 34, 71, 78, 92, 145, 237, 277, 285
Carbon monoxide 71 fn, 243 fn, 277, 285, 285 fn, 287
Carborundum (silicon carbide) 62
Caustic potash (potassium hydroxide) 75, 76
Caustic soda (sodium hydroxide) 75, 76, 94–97, 102 fn, 135, 135 fn, 136, 271, 271 fn, 347, 352
Cellulose acetate 90 fn, 96 fn
Cellulose acetates, acetone-soluble 96, 96 fn
Cellulose nitrate, *see* Nitrocellulose
Cellulose tri-acetate 96, 96 fn
Cellulose xanthate 95
Chile saltpetre 67
Chloroprene 93
Chlorovinylacetate 92
Chromium oxides 74 fn
Citric acid 83
Cobalt oxide 68
Collodion 89
Copper oxides 68, 235
Copper sulphide 235, 238
Copper sulphate 96, 97, 235, 238, 258
Cordite 89
Cream of tartar 84
Dextro-tartaric acid 83 fn
Di-ethyl ether ("ether") 84, 89
Di-ethyl tartrate 83
Di-methylaniline 88
Di-methyl ketone, *see* Acetone
Di-methyl tartrate 83
Di-nitro-benzene 87
Dynamite 89, 119 fn
Ether, *see* Di-ethyl ether

CHEMICAL PRODUCTS (*contd.*)—
Ethyl acetate 83
Ethyl alcohol ("alcohol") 80–82, 89, 116, 124
Ethyl lactate 83
Ferric silicate 67 fn, 68 fn
Ferrous silicate 67 fn, 68 fn
Formaldehyde 82, 91, 92
Formic acid 82, 340, 344
Furfuraldehyde (furfural) 92
Fructose (fruit sugar) 84
Gamma acid 88
Glucose (grape sugar) 84, 95, 97
Glycerol (glycerine) 89, 92, 119, 119 fn, 127 fn
Glycerol trinitrate, *see* nitroglycerin
Gun-cotton 89
H acid 88
Hydrochloric acid (muriatic acid) 74, 77, 93, 113, 340
Hydrogen chloride 74
Hydrogen sulphide (sulphuretted hydrogen) 75, 277
Iron sulphide 74
J acid 88
Lactic acid 83, 340
Lead acetate 78, 83
Lead carbonates 77
Lead linoleate 37
Lead oxides 66, 78
Lead nitrate 78
Lime ("quicklime") 58, 59, 62, 63, 135, 135 fn
bisulphite of, *see* Calcium bisulphite
chloride of, *see* Bleaching powder
phosphate of 63 fn
see also Bone ash
slaked (calcium hydroxide) 75–77, 138, 139 fn, 339, 340, 340 fn
superphosphate of ("superphosphate") 74, 76, 77
Linolenic acid 119
Litharge 67, 78
Magnesia 62, 63, 137 fn
Magnesium oxide 66, 67
see also Magnesia
Maltose (malt sugar) 84

CHEMICAL PRODUCTS (*contd.*)—
Manganese dioxide, etc. 67, 68, 68 fn, 74 fn
Mercaptans 272
Methanol, *see* Methyl alcohol
Methyl acetate 83
Methyl alcohol (methanol, "wood spirit") 80, 81, 81 fn, 82, 91
Methyl ethyl ketone 82
Monovinylacetylene 93
Muriatic acid, *see* Hydrochloric acid
Nickel oxide 68
Nitric acid 37, 75, 78, 87, 89
Nitro-benzene 87, 263
Nitrocellulose (cellulose nitrate) 89, 90, 90 fn, 116
Nitro-glycerin (glycerol trinitrate) 89
Nitro-naphthalene 88
Oleic acid 119
Ortho-dichlorbenzene 88
Ortho-nitraniline 88
Oxalic acid 83
Palmitic acid 83
Para-dichlorbenzene 88
Para-nitraniline 88
Phthalic anhydride 92
Picric acid 89
Potash (potassium carbonate) 63, 67, 76, 304
Potassium bichromate 76
Potassium carbonate, *see* Potash
Potassium chlorate 76
Potassium chloride 76
Potassium cyanide 235
Potassium hydroxide, *see* Caustic potash
Potassium muriate 76
Potassium nitrate 67, 76
Potassium oxide 66, 67
Potassium permanganate 76
Potassium sulphate 76
Propyl alcohol 82
Quicklime, *see* Lime
Red lead 37, 67, 78
Ricinoleic acid 119
Saccharose (cane sugar) 84
Sal ammoniac, *see* Ammonium chloride
Sal volatile, *see* Ammonium carbonate

CHEMICAL PRODUCTS (*contd.*)—
Salt 75, 337
Salt-cake 66, 75
Silicon carbide, *see* Carborundum
Silver bromide 56
Soda ash ("soda") 63, 66, 75, 135, 135 fn, 136, 304
Sodium acetate 75, 83
Sodium bicarbonate 75
Sodium bichromate 75
Sodium bisulphite 344
Sodium carbonate 75, 94
see also Soda ash
Sodium chlorate 75
Sodium chloride 75, 341
see also Salt
Sodium cyanide 76
Sodium hydroxide, *see* Caustic soda
Sodium hyposulphite 75
Sodium nitrate 67, 76
see also Chile saltpetre
Sodium nitrite 76
Sodium oxide 66
Sodium phosphate 76
Sodium prussiate 76
Sodium silicate 76
Sodium sulphate 75, 95, 136
see also Salt-cake
Sodium sulphide 76, 136, 339
Sodium sulphite 344
Starch 81, 84
Stearic acid 83, 119
Sulphanilic acid 88
Sulphur dioxide 74, 137, 237 fn, 263
Sulphur trioxide 74
Sulphuretted hydrogen, *see* Hydrogen sulphide
Sulphuric acid 36, 37, 74–77, 87, 89, 95–97, 235, 237, 258, 270, 283 fn, 337, 340, 352
Sulphurous acid 136, 137
Superphosphate, *see* Superphosphate of lime
Tartaric acid 83
Tetraethyl lead 275
Tri-nitrotoluene (T.N.T.) 89
Urea 92
Vinyl acetate 92
Vinyl chloride 92

CHEMICAL PRODUCTS (*contd.*)—
Viscose 95, 95 fn
White lead 37
Wood spirit, *see* Methyl alcohol
Zinc oxide 35, 66
Zinc sulphate 95
Zinc sulphide 74
CHEMICAL SUBSTITUTION GROUPS AND RADICALS—
Aldehyde group 87
Alkyl group 87
Amino group 87
Carbonyl group 82
Carboxyl group 82, 87
Cyanogen group 87
Hydroxyl group 74, 74 fn, 80, 81, 87
Nitro group 87
Sulphonic group 87
Vinyl 92, 92 fn
COAL AND COAL CLASSIFICATION—
Anthracite 162, 173, 174
Coal 23, 24, 148, 154, 156, 162, 167, 172–175, 199, 203, 203 fn, 211, 212, 284, 285
bituminous 162, 163 fn, 169, 173, 174 284
brown 162, 167, 169, 284
coking 174, 278 fn
gas 174, 278 fn
pulverised 241
semi-bituminous 174 fn
sub-bituminous 169, 169 fn
steam 174
Lignite 162, 167, 169, 172, 174
COAL-TAR AND COAL-TAR PLANT—
Coal-tar 24, 60, 60 fn, 86, 277, 277 fn, 279, 280, 282
low temperature 285, 286 fn
Electro-static precipitators 280
Tar extractors 280
COAL-TAR PRODUCTS—
Anthracene oil 282
Benzol—
crude 24, 274 fn, 282, 283
motor 283
Carbolic acid (phenol) 24, 39, 88, 91, 91 fn, 263, 282
Creosote oil 24, 282, 285, 356
Cresylic acid (cresol) 277 fn, 282
Naphtha, solvent 92
COAL-TAR PRODUCTS (*contd.*)—
Naphthalene 282
see also under "Hydrocarbons"
Pitch 24
Phenol, *see* Carbolic acid
Pyridine 282
Coalfields 167–169, 173, 173 fn, 174
Coalification 162
COKE AND ALLIED PRODUCTS—
Coalite 279 fn
Coke 24, 26 fn, 62, 71 fn, 72, 77, 241, 276, 277, 285
metallurgical 278, 279
Semi-coke 24, 276, 279, 279 fn
Colloidal state 230
Concrete 59
reinforced 59
Cordage, *see under* "Fibre products"
Cullet 67

Diatomaceous earth 89, 89 fn, 119 fn
Diluents 90 fn
Distillation—
coal, *see* Carbonisation
liquid air (fractional) 72
metal 255
oil shale 167
oleo-resin 348
petroleum (fractional), *see under* "Petroleum processing"
wood 81, 83
Dressing—
leather 126, 127
ore, *see under* "Minerals, preparation of"
Dyes 74, 75, 104
cotton 104, 104 fn
synthetic 24, 86

Ebonite 113
Electric current 281 fn
Electrodes 258, 281, 282
Electrolysis and electrolytic processes 68, 73
see also under "Metallurgical processes"
Electrolysis of water 71, 72
Electrolytes 230, 256
Electrolytic solutions 257
Electrons 257, 281, 282
Enamels, *see under* "Paints"

Esparto grass 137, 137 fn, 138
Exchange Equalisation Accounts 53
Explosives 74, 89, 119, 119 fn

Fat 82, 94, 97 fn, 162, 162 fn
see also under "Oils and fats, vegetable and animal"
Wool 303, 303 fn, 304
Fermentation 350
see also under "Fibre preparing processes"
Feeding stuff (feed) 121–126, 351
Fellmongers 350
Felting 304, 304 fn
Fertilisers 59, 74, 76, 77, 121, 126, 349
FIBRE CLASSIFICATION—
Fibre—
leaf 195, 288, 289
mineral 288, 330
seed 195, 288
stem 195, 288, 289
FIBRES, NATURAL—
Asbestos 107, 288, 330
see also under "Minerals"
cross-fibre 330
slip-fibre 330
Cotton 89, 94, 99, 102, 103, 105, 122, 145, 146, 146 fn, 288, 294
American 102, 103, 309, 310
Egyptian 102, 103, 310
Indian 102, 103
lint 308
linters 94, 94 fn, 309, 309 fn
Sea Island 102, 102 fn
lax 99, 103, 105, 120, 120 fn, 137, 288, 291, 320, 324–327
unretted ("green fibre") 322
Hemp—
common 105, 137, 288, 320, 322, 324, 325
Manila 105, 288, 327–329
Mauritius 107, 288, 327
New Zealand 107, 327, 329
Sunn 107
true, *see* Common hemp
Jute 105, 137, 288, 294, 320, 322, 324–327
Phromium tenax, *see* New Zealand hemp
FIBRES, NATURAL (*contd.*)—
Ramie 105, 106
Silk 99, 101, 102, 105, 313
wild 314, 314 fn
Sisal 105–107, 288, 327–329
Wool 98 fn, 99-101, 146, 294, 299, 301-307
Botany 307 fn
see also Merino wool
crossbred 100, 302, 307 fn
down 100
fleece 100
Leicester 307 fn
Lincoln 307 fn
merino 100, 302, 303, 306, 306 fn, 307 fn
scoured 302, 303
skin 100
FIBRE PREPARING MACHINERY—
Bale breakers 289, 290
Baling presses 309, 323, 328
Back-washing machines (wool) 307
Breakers (flax) 321
Card—
breaker (cotton) 311, 325
condenser (wool) 305
finisher (cotton) 311, 325
intermediate (wool) 305
revolving flat 294, 311
roller 294
Cards (carding engines) 293, 294, 305, 311, 325, 333
Centrifuge 328 fn
Comb, Noble 296
Combers 293, 296, 306
Decorticators (decorticating machines) 322, 327, 328
Delinters 309, 309 fn
Doffer 295
Drawing boxes 293, 298, 299, 307, 318
Drawing frame—
push-bar 325, 326
spiral (screw-gill machines) 325, 326, 329
Drawing frames (drawing machines) 293, 298, 311, 312, 325
Dressing frames (silk) 317
Fallers 298, 299
Fearnoughts 292, 305

FIBRE PREPARING MACHINERY (*contd.*)—
Filling machines (silk) 316
Flyer and bobbin system 294, 298–300, 327
Fly-frame, intermediate 312
Fly-frames 293, 298, 312
Gill boxes 293, 298, 299, 306, 307, 318
Gins 308
roller 308
saw 308
Hackle 324
Hackling machines 293, 295, 324, 325
Hackling sheet 295
Hopper bale breakers 290
Hopper feeders 289, 290, 310
Lapping-up apparatus 311
Openers 289, 291, 310
Crighton 291, 310
exhaust 291
exhaust, and scutcher, combined 310
porcupine 291, 310
Reeling machine (silk) 315, 315 fn
Ribbon-lap machine 312
Ripple 321
Rougher (hackle) 324
Roving frame 312, 327
Screw-gill machines, *see* Spiral drawing frames
Scribbler (card) 305
Scutchers 289, 291, 310, 311
Scutching machines (flax) 321
Sliver-lap machines 312
Slubbing frame 312
Softening machines (jute) 323
Spreader, Goods 329
Spreaders 296, 318, 324
Teazers 292, 305
Willeys (willows) 289, 292, 307
tenter-hook 292
see also Fearnoughts
Workers 294
FIBRE PREPARING PROCESSES—
Baling 309, 323, 328
Beating (silk) 316
Blending 305, 306
Carding 305, 311, 318
worsted 307
FIBRE PREPARING PROCESSES (*contd.*)—
Classing (wool) 289, 301, 302
Cleaning 310
Coiler system 313
Combing 296, 306, 312
Condenser system 313
Cooking (silk cocoons) 314
Decortication 327, 328
Degumming (silk) 315
Discharging (silk) 315
Doubling 94, 94 fn, 291, 298, 306
Drawing 293, 306, 316, 318, 329
"cone" 300
English 308
French 308
"open" 300
worsted 307
Dressing (silk) 316
Fermentation (silk) 315
Filling (silk) 316
Ginning 94, 122, 308
Hackling 296, 324, 329
Opening 310
Preparing, worsted 307
Retting 291, 320
dew 320
water 320
Rotting, *see* Retting
Scouring (wool) 77, 302, 304
Scutching 321
Skirting (wool fleeces) 301, 302
Sorting (wool) 303
Spreading 316, 329
Steeping (wool) 304 fn
Willowing
FIBRE, RECONDITIONED, AND WASTE—
Mungo (wool) 100, 305
Noils 100, 305
Shoddy (wool) 100, 305
Tow—
flax 324, 325
hemp 324, 325
Waste—
cotton 94, 313
silk 313, 315
FIBRE PRODUCTS, incl. intermediate forms—
Cordage 105–107, 323
Lap 291, 311, 312, 316, 317
Rope 329

FIBRE PRODUCTS (*contd.*)—
Roving 289, 294, 300, 307, 310–312, 323, 327
Schappe (silk) 315
Sliver 289, 293, 296, 297, 299, 300, 310, 311, 318, 323–325, 329
Slubbing 300
Tops (wool) 306
Twine 329
Yarn 99, 100, 102, 102 fn, 103, 104, 106, 107, 195, 313, 323, 324, 326, 332
cotton 103
silk (reeled) 313
silk (spun) 313
worsted 100, 100 fn, 304, 306
woollen 100, 100 fn, 304, 305
FIBRE SYNTHETIC AND SUBSTITUTE FIBRE—
Artificial silk 74, 75, 84, 90, 91, 93–99, 105, 133
Artificial silk manufacture—
Spinning 93 fn
bath (coagulating bath) 93, 93 fn, 97
dry 93 fn
solutions 93, 95–98
stretch 97
wet 93 fn
Artificial silks, various—
Acetate silk 95, 96, 104, 104 fn
Cuprammonium silk 95, 96, 104
Viscose silk 95, 104
Synthetic wool 90, 91, 97, 105
Lanital 97, 97 fn, 98, 105
Wool-like fibre 98
Fire-damp 163 fn
see also Methane under "Hydrocarbons"
Fish scrap 126
Flocculation 230
Floss 314
Flux—
glass 67
metallurgy 59, 241, 242
pottery 63, 64, 64 fn, 65
Fossils 149 fn
Fuller's earth 352
Fungi 197, 355, 356
dry-rot 355
Fuzz 309, 309 fn
Gangue 147, 195, 199, 200, 220, 221, 224, 225, 235, 241–243
Gas—
coal (crude) 24, 280, 283
blast-furnace 279
natural 163, 274
producer 72, 279, 279 fn
town 25
water 71, 71 fn, 72, 285, 287
Gaskets 107, 107 fn, 115
GEOLOGICAL AGES—
Era—
Archean 149
Cainozoic, *see* Tertiary era
Mesozoic 149, 167, 168
Palaeozoic 149, 167–170
Pre-Cambian, *see* Archean era
Primary, *see* Palaeozoic era
Secondary, *see* Mesozoic era
Tertiary 149, 167–171
Period—
Cambrian 149
Carboniferous 149, 167, 167 fn, 168
Cretaceous 149, 168–171
Devonian 149
Eocene 149
Jurassic 149
Miocene 149, 169
Oligocene 149
Ordovician 149, 169
Permian 149
Permo-Carboniferous 168
Pleistocene 149, 169
Pliocene 149, 169
Silurian 149
Triassic 149
Recent 149
GEOLOGICAL CLASSIFICATION—
Beds 148, 151, 152 fn, 153, 155, 156, 163, 166
Deposits—
alluvial 151, 154, 157 fn
lava 148
ore 150–152, 194
stratified 153–157
unstratified 153, 157, 161
Lodes 157
Ore bodies 157, 159

GEOLOGICAL CLASSIFICATION (*contd.*)—
Rock—
igneous 57, 147, 148, 150 fn
sedimentary 57, 147–149, 149 fn, 151
Seams 152 fn, 153, 155, 156, 161
Veins 150, 150 fn, 151, 152, 152 fn, 153, 157–159, 161, 161 fn
GEOLOGICAL FEATURES—
Anticlines 166
Bosses 148
Dykes 148
Geosynclines 170
Outcrops 152, 152 fn, 155, 155 fn
Sills 148
Glass 66–68
crystal 66, 67
plate 66
waste, *see* Cullet
Glazes—
alkaline 63
boracic 63
felspathic 64
lead 63, 64
salt 65
Glues 69, 97 fn
Gold Standard Systems 53
Greases 125, 275, 275 fn
Grog (pottery) 61, 63, 65
Guard magnets 228 fn
"Gums," *see* Resins 90 fn
Gums, true 115, 115 fn
Gushers 166

Hall marking 55
Hessians 105, 105 fn
HIDES AND SKINS—
Buffalo hides 108, 110, 111
Calfskins 108–110
Cattlehides 108–111
Goatskins 108–111, 335
Hides and skins—
fallen 108
immature 108, 108 fn
limed 339
mature 108, 108 fn
salted 337
Horsehides 108, 110, 111
HIDES AND SKINS (*contd.*)—
Kidskins 108, 109, 111
Kips 109
Lambskins 108–111, 336, 337, 339
Pigskins 108, 110, 111
Sheepskins 108–110, 336, 337, 339
Skins—
de-woolled 339
pickled 336
Splits 108 fn
HIDES AND SKINS, PREPARATORY PROCESSES—
Air-drying 335
Bating 341
Brining 336
Curing 335
De-hairing 336
De-liming 340
De-woolling 336, 337, 339
Drenching 341
Flaying 334
Fleshing 339
Liming 339
Pickling 336, 337
Puering 341
Salting 336
Soaking 337, 338
Sweating 338
Unhairing 339
see also De-hairing
HIDES AND SKINS, STRUCTURE—
Corium 334
Epidermis 334, 337–339
Grain 334, 338
Hyaline 334
Skin, true 196
Hoppers 241, 241 fn
Hydrocarbons 163–165, 195, 261, 262, 284, 285
HYDROCARBONS, CLASSIFICATION—
Hydrocarbons—
closed chain or cyclic 79, 86, 164, 165
open chain or acyclic 79, 164, 165
isomeric 80
normal 79
saturated 164, 164 fn, 165
unsaturated 164, 164 fn, 165

HYDROCARBON RADICALS AND GROUPS—
Alkyls 80–82, 84
Butyl 80
Ethyl 80
Methyl 80
Propyl 80
Butadiene group 92
HYDROCARBON SERIES—
Acetylene series 79
Aliphatic series 79
Anthracene series 79
Aromatic series 79, 165
see also Benzene series
Benzene series 79
Diolefine series 79, 165, 270 fn
Naphthalene series 79
Naphthene series 79, 165, 165 fn, 271
Olefine series 79, 164, 165, 165 fn, 270 fn
Paraffin series 271
HYDROCARBONS, VARIOUS—
Acetylene 72, 92, 93
Anthracene 86, 87
Benzene 86–88, 277, 350
Beta-methyl-butadiene, *see* Isoprene
Butane, normal 80
Ethane 80, 81
Ethylene 92, 277
Iso-butane 80
Isoprene 92
Methane (marsh gas) 24, 79–81, 163 fn, 164, 277
Naphthalene 86, 88, 277, 280 fn
Propane 80
Toluene 89
Hydrogenation, *see under* "Chemical processes" and "Petroleum processing"

Ice, production of 77
Ionisation 258
Ions 73, 230, 257, 281

Kieselguhr 119 fn

Lacquers 90, 116, 118
see also under "Varnishes"
Latex 112, 114, 196, 343–345
Leather 108, 110, 111, 196, 334, 341, 342
bag and case 111
chamois 111
clothing 111
fancy 111
glove 111
harness 111
kid 110 fn
mechanical 111 fn
morocco 111 fn
saddle 111
shoe 110
sole 110
strap 111
strop 111
upholstery 111
upper 110, 110 fn
Lignin 94, 95, 162, 162 fn, 355
Linen 103, 104
Liquefaction (air) 72
Lubricants 119, 123, 124, 126, 127
see also under "Petroleum products"

Margarine 122, 125, 128
Meat 146
Menhaden 126 fn
METALS—
Aluminium 30, 37, 37 fn, 39, 41, 43, 44, 46–48, 70, 150, 150 fn
Antimony 33, 45, 70, 199, 244
Barium 70, 150 fn
Bismuth 244
Cadmium 255 fn
Calcium 70, 145 fn
Chromium 26, 29 fn, 30, 70, 150 fn, 250
Cobalt 26, 70
Copper 30–32, 32 fn, 33, 33 fn, 41, 42, 42 fn, 43–48, 54, 55, 55 fn, 70, 97, 194, 199, 235, 236, 241 fn, 243, 244, 250, 252–254, 258
electrolytic 248, 248 fn
Gold 37 fn, 52, 53, 151, 154, 157 fn, 200, 201, 235, 236, 244
Iridium 56, 56 fn
Iron 24, 26, 27, 33, 44, 70, 72, 145 fn, 150 fn, 199, 242–244

METALS (*contd.*)—
Iron (*contd.*)—
Pig iron 26, 244
Steel 26, 27, 27 fn, 28, 28 fn, 29, 29 fn, 30, 32–34, 36, 38, 39, 42 fn, 77 fn
Wrought iron 26, 27, 251
Lead 30, 33 fn, 35–37, 41–45, 63, 70, 78, 199, 242, 244, 259
chemical 36
Magnesium 30, 37 fn, 39, 41, 47, 70, 145 fn, 150, 255 fn
Manganese 26, 28, 43, 44, 47, 48, 70, 150, 199, 244
Mercury 201, 236, 255 fn
Molybdenum 26, 29, 250
Nickel 26, 29 fn, 39, 41, 44, 47–52, 55 fn, 70, 150 fn, 199, 250, 259
Osmium 56 fn
Palladium 56 fn
Platinum 37 fn, 52, 56, 151, 154, 157 fn
Potassium 70, 145 fn
Rhodium 56 fn
Ruthenium 56 fn
Silver 37 fn, 52, 52 fn, 54–56, 200, 201, 235, 236, 244
British Standard 55
Sodium 70
Spelter, *see* Zinc
Tin 28 fn, 30, 32, 33, 33 fn, 39, 41–46, 151, 154, 194, 199, 242, 254, 259
Titanium 26, 150 fn
Tungsten 30
Vanadium 26, 30, 250
Zinc 28 fn, 30, 33–35, 41–43, 46, 47, 48, 54, 55 fn, 70, 199, 236, 244, 255, 255 fn, 259
METAL ALLOYS—
Alloy steels—
Steels—
copper 29
electrical 29, 30
high-speed 29, 30
manganese 29
nickel 29, 51
nickel-chromium 29, 51
silicon 30
stainless 29, 29 fn, 51
METAL ALLOYS (*contd.*)—
Ferro-alloys—
Ferro-chromium 27
Ferro-manganese 26, 27 fn, 247, 250
Ferro-silicon 27, 27 fn
Ferro-titanium 27
Ferro-vanadium 27
Nickel cast-irons (Ni-Hard, Ni-Resist, Ni-Tensyl) 51
Nickel-chromium-iron alloys 51
Nickel-iron alloys (Invar type alloys, Permalloys) 51
Spiegel 26, 27 fn, 247, 247 fn, 250
Non-ferrous alloys—
Aluminium alloys 46, 47
Anti-friction metals 46
Babbitt metal, *see* White metal
Bell metal 43
Brass(es) 43
see also Copper-zinc alloys
Brass, cartridge 43
Britannia metal 45
Bronze(s) 41, 57
see also Copper-tin alloys
Bronze, phosphor- 42, 42 fn
Bronzes, aluminium-, *see* Copper-aluminium alloys
"Bronzes," manganese- 44
Bronzes, silicon-, *see* Copper-silicon alloys
Copper-aluminium alloys 44
Copper-lead alloys 44
Copper-silicon alloys 44
Copper-tin alloys 41–43
Copper-zinc alloys 43, 44
Dowmetal 47
Duralumin 47
Electron alloys 47, 48
Gun metal 42, 42 fn
Inconel 50
Lead base alloys 45, 46
Magnesium alloys 47, 48
Monel metal 49, 50
Muntz metal 43
Nickel alloys 48–50
Nickel silvers 50
Pewter 33, 33 fn
Phosphor-copper 42 fn
Phosphor-tin 42 fn
Speculum metal 43

METAL ALLOYS (*contd.*)—
Non-ferrous alloys (*contd.*)—
Tin alloys 45
Type metals 46
White metal 45
Zinc alloys 45, 46
METAL CLASSIFICATION—
Metals—
base 37, 37 fn
noble 37 fn, 52
METAL PRODUCTS AND MANUFACTURING PROCESSES—
Aluminium foil 39
Anodised aluminium 37
Anodising 37, 47, 47 fn
Casting—
die 41 fn, 43–46, 48
gravity 41 fn
sand 41 fn, 43, 48
Chromium plating 40
Galvanised sheet 28, 28 fn, 34
Galvanising 34
electro- 34 fn
hot-dip 34 fn
Gold leaf 53
Hot-dipping 34
Nickel-clad steel 40
Nickel plating 40
Pickling 74
Quenching (steel) 123
Rolled gold 54
Sherardising 34fn
Tin foil 33
Tinning 34
Tin-plate 28, 28 fn, 32
METALLURGICAL PLANT—
Anode furnaces 248
Blast-furnaces 24, 26, 27, 27 fn, 237, 240–243
Converters 246, 247
Bessemer 26, 246
Electric furnaces 27, 27 fn, 245 fn, 260
Fore-hearths, *see* settlers
Open hearth furnaces 26, 249
Puddling furnaces 26, 251
Regenerators 249, 250
Reverberatory furnaces 240, 241, 241 fn, 242, 246, 248, 252–254
Settlers 241, 241 fn
Squeezers 252, 252 fn
METALLURGICAL PROCESSES (incl. electro-metallurgical processes)—
Acid process (steel) 246
Alloying (steel) 250
Amalgamation 201, 234, 236
Basic process (steel) 246
Boiling (tin) 254
Briquetting 242
Calcination 237
Cyanidation 235
Distillation 255
Electrolysis and electrolytic processes 234, 256–260
Leaching 200, 201, 234, 235, 238
Liquation 254
Open hearth process (steel) 245, 251
Poling 253
Precipitation 236
Recarburising 247, 250
Refining, electrolytic, *see* Electrolysis
Roast—
oxidising 237
reducing 238
sulphating 238
Roasting 228, 228 fn, 234, 236, 237, 237 fn, 238
continuous 239
fractional 238, 239 fn
Siemens-Martin process 250
Sintering 242
Smelting 24, 26, 26 fn, 27, 199, 200, 234, 237, 237 fn, 240, 242
copper 243
iron 243, 244
Tossing (tin) 254
METALLURGICAL PRODUCTS, INTERMEDIATE—
Anode copper 253, 259
Blister copper 194, 247, 248
Cathode copper 248, 253
Copper matte 194, 244, 247, 248
Muck bars 252
Sinter 240
White metal 248 fn
Milk 97, 97 fn
skim 98
Millboard 107

MINERALS (incl. Ores)—
Alumina 58, 259
Asbestos 59, 117, 157, 161, 211, 229 fn, 330–332
serpentine 330
Bauxite 62, 150, 259
Blende, zinc 74, 255 fn
Chalk 58, 59, 61, 61 fn, 63, 64 fn, 77, 211
Chalk-marl 58
Chromite 62
Clay 57, 58, 60, 61, 61 fn, 62–65, 147 fn, 148, 154, 163, 165, 166, 211, 270, 271, 274
Clays, various—
Ball clays 62, 64, 65
China clays 62, 64, 65, 67, 139, 155
Common clays 61
Fireclays 61
Kaolins 62
Conglomerates 165
Cornish stone 63–65, 65 fn
Cryolite 260
Dolomite 67
Felspar 63, 64, 147, 147 fn, 148, 157
Flint 63–65
Ganister 62
Granite 57, 58, 60, 147, 147 fn, 152 fn
Gravel 59, 147 fn, 151, 154
Grits 165
Gypsum 154
Hematite 228, 238
Ironstone 154, 157
see also Iron ores
Limestone 24, 57–61, 66, 67, 75, 76, 137, 147, 154, 157, 165, 177, 178, 181, 185–187, 242, 333
Limestones, various—
Bath stone 58
Portland stone 58
Loam 61, 61 fn
Magnesite 62, 67, 157
Magnetite 227
Marble 58, 147
Marl 61, 61 fn
Mica 59, 118, 147, 147 fn, 157, 161
Ores 147, 147 fn, 200, 202
MINERALS (incl. Ores) (*contd.*)—
Ores (*contd.*)—
copper 200, 225, 237, 237 fn, 243
gold 200
iron 150, 151, 154, 157 fn, 242, 243
lead 225
silver 200
tin (alluvial) 155
tin (lodes) 200
Phosphate rock 77, 154, 199
Potassium salts 154, 157
Pyrites, iron 74, 137, 157, 163, 237, 238
Quartz 63, 64, 66 fn, 147, 147 fn, 148, 152 fn
Quartzites 62
Salt 148, 154, 157
Sand 58, 59, 61, 62, 147 fn, 151, 154, 163, 165, 177, 179, 181–184
quartzose 66, 67
Sandstone 57, 58, 62, 147, 148, 165, 177, 181, 182, 185
Schist 152 fn
Shale 58, 61, 61 fn, 147, 148, 154, 163, 165, 166, 181
oil 157, 166
Silica 57, 58, 62, 66, 66 fn, 67 fn, 242, 333
Slate 147, 154, 157
Stone 57–60
MINERALS (incl. Ores)—PREPARATION
Classification 198, 216
Closed-circuit working 209, 217, 220
Cobbing 202, 330
Concentration 195, 198, 220
electro-static 229 fn
film 222
pneumatic 229 fn
water 221–224
Crushing 198, 200, 205–211
coarse 200, 205, 208
Crushing, fine, *see* Grinding
intermediate (medium) 200, 205–208
De-watering 229
Filtration 229

MINERALS (incl. Ores)—PREPARATION (*contd.*)—
Flotation—
froth 224–227
sand 203, 286
Grinding 205, 208–211
dry 210, 216
wet 200, 210, 216
Hand-picking (hand-sorting) 198, 201, 330
Magnetic separation 228, 229, 238
Milling 330, 331
Open-circuit working 209 fn
Screening 198, 211–215, 286
Settling 229
Sizing 211
see also Screening
Washing 198, 200, 202–204, 286
MINERALS (incl. Ores).—PREPARATORY PLANT—
Classifiers 216–220
Classifiers, various—
Air classifiers 216, 219, 220
Water classifiers 216–219
hydraulic type 218, 219
mechanical, surface type 217, 218
surface type 217, 218
Crushers—
cone 206
disc 206–208
gyratory 331
see also Cone crushers
jaw 205, 206, 331
Cyclonic collectors 219, 220 fn
Cyclonic separators 219, 220 fn
Dryers 233
Edge runners 210
Filter presses 233
Filters—
continuous disc type 232
continuous drum type 231, 232
Flotation machines—
Agitation machines 226
Sub-aeration type machines 226
Grinding pans 210, 211
Grizzlies 212
Jigs 204, 221
Magnetic separators 228
Mills—
ball 209, 210
beater type 211
MINERALS (incl. Ores)—PREPARATORY PLANT (*contd.*)—
Mills (*contd.*)—
cylinder 209
pebble 209, 210
pendulum 210
ring roller type 210
rod 209
tube, *see* Pebble mills
Rolls 206–208, 331
Screens 212–215, 331, 332
bar type 212
belt 215
overhung revolving 214, 215
revolving (trommels) 214
shaking 213
vibrating 213, 214
Settling tanks 229
Sluices 155, 202, 221
Stamps 206, 208
gravity 208
pneumatic 208
steam 208
Strakes 221
Tables—
concentrating 217, 222, 223
revolving 222
shaking 222, 223
Thickeners 230, 231
Washers 202–204
revolving (trommels) 204
MINING, QUARRYING AND PROSPECTING—
Benches 158
Bord and pillar working 156
Bore-holes 153
Caving 160, 160 fn
Chutes, ore 159, 161 fn
Drifts 155, 155 fn
Goaf 156, 156 fn
Haulageways 158, 159
Headings 154, 158
Hydraulicing 154, 155
Longwall advancing 156
Longwall retreating 156 fn
Manways 160
Milling method 158
Open-cast working (Open-pit working) 158, 161
Overburden 154, 154 fn
Pack-walls 156
Powder holes 154, 158

MINING, QUARRYING AND PROSPECTING (*contd.*)—
Props 160, 160 fn
Quarrying 154
Raises 159, 160
Square sets 160
Stoping—
overhand 159
shrinkage 160
underhand 159
Stopes 159, 160, 161 fn
Stowing 156, 156 fn
Stulls 160, 160 fn
Waste filling 160
Winzes 159, 160
Working districts 155
Working face 155, 160, 161
MINING, QUARRYING AND PROSPECTING EQUIPMENTS—
Drills, diamond 153 fn
Excavators, bucket 154
Shovels, steam or electric 154
Torsion balance 152
Molecules 73, 78, 90, 91, 165 fn, 285
Mortar 58
Moulding powders 117

Neat cattle 108
Newsprint 137

Oil cake 121–125, 349, 350
Oil, recycle 286 fn
Oil wells 167, 176–178
OIL WELLS—DRILLING EQUIPMENTS—
Drills, rotary 166
Oilfields 169–171, 176–189
OILS AND FATS, VEGETABLE AND ANIMAL—
Vegetable oil classification—
Drying oils 119, 120
Non-drying oils 119, 120, 123
Semi-drying oils 120, 122, 123
Vegetable oils and fats, various—
Castor oil 119, 123, 124, 275
China wood oil 120, 121
Coconut oil 120, 123–125
Colza oil, *see* Rape oil
Cottonseed oil 122, 128, 352
Ground nut oil 123, 128
Hemp seed oil 122
Kapok oil 123
OILS AND FATS (*contd.*)—
Vegetable oils and fats (*contd.*)—
Linseed oil 37, 78 fn, 116, 120, 121, 352
Linseed oil, treated—
Boiled linseed oil 120, 121
Stand oil 121
Mustard oil 123
Olive oil 123, 124, 275, 349, 350
Palm kernel oil 123, 125, 349
Palm oil 120, 123, 125, 349
Peanut oil, *see* Ground nut oil
Perilla oil 122
Poppy oil 122
Rape oil 122, 123, 128, 275, 352
Sesame oil 123
Soya bean oil 120, 121, 128
Sunflower oil 122
Tung oil, *see* China wood oil
Walnut oil 122
Animal oils and fats, various—
Butter fat 125
Kidney fat 126
Lard 125, 275
Marine oils 126, 127
Marine oils, various—
Blubber oils 127
Cod-liver oil 126
Dolphin jaw oil 127
Fish oils 126, 128
Fish-liver oils 126
Herring oil 126, 126 fn
Menhaden oil 126, 126 fn
Porpoise jaw oil 127
Salmon oil 126, 126 fn
Sardine oil, 126, 126 fn
Seal oil 127
Shark-liver oil 126
Sperm oil 127, 275, 275 fn
Whale oil 127, 128
Neatsfoot oil 126, 275, 275 fn
Suet 126
Tallow 125, 275
Oils, essential 115, 115 fn
OILS, ESSENTIAL, VARIOUS—
Pine oil 225
Turpentine 78 fn, 116, 117, 196, 348
Oils, fatty, and fats 118–120
see also under "Oils and fats, vegetable and animal"

OILS, FATTY, AND FATS—PREPARATION—
Bleaching 122
Coagulation 352
Decortication (seed) 196, 349
Deodorising 122, 128
Expression 196, 348, 349
Filtering 351
Macerating process 349
Oil hardening 71, 127, 128
Pressing—
hot 349
cold 349
Refining 352
Rendering 348
Settling 351
Softening process 349
Solvent extraction 350
Oils, mineral 118, 119, 123
see also under "Petroleum"
OIL-YIELDING SEEDS AND FRUITS—
Coconuts 124
Copra 124, 349
Cottonseed 119
Ground nuts 119
Linseed 119, 120
Olives 120
Palm kernels 120
Rape seed 119
Soya beans 119
Ores, *see under* "Minerals"
Ore dressing, *see under* "Minerals—Preparation"
ORE DRESSING PRODUCTS AND WASTE—
Concentrates 220–222, 229, 233, 242
Middling 221, 222
Pulp 200, 210, 220, 222, 229, 236
Sand 200, 212, 218, 223
Slime 200, 208, 212, 223
Tailing 221, 222

Paper 133, 134, 137–141, 194
broke 138
manila 106
PAPER-MAKING MATERIALS—
Half-stuffs 138
Wood pulp, *see* special section "Wood pulp"
PAPER-MAKING PLANT AND PROCESSES—
Calenders 141
Couch rolls 141
Dandy-rolls 141
Loading 139
Press-rolls 141
Sand tables 140
Sizing 139, 139 fn
Suction boxes 141
Wire 140
Paints 120, 121, 126
Paints—
aluminium 39
bituminous 34
enamel 121
red lead 37, 78
white lead 37, 78
zinc oxide 35
Patina 31, 31 fn
Peat 162
Petroleum 163–165
PETROLEUM CLASSIFICATION—
Paraffin base 165, 165 fn, 177, 180, 181, 183, 185, 186, 262, 262 fn, 263 fn
Mixed base 165, 177, 179, 181, 182, 186, 262
Naphthene (asphalt) base 165, 165 fn, 177, 177 fn, 180, 183, 185, 262 fn
PETROLEUM PROCESSING—
Acid process (refining) 270, 271
Batch agitation 271
Blending 274
Centrifuging 269
Compounding 262, 275
Contacting and contact process 271, 274
Cracking 266–268
Distillation 195
fractional 261, 263
see also Fractionation
steam 274
"Doctor treatment," *see* Sodium plumbite treatment
Flash-vaporisation 264
Fractionation—
atmospheric 266
steam 266
vacuum 266

PETROLEUM PROCESSING (*contd.*)—
Hypochlorite treatment 273
Re-distillation 274
Skimming, *see* Topping
Soda treatment 271, 272
Sodium plumbite treatment 273
Solvent extraction 263
Sweetening process 273, 274
Topping 261
PETROLEUM PROCESSING PLANT—
Agitators 271
Bubble towers 264
Centrifugal separators 269
Condensers 267
Evaporators 267
Fractionating towers 263–265, 267
Heat exchangers 263, 264
Mixers 272
Orifice columns 272
Reaction chambers 267, 267 fn
Settling tanks 272
Soaking drums 267, 267 fn
Steam stripping columns 265 fn
Stills 263
Tube furnaces 266
stills 263, 264
PETROLEUM PRODUCTS—
Asphalt 25, 165 fn, 180
Bitumen 60, 60 fn
Coke 267, 267 fn
Cylinder oils 25
Diesel oil 23, 25
Fuel oil 23, 25, 261
Gasoline 25, 261, 267 fn, 272
cracked 262, 273–275
natural 274, 275, 275 fn
straight-run 267, 274
Kerosene 25, 261, 271, 271 fn
Lubricating oils 25, 262, 263, 271, 272, 274, 275
Motor spirit (petrol) 23, 275
Naphtha, petroleum 261, 267 fn, 268
Paraffin wax (paraffin) 25, 165 fn, 268, 269
Petrol, *see* Motor spirit
Petroleum jelly 25, 25 fn, 269
"Vaseline" 25 fn
Wax, *see* Paraffin wax
White spirit 78 fn
PETROLEUM PRODUCTS—CHARACTERISTICS—
Anti-knock properties 262, 262 fn, 267, 267 fn, 270 fn, 275
Octane number 262 fn
Viscosity index 263, 263 fn
PETROLEUM PRODUCTS, INTERMEDIATE—
Brightstock 269
Cracked distillate 271, 274
Cylinder stock 262, 269
Lubricant stock 262, 266, 269
Petrolatum 268, 269
Pressed distillate 269
Wax distillate 262, 269
Pigments 90 fn, 117, 139
Plasticiers 90 fn
Pottery 60, 62–65
POTTERY CLASSIFICATION—
Bone china 64
Earthenware 63–65
calcareous 65
coarse 64
English 65
felspathic 65
fine 64
Porcelain, English, *see* Bone china
Porcelains 63, 64
hard 64, 64 fn
soft 64, 64 fn
Stoneware 63, 65
coarse 65
fine 65
Protein 94, 97 fn, 162
Protons 257, 257 fn

Rags 137, 138, 140
cotton 137
linen 137
Resins, natural ("gums") 90 fn, 115, 116, 116 fn, 162, 162 fn, 196
RESINS, NATURAL—CLASSIFICATION—
Balsams 115
Oleo-resins 116, 348
Resins—
gum 115, 115 fn
hard fossil 115, 347
soft 347
true 115
RESINS, NATURAL—PROCESSING—
Gum running 116

RESINS, NATURAL, VARIOUS—
Copals 115
Angola 347
Congo 347
Damar 347
Kauri gum 347
Lac 196, 347, 348
Lac products:
Lac dye 347
Seed lac 347
Shellac 117, 347
Stick-lac 347
Mastic 347
Rosin 116, 196, 347, 348
Sandarac 347
Resins, synthetic 82, 90–92, 117, 118
RESINS, SYNTHETIC—CLASSIFICATION—
Moulding resins 117
thermo-plastic 117
thermo-setting 117
Varnish resins 117
RESINS, SYNTHETIC, VARIOUS—
Acetone-furfural resins 92
Bakelite type resins 91, 117
Coumarone resins 91, 92, 118
Furfural resins 91, 92, 118
Glyptals 91, 92, 118
Phenol-formaldehyde resins 91, 118
Phenol-furfural resins 92
Urea-formaldehyde resins 91, 92, 117, 118
Vinyl resins 91, 92, 118
Retort—
Coalite 279
settings 278
Retorts 236, 236 fn, 255, 278
Rope, *see under* "Fibre products"
Rubber 38, 75, 112–114, 146, 196, 343
Rubber cements 112
RUBBER CLASSIFICATION (raw and manufactured)—
Crepe 194, 196, 343, 345, 346
Rubber—
latex 114
lump 346, 346 fn
raw 112, 112 fn
vulcanised 112, 113
Smoked sheet 194, 196, 343, 345, 346
RUBBER CLASSIFICATION (raw and manufactured) (*contd.*)—
Tree scrap 346, 346 fn
Rubber compound 33
RUBBER PREPARATION—
Anti-coagulants 344
Anti-oxidants 345
Coagulants 196, 343–345
Coagulation process 344
Coagulum 196, 343–345
Drying 346
Maceration process 344, 346
Rolling 345
Smoking 346
RUBBER, SYNTHETIC—
Buna rubbers 93, 114, 115
Buna S 115
Neoprene 93, 114, 115

Sand-blasting 347
Seapages 166, 166 fn, 187
Seeds, *see under* "Oil-yielding seeds and fruits"
Sericin 314, 315
Serum 343, 344, 346
Sheep 109, 146
merino 109
Silver coins 55, 55 fn
Silver Standard 55
Size 116
Skins, *see under* "Hides and skins"
Slag 60, 241–243
acid 251
basic 250
Soap 74–76, 116, 119, 121, 122, 124–128
Solders 45
Solvents 81, 82, 90 fn, 93, 96, 98, 116, 257, 263, 263 fn, 348, 350
Spermaceti 127
Staple 98, 100, 102, 103
Straw 137, 138
Suint 303

Tanning, chromium 337, 341
Tar, *see* Coal-tar
Tarmacadam 60 fn
Thinners 78 fn, 116, 117
see also Diluents
Timber 129, 194
see also Wood
Topmakers 303

TREES—SPECIES—
Cedar, Western red 131
Fir, Douglas 131
Oak 146
Palm 125
Pine 116
Northern (*Pinus sylvestris*) 130
Scots 130
Spruce—
Eastern Canadian 130
European (*Picea excelsa*) 130
Tung 121
Willows 146
Turpentine, *see under* "Essential Oils"
Twine, *see under* "Fibre Products"
Type formula 165, 165 fn

Valency 73, 73 fn, 164 fn, 257 fn
Varnish 116–118, 120, 121, 126
Varnishes, rosin—China wood oil 116 fn, 121
VARNISHES—CLASSIFICATION—
Varnishes—
insulating 117
oil 116
spirit 116, 117
see also Lacquers
Veneers 132, 133
Verdigris 31 fn
Vitamins 97 fn
Voltage 281 fn

Water-marks 141
Wax, sealing 117
Waxes 94, 127, 127 fn, 162, 162 fn, 163
see also under "Petroleum Products"
Whey 98
Wire cloth 212
Wood 94, 197, 352–356
WOOD CLASSIFICATION—
Hardwoods 129, 131–133
Red deal 130
Redwood 130
Soft woods 129–131
White deal 130
Whitewood 130
Yellow deal 130 fn
Wood, dry-weight 353
Wood impregnation 356
WOOD MACHINERY—
Saws—
band 354, 355
circular 354
reciprocating 355
WOOD, MANUFACTURED AND SEMI-MANUFACTURED—
Battens 130, 133, 197
Boards 130, 133, 197
Deals 130, 133
Flooring 129, 130–133
Pitprops 129, 133
Pitwood 133
Planks 130, 133, 197
Plywood 133
Scantlings 133
Ship-decking 129, 133
Sleepers 129, 131, 133
Staves 133
Wood meal 117
WOOD PROCESSING—
Fibre saturation point 353
Seasoning 353
air 353, 354
kiln 353, 354
Wood pulp 71, 75, 133, 194, 197
WOOD PULP CLASSIFICATION—
Pulp—
chemical 134
mechanical 134
mechanical, brown 134
WOOD PULP (CHEMICAL) MANUFACTURE—
Black liquor 135, 136
Cooking liquor 135, 136
Soda process 135, 136
Sulphate process 135, 136
Sulphite process 135–137
WOOD—VARIETIES—
Alder 133
Ash 130, 132, 133
Beech 130, 132
Birch 133
Cedar 129
Western red 131
Chestnut, sweet 130, 132
Ebony 130, 133
Elm 130, 132
Fir 129, 137
Douglas 131
Hickory 130, 132
Jarrah 130, 132, 133

WOOD—VARIETIES (*contd.*)—
Karri 130, 132, 133
Larch 129
Mahogany 130, 132
Maple 130, 132
Oak 130, 130 fn, 131–133
Pine 129, 133, 134, 136
pitch- 130
Poplar 136
Rosewood 130, 133
Sandalwood 130, 133
Spruce 129, 134, 136, 137
Teak 130, 132
WOOD—VARIETIES (*contd.*)—
Walnut 132

X-rays 36, 36 fn

Yarn, *see under* "Fibre Products"
YARN—MEASURES AND TYPES—
Count 100, 103, 306, 306 fn
denier (silk) 101
Warp 101, 106
Weft 101
Yolk 303, 304, 304 fn

B. GEOGRAPHICAL INDEX

Aachen District (Germany) 174
Abadan 186
Akita 188
Amazonas Territory 181
Ancon oilfield 182
Andes Mountains 182
Appalachian Plateau 170
Argentina 171, 175, 176
Arkansas 177
Artem, Island of 183
Asia 168, 169
Asia, Central 184
Asia Minor 169
Aspheron Peninsula 182
Assam 187
Australia 172, 302

Bahama Islands 102
Bahrein 176, 187
Baicoi oilfield 184
Baku 183
Balakhany-Romany-Sabunchi oilfields 183
Balik Papan 189
Barrackpore oilfield 180
Batum 183
Belgium 168, 172, 175, 320
Bengal, Eastern 187
Bibi-Eibat oilfield 183
Binagady oilfield 183
Black Sea 183, 184
Bohemia 168
Boldesti oilfield 184
Bolivia 182
Boryslaw-Tustanowice oilfield 185
Brighton (Trinidad) 180
Brighton oilfield 180
Bristol Area (Great Britain) 173 fn
British Columbia 168
British Malaya 194
Brunei 176, 189
Bucarest 184
Bulgaria 168, 173
Burma 171, 176, 188
Bustenari oilfield 184

Californian oilfields 177, 177 fn
Campina oilfield 184
Canada 130, 170, 172, 173, 176, 194, 331
Cannock Chase 173
Carpathian Mountains 184, 185
Caspian Sea 182, 183
Caucasus Mountains 182
Caucasus Region (U.S.S.R.) 183
Central Germany 174
Ceptura oilfield 184
Cheshire 173
Chile 172, 194
China 54, 121, 168, 172
Chubut Territory (Argentina) 182
Colombia 169 fn, 171, 176
Commodoro Rivadavia 182
Cumberland 173 fn

Danube, River 184
Denmark 175
Derbyshire 173, 154
Dhulian oilfield 187
Donetz Basin (U.S.S.R.) 168, 174
Durham 173, 174
Dutch Borneo 188
Dutch East Indies 176

East Indies 169
Ecuador 169 fn, 171, 176, 181
Egypt 171, 176
Elbe, River 174
El Mene oilfield 179
Emba Region (U.S.S.R.) 183
Erie, Lake 178
Euphrates, River 186 fn, 187
Europe 168, 169, 185

"Faja de Oro," *see* "Golden Lane" oilfields
Ferghana Valley 183
Florida 102 fn
Forest of Dean 173 fn
Formosa, Island of 188
France 168, 171, 172, 175, 315
Fyzabad oilfield 180

Galicia 171

Gefatin, Island of 186
Georgia 102 fn
Germany 114, 115, 169, 171, 172, 174, 175, 176, 185, 284
Giurgiu 184
"Golden Lane" oilfields 178
Great Britain 154, 168, 172, 173, 174, 174 fn, 175, 302 fn
Greece 175
Grozni oilfields 183
Guayaguayare oilfield 180
Gulf Coast oilfields (U.S.A.) 171, 177
Gura Ocnitu oilfield 184

Haft Kel oilfield 186
Haifa 187
Hanover 185
Higashiyama oilfield 188
Hokkaido, Island of 188
Holland 172, 175
Honshiu, Island of 188
Hungary 173
Hurghada oilfield 186
Huron, Lake 178

Illinois 173, 177
India 54, 106, 168, 172, 176, 187
Infantas oilfield 181
Iran 171, 176, 186, 187
Iraq 171, 176, 186, 187
Irrawaddy, River 188
Italy 171, 175

Japan 169, 171, 172, 176, 184 fn
Java 188
Jugo-Slavia 168, 173

Kali oilfield 183
Kansas 177
Kara-Chukkur oilfield 183
Kent 173 fn
Kentucky 173
Khaur oilfield 187
Kirkuk 187

La Brea, Asphalt Lake of 180
La Cira oilfield 181
La Concepcion oilfield 179
La Rosa oilfield 179
Lagunillas oilfield 179
Lancashire 173
Las Cruces oilfield 179
Las Paz oilfield 179
Leicestershire 173
Lincolnshire 154
Lobitos oilfield 181
Lok-Batan oilfield 183
Los Bajos oilfield 180
Louisiana 177
Lower Rhineland 174
Lower Silesia 174
Lvov 185
Lys, River 320

Magdalena Valley (Colombia) 181
Maikop oilfield 183
Manchuria 121, 172
Maracaibo, Lake 179
Masjid-i-Suleiman oilfield 186
Mendoza, Province of 182
Mene Grande oilfield 179
Mexico 171, 176, 178, 179
Mexico, Gulf of 169
Michigan 177
Mid-Continent oilfields (U.S.A.) 177
Mid-Lothian Area (Scotland) 167
Miri oilfield 189
Montana 177
Moreni oilfield 184
Moscow Area (U.S.S.R.) 168
Mosul 187

Naft-i-Shah oilfield 186
Negritos oilfield 181
Neuquen Territory (Argentina) 182
New Mexico 177
New South Wales 168
New York 177
New Zealand 169
Nienhagen Area (Germany) 185
Niitsu oilfield 188
Nishiyama oilfield 188
Northumberland 173
North Wales 173 fn
Norway 175
Nottinghamshire 173

Oceania 169
Oelheim-Eddesse Area (Germany) 185
Ohio 177

Oil Springs oilfield (Canada) 177
Oklahoma 177
Ontario 177
Orinoco Basin 179

Pacific Coast oilfields (U.S.A.) 171
Palestine 187
Palo Seco 180
Palo Seco oilfield 180
Pangkalan Brandan 188
Panuco oilfield 178
Parrylands oilfield 180
Pennsylvania 168, 173, 177
Persian Gulf 186, 187
Peru 169 fn, 171, 176, 181
Petrolia oilfield (Canada) 177
Pladjoe 188
Ploesti 184
Point Fortin oilfield 180
Poland 168, 176
Poza Rica oilfield 178
Punjab 187
Puta oilfield 183

Quiriquire oilfield 179

Ras Gharib 186
Rawalpindi 188
Red Sea 186
Rocky Mountain oilfields (U.S.A.) 170
Roumania 171, 173, 176, 184
Ruhr 168, 174
Russia (U.S.S.R.) 168, 169, 171, 172, 174, 176, 182, 183

Saar 174
S. Gerong 188
Sakhalin, Island of 184, 184 fn
Salta, Province of (Argentina) 182
Santa Elena, Peninsula of 181, 182
Sarawak 176, 189
Saudi Arabia 176, 186
Saxony 174
Scotland 167, 173
Seria oilfield 189
Shatt-al-Arab, River 186, 186 fn
Shropshire 173 fn
Siberia, Eastern 184
Siberia, Northern 169
Singu oilfield 188
Somerset 173 fn
South Africa 168, 302
South America 169, 181, 182
South Carolina 102 fn
South Wales 173
Spain 168, 172
Spitzbergen 169
Staffordshire 173 fn
St. George, Gulf of 182
Suez 186
Suez, Gulf of 186
Sumatra 188
Surakhany oilfield 183
Sweden 168, 175
Switzerland 175
Syria 187

Tabaquite oilfield 180, 181
Tampico 178
Tarakan, Island of 189
Tehuantepec, Isthmus of 178
Texas 177
Tigris, River 186 fn, 187
Tintea oilfield 184
Tjepoe 188
Trinidad 171, 176, 179, 180, 181
Tripoli 187
Turkestan Mountains 184
Turkey 172
Turkomenian Region (U S.S.R.) 183
Turner Valley 178
Tuxpan 178

Union of South Africa 172
United States 107, 114, 126 fn, 168, 169, 170, 172, 173, 175, 176, 177, 194
Upper Silesia 174
Urals (U.S.S.R.) 168, 174

Venezuela 169 fn, 171, 176, 179
Vessigny oilfield 180
Victoria 169
Volga–Ural Region (U.S.S.R.) 183

Warwickshire 173
West Lothian Area (Scotland) 167
West Virginia 173, 177
Wyoming 177

Yenangyoung oilfield 188
Yorkshire 157, 173

C. NAME INDEX

Allen, A. W. 360
Altmayer, M. 360
American Society of Metals 360
Andés, L. E. 364
Armstrong, J. 357
Arnold, J. R. 363

Barker, A. F. 362
Barron, H. 363
Barry, T. H. 364
Bell, H. S. 358
Bell, R. P. 365
Bergius 284
Bevan, E. J. 354
Blanc, E. C. 357
Bone, W. A. 357
Brand, A. 362
Brown, W. B. 362
Bulman, H. F. 357

Camp, J. M. 359
Cansdale, C. H. C. 362
Carter, H. R. 362
Chalmers, T. W. 364
Chamberlain, J. S. 361
Chaudhury, N. C. 362
Clapperton, R. H. 365
Cleaves, H. E. 359
Cousin, A. 361
Crane, W. R. 357
Cross, C. F. 364
Crump, N. E. 360
Cuthill, R. 362

Davidson, W. B. 358
Davies, C. W. 365
Dawson, T. R. 364
Doan, G. E. 359
Dornblatt, A. J. 360
Dorr, J. V. N. 360
Drummond, A. A. 364
Dunstan, A. E. 359
Du Pont de Nemours & Co., Inc. 93 fn, 114

Edwards, J. D. 360
Ellis, C. 361

Emmons, W. H. 359
Escard, J. 359
Eve, A. S. 357

Falkenhagen, H. 365
Farbenindustries, I.G. 284
Flint, C. F. 364
Foltzer, J. 363
Francis, C. B. 359
Frary, F. G. 360
Furlong, J. R. 363
Fyleman, E. 363

Garner, F. H. 359
Gaudin, A. M. 357
Gibson, W. 358
Gluud, W. 358
Gordon, K. 285
Gruse, W. A. 359
Guillet, L. 360
Gurwitsch, L. 359

Haddock, M. H. 357
Haughton, J. Z. 360
Hayward, C. R. 360
Henderson, W. 365
Hess, K. P. 362
Himus, G. W. 357
Hind, J. R. 362
Hodkin, F. W. 361
Hofman, H. O. 360
Hottenroth, V. 363
Howard, A. L. 364
Howling, G. E. 361

Imperial Chemical Industries Ltd. 284, 285
Imperial Institute 361, 363
Institute of Fuel 285
Institute of Petroleum 359
International Geological Congress 358
International Hydrogenation Patents Co. 284
International Labour Office 358

Jeffries, Z. 360
Jenker, A. 358
Jones, A. 361
Julian, H. F. 360

Kalichevsky, A. 358
Keys, D. A. 357
Kilgour, P. 362

Laucks, I. F. 364
Lazarkévitch, N. A. 362
League of Nations 172 fn
Leeuw, H. de 363
Liddell, D. N. 359
Lilley, E. R. 359
Louis, H. 357
Low Temperature Carbonisation Co. Ltd. 279
Luff, D. W. 363

Manchester Guardian 360
Mantell, C. L. 360
Matthews, J. N. 363
Meade, A. 358
Meunier, L. 363
Millikan, R. A. 365
Mitchell, C. A. 364

Naunton, W. J. S. 364
Nelson, W. L. 358
Newman, F. W. 365
Newman, W. A. C. 360

Parry, E. J. 364
Porritt, B. D. 364
Pratt, D. D. 361
Priestman, H. 362
Procter, H. R. 363
Prytherch, W. E. 360

Radcliffe, J. H. 362
Research Association of British Rubber Manufacturers 364
Richardson, C. H. 361
Roberts, J. 358
Rose, T. K. 360
Ross, J. G. 361

Schober, J. 362
Scholes, S. R. 361
Schotz, S. P. 364
Searle, A. B. 361
Shoe and Leather Weekly 363
Skelton, H. J. 359
Smart, E. 360
Smith, H. H. 362
Soc. Nazionale Industria Applicazioni Viscosa 97 fn
Stagner, B. K. 358
Stocks, H. B. 364
Stoughton, B. 359
Sutermeister, E. 365

Taggart, A. F. 357
Taggart, W. S. 362
The Times 360
Thompson, A. B. 359
Thompson, J. G. 359
Thornley, T. 362

Uren, L. C. 358

Vickers, C. 360

Warnes, A. R. 358, 361
Wigginton, R. 357
Woldman, N. E. 360
Woodhouse, T. 362, 363
World Petroleum 176 fn
Wright, C. R. A. 364

Young, G. J. 357