CANADA
DEPARTMENT OF MINES
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MINES BRANCH
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DEVELOPMENT OF CHEMICAL, METALLURGICAL, AND ALLIED INDUSTRIES IN CANADA

IN

RELATION TO THE MINERAL INDUSTRY

BY ALFRED W. G. WILSON, PH.D.

In Two Volumes

VOLUME II

METALLURGICAL AND ALLIED INDUSTRIES

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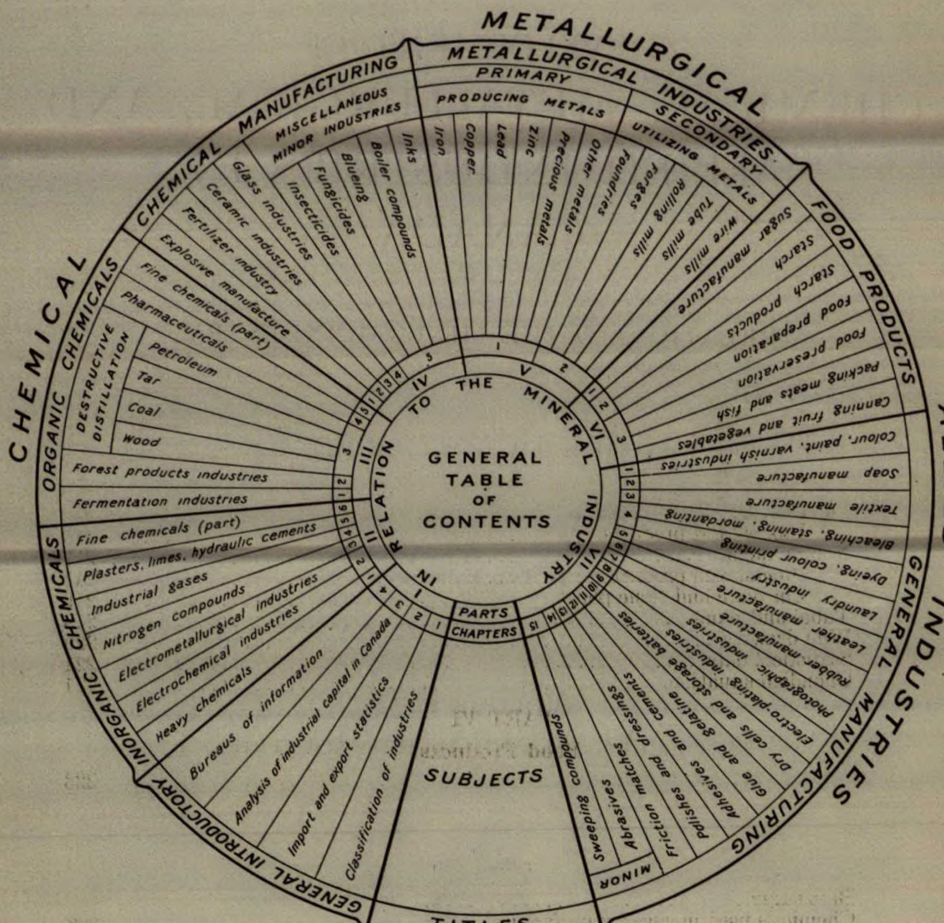
METALLURGICAL
METALLURGICAL INDUSTRIES
PRIMARY
PRODUCING METALS
Iron
Copper
Lead
Zinc
Precious metals
Other metals
SECONDARY
UTILIZING METALS
Foundries
Forges
Rolling mills
Tube mills
Wire mills
FOOD PRODUCTS
Sugar manufacture
Starch
Starch products
Food preparation
Food preservation
Packing meats and fish
Canning fruit and vegetables
ALLIED INDUSTRIES
GENERAL MANUFACTURING
Colour, paint, varnish industries
Soap manufacture
Textile manufacture
Bleaching, staining, mordanting
Dyeing, colour printing
Laundry industry
Leather manufacture
Rubber manufacture
Photographic industries
Electro-plating industries
Dry cells and storage batteries
Glue and gelatine
Adhesives and cements
Polishes and dressings
Friction matches
Abrasives
Sweeping compounds
MINOR
TITLES
SUBJECTS
GENERAL INTRODUCTORY
Classification of industries
Import and export statistics
Analysis of industrial capital in Canada
Bureaus of information
INORGANIC CHEMICALS
Heavy chemicals
Electrochemical industries
Electrometallurgical industries
Nitrogen compounds
Industrial gases
Plasters, limes, hydraulic cements
Fine chemicals (part)
CHEMICAL
ORGANIC CHEMICALS
Fermentation industries
Forest products industries
DESTRUCTIVE DISTILLATION
Wood
Coal
Tar
Petroleum
Pharmaceuticals
Fine chemicals (part)
Explosive manufacture
Fertilizer industry
Ceramic industries
Glass industries
CHEMICAL MANUFACTURING
MISCELLANEOUS MINOR INDUSTRIES
Insecticides
Fungicides
Blueing
Boiler compounds
Inks
GENERAL TABLE OF CONTENTS
RELATION TO THE MINERAL INDUSTRY
I
II
III
IV
V
VI
VII
PARTS
CHAPTERS

Diagram 1

CONTENTS

VOLUME II

PART V

PAGE

Metallurgical Industries

PART VI

Food Products

77921—1½

TABLES

DIAGRAMS

Development of Chemical, Metallurgical, and Allied Industries in Canada in Relation to the Mineral Industry

PART V

METALLURGICAL INDUSTRIES

INTRODUCTORY

Metallurgy, in its broadest sense, is the science of extracting metals from their ores. The raw materials of metallurgy are all products derived from minerals of various kinds. The desired metal is separated from the associated constituents of the appropriate raw materials by the application of chemical and physical processes under suitable conditions. The extracted metallic product, recovered in a more or less pure state, is then ready for fabrication into the several manufactural products for which it is required.

According to the type of process employed, the science of metallurgy can be subdivided into thermo-, hydro-, and electro-metallurgy. Some metals can be extracted from their ores by any one of two or more processes belonging to one or more of these sub-groups. Owing to the industrial importance of iron and its products the metallurgy of this metal and its alloys is sometimes termed ferrous metallurgy, while that of all other metals is grouped under the sub-title non-ferrous metallurgy.

In studying the developments of metallurgy from the industrial point of view two principal types of metallurgical industries are recognized.

The first group embraces all metallurgical industries in which the individual metals extracted are primary products such as iron, copper, lead, zinc, and certain alloys made directly from ores. The second group embraces all metallurgical industries in which metals are treated by metallurgical processes during the course of their fabrication into products useful in the arts. Secondary metallurgical operations would include foundry practice and the production of many alloys such as solder, brass or bronze. The industries engaged in the production of metals in the form of sheets, rods, wires, or tubes, and galvanizing processes may be classed as secondary metallurgical industries.

The present development of the metallurgical industries in Canada may be summarized as follows:

Aluminium is made in one plant only and all ores are imported.

Antimony has been produced irregularly and there is no steady production either of ore or metal.

Cadmium occurs in association with certain zinc ores. Gallium also may be present though it does not appear to have been reported. Cadmium (and gallium if present) is removed from the zinc solutions before eletrolytic treatment, and the residues are discarded. At present there is no commercial production of this metal or its salts.

Calcium could be produced commercially if there were a market demand.

Chromium has not been produced, and one plant which was preparing to produce ferro-chrome has abandoned the enterprise.

Cobalt is made at three plants from native ores.

Copper in the form of blister copper is produced at four plants, and refined copper at two.

Gold is obtained from placer deposits, from free milling quartz ores, and from ores and concentrates of other metals. In 1918, 27·1 per cent of the gold produced in Canada was derived from alluvial deposits, 60·6 per cent was recovered as bullion from milling ores, 8·3 per cent was derived from ores and concentrates of other metals, and 4 per cent was exported in ores and concentrates of other metals sent to foreign metallurgical works. Refined gold is produced only at one plant. The Royal Mint in Ottawa purchases placer gold and bullion for refining purposes. These products are refined for coinage purposes, or for export as refined bars. The Dominion Assay Office functions as a purchasing office only.

Iron in the form of pig iron is made in Canada from both domestic and imported ores. In 1918, 4·4 per cent of the ores used were of domestic origin, while 95·6 per cent were imported.

Lead is produced by two firms from native ores.

Magnesium was produced for a short time by one firm from imported materials. It has also been made from Canadian magnesite.

Manganese is not produced, but a small quantity of spiegeleisen is made by one firm from imported ores.

Molybdenum is not produced in metallic form but ferro-molybdenum has been made from native ores in two plants, both of which are now idle.

Nickel is produced in five plants, one of which uses an electrolytic process. Copper-nickel matte for export is produced at two plants, one of the operators being also a producer of metallic nickel. The ores used are all domestic.

Palladium is found associated with platinum and a small amount is recovered from Canadian mineral products, particularly from the nickel ores of the Sudbury district. Refined palladium will be produced in Canada at one nickel refinery.

Platinum has not been hitherto refined in Canada. A small amount is produced annually from alluvial deposits. A considerable quantity is exported incidentally in copper-nickel mattes. This platinum is recovered from the sludge left in the vats of the electrolytic refineries. One plant in Canada plans to refine its own platinum.

Rhodium occurs in association with palladium and platinum in some of the nickel ores of Sudbury. A small amount is recovered annually from the exported copper-nickel matte produced from these ores. As yet none has been recovered in Canada, except experimentally. It will probably be produced by one nickel refinery.

Silver bullion and refined silver are both produced from native ores. There are two refineries in operation. Bullion is produced at a number of the mines, and also at four independent plants which purchase ores.

In 1918, 76·9 per cent of the silver produced in Canada from native ores was recovered as refined silver or bullion, 3·4 per cent was contained in blister copper and copper matte which was exported, and 19·7 per cent was contained in exported ores.

Tin was produced at one plant for a short time from imported Bolivian ores. This plant is now idle.

Zinc is produced by an electrolytic process at one plant from native ores. Zinc ores are also exported.

CHAPTER I

PRIMARY METALLURGICAL INDUSTRIES

This group of metallurgical industries is engaged in producing metals direct from their ores. As a general rule metals are prepared as intermediate products for use in manufacturing processes. In a very few instances finished products are made direct from the metal as recovered from the ore. Where steel is made by a continuous process direct from ore it may be considered a primary product. Finished iron or steel castings might thus be made of primary metal. Ferro-alloys made from ores by direct process, monel metal made from the cupro-nickel pyrrhotites of the Sudbury district, and ferro-nickel-copper alloys from the same ores by a direct reduction process would all be included in this group.

The following sections briefly review the metallurgy of the principal metals that are or have been produced in Canada from native or imported ores. Reference has been made in each case to the type of ore used, to the process employed, and to the source of supply. The descriptions are each concluded with some general statements on the present Canadian situation.

Statistical information is not given in these sections because annual reports covering Canada's mineral industry are issued by the Dominion Bureau of Statistics. A special table has, however, been prepared in which is shown the average production of certain metals for the three year period prior to the beginning of the war and for an equal period since the armistice.

The recovery of metals from their ores is frequently preceded by special treatment of the natural ores to concentrate the valuable mineral constituents. Concentration of certain classes of minerals is materially helped by the use of certain kinds of chemical reagents. Ore-dressing and treatment thus afford a market for chemical products of certain classes. A list of chemicals that are used for this purpose has been compiled from data supplied by C. S. Parsons of the Mines Branch staff, and is included herewith.

ALUMINIUM

Raw Materials. Metallic aluminium is prepared from aluminium oxide. The principal source of the oxide is the mineral bauxite, a natural hydrate of alumina containing some iron and silica. Commercial bauxite contains 50 to 60 per cent alumina or 26·5 to 31·8 per cent metallic aluminium.

The mineral cryolite, a natural fluoride of sodium and aluminium ($3NaF \cdot AlF_3$), and artificial fluoride of aluminium are also required in the electrolytic process for making the fluid bath in which the electrolysis of the alumina takes place. Alumina is soluble in the fused bath containing these materials. These materials are not themselves a source of the metal during the operation of the process, but they act as solvent for the oxide and form the bath in which the electrolysis takes place. Small mechanical losses are experienced.

Sources. Bauxite is produced chiefly in France and the United States. Deposits have also been discovered in British Guiana and in India. Development of the British Guiana deposits has only just commenced and their extent is not known. A lease on six areas in British Guiana has recently been granted the corporation operating at Shawinigan Falls, Quebec, on condition that within seven years refining works capable of producing 4,000 tons of aluminium per annum will be established in British territory. It is expected that works will be established in eastern Canada, or the plant at Shawinigan will be expanded.

The principal sources of the supply of bauxite at present used in Canada are certain of the southern states. Bauxite or alumina were also imported from France and Germany prior to the war.

Cryolite in commercial quantities is produced at Ivigtut on the west coast of Greenland. The small quantity used in Canada appears to be imported through the United States.

Process. The process employed for making metallic aluminium is a modification of the Hall electrolytic process (U. S. patent No. 400,665).

Remarks. Minerals containing aluminium are very widely distributed. The potash feldspar, orthoclase, contains, when pure, 9·75 per cent in combination with potassium oxide and silica. Pure kaolin, formed by the decomposition of this feldspar, contains about 20·9 per cent, while ordinary glacial clays contain slightly less. Nepheline, an orthosilicate of sodium, potassium, and aluminium, contains 17·6 per cent, and anorthite, calcium aluminium silicate, contains 19·45 per cent of the metal. The mineral corundum when pure contains 52·9 per cent aluminium, being a natural oxide.

Bauxite, the only mineral now used in America as a source of aluminium, has not yet been discovered in commercial quantities in Canada. Prior to the discovery of the processes now used for preparing the oxide from bauxite small quantities of metallic aluminium were prepared by using corundum. This mineral does not occur in sufficient quantity to make it commercially practicable to use it as a source of supply.

Numerous attempts have been made to obtain aluminium commercially from clays. These silicates are difficult to decompose, the operation is costly, and no successful process is yet known to have been developed.

Anorthite, the lime soda feldspar, is more easily decomposed than orthoclase and its derivative kaolin. Attempts are being made to use this material as a source of supply for the oxide of aluminium. If the process, which is now in course of development, proves successful the event will be of great importance to Canada since large areas of rocks containing anorthite are known and local concentrations of this material rich enough to quarry profitably may be discovered. The mineral nepheline is also abundant in certain localities, but no attempt has ever been made to produce nepheline concentrates. There appears to be opportunity here for research.

Commercial Notes. Metallic aluminium as discharged from the furnaces may be cast into ingots for commercial distribution. The secondary products of this industry are castings, sheets, bars, rods, wire, and tubing. The first five products are made in Canada, but tubing is imported. Aluminium is also used to form alloys with other metals, particularly iron, copper, and magnesium. Some of these alloys are made in Canada, others are imported as required. No data on this point are available, though it is known that the majority of alloys required could be made here if the demand warranted.

The industrial uses of aluminium and its products, including the products made from aluminium alloys, are exceedingly numerous and important. The metal is probably equally as important as copper. For many industrial uses the choice of metals depends largely upon the available supply and relative market prices.

Some of the principal industrial uses of this metal or its alloys are for making numerous parts of gasoline engines, motor cars, motor trucks, aeroplanes, and power boats, electric transmission lines, domestic utensils, sheet, pressed metal, stamp work, and in the construction of scientific instruments. It is also used as the basis of a rust-resisting paint, in thermit welding, and to purify molten metals.

ANTIMONY

Raw Materials. The principal ore of antimony is the mineral stibnite, the sulphide (Sb_2S_3), which contains, when pure, 71·4 per cent antimony and 28·6 per cent sulphur.

In addition to antimony ore the production of metallic antimony necessitates the use of fuel (coal, wood, or gas) as a source of heat, coal as a reducing agent, and fusible alkaline materials such as sodium carbonate, sodium chloride, and sodium sulphate which form a fusible slag that floats upon the metal bath. This fused alkaline bath prevents volatilization of the metal and also refines the metal by taking many impurities into solution.

Sources. Stibnite has been produced in Yukon, British Columbia, New Brunswick, and Nova Scotia. The production has always been irregular. Metallic antimony has been produced at the mines near Lake George, New Brunswick, on several occasions, but only intermittently, and the mines are now idle.

Antimony has also been produced as a byproduct of the lead industry in British Columbia. It is probable that some galena ores contain small quantities of stibnite from which this antimony is derived.

Most of the Canadian ore production has been exported. Foreign ores have not been imported for reduction in Canada.

Process. A smelting process using a special type of reverberatory furnace is usually employed for reducing metallic antimony from its ores.

Remarks. Metallic antimony is rarely used alone. In commercial practice it is usually alloyed with other metals, the chief of which are tin, copper, lead, and zinc. There are a large number of alloys made for special purposes in which this metal is used. Only the principal alloys are mentioned here. Most of these are made in Canada from imported metal.

The principal alloys employed in industry are the following:—

Britannia Metal. This is essentially an alloy of tin and antimony with small amounts of copper and occasionally small quantities of zinc, lead, or bismuth. English Britannia metal contains 94 per cent tin, 5 per cent antimony, and 1 per cent copper. The tin content of various alloys of this class varies from 7 to over 90 per cent, the antimony content from 6 to about 70 per cent, the copper from less than 1 per cent to 31 per cent. The other metals are not present in all alloys of this class.

These alloys are used for making spoons, containers of various kinds, and ornamental articles.

Bearing Metals. These alloys contain tin, antimony, and copper, and occasionally lead or zinc. The antimony content varies from 6 to 26 per cent, the copper from 1 to 11 per cent, and the tin from 2 to 85 per cent. In some types of anti-friction metal the lead content may be as high as 88 per cent. The original Babbitt metal contained 7·30 per cent antimony, 89 per cent tin, and 3·7 per cent copper. Magnolia metal contains 16·45 per cent antimony and 83·55 per cent lead.

These alloys are used for making machinery bearings to facilitate smooth operation. The character of the alloy used will depend upon the weight of the parts to be supported and upon the speed of rotation.

Type Metal. These alloys contain antimony, lead, and tin, and occasionally copper. Ordinary type metal contains from 14 to about 30 per cent antimony, 50 to 82 per cent lead, and 3 to 22 per cent tin. Linotype metal usually contains 13·5 per cent antimony, 2 per cent tin, and 84·5 per cent lead. The alloys are used for making type and plates for use in the printing industry.

Hard Lead. Ordinary hard lead contains 22 per cent antimony and 78 per cent lead. The antimony content may, however, vary from 2 to over 50 per cent.

The addition of antimony to lead raises the melting point and increases the hardness, and these alloys are therefore used where a metal is required whose physical properties are similar to lead, but where a greater degree of hardness, a higher melting point, and power to resist corrosive solutions are required. They are used for making utensils or vessels, pipes, stop-cocks, and valves for use in industrial works where certain acid solutions are employed.

Minor Uses. There are a number of alloys of antimony produced which have minor industrial uses. Mention may be made of an alloy with potassium, which, owing to the process of manufacture, also contains free carbon. This alloy is useful for making matches which are moisture proof. An alloy with gold is used for making some grades of jewelry. An alloy consisting of equal parts of copper and antimony has a beautiful violet colour. This alloy, modified by the addition of tin, has certain industrial uses for ornamental work. Alloys of antimony with aluminium are known but do not appear to have been industrially developed.

ARSENIC

Raw Materials. Elemental arsenic is occasionally found native. When made in Canada it was prepared from arsenious oxide (As_2O_3), the oxide in turn being obtained from smaltite ($CoAs_2$) as a byproduct in the production of silver, cobalt, and nickel. The oxide has also been prepared from arsenopyrite (or mismickel) a natural sulph-arsenide of iron ($FeS_2.FeAs_2$). Metallic arsenic can be prepared directly from arsenopyrite, but this does not appear to have been done in Canada.

Sources. Smaltite occurs as one of the group of associated minerals containing silver-nickel and cobalt found in the Cobalt district of Ontario. Arsenopyrite has been mined chiefly in the province of Ontario. It does not appear ever to have been used as a source of elemental arsenic.

Process. Elemental arsenic has been prepared from the oxide by reduction with coal dust in a furnace of special construction, so arranged that the volatilized metal is condensed in a specially arranged retort.

Remarks. The demand for elemental arsenic is small and the industrial uses are few. It appears to be used occasionally for making certain types of alloys.

The only alloy that finds extensive commercial application is the lead alloy used in making shot. The addition of a small amount of arsenic to lead hardens the latter and promotes the formation of spherical drops of molten metal in the shot towers. The alloy is usually made by reducing the oxide in the lead bath by the use of charcoal. Occasionally the red sulphide is used instead of the white oxide.

No information is available with respect to direct industrial uses of metallic arsenic.

Production. A small quantity of metallic arsenic was produced in Canada during the war for special purposes. No records are available as to the quantity produced, and production has ceased.

CALCIUM

Raw Material. Metallic calcium is made by the electrolysis of the fused chloride ($CaCl_2$). Calcium chloride is obtained from the bittern at salt works and by the decomposition of pure limestone with hydrochloric acid. It is also produced as a byproduct in the manufacture of soda ash by the ammonia-soda process.

Source. Limestones are available in Canada if required. At present calcium chloride for this purpose is not produced.

Process. Electrolysis of the fused chloride in special types of furnaces.

Remarks. Metallic calcium makes certain alloys with aluminium and magnesium which may be desirable for special purposes. Little is known about the properties of these alloys and industrial development has not taken place. Metallic calcium is occasionally used as a carbon remover in the purifying of metals or alloys, and it can be used as a reducing agent in organic chemical operations.

COBALT

Raw Materials. Metallic cobalt is recovered as a byproduct from the silver-cobalt-nickel ores of the Cobalt district, Ontario. In these ores the principal cobalt-bearing mineral present is smaltite ($CoAs_2$), the diarsenide of cobalt. Other cobalt-bearing minerals occasionally present in small amounts are erythrite ($Co_3As_2O_8 \cdot 8H_2O$) and cobaltite ($CoAsS$.)

Cobalt is also present in all the pyrrhotite-chalcopyrite ores of the Sudbury district. Formerly a small amount was recovered as a byproduct of the nickel industry. Most of the cobalt present in these ores is lost in the blast furnace slag.

Other raw materials required for the various metallurgical processes in use are coke, coal, or oil for fuel, coke dust or coal dust as reducing agents, limestone and iron ore as fluxes, the hydroxide, chloride, hypochlorite, carbonate, and nitrate of sodium, the carbonate, oxide or hypochlorite of calcium, and sulphuric acid.

Sources. Almost exclusively from the silver-cobalt-nickel ores of the Cobalt district, Ontario. Small quantities of cobaltiferous minerals have been found elsewhere in Canada, especially in British Columbia, but there has been no commercial production.

Processes. The processes employed are complex owing to the complex character of the ore and the commercial importance of the four elements, silver, arsenic, cobalt, and nickel, which these ores contain. Usually both thermometallurgical and hydrometallurgical processes are employed.

Remarks. Metallic cobalt finds its principal industrial application in the manufacture of alloys for the production of tools. Certain cobalt steels for making high speed tools contain cobalt as a principal constituent. It is also alloyed with chromium, tungsten, and occasionally molybdenum to make a series of alloys used in the tool trade. Certain cobalt alloys are used for making resistance elements and thermo-electric couples.

COPPER

Raw Materials. Native copper occurs in Canada in a number of different localities, but it has not been mined in commercial quantities. Minerals containing copper as an essential constituent occur in many places throughout Canada. The ores of present commercial importance are the sulphides; carbonates and oxides also occur, usually in association with sulphide deposits, but they are relatively of minor importance. The two sulphides, chalcopyrite ($CuFeS_2$) and bornite (Cu_3FeS_3), are the most important; locally chalcocite (Cu_2S) is also found occasionally.

Sources. Copper sulphide minerals have been found at a number of localities in Nova Scotia, but no important producing mines have been developed. In New Brunswick also, no ore bodies of known commercial importance have been discovered, although small deposits have been found in a number of localities in the southern part of the province.

In Quebec, particularly in the Eastern Townships, numerous occurrences of sulphide minerals have been discovered during the past seventy-five years. Some of these discoveries were important enough to warrant explorations and commercial development, and many small mines have been in operation for varying periods of time. The most important producing district occurs in the vicinity of Sherbrooke. In 1918 there were four active mines in this district, one of which had been in almost continuous operation for about 35 years, but these mines have since been closed. There are a number of other properties that appear to be worthy of further investigation. The ores from three of the active mines were almost pure pyrites containing some chalcopyrite, and occasionally a little chalcocite. The sulphur content of the ore, which averages over 40 per cent, was utilized for the manufacture of sulphuric acid, and the copper was then recovered from the cinder residues of the acid works by treatment with the ores in a blast furnace. The ore from the fourth property was concentrated and sold for its copper content only. All the ores contain small amounts of gold and silver. All these ores were exported for treatment.

In Ontario copper-bearing minerals occur in five districts—North Hastings, chalcopyrite in association with pyrites; Parry Sound, bornite and chalcopyrite in small pockets; Sudbury, chiefly chalcopyrite in association with pyrrhotite and nickel sulphides; north shore of lake Huron, comprising a belt about 40 miles wide between Sudbury and lake Superior, chalcopyrite associated with quartz; west of Port Arthur, chalcopyrite and pyrites. Commercial production comes almost entirely from the pyrrhotite ores of the Sudbury district where copper-nickel mattes are produced in three plants. These mattes are subsequently treated elsewhere for the recovery of their valuable constituents.

British Columbia is at present the principal copper-producing province of the Dominion of Canada. The important copper-bearing minerals produced are usually chalcopyrite or bornite or both. These may occur alone, but usually they are found in association with other minerals, the commonest of which are pyrrhotite, magnetite, pyrite, mispickel, and occasionally blende and galena. The principal districts in which important discoveries have been made are in southern British Columbia in the West Kootenay and Kamloops district, and in the coast district at a number of points along the mainland, and on Vancouver Island, and on some of the coastal islands. The most important active producing mines are at Rossland, and near Princeton in the interior, and at Britannia on Howe Sound, Texada, and Anyox on the coast.

There is one copper smelting plant in operation in British Columbia and two are idle. Formerly there were five plants two of which produced a low grade matte (about 33—36 per cent copper) that was shipped to foreign refineries while three of them produced blister copper (95—98 per cent pure) which was shipped to foreign refineries for the recovery of the contained copper and precious metals. At the time of writing the plant at Trail, B.C., owns a copper refinery which is idle, and the plant at Anyox produces blister copper which is shipped to the United States for refining. A certain proportion of the copper ores produced in British Columbia is exported for treatment either as ore or as concentrates.

There is one copper refinery ready for operation at Trail, B.C., and another has been built at Deschenes, Quebec, to treat copper-nickel mattes produced at the works of the British America Nickel Corporation at Nickelton, Ontario.

At the present time only a very small proportion of the copper ores treated in Canada is imported.

Processes. Lean ores are subjected to a preliminary treatment by water concentration or oil flotation. Rich ores and concentrates are smelted in blast furnaces to produce a matte containing 30 per cent or more of copper. These mattes are converted into blister copper in basic converters. Blister copper is refined eletrolytically.

Remarks. The Canadian situation with respect to the production and consumption of copper and copper products is very clearly demonstrated by the following statistical data. In the year 1918 the total production of copper credited to Canadian mines was 118,769,434 pounds. Only 6·45 per cent of this was refined or recovered in Canada (7,616,339 pounds as metallic copper, 44,241 pounds as copper sulphate); 22·26 per cent (26,446,534 pounds) was exported in ore and concentrates and recovered in foreign plants; 39·58 per cent (46,964,651 pounds) was exported in copper-nickel matte for foreign refining; 31·74 per cent (37,696,668 pounds) was contained in blister copper that was exported for refining.

Prior to 1916 no refined copper was produced in Canada. On the contrary, the whole of our copper production was exported for refining, and we imported copper products in manufactured form. At present the total refinery capacity available, or soon to be available, will be between twenty-five and thirty million pounds per annum. About one-third of this capacity is located in British Columbia, which produces nearly two-thirds of the copper, and about two-thirds is located in Ontario and Quebec.

At the present time our total annual requirements of manufactured copper products (bars, rods, wire, tubes, and sheets, but excluding brass) is about forty million pounds. Some of these products are now made in this country, though most of them are still imported.

GOLD

Raw Materials. Metallic gold occurs native in alluvial gravels and in free milling quartz ores. It also occurs associated with ores of other metals, more commonly copper and nickel.

The accessory materials used in the production of gold naturally depend upon the process employed. The principal substances are mercury for amalgamation; sodium cyanide or chlorine in hydrometallurgical processes; metallurgical coke and certain fluxes in smelting processes; and sulphuric acid, iron sulphate, and borax.

Sources. Alluvial deposits containing gold in nugget form are worked in Quebec, British Columbia, and Yukon. Free milling ores containing gold are mined in Nova Scotia, Ontario, Manitoba, British Columbia, and Yukon. Ores of other metals which also contain recoverable amounts of gold are mined in Nova Scotia, Quebec, Ontario, Manitoba, British Columbia, and Yukon.

Processes. Alluvial gold is recovered by washing. Free milling gold is usually recovered by a process of crushing, washing, and amalgamating, or by the use of certain hydrometallurgical processes after crushing and concentrating. Gold in association with the base metals is usually recovered by a smelting process followed by electrolytic treatment and refining.

Remarks. Gold is received by the Dominion Assay Office in Vancouver and by the Royal Mint at Ottawa direct from the producer in the forms of nuggets and dust, amalgamated with mercury, or as bullion. During the last few years at least 560 properties in Canada have produced some gold, about 275 of these being producers of alluvial dust and nuggets. One hundred and forty-seven produced chiefly free milling ores, and in 138 the gold was recovered in association with baser metals. All of these properties were not producing gold at the same time in any one year, and the production of the larger number is irregular.

There are two refining plants in Canada, one at Trail, B.C., operated by the Consolidated Mining and Smelting Company of Canada, Limited, and one at the Royal Mint in Ottawa, Ontario. The former plant refines gold recovered from ores produced by the owner's mines or purchased as custom ores. The latter mentioned plant refines gold procured through the Dominion Assay Office in Vancouver or purchased as bullion direct from producers. A considerable proportion of the Canadian gold production is exported in the form of dust, nuggets, or bullion. Canada also imports a small amount as bullion or in coins, or in manufactured articles.

IRON

Raw Materials. The principal commercial ores of iron are, in order of their importance, hematite, magnetite, and limonite. The first two minerals are oxides of iron containing, when pure, 70 per cent and 77·7 per cent iron respectively; the last named is a hydroxide containing, when pure, 59·8 per cent iron. Commercial hematites usually contain from 55 per cent to 68 per cent iron.

The principal accessory materials used in the iron industry are coke for reducing purposes and limestone as a flux. Small quantities of other materials such as silica and fluorspar are occasionally required as fluxes. The construction and maintenance of the furnaces in which the metallurgical operations are performed require large quantities of refractories, both acid and basic, such as ganister, fire brick, magnesite, magnesite brick, and dolomite.

Sources. Although iron ores are widely distributed in Canada, the iron and steel industry has been developed, to a very large extent, upon imported ores, native ores being usually of too low a grade for use in present commercial practice.

The home production comes chiefly from Ontario, with smaller tonnages from Quebec and British Columbia. Iron ores are imported from Minnesota, northern Michigan, and from Bell Island, Newfoundland.

Processes. Pig iron, the crude product of the iron industry, is produced from the natural ores by suitable treatment in iron blast furnaces. Small quantities of pig iron have also been produced from scrap iron and scrap steel, and more rarely directly from ores in electric furnaces. Steel is made chiefly from pig iron, but there is also a considerable production from iron scrap.

Remarks. The total production of iron ore from Canadian mines was 211,608 short tons in 1918. Only 93,136 tons were sold to Canadian furnaces and the balance, 118,472 tons, was shipped to the United States. During the same period 754,622 tons of ore were imported from Newfoundland and 1,392,373 tons came from the lake region of the United States. The Statistical Division of the Mines Branch estimated that since 1886 the total quantity of native ores mined has been 6,186,387 tons. Only 3,952,331 tons of native ore have been charged to Canadian blast furnaces during this interval, or 14·3 per cent of the total amount charged. The rest of the native ores mined, 2,234,056 tons, allowing for a small local consumption in other industries requiring iron ore, was exported, chiefly to the United States. Since 1886 the total amount of imported ores charged into Canadian blast furnaces is estimated to be 23,640,120 tons, or 85·7 per cent of the whole. The records for 1896, the earliest available for comparison purposes, show Canadian iron furnaces using 67·6 per cent native ores and 32·4 per cent of imported. The percentage amount of imported ores used has gradually increased during the last 23 years, with corresponding diminution of the percentage of native ores charged, until in 1918 it was 95·8 per cent. In recent years it has been even higher. In short the use of native iron ores in our blast furnaces is rapidly approaching the vanishing point.

A reference to the tables of imports published by the Dominion Bureau of Statistics will show that in addition to large imports of foreign ore for the production of iron and steel products, we also import a large tonnage of iron and steel in manufactured forms.

With respect to the principal accessory supplies used by this industry it may be noted that in 1918 a total of 1,422,657 tons of coke was required, of which 561,135 tons or 39·4 per cent was made from native coals, and the balance, 861,522 tons (60·6 per cent), was imported. The total weight of limestone required for fluxing purposes was 755,660 tons, most of which was of native origin, though some of this was also imported.

The dependence of the Canadian iron industry upon foreign sources of supply for nearly all the iron ores required, for a large portion of the fuel, and for some of the limestone is due to natural conditions. The iron ore deposits of this country, so far as they are known, are on the whole of too low grade to compete with foreign ores in the present markets. The use of foreign fuels is due chiefly to geographic limitations and to physiographic conditions which have influenced both the distribution of population and the location of certain iron and steel works.

Commercial Notes. An attempt has been made to compile some general statistics to present a comprehensive view of the present development of this industry in Canada. The generalized statements with respect to monthly capacities of certain types of equipment, as given below, must be accepted as approximations and must be used with caution. The rated capacity of any type of furnace and the actual production under varying labour conditions and different types of operators are often widely different. Operating and market conditions also vary greatly from time to time and make it necessary to reduce or augment the production of any given furnace. It would be possible to greatly increase the output of this industry beyond present requirements without serious alterations or additions to present equipment.

The present equipment of the Canadian Iron and Steel industry is as follows:—

Blast furnaces—19, rated capacity 4,800 tons of ore per day, exclusive of fuel and fluxes.

Basic open hearth steel furnaces—45, ranging in size from 18 tons to 80 tons per heat. The combined monthly capacity is approximately 120,000 tons of steel.

Acid open hearth steel furnaces—30, ranging in size from 10 tons to 25 tons per heat. The combined monthly capacity is approximately 51,000 tons of steel.

Basic bessemer converters—3 of 15 tons capacity and 1 of 20 tons.

Acid converters—several types, 11 in all, combined capacity approximately 2,100 tons of steel monthly. Nine of these converters are of two tons capacity, and the remaining two are of one, and one and a half tons capacity each per heat.

Crucible steel furnaces—7, combined capacity for 90 pots, approximate monthly capacity for production 540 tons.

Electric furnaces for steel—36, total rated capacity per heat 175 tons, approximate monthly capacity for production 20,000 tons. These furnaces range in rated capacity from one ton per heat to seven tons.

Electric furnaces for low phosphorus pig iron—10, total rated capacity per heat 40 tons, approximate monthly capacity for production 3,000 tons. These furnaces range in rated capacity from half a ton per heat to six tons.

The total monthly capacity for steel production of all kinds is approximately 200,000 tons, or 2,000,000 tons per annum. The actual production in 1918 was 1,873,708 tons, as compared with 1,745,734 tons in 1917 and 828,641 tons in 1914. The average production for the five-year period 1909 to 1914 was 931,999 tons per annum.

Products. It is impracticable to give an extensive review of the industrial applications of iron and steel, or even to mention all the products of this industry within the limits of this report. Brief reference is made only to the primary and to the principal secondary products of manufacture.

The successive stages in the progress of iron through the various processes and machines by which it is separated from the undesirable constituents of the ore and converted into finished products are briefly as follows:—

Treatment in the blast furnace with coke and fluxes to produce pig iron. The pig iron is treated in special types of furnaces, and by special processes to produce the following principal varieties of products: Wrought iron, Bessemer steel, Acid Open Hearth steel, Basic Open Hearth steel, Crucible steel, Electric steel, Cast iron, Malleable iron, Special steels.

The primary commercial product of the iron industry is blast furnace pig iron. Molten iron from the furnaces is run into a series of open topped sand moulds, so arranged that the metal is cast into a number of oblong masses of metal. These bars are usually of a weight (28 lbs.) convenient for handling. Where operations for the manufacture of steel are being conducted on a large scale the molten iron from the blast furnaces is utilized directly for subsequent operations, without being permitted to cool.

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IRON INDUSTRY

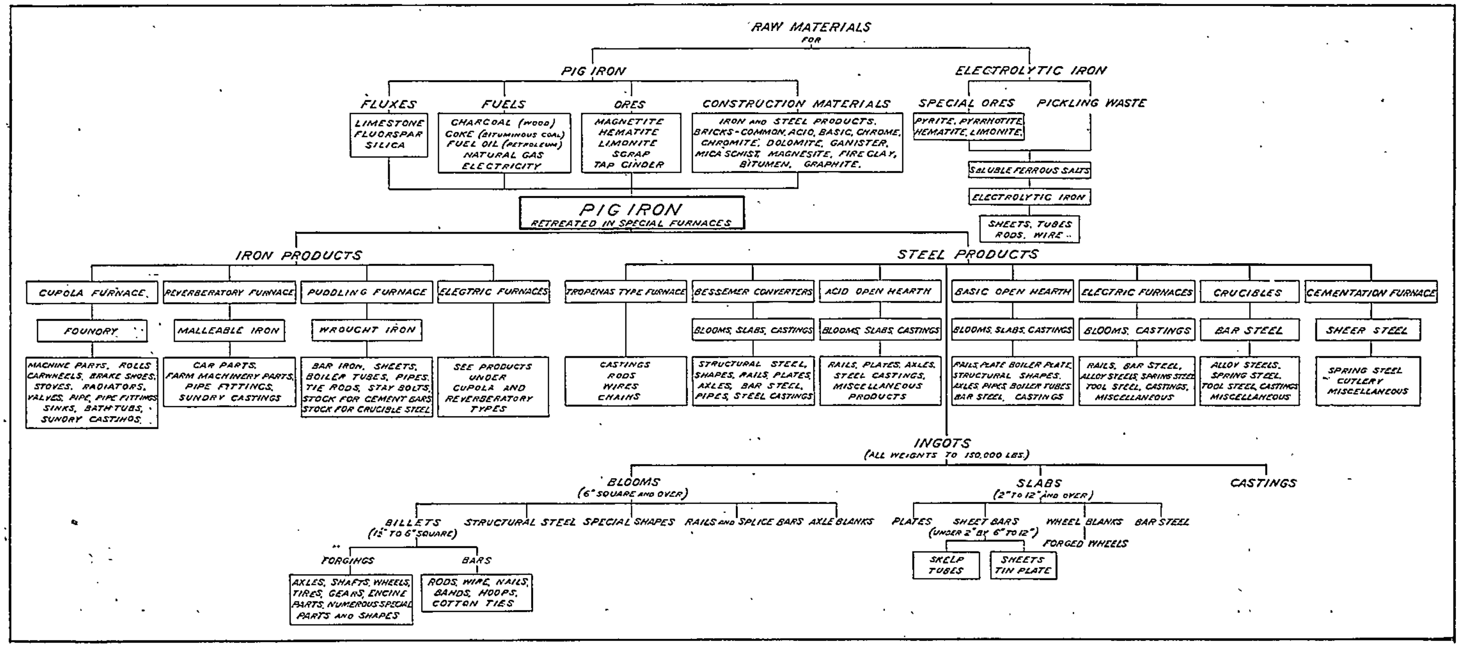


Diagram 11

The primary commercial product of the steel industry is the steel ingot. Ingots vary from a few pounds to over 75 tons in weight each, the size depending upon the purpose to which the steel is to be applied.

The principal products of the iron and steel industry and the principal processes through which they pass during fabrication are discussed at more length in the chapter on secondary metallurgical operations.

LEAD

Raw Materials. The principal lead ore mined in Canada is galena (PbS), which contains, when pure, 86·6 per cent lead. Small quantities of the carbonate, cerussite ($PbCO_3$), and the sulphate, anglesite ($PbSO_4$), are also mined occasionally. Lead ores from western Canada are almost always argentiferous, and are very frequently associated with sphalerite (zinc sulphide).

Sources. Argentiferous galena has been found in Nova Scotia, in New Brunswick, and in Quebec, but no important commercial production has followed. Small quantities of lead ores have been mined in central Ontario at irregular intervals, and one mine and smelter are in operation. The principal lead-producing area of Canada is the Kootenay district in southern British Columbia, and during recent years there has been some production from the northern part of the province. Lead ores also occur in Yukon. Occasionally lead ores have been imported from the western United States.

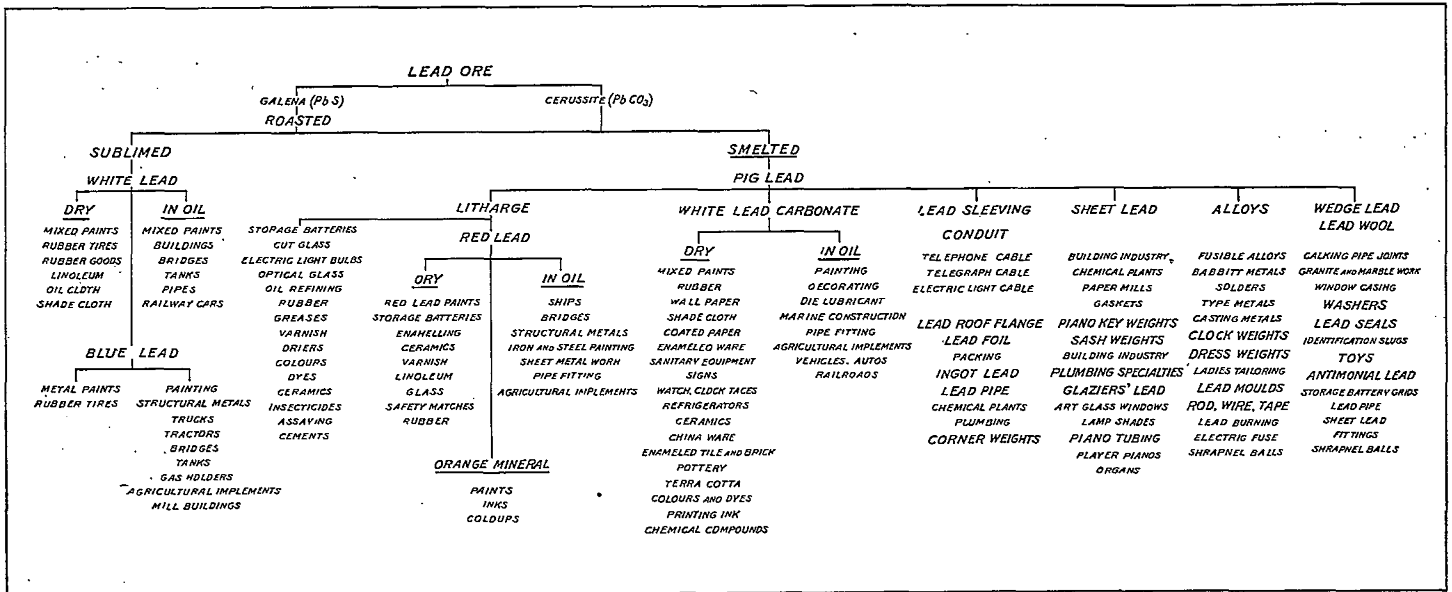
Process. One Scotch hearth, 18-ton capacity, is in operation in Ontario. Another plant, comprising a 30-ton water-jacketed blast furnace and two 10-ton open hearth furnaces, also located in Ontario, is at present idle. In British Columbia a large blast furnace plant and an electrolytic lead refinery are in operation at Trail.

Commercial Notes. Lead is used extensively in the form of sheets and pipe. It alloys readily with tin, antimony, bismuth, silver, and gold. The industrial uses of this metal, its alloys, and products are numerous and important.

MAGNESIUM

Raw Materials. Minerals containing magnesium are very widespread, though not so abundant as those containing calcium. The most abundant minerals are magnesite ($MgCO_3$), the carbonate; dolomite ($CaCO_3 \cdot MgCO_3$), a double carbonate of magnesium and calcium; and certain magnesium silicates such as serpentine, talc, soapstone, meerschaum, and hornblende. Soluble salts of the metal occur in many saline springs and alkaline lakes. The principal soluble salt found is the sulphate, epsomite ($MgSO_4 \cdot 7H_2O$). Kainite, a natural mineral, contains the sulphate in association with potassium chloride ($MgSO_4 \cdot KCl \cdot 3H_2O$). Kieserite, a sulphate ($MgSO_4 \cdot H_2O$), and carnallite, a double chloride ($KCl \cdot MgCl_2 \cdot 6H_2O$), also occur. The magnesium compounds are found in many soils and are formed from the decomposition of minerals containing this element.

INDUSTRIAL USES OF LEAD



Adapted from a commercial advertisement of the Eagle-Picher Lead Company

Diagram 12

CHEMICAL COMPOUNDS OF LEAD

ACETATE	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	MEDICINE, SALTS, DYEING, PRINTING COTTON, VARNISHES
ACETATE, MONOBASIC	$Pb_2O(CH_3COO)_2$	MEDICINE, SALTS, ANALYTICAL CHEMISTRY
ACETATE, TRIBASIC	$Pb(C_2H_3O_2)_2 \cdot 2PbO \cdot H_2O$	WEIGHTING SILK, TEXTILE PRINTING
ANTIMONATE	$Pb_3(SbO_4)_2$ (NAPLES YELLOW)	PIGMENT, STAINING GLASS, CROCKERY, AND PORCELAIN
ARSENATE	$Pb_3(AsO_4)_2$	INSECTICIDE
BORATE	$Pb(BO_2)_2 \cdot H_2O$	VARNISH AND PAINT DRIER
CARBONATE	$PbCO_3$	PIGMENT
CARBONATE, BASIC	$2PbCO_3 \cdot Pb(OH)_2$	PIGMENT, PUTTY
CHLORIDE	$PbCl_2$	PREPARATION OF OTHER SALTS
CHROMATE	$PbCrO_4$ (LEIPZIG YELLOW)	PIGMENT
CYANIDE	$Pb(CN)_2$	METALLURGY
HYDROXIDE	$2PbO \cdot H_2O$	LEAD SALTS
IODIDE	PbI_2	MEDICINE, BRAZING, MOSAIC GOLD, PRINTING, PHOTOGRAPHY
LINOLEATE	$Pb(C_{18}H_{31}O_2)_2$	MEDICINE, VARNISH
MOLYBDATE	$PbMoO_4$	ANALYTICAL CHEMISTRY
BETA NAPHTHALENESULPHONATE	$Pb(C_{10}H_7SO_3)_2$	ORGANIC PREPARATIONS
NITRATE	$Pb(NO_3)_2$	MEDICINE, SALTS, MORDANT IN DYEING, AND PRINTING CALICO, AND STAINING MOTHER OF PEARL, OXIDIZER IN DYESTUFF INDUSTRY, MATCHES, PIGMENT, SENSITIZER
OLEATE	$Pb(C_{18}H_{33}O_2)_2$	VARNISHES, LACQUERS, DRIER
OXIDE, BROWN	PbO_2	MEDICINE, OXIDIZER
OXIDE, RED	Pb_3O_4	MEDICINE, CERAMICS, CERAMIC CEMENTS, MATCHES, RED PENCILS, PIGMENT, LEAD PEROXIDE
OXIDE, YELLOW	PbO (LITHARGE)	MEDICINE, CERAMICS, CERAMIC CEMENTS, METALLURGY, LUTES, PIGMENTS, VARNISHES, RUBBER, ACID RESISTING CEMENT
PHENATE	$Pb(OH)OC_6H_5$	MEDICINE
RESINATE	$Pb(C_{20}H_{29}O_2)_2$	DRIER IN PAINT AND VARNISH
SESQUIOXIDE	Pb_2O_3	MEDICINE, CERAMICS, CERAMIC CEMENTS, METALLURGY, PIGMENT, VARNISHES
SILICATE	$PbSiO_3$	CERAMICS, FIREPROOFING FABRICS
STEARATE	$Pb(C_{18}H_{35}O_2)_2$	DRIER IN VARNISH AND LACQUER
SULPHATE	$PbSO_4$	PIGMENT
SULPHIDE	PbS	CERAMICS, METALLIC LEAD
TETRACHLORIDE	$PbCl_4$	CHEMICALS
THIOSULPHATE	PbS_2O_3	MATCHES
TUNGSTATE	$PbWO_4$	PIGMENT
FLUOSILICATE	$PbSiF_6$	ELECTROLYTE

Table 18

Sources. The principal Canadian sources of supply of the element and its compounds will be found in natural deposits of magnesite and epsomite. The former are found in Quebec and British Columbia, while the latter occur in Saskatchewan, Alberta, and British Columbia. Magnesium chloride also occurs in the residual liquors after the extraction of salt from brine. So far as known none is prepared from this source in Canada, but chloride prepared in this way has been imported from time to time for the production of metallic magnesium.

Processes. Metallic magnesium can be prepared from the oxide, the chloride, or from one of the double chlorides. It has been made of a low grade of purity by direct reduction of the oxide. A process for producing the metal by electrolysis of the dissolved oxide is in course of development. Commercially the metal has been produced by the electrolysis of the fused chloride, or one of the double chlorides (usually $MgCl_2 \cdot KCl$). It is also produced by decomposing the chloride with metallic sodium.

In Canada the process formerly in use was an electrolytic one in which the fused chloride forms the electrolyte. Magnesium chloride for this purpose has been imported. It could also be prepared from native magnesite by treatment with hydrochloric acid.

Remarks. The principal uses of this metal are for forming alloys with aluminium or with aluminium and small quantities of such other metals as copper, nickel, zinc, lead, antimony, or bismuth, or for scavenging alloys. This latter use depends upon the ease with which magnesium reacts with oxygen and nitrogen. When metallic magnesium is added by suitable means to a bath of a molten material, such as aluminium, brass, bronze, copper, or nickel, it quickly cleans up the oxides of these metals present in the bath, rendering the resulting product cleaner, denser, more homogeneous throughout, and therefore stronger and tougher. It is also used in a similar way in the production of special steels.

Another important use is in artificial illumination. The use in photographic flash lights is well known. Its use for star bombs, flare lights, and shell trailers was greatly increased during the war.

Magnesium is about one-third lighter than aluminium, with which it can be alloyed to produce a metal of much higher tensile strength. This alloy makes excellent castings and can be machined easily. The skeleton of the British air-ship R. 34S and the gaffs of the yacht Resolute were made of alloys of magnesium and aluminium. A similar alloy was used for making the pistons and connecting rods in Italian airplane engines and automobiles. The Dow Chemical Company, Midland, Michigan, have recently introduced an alloy of this type said to contain about 90 per cent magnesium, having a specific gravity of 1·79 while possessing a tensile strength between 22,000 and 25,000 pounds per square inch. It is probable that the future may see extended use of these alloys as substitutes for aluminium in electric conductors, in aeroplane and dirigible parts, and in engine construction. Cheap production on a large scale will render this metal a serious competitor of aluminium and copper in certain fields.

Magnesium is at present prepared for the market in three forms, as a silvery powder or a grey granular material for flashlights and use in chemical laboratories, as a ribbon for flashlights, marine signalling, and in chemical laboratories, and in sticks or short rods which are circular or square in section. Magnesium sticks are used in alloys, as a deoxidizing agent or as a constituent, as a dehydrating agent, and as electrodes in special electrolytic operations.

Production. Metallic magnesium was first produced in Canada on a commercial scale in 1917. Production has been intermittent and the total amount made is small. There is only one plant in Canada for producing metallic magnesium and this is idle at the present time. Statistics of production are not published.

MANGANESE

Raw Materials. The principal ores of manganese are pyrolusite (MnO_2), manganite ($Mn_2O_3 \cdot H_2O$), psilomelane, wad or bog manganese, a hydrated manganese oxide. Manganese is also found occasionally in association with zinc ores and with certain iron ores.

Sources. Manganese oxides and hydrates are mined at irregular intervals at a number of points in Nova Scotia and in New Brunswick. They are also found in British Columbia. The greater portion of the manganese ores that have been produced in eastern Canada were exported.

The manganese required by the Canadian steel industry is imported either in the form of ferro-manganese, or spiegeleisen, chiefly from the United States. A small quantity of manganese ore has also been imported from time to time for the production of spiegeleisen.

Process. Spiegeleisen, which is practically a pig iron very high in manganese, is made in an ordinary iron blast furnace. Ferro-manganese, which usually contains a high percentage of manganese and relatively little iron, is usually made in the electric furnace, when it is high in carbon, or by the thermit process, when the carbon content can be kept low.

Silico-manganese is also made in the electric furnace. Metallic manganese can be made in electric furnaces by reduction of the oxide with carbon, or by the thermit process, the latter process producing a metal practically free from carbon.

Remarks. Manganese finds its principal industrial application in the manufacture of steel, where it acts as a deoxidizer and recarburizer of the molten metal, making it possible to produce clean sound ingots. It also imparts certain desirable qualities to the steel, the presence of small quantities (0·4 to 0·8 per cent) rendering steel easier to work and increasing the tensile strength. When used in larger quantities (10 to 15 per cent) the steel produced possesses certain special qualities of toughness without brittleness, and strength which makes the steel desirable for certain industrial uses. The quantity of special manganese steels of this type which are made is small in comparison with the tonnages of low manganese steels.

Only small quantities of metallic manganese are produced (none in Canada) because the pure metal has few industrial uses. Manganese bronzes—which offer a high resistance to corrosion and which have considerable strength—are becoming increasingly important in marine construction and in the construction of mine pumps and other machinery. These bronzes are essentially copper-zinc alloys to which a small quantity of manganese has been added.

Manganese ores are also used as oxidizing agents in dry-cell batteries; for decolorizing glass; for the production of driers in the paint and varnish industry; occasionally for the preparation of oxygen; and in the manufacture of disinfectants. They are used to impart colour to glass, and to glazes used in the production of pottery, tiles and bricks. They are also used to a slight extent in the dyeing industry and in the printing of calico. The quantity of ores consumed in these industries is very small in comparison with that required in the steel industry.

MOLYBDENUM

Raw Materials. The principal ore of molybdenum found in Canada is molybdenite (MoS_2). This material is also the principal source of the world's supply of this metal. Wulfenite, a molybdate of lead ($PbMoO_4$), is also produced in commercial quantities in some localities.

The two principal accessory materials used in the production of molybdenum or ferro-molybdenum are carbon and limestone. Heat is usually obtained from electric power, while in one process it is obtained by promoting certain chemical reactions.

Sources. Molybdenite has been reported from the provinces of Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, British Columbia, and Yukon. Commercial production has taken place in Quebec, Ontario, and British Columbia, the largest output having been from Quebec.

Processes. Metallic molybdenum is produced from the ore by a roasting process which converts the sulphide into an oxide. The oxide is then reduced by carbon in an electric furnace. Carbon free metal is produced by the thermit process. When particularly pure metal is desired the oxide is prepared by a chemical process, and this oxide is reduced with pure hydrogen.

Ferro-molybdenum is made directly from the ore in electric furnaces. This alloy is the principal product of molybdenum ores, and is used in the manufacture of alloy steels containing this metal.

Molybdenum wire, made from pure metal, finds a very limited use in the incandescent lamp industry. In certain kinds of lamps the spider which supports the incandescent fibre is made of this material. Some special forms of electric heating furnaces are in use in which the heating element is molybdenum wire, carefully protected from contact with the air to prevent oxidation.

Metallic molybdenum is used in sheets and in wire for the construction of radiotrons. The metal is also used for contact points in electric apparatus and for spark plug points. It is substituted for platinum in jewelry and dentistry.

Molybdenum is used for making certain classes of structural steels, the market for which has been expanding rapidly. These alloys are low molybdenum steels, and they have been successfully used in the manufacture of springs for automobiles and trucks. They have also been used for cranks, shafts, propeller shafts, axles and other engine parts, numerous small forgings, armour plate, shovels, plow shares, parts for agricultural machinery, and other uses. Recently it has been alloyed with cast iron, and large mill rolls have been made successfully. High molybdenum steels are used for magnet steels, and some self-hardening steels also contain this metal. Certain manufacturers are offering tool steels containing molybdenum and cobalt, for which superior cutting properties are claimed. The metal also enters into the composition of some varieties of the alloy named stellite, and is used in some stainless steels.

Production. Metallic molybdenum has not been produced in Canada in commercial quantities. During the war ferro-molybdenum was produced by two firms direct from native ores. Owing to lack of demand production has ceased for the present. It is expected that the newly developed low molybdenum steels will stimulate a revival of production which will be on a steady basis owing to the broad market for these alloys.

NICKEL

Raw Materials. The commercially important ores of nickel mined in Canada are pyrrhotite and niccolite. The nickel-bearing minerals that have been reported from the Sudbury region, in addition to the pyrrhotites (Fe_nS_{n+1}), are pyrite (FeS_2), marcasite (FeS_2), pentlandite [$(Fe{\cdot}Ni)S$] polydymite (Ni_4S_5), gersdorffite (NiAsS), millerite (NiS), and niccolite (NiAs). Pyrrhotite and pentlandite are the only minerals having any important relation to the ores, and the first mentioned is the only one visibly present in all the ore deposits. There is some doubt, however, as to whether pyrrhotite is itself nickel-bearing, or whether the nickel content may be due to finely disseminated pentlandite. In addition to the sulphides containing nickel and iron, a sulphide of copper and iron, in the form of chalcopyrite, is almost invariably present. It comes next in amount to pyrrhotite and pentlandite and is always a more conspicuous component of the ore, because of its colour. Copper pyrites may be either intimately mixed with the pyrrhotite or may form considerable masses by itself. The metallic content of the ores varies considerably in the different mines. The nickel content reported averages about 2·09 per cent and the copper 1·85 per cent. If the losses in roasting and smelting are assumed to be 15 per cent of the metallic contents, the proportions of metals in the ores will be 3·09 per cent of nickel and 2·12 per cent of copper, making a total of 5·21 per cent. These ores also contain small amounts of the precious metals, including platinum, palladium, and rhodium.

The mineral niccolite, an arsenide of nickel, occurs either alone or associated with other less important nickel-bearing minerals in the veins in which the native silver and silver-bearing minerals are found in the Cobalt (Ontario) district. The average percentage of nickel in the ores shipped from Cobalt varies considerably for the different mines. For the whole district the average is probably between 3 and 5 per cent. The total tonnage is very small.

Sources. The important commercial ores of nickel are the nickeliferous pyrrhotites of the Sudbury district. One mine, the Alexo in northern Ontario, formerly contributed a small tonnage of nickeliferous pyrrhotite to the production of the Sudbury smelters. A small production of metallic nickel and nickel oxide is obtained from the niccolite ores of the Cobalt district. The ore bodies in the Sudbury district contain very large reserves and are at present the principal source of the world's supply of this metal.

Pyrrhotites carrying small amounts of nickel are known to occur near St. Stephens, New Brunswick, in several other localities in Ontario, and have also been reported from British Columbia, northern Alberta, and northern Manitoba. A body of magnetic iron ore containing titanium and small amounts of nickel and vanadium is also reported from Ontario. The nickel content of all of these ores is very low and there is no production from any of them at the present time because they are unable to compete under present market conditions with the higher grade production of the Sudbury district.

Processes. Nickel oxides are made from the niccolite of the Cobalt district by a special chemical process which involves roasting, solution, and precipitation for the separation from Cobalt and the recovery of the commercial oxide. Nickel metal is prepared from this oxide by reduction with carbon.

The greater portion of the nickel production of the Sudbury district is obtained by metallurgical processes which involve four distinct types of operation. These steps are:—

1. Roasting part or all of the ores in open heaps (or in special roasting furnaces), to remove part of the sulphur.

2. Smelting in water-jacketed blast furnaces, to produce a low grade matte, containing from 10 to about 20 per cent copper-nickel and nearly all the precious metals.

3. Converting the furnace matte in Bessemer basic converters to make a matte containing about 80 per cent copper-nickel.

4. Refining the converter matte, separating the nickel, copper, and precious metals.

Some progress has been made in the development of a process for making a nickel-copper steel directly from Sudbury ores by roasting and subsequently reducing the oxides in an electric furnace with carbon. By this process most of the iron of the pyrrhotites is recovered instead of being lost in the slag.

Another natural alloy of nickel and copper, named monel metal, is produced at one refinery. This alloy finds important industrial uses owing to its power to resist corrosion and to its high tensile strength.

Remarks. There are four firms producing nickel oxides from the niccolite ores of Cobalt. Two of these firms also produce metallic nickel.

There are three large corporations engaged in the nickel industry in the Sudbury district. The first three steps in the production of metallic nickel from the Sudbury pyrrhotites are all carried out in Canada. The converter matte which results from the third step of the series is shipped from the Sudbury district to different refining centres. Formerly the larger portion went to the United States to be refined. Recently a refinery has been erected at Port Colborne, Ontario, and a portion of the matte that formerly went to the United States is refined here. Another firm ships all its matte to Great Britain for refining, while the third producer has arranged to operate a refinery in Canada.

Industrial Applications. Nickel has a great many important industrial uses. Brief references only can be made to some of these applications.

This metal can be either cast or forged, and it can be welded with care. Its malleability and ductility make it possible to produce very thin sheet metal by rolling. Its hardness, durability, and brilliance when polished make it suitable for many purposes, such as table ware.

Nickel plating is applied to a great variety of articles, such as automobile parts, instruments and instrument cases, art objects, table ware, and numerous other articles. Plating is usually accomplished electrolytically. The anodes are cast and then rolled to a required thickness. The process of rolling improves the quality of the anodes, increasing their density and homogeneity and causing them to dissolve uniformly in the plating bath. The electrolyte used is usually a solution of the double chloride, or of the sulphate of nickel and ammonium.

Thin hot rolled nickel sheets have been successfully welded to iron and steel, but this method of plating is only employed where material of special durability is required.

Nickel coinage was commenced about 1850 by Switzerland and was adopted in the United States about 1857. At the present time over seventy countries or dependencies have adopted nickel or nickel alloy coins. Nickel alloys are used for most of the coinage but eleven countries have adopted pure nickel. Curiously enough Canada, which produces by far the largest portion of the nickel supply of the world, only recently adopted this metal for coining a 5-cent piece.

There are numerous nickel alloys, containing from less than one to more than fifty-five per cent nickel, which find applications in the industrial arts. The principal metals with which nickel is alloyed are copper, zinc, and iron. There are other alloys of less importance into whose composition enter one or more of the metals aluminium, lead, tin, antimony, or silver. In all there are about sixty or more alloys in use containing nickel.

The principal series of nickel alloys is the nickel steels. The addition of 2·5 to 3·5 per cent nickel greatly improves the quality of structural steel and rails. These steels also find extensive uses in the automobile industry. Armour plate for battleships contains nickel. There are also a number of special alloys containing large percentages of nickel. One of these, known as invar steel, contains about 36 per cent nickel, possesses a very low coefficient of expansion and is used for surveyor's tapes, and for other standards of measurement.

The natural alloy of nickel and copper, made directly from bessemer matte, and named monel metal, is probably the next most important product containing nickel. The alloy contains 68—72 per cent of nickel and the balance copper, there being also slight impurities such as iron, carbon, and sulphur. This alloy is silver white in colour, polishes well, but turns slightly greyish on exposure. It offers a high resistance to corrosion and has a tensile strength which makes it stronger than steel or manganese bronze. It is supplied to the trade in ingots, sheets, bars, rods, castings, tubes, and wire. It finds extensive use in places where a non-corroding metal is required, in marine work for propellers and shafts, in acid works for fan blades, tubes, and various other uses such as roofing sheets, boilers, utensils, and other articles.

Alloys of nickel with copper, zinc, and other special metals mentioned above are used for special purposes. German silver is an alloy containing nickel, copper, and zinc that finds extensive use in the manufacture of cheap table ware and similar purposes. The compositions of this alloy vary considerably among the different manufacturers. One Canadian manufacturer produces a series of alloys of this kind under the trade name of "Canada nickel silver sheet."

PLATINUM

Raw Materials. Platinum is usually found as native metal in the form of nuggets in certain alluvial gravels. It also occurs in association with ores of copper and nickel in sulphide ores.

Sources. Native platinum has been found occasionally in a number of localities in Canada—Riviere du Loup, Quebec; on the Similkameen, Tulameen, Tranquille, Fraser, North Thompson, and other creeks and rivers of British Columbia; on the Yukon and its tributaries, on the Teslin, and on other rivers of Yukon.

Platinum associated with palladium occurs as one of the constituents of the nickel-copper ores of the Sudbury district (Ontario). The bessemer matte, which contains about 80 per cent copper-nickel, also contains from 0·17 to 0·50 ounces of platinum per ton, the amount varying in the ores of the different mines. Both platinum and palladium are recovered from the residues found in the electrolytic cells after the nickel and copper have been removed.

Processes. Native platinum is refined much the same way as gold is refined. The platiniferous residues from electrolytic copper and nickel refineries are subjected to special chemical and metallurgical treatment for the separation of the precious metals which they contain.

Remarks. Platinum is classed as a precious metal, and at present is worth about four times as much as gold. Metallic platinum is used for making chains, gem mountings, and other effects in jewelry. A large quantity is also required for making crucibles, evaporating dishes, and other special articles used in chemical laboratories and in certain chemical manufacturing industries. A considerable quantity, in the special form known as platinum black, finds industrial application as a catalyzer, especially in the manufacture of strong sulphuric acid for the manufacture of explosives.

Certain platinum salts find industrial application in photography.

SILVER

Raw Materials. This metal occurs native in flakes, leaves, stringers, and wire-like forms. There are also a number of minerals containing silver from which commercial recovery is made. The more important of these are cerargyrite ($AgCl$); argentite (Ag_2S); stephanite ($5Ag_2S.Sb_2S_3$); pyrargyrite ($3Ag_2S{\cdot}Sb_2S_3$); proustite ($3Ag_2S{\cdot}As_2S_3$); dyscrasite (Ag_3Sb).

The several different metallurgical processes in use for the recovery of metallic silver require a number of secondary materials according to the process employed. The principal accessory raw materials of the silver industry are coal or oil as a source of heat, mercury for amalgamation, sodium chloride for chlorination roasting; sodium hyposulphite, sodium sulphide, sodium cyanide (or corresponding potassium salts), lead acetate, and lime for certain leaching processes; metallic zinc or aluminium in the form of powder or shavings for precipitation.

Sources. The silver production of Canada is derived from three principal sources. These are the silver-cobalt nickel ores of the Cobalt district, Ontario, the argentiferous galena (and blende) of British Columbia and Yukon, and the copper-bearing ores of Quebec, Ontario, and British Columbia.

Argentiferous ores have been reported from other points in Canada, and there has been a small but irregular production from many localities. Deposits of silver-bearing galena have been found in Nova Scotia, Quebec, and Ontario. Native silver was found in certain veins on Silver Islet, lake Superior, near Port Arthur, Ontario, and mining operations were carried on at this point for 18 years.

The silver production of the Cobalt district comes from the native silver ores found in mineral veins in this region. With the native silver are associated certain silver-bearing minerals, such as dyscrasite, argentite, pyrargyrite, and also ores of cobalt and nickel-smaltite, niccolite more particularly.

The silver production of British Columbia is derived in large part from the argentiferous galena and blende found in the mines of the Kootenay district (see under Lead). Ores containing little galena, some native silver, and silver-bearing minerals are produced in the Lardeau mining division and in the vicinity of Slocan city; argentiferous galena has also been produced in the Boundary district near Greenwood, and near Hazelton on the Skeena river in northern British Columbia. Argentiferous galena also occurs in Yukon.

Silver is found in many of the auriferous copper sulphide ores found throughout Canada. Both gold and silver are recovered from the residues after the electrolytic recovery of copper or nickel.

Processes. The preliminary treatment of the majority of the silver ores produced in Canada—excepting a limited production of native silver—involves standard milling processes suitable for concentrating the ore under treatment.

The concentrates produced from the silver-lead ores (consisting chiefly of galena) are subjected to a special roasting process followed by treatment in a lead blast furnace. The resulting argentiferous lead is cast into anodes for treatment by the electrolytic process. The sludge which collects in the electrolytic vats consists largely of silver, which is refined by a standard furnace process.

The silver associated with the ores of copper and nickel is recovered from the residues found in the electrolytic vats after the copper or nickel has been removed from the electrolyte. There are two refineries operating in Canada, one in British Columbia and one in Quebec, producing refined silver which has been recovered as a byproduct in the process of refining copper, lead, or nickel, originally occurring in sulphide ores. A large proportion of the ores of this class is exported to the United States for treatment (see under Copper), and any silver recovered from these exported ores is treated in foreign refineries.

The principal silver production of Canada at the present time is derived from the argentiferous ores of the Cobalt region. A portion of these ores containing native silver is subjected to direct treatment in smelters. Most of the ores are subjected to preliminary treatment which differs somewhat with the nature of the ore to be treated. The methods of preliminary treatment employed include standard ore dressing practice, and hydrometallurgical processes, cyaniding being the process chiefly employed.

Commercial Notes. Refined silver is produced in the forms of ingots, bars, rods, sheet, and wire. Its physical properties, its ability to resist corrosion, and its comparative rarity have combined to make it one of the precious metals.

The principal uses of this metal are for coinage, jewelry, ornamental art work, table ware, and plating. It also finds many applications in chemical laboratories and in surgery.

ZINC

Raw Materials. The principal ore of zinc found in Canada is the sulphide, blende (ZnS). A small amount of the carbonate, smithsonite ($ZnCO_3$), is also produced commercially. Other minerals which are important commercial sources of zinc in other countries are the silicate, willemite (Zn_2SiO_4); the hydrous silicate, calamine ($H_2Zn_2SO_5$); the triple oxide of iron, manganese, and zinc termed franklinite [$(FeZnMn)O \cdot (FeMn)_2O_3$] and the red oxide, zincite (ZnO).

The principal accessory materials required in the zinc smelting industry are coal, petroleum or natural gas for heating, carbon as a reducing agent, and clay for the manufacture of retorts. The electrolytic processes for the production of zinc require sulphuric acid to make the electrolyte, manganese oxide to prevent corrosion of the cathodes and to maintain the purity of the electrolyte, and shot copper to purify the electrolyte.

Sources. Zinc blende has been produced in small quantities from prospects in the provinces of Nova Scotia, Quebec, Ontario, and British Columbia. There has never been steady production from prospects in eastern Canada, and there has been little incentive to thoroughly investigate the known prospects owing to the difficulty of marketing the ores. There are a number of promising prospects, however, from which production may be expected in the future.

The principal production of zinc ore in Canada has been from British Columbia mines, where zinc blende occurs in association with other sulphides, particularly galena and pyrites. These ores are often argentiferous.

In many of the British Columbia mines the ores are complex silver-lead ores containing zinc blende, which has to be removed to make the lead ore marketable. Zinc ore from such a mine is in the nature of a byproduct; it usually contains a considerable amount of silver, however. A few mines produce zinc blende with which is associated only a small amount of lead. One mine also has produced a considerable tonnage of carbonate ore containing some silicates, obviously the products of the partial decomposition of large sulphide ore bodies. Zinc ores prepared for shipment in British Columbia consist in part of hand-sorted lump ore and in part of mill concentrates.

Process. Metallic zinc is reduced from the ores of zinc by the application of one or the other of two principal types of treatment. The older treatment process involves preliminary roasting of the sulphide ores followed by reduction with carbon in a special type of distillation furnace. The newer method of treatment also involves preliminary roasting of the sulphide ores followed by leaching with sulphuric acid. The resulting solutions are subjected to further treatment to remove impurities and undesirable constituents, and are then treated electrolytically. The cathode zinc produced is melted down and cast into ingots.

Metallic zinc is also produced by the Belgian retorting process, but no plant of this kind is operated in Canada. In this process the ore is roasted to the oxide, and the oxide is mixed with coal and charged into special retorts. Under suitable conditions of temperature the oxide is reduced, and metallic zinc distils out of the mixture and is recovered in special condensers.

Remarks. Western Canada does not produce enough zinc ore annually to support a smelter of the minimum capacity that could be operated commercially. As a consequence Canadian zinc ores have been exported for treatment, and our requirements for this metal have all been imported.

During the war period three separate processes for producing metallic zinc electrolytically were under trial. One of these reached commercial production and is still in operation. The output of this plant is in the neighbourhood of 100 tons daily. The plant is located at Trail, British Columbia, and operates chiefly on zinc ores produced from mines owned by the operator, custom ores are also purchased.

Commercial Notes. Metallic zinc is produced in ingots, blocks, and bars, which are generally marketed under the trade name of spelter. It can be rolled into sheets and rods. It is alloyed in varying proportions with copper to form brasses, with tin and copper to form bronzes, and with nickel to form many varieties of German silver.

Iron or steel in sheets, rods, or any other form can easily be coated with metallic zinc in a thin film. This is done by thoroughly cleaning the surfaces to be coated and then dipping the article in molten zinc, the surplus metal being removed by shaking or wiping. This operation, known as galvanizing, protects the iron or steel from corrosion. Protective coatings are also applied to metal sheets by sherardizing or spraying.

Rolled zinc sheet, and galvanized iron or steel sheets are employed for roofing and in the construction of tanks, barrels, water pipes, and many other products.

Minor uses of metallic zinc are in battery plates, photo-engraving, to prevent the corrosion of boilers, for the precipitation of gold and silver in certain hydrometallurgical processes. Zinc for the last use is usually prepared in the form of shavings, or powder, zinc powder being marketed under such trade names as blue powder, zinc dust, or zinc grey. This powder is also used as a reducing agent in the dye industry, and for making a paint to protect iron surfaces.

Statistical Data

The production of ores and metals constitutes Canada's second largest industry. Annual reports on the Mining Industry were issued by the Department of Mines between the years 1896 and 1920. Since 1920 the compilation of mining statistics has been undertaken by the Dominion Bureau of Statistics and annual reports covering the calendar year are issued by that office.

It has not been considered necessary to include annual production statistics in this report. A table has, however, been compiled from the best available data showing the average annual production of certain metals for the three-year period just prior to the beginning of the war, and also for a similar period since the armistice. A comparison of the two sets of production figures will serve as a measure of the progress that has been made in the metallurgy of the metals in Canada during the last decade.

Table 19.—Canadian Pre-War and Post-War Averages*

—	Production		Imports		Exports	
	Quantity	Value	Quantity	Value	Quantity	Value
		$		$		$
Aluminium—						
Pre-war[1] .... tons[2]	*a*	....	1,616	593,395	7,635	2,043,161
Post-war .... "	*a*	....	563	367,575	6,615	4,027,588
Antimony—						
Pre-war .... "	nil	....	407	59,066	*b*	*b*
Post-war .... "	nil	....	460	75,740	*c*	....
Arsenic—						
Pre-war .... "	1,825	98,247	183	14,721	1,701	113,657
Post-war .... "	2,446	397,178	150	37,798	1,643	259,167
Cobalt—						
Pre-war .... "	400	*b*	....	....	*b*	*b*
Post-war .... "	221	1,148,981	....	....	*d* 291	1,091,526
Copper—						
Pre-war .... "	38,424	11,591,253	*e*18,885	6,239,622	40,172	9,078,327
Post-war .... "	34,046	11,408,679	17,135	7,312,069	36,584	12,652,497
Gold—						
Pre-war .... Oz. fine	729,345	15,076,908	*f*	51,486,261	*g*	12,675,897
Post-war .... "	819,367	16,937,814	*h*	39,129	....	4,076,852
Iron, pig[3]—						
Pre-war .... tons	975,573	13,697,956	196,043	2,580,854	10,788	382,905
Post-war .... "	885,349	23,225,112	37,306	1,302,577	56,306	1,839,868
Lead—						
Pre-war .... "	18,294	1,659,942	14,853	1,380,640	231	13,172
Post-war .... "	24,410	3,032,014	8,634	1,506,042	10,342	1,008,672
Magnesium—						
Pre-war	nil	....	....	....	....	....
Post-war	*k*	....	....	....	....	....
Manganese—						
Pre-war .... tons	31	998	*m*1,849	38,995	*n* 16	451
Post-war .... "	1,680	35,503	1,409	76,513	424	11,854
Mercury—						
Pre-war .... "	nil	....	94	93,038	....	....
Post-war .... "	nil	....	44	108,098	....	....
Molybdenum—						
Pre-war .... "	*p*	....	....	*b*	*b*	*b*
Post-war .... "	*q*	....	....	....	19	28,307

[1]Pre-war period consists of the calendar years 1912, 1913 and 1914, the figures given being averages. Post-war period consists of the calendar years 1919, 1920 and 1921. [2]Short tons throughout. [3]Blast furnace only. *a*Confidential. *b*Not available. *c*In 1919 exports were 56 tons valued at $8,420. *d*Metallic, oxide and salts, alloys. *e*For which quantities are given. *f*Bullion, coins, fringe; manufactures of gold and silver included under 'silver'. *g*Dust and nuggets. *h*Fringe only, no bullion reported. *k*Small production in 1919 by chlorine process; balance of period experimenting by oxide process. *m*Oxide only. *n*Ore. *p*Figures for 1912–13 not available; production in 1914 was 3,814 pounds valued at $2,063. *q*Production in 1919 was 83,002 pounds valued at $69,203. *r*Excluding nickel plated ware; and manufactures of German, Nevada and nickel silver, not plated. *s*Bullion, coin and sterling; also silver and manufactures of gold and silver. *t*Small experimental shipment at Brantford in 1920, from Bolivian ore. *w*Small shipment of 14 tons in 1912, none since. *y*Ore and metallics. *Compiled by John Casey, Mines Branch.

Table 19.—Canadian Pre-War and Post-War Averages*—Concluded

—		Production		Imports		Exports	
		Quantity	Value	Quantity	Value	Quantity	Value
			$		$		$
NICKEL—							
Pre-war................	tons	23,339	14,003,625	r 315	163,430	23,368	5,002,248
Post-war...............	"	20,862	16,368,269	299	208,399	19,012	7,723,131
PLATINUM—							
Pre-war................	oz.	494·2	b	....	152,503	98	4,637
Post-war...............	"	492·5	....	....	127,138	880	76,893
SILVER—							
Pre-war................	"	30,750,395	18,024,907	....	s1,808,323	33,434,527	18,840,150
Post-war...............	"	14,293,071	13,246,053	....	2,985,515	13,135,497	12,282,890
TIN—							
Pre-war................	tons	nil	....	2,842	2,670,840	....	49,335
Post-war...............	"	t	....	2,137	3,197,132	....	59,053
TUNGSTEN—							
Pre-war......................		w	....	....	....	....	....
Post-war.....................		w	....	....	....	....	....
ZINC—							
Pre-war................	tons	2,862	331,239	14,796	1,537,371	b	b
Post-war...............	"	20,858	2,630,573	11,864	2,000,409	y91,235	989,936

FLOTATION REAGENTS

Many natural ores must be crushed and subjected to special treatment to separate the valuable mineral constituents from waste rock and useless minerals. This is accomplished by crushing and grinding followed by treatment with water alone, or with water to which certain chemical reagents have been added. In some cases reagents are added to the ore during the process of crushing and grinding. Different classes of ores require different treatments, and the number of different chemicals that are used for various kinds of ores and for various purposes is very large. The following list names most of the reagents that are used for this purpose.

Table 20.—Flotation Reagents [1]

(The more important reagents are indicated by an asterisk. Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

OILS, OR REAGENTS HAVING THE EFFECT OF OILS.

Products of pine distillation such as *pine oils (steam distilled or destructive distilled); *pine tar oils; *pine tar; *rosin oils; **turpentine;* *crude distilled pine oil; *pine creosote.

Combinations of the above pine products with *hardwood oil;* **hardwood creosote;* **hardwood tars;* eucalyptus oil; fir oil; sagewood oil; *oils obtained from the tops of sulphate pulp digesters; special fractions of the above named hardwood products; byproducts from the manufacture of calcium acetate,* including *ketone oils, ketone residues.*

Animal oils or derivatives such as oleic acid.

[1] Compiled from data supplied by C. S. Parsons, Mines Branch, Ottawa.

Reagents from Other Sources having effect of Oils.

*Aldols; *fumols; modified products of these with sulphur.* (Produced by Electro-Products Co., Shawinigan Falls, Que.)

Coal Tar Products.

The commonly used products are **coal tar creosote; cresol; phenol; *gas tar; *coke oven tar; *water-gas tar; crude solvent naphtha.*

Special products used in fair quantities are *alpha-naphthylamine; *ortho-toluidine; *thiocarbanilide; *xylidine.

Special products used in exceptional cases are *crude cresylic acid; mixed toluidine; benzol; toluol; xylol; naphthalene; heavy naphtha;* pyridine; meta-para-cresol mixtures; anthracene; special fractions of coal tar and coal tar chemicals and combinations of them such as "thio-fizzan."

Petroleum Products.

Crude oils with asphaltic and paraffin bases; products and fractions from refining such as *"gravity fuel oils," gasoline, kerosene, paraffin; *kerosene acid sludge;* modified products by combination with sulphur.

Auxiliary Flotation Reagents (chemicals).

Acids (*hydrochloric, *sulphuric*); calcium compounds (*chloride, hypochlorite,* *oxide, sulphide); *chlorine;* chromates; *copper* (*metal*); **copper sulphate; ferrous sulphate; hydrogen sulphide;* magnesium chloride; *manganese dioxide;* mercury (metal); potassium permanganate; sodium compounds (**carbonate; chloride, *cyanide,* *sulphate, *sulphide, *sulphite); *sulphur dioxide;* zinc chloride.

CHAPTER II

SECONDARY METALLURGICAL INDUSTRIES

The fabrication of finished products from primary metals recovered from ores involves both mechanical and metallurgical operations. Cold working of metals by machining, grinding, rolling, pressing, or drawing is chiefly a mechanical operation. The physical changes which the material undergoes in cold rolling, drawing, or pressing, are regarded as coming within the province of metallurgy, although the shop operation would not be classed as metallurgical. Mechanical treatment, combined with heat treatment, for the purpose of altering the texture, structure, and physical characteristics of a metal is more obviously a metallurgical operation, although the mechanical manipulations are usually so applied that finished shapes are produced. No sharp line of differentiation can be drawn between the two classes of operations as most factory processes combine applications of both mechanics and metallurgy. Where heat treatments of any kind are employed to facilitate the mechanical operations by rendering the materials more plastic, to anneal the metal during the progress of the mechanical treatment or afterwards, to harden it after treatment, or for similar purposes, these portions of the fabrication process must be regarded as distinctly metallurgical. Fusions of metals, with or without fluxes, either to make alloys for treatment by other processes, for the purpose of casting in moulds, or to promote adhesions or cohesions, are metallurgical operations.

Secondary metallurgical industries may then be considered to include those metal industries which employ processes involving heat treatments when fabricating primary metals and alloys, as recovered from metallic ores, into the finished products of industry. *Ferro-alloys* made from pig iron, iron and steel scrap, and certain alloying metals; *steels* made from pig iron, iron and steel scrap, and ferro-alloys; and the numerous *non-ferrous alloys* used in industry come within this group. The operations of casting, forging, hot rolling, extruding, drawing, annealing, and heat treating including quenching and tempering, may all be classed as secondary metallurgical processes. With the exception of casting, all these operations also include mechanical working. Castings, after cooling, are occasionally annealed and they are usually subjected to finishing operations in a machine shop. Brazing, soldering, welding, oxy-acetylene welding, lead burning, and similar operations are also secondary metallurgical processes carried on in conjunction with other work in many machine shops.

Metal working industries can therefore be classified on the basis of the processes employed into those in which purely metallurgical processes are employed, those in which purely mechanical processes are employed, and those in which mechanical processes predominate but in which heat treatments on various scales are employed during the progress of the mechanical treatment. *Machine shops* would be defined as those devoted to the cold working of metals, metallurgical processes being used in these shops for the purpose of preparing tools and for welding. *Foundries* are plants engaged in making castings from molten metals, and, incidentally, in the production of alloys. *Forges* are plants making various products such as car axles, drill steels, shafts, motor car parts, crank shafts, and similar products from metal ingots or bars by hammering or pressing when hot. *Rolling mills* are plants engaged in the fabrication of metals into bars, rods, rails, structural shapes, commercial shapes, and sheets. *Tube mills* are plants engaged in the production of metal tubes from ingots, bars, or sheets. *Wire mills* are plants making wires from ingots, wire bars, or rods.

Forges are usually established in connection with a steel mill or an iron foundry to facilitate the obtaining of raw materials and the disposal of scrap. They are also established as an adjunct to many machine shops and rolling mills.

Steel rolling mills are usually operated in connection with iron blast furnaces and steel plants. Otherwise they find it necessary to install melting furnaces and a foundry for treating scrap. Non-ferrous metal rolling mills, tube mills, and wire drawing mills are usually provided with melting furnaces and foundries for treating scrap and for preparing alloys.

Many large industrial concerns maintain shops for carrying on two or more of the several principal secondary metallurgical operations to which reference has been made.

Machine shops in Canada have not been investigated and are not discussed. It may be mentioned, however, that in addition to the various metal products required for manufacturing purposes, they offer a market for cutting compounds, lubricating oils, and the few chemicals used as fluxes in brazing, welding, tempering, and cleaning metal surfaces. They also consume large quantities of abrasive products and alloy tool metals, chiefly steels. No accurate data with respect to machine shops in Canada are available, as to their numbers, character, capacity, and output. Forges in Canada have not been studied but processes and products are discussed briefly. Small forges are maintained in connection with most machine shops. Forges provided with heavy equipment are usually maintained in connection only with the large shops engaged in building or repairing railway cars, locomotives, and heavy machinery. These plants consume large quantities of fuel either directly for heating purposes, or indirectly in the production of steam power. Some fluxes are also used in some operations, but the market they offer for chemical products is very limited. There are a number of large forges established in Nova Scotia, Quebec, Ontario, Manitoba, and British Columbia. No accurate statistical data are available relating either to the capacity of individual plants, or to the industry as a whole.

FOUNDRIES

Foundries, as the name implies, are plants engaged in making castings by pouring molten metals into previously prepared moulds. Iron, steels, and non-ferrous alloys of many different kinds are used in the fabrication of articles by this method. Alloy steels and the necessary non-ferrous alloys are usually made in melting furnaces from the requisite materials in the foundries where they are to be used. Such alloys can also be cast into ingots or bars for further treatment in forges, rolling mills, wire mills, or other works.

Foundries are frequently designated as iron foundries, steel foundries, or brass foundries, indicative of the principal metal or alloy used in making the products turned out by the individual plants. The metals or alloys most frequently used in foundries of their respective kinds are iron, steel, nickel, copper, zinc, tin, lead, aluminium, magnesium, manganese, brass, bronze, and white metal alloys. In adddition to the primary metals as produced by smelters and refineries, large quantities of numerous varieties of scrap metals constitute the principal raw materials of the several founding industries.

The steels used in foundry practice are largely carbon steels of various kinds, and also alloy steels, made by the use of ferro-alloys. The principal ferro-alloys employed are ferro-chromium, *ferro-manganese* (including *spiegeleisen*), *ferro-molybdenum, ferro-phosphorus, ferro-silicon,* ferro-titanium, ferro-tungsten, and ferro-vanadium.[1] *Nickel, cobalt,* less frequently *copper,* and some other metals are also used in making special alloy steels, not so much for casting purposes as for making rolling mill products.

Cast irons are made from various kinds of pig irons produced by different iron furnaces from the different iron ores available. The iron founder also uses large quantities of scrap iron derived from the worn out castings and other iron or steel products used in the numerous industries which absorb castings and other iron products. Thus we find railroad scrap, agricultural scrap, steel scrap, wrought iron scrap, malleable scrap, stove plate scrap, car wheel scrap, grey iron scrap, and a number of other varieties on the market. The foundry also requires limited quantities of ferro-alloys such as ferro-silicon, ferro-manganese, and less frequently other alloys for special purposes. To improve the condition of the metals and to facilitate pouring deoxidizers such as titanium, aluminium, manganese, silicon, and (less often) magnesium are sometimes used.

Cast irons vary considerably in the relative amounts of sulphur, manganese, silicon, phosphorus, and carbon which are present. These variations determine to a large extent the physical properties of the finished products. The character of the castings is also influenced to a certain extent by the type of melting furnace used. Cast irons are sometimes described as grey iron or white iron on the basis of their appearance on freshly fractured surfaces. These differences are due to the condition of the carbon present in the iron, which in turn affects the appearance and the crystalline structure. In white iron all the carbon is present in combined form, while in typical grey iron at least 60 per cent of the carbon is present in an uncombined condition.

Malleable cast iron is a low silicon hard cast iron with a white fracture and somewhat glassy appearance when first cast. If subjected to an

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[1] Italics indicate that the alloy is made in Canada.

annealing process at a high temperature for some time such castings become soft, the tensile strength is increased, and a tough malleable product results. The annealing process, if continued long enough at a suitable temperature, changes the character of the carbon present in the original white iron from combined carbon to free carbon in graphitic form, and the total carbon present in the surface portion of the casting is incidentally reduced. Malleable iron is made from special low phosphorus pig iron, malleable scrap from various sources, and steel scrap. This special type of annealed cast iron is used for making parts for automobiles, agricultural machinery, and numerous forms of small articles and shelf hardware where the special properties of this grade of iron are desirable.

The best commercial practice requires that the composition of castings be controlled by chemical analyses of both raw materials and finished castings. Systematic chemical investigations in conjunction with practical experience have established certain commercial limits for the composition of cast irons for making various products. The more common types of castings are included in the following list of products of the iron founding industry; where such products are known to be made in Canada this has been indicated by using italics: *Agricultural machinery; annealing boxes; balls* and *shoes* for rock crushing and polishing machinery; *boiler parts; brake shoes; car wheels; chilled castings,* such as jaws for *rock crushers, crushing rolls, shoes,* and types of armour plate; *chills* for making certain types of castings; *dies* for power presses or forging hammers; *electrical castings* of all kinds, including *dynamo, generator,* and *transformer* parts, *armature cores, magneto parts,* and numerous *light boxes, covers* and *other shapes* used in electrical work; *engine parts* (steam, oil, or gas) such as *cylinders, beds, frames,* or *flywheels; furnace parts; gears; grate bars; heat resisting castings* for *fire pots, linings* for stoves or furnaces, *moulds* for iron and copper castings; *hydraulic press cylinders* and *piston* heads; *locomotive frames* and other parts; *machinery castings* of all kinds, such as *mine machinery, paper mill* equipment, *cranes, elevators, conveyers,* and numerous other parts; *moulds* for glass shapes and for many non-ferrous metals or alloy castings; *ornamental iron work* such as fences, rails, stove ornaments and small articles; *piano plates; pipes* of various kinds; *pipe fittings; piston rings; plow points; pulleys; radiators; rolls; shelf hardware* of certain kinds; *stove plate* and *radiator grates; valves* and *valve parts; wheels.*

Foundry practice in the use of metals other than iron is confined chiefly to the production of *lead articles* for factory and domestic use, *nickel castings* chiefly for factory and plant use, *aluminium products* which find numerous applications, and *non-ferrous alloy castings.*

The non-ferrous alloys used not alone for casting, but also for rolling, drawing, and pressing, are very numerous. Binary and ternary alloys are commonly used, but some alloys containing four or more metals are also in demand. These alloys are so numerous that only a brief reference can be made to the more important compositions. Monel metal, a natural alloy of copper and nickel, finds numerous applications varying from golf clubs to non-corrodible propellers for ocean steamships. Aluminium makes an important series of alloys with copper, alone or with other metals, and another series with magnesium; copper and zinc are alloyed alone or with other metals in different proportions to make brasses of which there are many kinds; copper and tin, with or without other metals are alloyed to make bronzes and gun-metals; tin, lead, zinc, and occasionally bismuth or cadmium are alloyed to make solders; antimony, copper, tin, lead, and other metals are alloyed to make anti-friction or bearing metals; antimony, tin, and copper are alloyed to make Britannia metal and similar white metals. All of these type alloys have been made in Canadian plants from time to time as required. Brasses, bronzes, white metal alloys, bearing metals, solders, and certain aluminium alloys are made continuously in several plants.

Steel foundries employ open hearth furnaces, crucibles, or electric furnaces for melting. Iron foundries use cupola furnaces or air furnaces (a type of reverberatory) for melting metals; the electric furnace was rarely used in the past for casting iron, but its use in this industry is now growing. Plants casting copper-nickel alloys, brasses, or bronzes may use reverberatory furnaces, crucible furnaces, or electric furnaces. Non-ferrous alloys, other than copper-nickel alloys, do not require such high temperatures as irons or steels. White metals, solders, babbitt metals, and other alloys fusing at relatively lower temperatures are made in crucibles or in cast iron or cast steel pots, the heat being furnished by a gas or oil flame. Occasionally an electric furnace may be employed for this purpose.

The various foundry industries require annually a large number of accessory raw materials used for producing heat, for repairing furnace equipment, and for making the numerous and various kinds of moulds and cores used for shaping the castings as made in the different types of foundries. Plants or parts of plants using low fusion alloys require a minimum of these accessories The subjoined list of accessory materials refers chiefly to the requirements of the iron founding industry. Steel founding uses much the same classes of materials. Brass and bronze foundries use much the same materials but in less quantities. They can dispense with many of the materials needed to make sand and loam moulds by using casting machines and metal moulds. Other non-ferrous metals and alloys require much the same class of equipment as is used in brass founding. The specifications for such materials as moulding sand, core materials, and other items will naturally differ with the type of casting that is being done. It has not been deemed advisable to enter into a discussion of detailed differences in the specifications of the several accessory raw materials used in foundry practice, these subjects being dealt with in other reports.

Table 21.—Accessory Materials used in Foundry Industries

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

FUELS: *Wood* (chiefly for lighting and drying out of furnaces); *charcoal* (special purposes, cover for metals held molten in ladles); *bituminous coal* (reverberatory furnaces, firing annealing ovens); anthracite coal (occasionally in cupola melting, producers); *coke; fuel oil; producer gas; natural gas; byproduct oven gas.*

REFRACTORIES: Bricks (bauxite, chrome, *common, fire bricks of several grades, flue bricks*, magnesite, *silica*); *carbon; chrome iron ore;* clays (*several kinds, "fat" clays, fire clays*); *magnesite* (*calcined*); *sands* (*siliceous, pure silica*); *schists* (*mica, steatite*).

FLUXES: *Calcium carbonate* (*oyster shells, calcite, marble spalls, limestones, dolomites*); *calcium fluoride* (*fluorspar*); *sodium carbonate; sodium chloride.*

SANDS: *Core sands; facing sands; moulding sands.* (Natural sands derived from sandstones or alluvial deposits, or prepared artificially by mixing siliceous sands, fat clays, loams, and pulverized gas coals, special specifications requisite for different uses, products, and metals.)

CORE BINDERS: Colloidal materials [aluminium hydroxide, *calcium hydroxide* (*milk of lime*); *clays, glue, iron hydroxide,* magnesia]; gums (rosin); oils (filling oils, such as *petroleum,* resin, and *tar* and *wood distillation oils;* oils such as Chinawood, cottonseed, *linseed,* soya bean, *prepared fish,* and other drying oils); paste binders (made from *dextrine, flour* or *starch*); pitch (*coal tar*); water-soluble binders [beer (soured), *glutrin* (the product obtained when waste sulphite liquor is evaporated), *molasses, refuse from distilleries,* sodium silicate].

BLACKINGS: *Graphite, coke, charcoal* (with adhesive liquids such as molasses in water, soluble resinous residue obtained by evaporating waste liquors from pulp mills, fire clay wash).

MINERAL FACINGS: *Carborundum; cement; ferro-manganese; silica; soapstone; talc.*

PARTING MATERIALS: *Powdered charcoal,* lycopodium powder, parting sand (pure silica, fine texture).

SUNDRIES: *Chaplets* and *gaggers; gasoline for core blackings; moulder's nails; lubricating oils; pattern materials,* chiefly fine grained woods and white metal; *varnishes.*

EQUIPMENT: *Cranes; flask; furnaces; ladles; tumbling barrels.*

Alloys

An alloy may be defined as a compound or mixture of two or more metals. Usually these products are of artificial origin, although natural alloys are known, and it is possible to prepare some alloys directly from natural mineral products.

Where an alloy such as monel metal or copper-nickel-iron is prepared directly from natural ores by reduction of the ores the finished product is to be considered both as a natural alloy and as a primary metallurgical product. Where the alloy is made by fusing together, under suitable conditions, two or more primary metals that have been secured through previous metallurgical operations the product is to be considered as an artificial alloy and as a secondary metallurgical product.

In the first chapter of this part reference has been made to a number of alloys which are made by utilizing the various metals described. The purpose of this section is to give a brief résumé of the general subject of alloys which are usually made in foundries.

Iron forms a series of alloys with such metals as nickel, copper, manganese, tungsten, chromium, molybdenum, vanadium, silicon, and others. These are generally designated ferro-alloys. These products in turn are used for making certain kinds of steels, of which there are a great many varieties. These steels are usually called alloy steels, and they are characterized by the possession of certain well defined properties dependent upon the alloying elements used and upon the relative proportions in which they are present. Steels themselves may be regarded as alloys of iron with carbon and silicon. References are made in other parts of this report to the production of ferro-alloys and alloy steels. A discussion of processes would be out of place here.

Alloys which do not contain iron as an essential constituent are commonly classed as non-ferrous alloys. A recent publication lists about 1,500 alloys which have been proposed for various industrial purposes.

The metals most frequently employed for the production of non-ferrous alloys are aluminium, copper, gold, lead, tin, and silver. Two or more of these metals may be fused together in various proportions, forming an almost endless variety of modifications. Commercial practice has, however, developed a number of standard formulae for the production of certain well known products. Brasses, bronzes and gun metal, coinage metals, white metals, and aluminium bronzes are well known.

The principal elements which are used in the production of non-ferrous alloys are aluminium, arsenic, bismuth, calcium, copper, gold, iron, lead, magnesium, manganese, mercury, nickel, phosphorus, platinum, silicon, silver, sulphur, tellurium, tin, and zinc. Non-ferrous alloys are also made with the rare metals palladium, iridium, rhodium, cerium, as well as with tungsten, molybdenum, vanadium, and the other metals usually alloyed with iron.

The ordinary process of making alloys consists in fusing the metals to be alloyed together in suitable furnaces, the one with the highest fusion point being first melted and then the others added as rapidly as possible. Low fusion alloys are made in ladles or crucibles, while various types of furnaces are utilized in making those with higher fusion temperatures. A few alloys are made most successfully by the use of the electric furnace.

Many alloys are prepared in foundries or other plants for subsequent treatment in forges or mills. General references are made to the working of these products in the succeeding sections of this chapter.

The accessory materials used in the manufacture of alloys, in addition to furnaces, ladles, crucibles, moulds, and fuels, are: charcoal, coke breeze, or coal dust to prevent oxidation; fats or rosin to promote combination by the mechanical action of escaping gases, and also to reduce oxides; fluxes to exclude air such as sodium biborate, sodium chloride, or glass.

No special study has been made of the manufacture of alloys in Canada. Many references will, however, be found to this subject in other parts of the text.

Forges

Forging is the process of moulding or shaping masses of metals (iron, steel, aluminium, alloy steels, copper, brass, bronze, or other metals or alloys) into desired shapes by working at full red or white heat. At forging temperatures the metals are more or less viscous, never fluid, and the application of pressure, momentarily applied as with a hammer, or continuously applied as in a press, causes the metal to flow. Forging also tends to increase the toughness and tensile strength of certain iron and steel products. Forges are used for welding such metals and alloys as can be caused to unite in this way. The process is commonly applied to iron and steel products. The same methods can be used with aluminium, copper, alloy steels, brass, bronze, delta metal, and other alloys, the differences being chiefly in the temperature at which the process is applied. The discussion in the following paragraphs relates chiefly to iron and steel products, although die-pressing is applied to many other metals and alloys.

There are certain classes of steel products which are manufactured by hammering or pressing a special casting, ingot, bloom, slab, or other rolled product into a definite form or shape. The forged shape may afterwards be subjected to a finishing process in a machine shop.

The heaviest class of forging is the production of armour plate from special large sized alloy steel ingots. Forged armour plates are machined to exact dimensions in special machines and they are afterwards annealed.

Propeller shafts for steamships are also forged from special steel ingots. Standard forged products include stamp shafts, railroad car axles, car wheels, and tires for the driving wheels of locomotives and for certain kinds of rolls. Small forgings, especially where large quantities are required, are made by drop forging. Special dies in pairs are used in drop forging, one die being mounted on the hammer so that it will move with it, while the other is fixed upon the anvil. Pieces of metal of suitable size, heated to proper forging temperature, are placed upon the lower die on the anvil and forced into the dies by a single stroke of the hammer. The excess of metal forms a thin web or flash around the edge of the forged article where the upper and lower dies meet. This is removed in a special trimming machine, and the forged article is then ready for machining.

Drop forgings are used for certain parts in the manufacture of automobiles, agricultural machinery, gas and oil engines, and other types of equipment. The same process is used in making lock parts, taps, valves, and other small hardware. The process is commonly applied in the manufacture of iron and steel products. It may also be used to hot press articles of aluminium, brass, bronze, copper, or nickel.

Forged products produced in Canada are steamship propeller shafts, engine shafts and axles, stamp mill shafts, car axles, car wheels, locomotive driver tires, and numerous varieties of drop forgings.

Where welding is performed at a forge certain fluxes are usually employed to assist in removing scale or oxides, and to produce clean surfaces at the place of contact of the two pieces being welded together. Wrought iron can be welded without the use of a flux, but pure sand is frequently applied to the surface before the final heating. Steel welding always requires a flux, which is applied to the prepared surfaces while in the heating fire and also dusted on the joint before the actual welding. Sodium biborate, or borax, is the flux usually used for this purpose.

ROLLING MILLS

Rolling differs from forging chiefly in the method used for moulding or shaping hot plastic masses of metal. In rolling pressure is applied continuously to extend and to shape the piece of metal undergoing treatment. The process is usually employed where it is intended that the lengths of finished pieces shall much exceed their cross sections.

Rolling mills are plants designed to shape masses of metals or alloys into desired shapes and sizes by the method of squeezing between prepared rolls. A single pair of rolls consists of two cast iron or cast steel cylinders with chilled surfaces, mounted in a roll housing or frame one above the other with their axes parallel, and usually horizontal. The distance between the centres of the two rolls can be varied slightly, and the distances between the faces of opposite portions of the two rolls determine the thickness and shape of the section of any piece of metal that has been passed between them. The rolls are rotated by electric motors or steam engines, the power being applied through gears. They rotate in opposite directions so that any piece of metal of suitable thickness pressed against them from the proper side will be drawn between them. Sometimes the heavier two-high type of mill is made reversible so that the piece of metal undergoing treatment can be passed through the rolls alternately forward and backward. The surfaces of the rolls may be corrugated, grained, smooth, or provided with grooves of different sections, dependent upon the purpose for which they are intended and the shape of finished product required.

Some types of mills are provided with three rolls, one above the other; the top and bottom rolls rotate in the same direction, while the middle roll rotates in the contrary direction. With a two-high mill the stock must be passed back over the top of the rolls unless the rolls are reversible. With a three-high mill it can be lifted or lowered mechanically through a height equal to the diameter of the middle roll, being fed forward between the lower pair and returned between the upper pair.

The rolling operation tends to greatly reduce the cross-sectional area of the pieces of metal passed between the rolls, and to greatly increase the length. The first pass is made on metal at a white heat and it continues until the metal has become red, or even dark. During the process the metal is subjected to great internal stresses, and to avoid injury the reductions in area must be made gradually. This is also accomplished in certain kinds of sections by applying the pressure alternately in two directions at right angles by turning the feed stock ninety degrees after each pass. Where shaped pieces are being rolled the sizes of the grooves through which they are passing in the rolling operation are gradually and progressively changed in shape or diminished in size.

A single mill usually consists of a series of roll stands, each stand having at least two rolls, the stands being so arranged with respect to each other that a train of rolls is formed. The stock if heavy is moved to and from the rolls by line rollers set in the tables in front of and behind the rolls and it is turned by specially designed mechanical arms. Light stock is at least partly moved by means of tongs in the hands of feeders.

Ingots and heavy castings that are to be rolled are heated to a white heat in soaking pits—a special type of gas-fired furnace—for several hours, the time required depending upon the size of the ingot. They are then passed, one at a time, through large heavy mills designed to break down the structure of the metal and to press it into shapes for treatment in other mills. The preliminary mills are called cogging, blooming, or slabbing mills according as the finished product is intended for structural shapes, rails, or plates. Where smaller sized pieces are required blooms are reduced to billets in a billet mill, and these may be further reduced to sheet bars or wire bars each in its own type of mill.

A mill designed to produce plate is called a plate mill. An ordinary plate mill produces sheets of metal varying from one-quarter of an inch to two inches in thickness and of varying lengths. A sheet mill is designed to produce thin plates or sheets less than one-quarter of an inch in thickness. An armour plate mill produces only heavy plates. A rod mill uses grooved rolls and produces various kinds of metal rods and shapes. There are also special mills designed for producing rails, girders, structural shapes, channel sections, sheet bars, merchant bars, rod and wire, strips, skelp, hoops and cotton tires, tubes, and other products. Special mills may be used for slitting, punching, making tires, or for cold rolling certain classes of materials.

The various products are named in accordance with arbitrarily chosen standards. A bloom is an ingot reduced by rolling to not less than six inches square; a slab is not less than two inches thick and at least twelve inches wide; a billet is less than six inches across (either round or square) and not less than one and a half inches, cut into standard lengths; a sheet bar is less than two inches in thickness and between six and twelve inches in width. Rods and bars vary in diameter from one and a half inches to 0·203 inches; when thinner than this the product is called a wire.

A number of other finished products are also produced by rolling mills, the names of which are more or less self explanatory—structural shapes, merchant bars, splice bars, reinforced concrete bars and rods, nail plate, spike plate, skelp, bands, sheet piling, railroad ties, forging blooms, forging billets.

The greater number of rolling mills are designed for the production of iron and steel products which together form the largest single item of rolled metal products. Mills are also designed for the production of rolled products in aluminium and aluminium alloys, copper and copper alloys including brass and bronze, monel metal, nickel, zinc, lead, and occasionally other metals or alloys. Rolled gold, silver, and platinum plate is also made in small special mills.

Rolling mills, in addition to the rolls, are equipped with various kinds of heating furnaces, either for heating the material to be rolled or for the purpose of annealing partially finished products during the process of rolling. Certain plants making coated sheets, or plants rolling copper and brass products, must also be equipped with dipping tanks and washing tanks for pickling, cleaning, and removing scale and oxides after annealing and prior to final rolling or coating with other metal. The principal accessory supplies required by rolling mills include large quantities of refractory bricks for furnace construction,refractories for repairs, and in some cases dilute sulphuric acid for pickling, and lubricants.

It might be noted that bars, rods, wire, hoops, and bands are the raw materials from which are fashioned such products as screws, bolts, nuts, spikes, chains, rivets, wire, wire nails, springs, hoops, cotton ties, baling wire, and numerous other products.

Tin plate and Terne plate.

Iron or steel sheets in thin sections corrode easily. This can be prevented or retarded by coating the sheets with a metal which oxidizes less readily than iron. Tin coatings are the best known, but galvanized sheets, where the coating is zinc, and lead coated sheets are also manufactured and marketed.

The process of manufacture is practically the same. Rolled sheets to be coated are first treated in an alkaline bath to remove oil and grease and they are then pickled in dilute sulphuric acid to remove iron oxide (scale). After washing they are annealed in a special furnace and then cold rolled to produce a smooth polished surface. After rolling they are again pickled, washed, and annealed, and then passed directly into a bath containing fused coating metal. Rolls are used to pass them through the bath and to withdraw them. At the same time the rolls distribute the coating metal evenly over the surface. Oxidation of the hot coating metal is prevented by covering the bath with a layer of palm oil through which the sheets must pass. The surplus which clings to the sheets is removed by using mechanically driven brushes which apply bran or a mixture of sawdust and lime to the surface.

Where the coating metal is tin the product is marketed as tin plate. Where an alloy, consisting of about three-quarters lead and one-quarter tin, is used the product is called terne plate. Galvanized sheets are prepared by passing the cleaned sheets through a bath of molten zinc. Enameled sheets and articles are prepared by coating the cleaned metallic surface with a ceramic enamel, reference to which is made in the section on Ceramics, drying, and fusing in special enameling ovens.

TUBES AND PIPES

Hollow cylinders, especially of small size, where the length is many times the diameter are called tubes or pipes. No sharp distinction can be drawn between the two words from the point of view of the process employed in their manufacture. When the form alone is considered *tube* is usually employed; sometimes the material employed influences the choice of the term to be used, as we habitually refer to an iron pipe and to a rubber tube or a brass tube. Commercially, tubes are measured across their outside diameter, while pipes are measured across the inside diameter. Metallic tubes and pipes are commonly made from wrought iron, cast iron, wrought steel, copper and brass. Tubes of other metals may be made for special purposes.

Cast iron pipes for water services, soil pipes, and other uses are made in foundries by the use of moulds. A centrifugal process is also being successfully used for this purpose. Wrought steel pipes are made from rolled plate and they may be either riveted or welded. Riveted pipes may be either spiral wound and riveted, or they may be made in sections with overlapping joints. Welded pipes are either butt-welded, or lap-welded according to the kind of joint made in forming the tube from the flat sheet.

Seamless tubes are made directly from blooms, billets, or bars by special processes. The more common method is to heat the billet or bar and pierce it in a special press. The cylinder thus formed is then worked into shape by rolling over a mandrel or by drawing much as in the case of wire drawing, except that the operations are usually performed on hot metal. The final drawing may be done either hot or cold. Usually tubes must be annealed after each drawing, and frequent pickling is also necessary to remove oxidized metal or scale. Seamless tubes can also be made from plate by pressing a circular plate into a succession of cup forms, finally piercing the bottom of the cup. The cylinder thus made is then further shaped with a mandrel and finally drawn to the finished size.

Iron and steel pipes, especially those intended for domestic water services, are usually pickled, cleaned, and galvanized with zinc. Occasionally a tin or lead coating is applied. These coating metals are usually applied by dipping the perfectly cleaned tubing in a bath of the molten coating metal, and then draining. The operations are usually carried out in a separate plant. Tin coatings may be applied to the inside or outside of copper tubes. Tubes of metals, other than iron, steel, or copper, are usually left in their natural condition for industrial use.

WIRE DRAWING

Small filaments of metal of considerable length are commonly called wires. They are usually circular in cross section, but they are also made with sections that are square, triangular, half round, oval, or flat. An arbitrary standard of 0·203 inches has been adopted in America as the dividing line between wire and rods; this corresponds to No. 6, B. W. G.

Wire may be made from any ductile metal or alloy. The more common kinds of wire are iron, steel, copper, brass, and aluminium. Wires are also made of gold, silver, platinum, lead, white metal alloys, precious metal alloys, tungsten, molybdenum, and certain steel alloys.

Iron and steel wires are used for making innumerable products. Some of the more common are barbed wire and other fence wires, telephone and telegraph wires, chain wire, wire ropes and cables, woven wire products in various forms such as fencing, netting, cloth, bed springs, guards, fabric for reinforcement of concrete, bale ties, hoops, springs, piano wire, spikes, nails, screws, rivets, staples, tacks, baskets, and numerous other articles used for industrial or domestic purposes.

Wires are made from bars and rods of small section by a process of drawing through a series of dies of successively smaller size. The operation consists in successively reducing the cross section by small amounts and at the same time extending the length. Dies for the larger sizes are made from cast chilled iron or from tungsten steel. Small sizes of wires, especially where precious metals and their alloys are used, or wires for lamp filaments, telescope cross hairs, and similar purposes where small cross sections are required are drawn through holes bored in black diamonds. Such dies are also used in making the smaller sizes of steel, copper or brass wires. Tungsten and molybdenum wires, and certain alloy steel wires are drawn hot through diamond dies. Wires of iron, steel, copper, brass, and other metals or alloys are usually cold drawn. The drawing process tends to harden and stiffen the metal, and unless hard drawn products are required it is necessary to anneal the finished wire by use of an annealing furnace. Wires direct from the dies possess a highly polished surface. This lustre can be retained if the annealing furnaces are air tight, the wire coils being fed through a water seal at one end of the furnace and delivered through a similar seal at the other end Where more than one series of drawings is required in the production of fine wires one or more intermediate annealing treatments are required.

Lubricants are used in cold drawing to reduce the friction. Larger sizes are drawn dry with tallow, ground talc, or graphite as the lubricant. Smaller sizes are usually drawn wet, rye flour and water being used for lubrication.

Statistical Data

The Dominion Bureau of Statistics issues monthly, semi-annual, and annual reports on the iron and steel industries of Canada. The first two series deal with the pig iron and steel production; the last deals also with iron and steel products. There are also issued at irregular intervals special reports dealing with certain arbitrarily chosen groups of industries such as the Brass and Copper Industry, 1919, and Foundry and Machine Shop Products, 1919. This latter report groups foundries with machine shops in such a way that neither the extent of foundry industries in Canada nor their capacity for absorbing raw materials can be ascertained.

The Canadian metal treating industries have not been studied statistically in such a way that any reliable segregated information can be obtained with respect to such individual groups of industries as iron foundries, steel foundries, brass and bronze foundries, forges, steel wire mills, copper and brass wire mills, and similar manufacturing units. Data of this kind are essential to the determination of the market which exists in Canada for certain metals and for the accessory materials such as refractories, lubricants, and chemicals required by industries of this type.

Canadian Situation

It has been possible only to make a partial survey of the secondary metallurgical industries established in Canada. Available records show 712 iron foundries, 23 malleable iron foundries, 50 steel foundries, and 204 brass and bronze foundries. Other metals or alloys, and especially aluminium and white metal, are sometimes used in some of the plants included in the brass and bronze foundries in the above enumeration. There are also three plants in Ontario which make white metal castings on occasion as required, but do not maintain special foundries. Some brass and bronze casting is also done in many of the iron or steel works, chiefly for immediate use; such firms are listed only as iron founders, to avoid duplication. The distribution of these plants by provinces is shown in the list below.

Table 22.—Distribution of Canadian Foundries

Province	Cast iron	Malleable iron	Steel	Brass and Bronze
Prince Edward Island	3	....	....	....
Nova Scotia	45	2	2	12
New Brunswick	23	....	1	8
Quebec	186	5	18	37
Ontario	346	15	21	104
Manitoba	22	....	3	8
Saskatchewan	12	....	....	3
Alberta	24	1	1	11
British Columbia	51	....	4	21
	712	23	50	204

The number of forges established in Canada is not known. Such plants are usually established in connection with steel mills, ship yards, car and locomotive works, plants making heavy machinery, spring works, and similar machine shops. Small forgings are made in connection with sheet metal works, and in some machine shops. Drop forgings in metals other than iron or steel are made in some shops producing locks, electric light and gas fixtures, valves, taps, and similar products.

The number of rolling mills engaged in making iron and steel products is twenty-six, six of these being established in conjunction with steel plants, and twenty obtaining their supplies in a partially rolled condition. These are distributed as follows: four in Nova Scotia, one in New Brunswick, six in Quebec, twelve in Ontario, one in Manitoba, and two in British Columbia. One firm operates five plants, another two, and there are nineteen firms owning single plants. One plant makes tin plate, terne plate, and black sheets. There are two plants rolling copper and brass and occasionally white metal alloys, and one plant making aluminium products. Several plants produce galvanized products, sheets, wires, pipes, and finished articles. No sheet zinc is rolled in Canada.

The number of tube mills operating in Canada is at least eleven. So far as known, seamless steel tubing is not made here, but lap- and butt-welded wrought iron or steel pipes are made from strips or skelp at eight plants. There are four plants making copper and brass tubes, one of which makes only small sizes, and one other making aluminium tubing. Extruded lead pipe is also made by six plants and zinc tubes at one.

There are twenty-four wire mills operating in Canada; iron and steel wires are made at thirteen plants, three of which also make copper and brass wires; nine other plants make copper, brass, and occasionally other alloy wires; aluminium wire is made at three plants, two of which also make copper wires. Galvanized wire is made at ten plants. In addition to the wire mills special kinds of wires are made at a number of plants; lead wires can be made as required at six plants, and zinc wire at one; fuse wires and wire solders are made at one plant; gold, silver, platinum, and plated wires are made at two plants, and tungsten and molybdenum wires are drawn at one plant.

PART VI

ALLIED INDUSTRIES

FOOD PRODUCTS

INTRODUCTORY

There are a number of very important industries engaged in fabricating products from materials of very diverse origin. All of these industries have at least one feature in common, chemicals and chemical processes are used to prepare the materials for use or for fabrication. Many of the industries use mineral products, or chemicals derived from minerals in association with raw materials of more or less complex origin from other sources. These industries have therefore been grouped under the title of *Allied Industries,* that is allied either to the Chemical or to the Metallurgical groups which have been discussed in previous sections.

It has been found convenient to subdivide the allied industries into two groups. The first group, which is considered in this part, comprises those industries whose primary purpose is the preparation of food products. The first two products discussed, sugar and starch, are also used industrially for many purposes, other than foods, and some reference to these industrial uses has also been made in the text. The subject of food preparation and preservation, which is dealt with in the third chapter of this part of this report, is considered more from the domestic point of view than from the factory side. There are no statistical data available to show positively which is more important, but the domestic side concerns by far the largest number of individual operators, and probably also offers the largest market for the various accessory chemicals used in the preparation and preservation of foods. Some materials that have been mentioned in this section, and some processes to which reference is made are, however, suitable for use only in factory operations.

It has not been feasible to prepare special chapters dealing with a number of special industries engaged in the preparation or preservation of foods. Meat packing and fish packing are important industries in Canada. Both give rise to a number of byproducts which are absorbed by other industries. The packer of meats or of fish requires a number of chemicals, and also uses chemical processes in the preparation of his products. Incidental reference has been made in other sections to the utilization of waste from these industries; the chemicals required by them are included in the chapter on general food preservation. The industries engaged in canning fruits and vegetables, and those engaged in preparing desiccated fruits and vegetables use chemical processes and give rise to byproducts,

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many of which are not yet utilized; they also require certain products supplied by the chemical industries.

Other industries which might be mentioned are dairying and the manufacture of butter, cheese, and milk products, including milk and cream powders, casein, and other products; the preparation of edible oils and fats; the manufacture of baking powders, which is discussed briefly here; the production of fruit essences and flavouring industries; the production of chocolate, ice cream, candies, and soft drinks, and carbonated products as beverages, and a number of related industries. All of these offer markets for chemicals or chemical products, and all use chemical processes; some produce important byproducts.

There has been no opportunity to study the requirements of these industries in sufficient detail to warrant special discussion in this report. Statistical reports with respect to these industries are issued by the Dominion Bureau of Statistics. These reports, however, do not devote attention to the chemical requirements of these industries in a way to enable the manufacturer of chemicals to judge of the markets which they offer for his products. The chemical processes employed by these industries are very interesting, but only limited amounts of inorganic chemicals derived from minerals are required.

The second group of *Allied Industries* discussed in this report comprises a number of industries which have been grouped under the title of *General Manufacturing*. They are discussed in a separate section—part VII.

CHAPTER I

SUGAR MANUFACTURE

Commercial sugar consists of the chemical compound sucrose, either in a pure condition or in association with small quantities of other materials derived from the same source as the sucrose. This compound is formed by many varieties of plants and is present in the juices or is stored in the tissues. Commercial supplies are obtained almost altogether from the sugar cane or from sugar beets. Locally sugars may be made from the juices of other plants. Palm sugar is obtained in tropical countries from certain species of palms. Maple sugar is the best known of this class of product in Canada. Birch sugar is also made from the spring sap of the yellow birch.

The world's markets for sugar are about equally divided between that produced from sugar cane and that produced from sugar beets. Sugar cane, which is a giant variety of grass that grows only in tropical and sub-tropical areas where soil and moisture conditions are favourable, does not grow in Canada. The Canadian supplies of this sugar are imported as raw sugar for treatment in refineries, or as refined products. Various grades of molasses and syrups which contain this sugar are also imported. Sugar beets are grown in small quantities in certain parts of Ontario, and beet sugar is made in this province. Maple sugar is a characteristic local product made by individuals in all the eastern provinces. Circumstances prevent its manufacture in central establishments and the market for the crude product readily absorbs all that is available. This product is never subjected to a refining process, other than the clarifying of the syrup, because refining would destroy its characteristic properties. Mention should also be made of the sorghum cane which is sometimes cultivated in temperate regions where the soil and climatic conditions are suitable. The sucrose present in this plant is associated with other kinds of sugar and with certain non-saccharose products which make it difficult to extract pure sucrose. It is possible, however, to make certain excellent syrups from the juices of this cane. Sorghum syrups are occasionally imported.

Cane Sugar

Sugar cane for the manufacture of raw sugar is grown on large plantations in tropical and sub-tropical countries under suitable conditions of soil and moisture. The principal producing areas are located in Cuba, Jamaica, and other West Indian islands, in Brazil, Peru, and the Guianas, in South America, in Mexico, in the state of Louisiana, in many of the islands of the Pacific, particularly the Hawaiian and Philippine groups, in Java, Sumatra, Borneo, Mauritius, and India. The cultivated cane is hand gathered at maturity and stripped of leaves and tops, the stalks alone being utilized for sugar production. These are conveyed to a sugar mill where they are crushed and macerated, the juices being squeezed out and collected. Raw juice is a greenish or yellowish coloured liquid which contains nearly all the soluble constituents of the cane such as sucrose, other sugars, gums, pectin, soluble mineral salts, and many other products including colouring matter derived from the plant, sand, and fragments of the cane.

The juice is subjected to a succession of treatment processes whereby it is clarified and many of the undesirable constituents are removed. The clarified juice is then subjected to chemical treatment to remove other undesirable constituents, followed by evaporation, cooling, and crystallization, whereby the commercial product sold as raw sugar is obtained. Raw sugar contains a considerable quantity of molasses, from which sugar cannot be extracted, and other impurities. It is necessary to subject raw sugar to a further refining process before the pure white commercial sugars are obtained.

Canadian sugar refineries obtain raw sugar from almost all the producing areas. The largest importations recorded are entered from the United States, but it is possible that these entries include raw sugars produced in other countries. Large supplies are also received from British Guiana, Cuba, San Domingo, and from producing island areas in the Pacific ocean.

Refining raw sugar. The first step in the refining of raw sugar is washing, syrup from a previous operation being used for this purpose. This removes much of the molasses and non-sugars present in the raw product. The washed sugar is separated from the washing liquid in centrifugal machines. The separated washed sugar is then melted with water or weak syrup treated with a little milk of lime, only enough being added to render the solution slightly alkaline. Infusorial earth[1] is sometimes added also to aid in the clarifying of the solution in the filtering operation which follows. The clarified liquor, after filtration, is boiled to grain in vacuum evaporators and then treated in a crystallizer. The crystallized sugar is separated from the syrup in centrifugal machines. The recovered sugar is washed quickly with a water spray to remove the syrup which adheres to the grain. It is then dried in a steam heated revolving cylinder in a current of air, and is packed for shipment.

The syrup is returned to the evaporating system to obtain another batch of crystals. When most of the crystallizable sugar has been recovered the residual product is utilized as an edible table syrup, the grade depending upon its sugar content, clarity, and other properties.

The washings obtained from the first treatment of the raw sugar are also clarified and treated separately to remove the dirt and other undesirable constituents, and to recover the sugar and molasses.

Sometimes phosphoric acid or sulphurous acid is used in clarifying syrups before graining.

Ultramarine blue is used in small quantities to improve the colour of white sugar. The yellow colour of soft sugars is often improved by the addition of a small quantity of yellow colouring compound, such as turmeric or saffron.

Beet Sugar

The principal source of supply of sucrose in the temperate zones is the white sugar beet which will thrive under suitable conditions of soil and moisture. Canada, for the most part, lies north of the area on this con-

[1] Sawdust has also been used.

tinent where these beets grow best. They are now being raised successfully on the Ontario peninsula north of lake Erie and east of lake St. Clair. They have also been raised successfully in other parts of Canada, but not on a commercial scale. The careful hand cultivation needed and the high cost as well as scarcity of suitable labour tend to retard the expansion of the sugar beet industry. The quantity raised annually in the producing districts is not sufficient to keep the three factories now located there in continuous operation, and it is customary to refine considerable quantities of imported raw sugars in these plants during the off season.

The production of sugar beets is a highly specialized agricultural industry. Much attention must be paid to the production of seed of the best strains, and the crop must be harvested and stored with care.

In the process of manufacturing sugar the raw beets are washed thoroughly and then sliced into thin prisms or special shaped slices, termed cossettes, in a special machine. The prepared cossettes are charged into special vessels for the extraction of the sugar which they contain by a process of diffusion. When exhausted the residue is pressed to extract as much juice as possible. The resulting cake is utilized as a cattle food either when fresh, or after drying.

The liquid obtained from the diffusion equipment contains most of the soluble constituents of the beets as well as the sucrose. It is purified and clarified by successive treatments with small amounts of lime followed by carbonation with carbon dioxide gas and filtration. This treatment may be repeated once or twice. Sometimes sulphur dioxide gas is used following the carbonation treatment. The resulting clear syrup is boiled in vacuum pans until it reaches a suitable density. It is then run into stirring pans and crystallized while in motion, the resulting sugar crystals being recovered in centrifugals. The syrup may be treated for a second crop of crystals by a second boiling and crystallizing operation.

The final syrup or beet molasses is not an edible product on account of the concentration in this product of a number of the soluble constituents of the original beets. It is sometimes used for making cattle foods, by absorbing it in a suitable material. It may also be treated by a fermentation process and distilled for the production of alcohol. It is also possible to extract the remaining sugar by a chemical process. When this is done the final residue is usually evaporated to dryness and sold as a fertilizer ingredient on the basis of its potash and nitrogen content.

There are several processes in use for the recovery of the sucrose in beet molasses These processes depend upon the fact that sucrose will form an insoluble salt with calcium, barium, or strontium. This salt is obtained by treating the molasses with the proper amount of the hydroxide of one of these substances, recovering the resulting salt, and decomposing it by a simple process. The lime process is largely used in the United States. Both the barium and the strontium process are in use in Canada. Where barium hydroxide or strontium hydroxide is used for the recovery of sucrose it is customary to recover as much as possible of the final residue of these materials as a carbonate. The carbonate is calcined and hydrated and then used again, the mechanical losses being compensated by the addition of new material.

Chemicals used in Sugar Manufacture

The manufacture of sugar is largely a physical process of concentration and recovery of soluble constituents applied in conjunction with the use of chemical means for the removal of undesirable constituents from the liquids to be concentrated.

The principal accessory chemical required is calcium hydroxide, which may be added as milk of lime. Much of the lime used in the Canadian sugar industry is imported from the United States as dry slaked lime, or as powdered quicklime.

Animal charcoal is used for filtering. The waste charcoal is sometimes calcined and used as a source of phosphoric acid.

The other chemicals used at some stage of the process of refining are phosphoric acid or acid phosphate of lime, sulphur, calcium carbonate (limestone), ultramarine, and certain yellow colouring products.

Kieselguhr used for clarifying is nearly all imported from California.

The quantities of these products which are used in this industry, in proportion to the sugar recovered, are small, but the total annual consumption must reach a considerable amount. No statistical data are available.

Canadian Situation

As previously noted, the larger proportion of the Canadian supply of sugar is imported as raw sugar. There are five refineries in Canada employed exclusively in the treatment of raw sugars, two being located in the Maritime Provinces, two in Quebec, and one in British Columbia. There are also three refineries in Ontario which produce beet sugar during a portion of the year and where imported raw sugars are also at times refined.

Statistical data with respect to the Canadian production of sugars are issued by the Department of Trade and Commerce. Information with respect to some of the imports of raw and refined sugars and syrups is available in the monthly reports of the Trade of Canada, issued by the same Department.

CHAPTER II

STARCH AND STARCH PRODUCTS

General

Starch is a white lustrous carbohydrate found in all plants except fungi. It is produced by the metabolic processes of the plant and is stored in granular form in cells in various parts of the organism. Next to cellulose, to which reference has already been made, starch is probably the most abundant organic material produced by plants. It is found in considerable quantity stored in the cells of seeds, such as beans, peas, grains, and similar fruits. It occurs stored in special parts of the stems of some plants as in tubers like potatoes or artichokes, or in the pith of the sago palm, or in the roots of many forms of vegetables and some trees. Starch is one of our most important food products. It is also an important industrial commodity which finds many applications in the arts.

Starch as a food product may be consumed in association with the other parts of the plant with which it is associated in nature. It is also prepared for consumption as food by separating it from the other associated parts of the plant which produced it. Starch for industrial purposes is nearly always separated from the vegetable material with which it is associated in its natural state.

Starch is generally obtained from grains, the principal grain used for this purpose being corn. Rice or wheat may also be utilized. In Europe the principal source of supply is potatoes. Special varieties of starch are also prepared from other sources. Such starches are arrowroot, sago, or tapioca, all of which are used for food purposes and also industrially, though none of these are produced in Canada.

The principal starch produced in Canada is obtained from corn. The corn used for this purpose is largely imported, though home grown grain is also used. Potato starch is produced in a small way from home grown potatoes for the manufacture of potato flour and laundry starch.

Ordinary corn contains slightly in excess of 54 per cent starch. The balance consists of oil, protein, fiber, certain other carbohydrates, and a small amount of mineral matter. The process of manufacture consists briefly in softening the grain by soaking in warm water into which is passed a small amount of sulphur dioxide. The sulphurous acid solution thus formed softens the gluten of the grain and prevents fermentation. After softening the grains are disintegrated in a special machine, which crushes without grinding. The germs, which contain the oil and most of the protein, do not disintegrate, and are easily separated from the rest of the material by suitable agitation in a tank with water.

The rest of the grain, consisting of the starch, gluten, and husk, is reground in some variety of buhr stone mill, and then subjected to special treatment by which the three principal constituents are recovered separately. The husks are recovered as bran, subjected to pressure to remove the excess water, dried, and marketed as cattle food. Some of the gluten is lost with the wash water but a considerable proportion, with a certain amount of adherent starch, may be recovered from the glutinous wash waters by settling and decantation. The settled residues are treated in a filter press. The filter cake is ground, dried and marketed as gluten meal, or as a cattle food. The bran and gluten meal are also mixed and marketed as a cattle food. Gluten, specially prepared, has been used in certain branches of the textile industry as a substitute for albumen. Corn gluten is not marketed as a food for mankind.

The germs which are collected separately are washed to remove any adhering starch and are then dried. The dried germs are pressed in oil presses to remove the oil—as corn oil—and the remaining oil cake is utilized as a food for stock, for which purpose it is particularly valuable owing to its high protein content (22 per cent). The corn oil extracted from the germs is used in making soaps and also in the production of edible oils and other products for table use. Germ meal for human food is also made from this product.

The separated starch is freed from water by running into cloth bottomed draining boxes, or is filter pressed. It is then partially dried until it cakes and the cake is transferred to special kilns for final drying. The exterior portion of the dried cake contains some impurities deposited there by the moisture during the drying process. This is removed and the residue forms the pure white starch of commerce. It may be marketed as "cake" or "crystals," as it comes from the kilns, or it may be pulverized or otherwise prepared before marketing.

Starch is also prepared by adding dilute caustic soda to the product obtained after the germs have been removed. The alkali increases the solubility of the gluten, removes any oil that may be present, and aids in the separation of the starch proper. Starch made in this way is purer than that made by the use of sulphurous acid alone and it also makes more coherent pastes.

Prepared starches are sometimes subjected to a further treatment with dilute sulphuric or hydrochloric acid resulting in a product termed "thin-boiling" starch which finds special application in commercial laundry work.

The characteristics of a commercial starch can be varied greatly in its preparation, and it is customary to grade the product according to its paste making properties. Two general types are recognized—thick-boiling and thin-boiling starches. Corn starch, as a food preparation, is a characteristic thick-boiling starch. Thick-boiling starches are also used commercially in such industries as box making where it is not desirable that the starch paste penetrate the fabrics used. Thin-boiling starches are used industrially in laundry work, in textile dressing, and in confectionery. Paste made from thin-boiling starch is thin enough to penetrate a textile fabric when hot without coating the surface, and still possesses enough "body" to impart stiffness to the fabric treated, when cold.

Starch Products

Starch is a complex carbohydrate which can be reduced to simpler compounds by suitable treatment with dilute acids or by heat treatment. The nature of the change that can be induced by the first method and the rate of change depend upon the degree of dilution of the acid and the temperature. The process of changing starch into these less complex compounds by treatment with dilute warm acids is termed "conversion," and the changes induced are due to "hydrolysis." During the course of treatment with warm dilute acids intermediate compounds of very complex structure are formed, but when the hydrolysis is carried to completion the final product is dextrose.

Advantage is taken of this property of starch to prepare certain well defined products which are important industrially. The principal products made by hydrolyzing starch are glucose (corn syrup), grape sugar, dextrine (British gum), and soluble starch.

Glucose is used in large quantities in the manufacture of confectionery. It is also used to make certain grades of table syrups and in the production of jellies, preserves, beers, and "soft drinks." In addition to its use as a food product there are many industrial applications, such as a filler for sole leather, as a constituent of certain tanning extracts, and in the manufacture of plug tobacco.

Grape sugar, a solid product closely related to glucose, is used in the manufacture of vinegars and beers, in the dyeing industry, in the manufacture of mirrors, and as a reducing agent.

Dextrine, or British gum, frequently made by heating starch under suitable conditions, is widely used in the textile industry, particularly in calico printing and in the printing of colours upon many other classes of textiles. It is used also as an adhesive in the manufacture of many paper products, including envelopes, postage stamps, and gummed labels.

Soluble starch is a product closely related to dextrine, which is used in the laundry trade and in textile manufacture.

Chemicals used in the Starch Industry

Sulphur is generally used for the production of the sulphur dioxide used in making the weak sulphurous acid solution required in the steeping tanks.

Caustic soda is used for making "alkaline" starch, and also for neutralizing acid solutions in some processes.

Hydrochloric acid is generally used for hydrolyzing starch in the manufacture of the principal starch products. Dilute sulphuric acid is also used for this purpose. Nitric acid, acid sodium sulphite, hydrofluoric acid, oxalic acid, or acetic acid can also be used.

Marble dust is used for neutralizing sulphuric acid when preparing conversion products. Sodium carbonate can also be used for this purpose.

Bone charcoal is used for clarifying solutions of glucose or cane sugar in the preparation of edible glucose products.

No statistical data are available showing the consumption of chemical products in the starch products industry in Canada.

Canadian Situation

There are two firms in Canada operating three factories for the production of starch from corn. In addition to corn starch as a food product, laundry starches and gluten feeds are marketed. These factories also produce glucose and grape sugar, particularly for confectioners' use. There are eight firms producing starch from potatoes; six of these operate in Prince Edward Island; one in New Brunswick; and one in Ontario. This product is marketed in part as potato flour and in part as textile and laundry starches. Dextrine is produced by four firms, three of which are located in Ontario and one in Quebec. The information at present available indicates that there are no plants in Canada west of Fort William engaged in the manufacture of starch or starch products.

There are no statistical data available to indicate our annual requirements of these commodities. The total value of our imports of starch products is close to $350,000. The value of the corn imported for the manufacture of starch has not been segregated. A summary of the available statistical data will be found in the tabulated statement which accompanies this report, classified under the items, dextrine, starch, and glucose. Unfortunately no attempt has been made to separate the individual items, and the quantities of each product are not recorded separately. The item under dextrine includes several grades of British gum as well as certain sizings and enamel creams of different degrees of dilution. Starch includes all starch food products, textile starches, and laundry starches. Under the item glucose are classified not only the solid grape sugar and the liquid glucose, but also glucose syrups, and no distinction is made between food products and products for industrial uses.

CHAPTER III

FOOD PREPARATION AND PRESERVATION

General

Every day nearly everyone uses food products that have been subjected to preparatory treatment. Very few persons recognize that there is a scientific basis underlying culinary operations, although the health and well being of the nation depend upon the knowledge and skill with which these processes are applied. A notable sidelight on the general attitude towards these matters is shown by our census returns which classify 62·6 per cent of our population[1] as persons having no occupation. As a matter of fact, at least one-third of the persons included in this category, over 20 per cent of the population, are more or less skilled in some or more of the various arts of food preparation, and are actively engaged for a considerable portion of their time in the actual practice of these arts. These persons constitute the active market for all the chemical products used within the domestic circle for household purposes.

Originally all food preparation was local, for the use of the individual, the family, or the community. To-day under conditions which we are prone to term modern civilization, many of our staple food products are subjected to various kinds of preparatory treatment at central points in factories and under the direction of specialists. Scientific treatment of food for preservation or in preparation for immediate consumption can be applied within the household as well as within the factory.

Food products which are not consumed in their natural state are subjected to preparatory treatment either to preserve them for future consumption or to render them more suitable and satisfactory for immediate use. These two purposes often merge more or less when both ends are accomplished by any given process. Micro-organisms develop in foods under favourable conditions of moisture and temperature and produce enzymes that are responsible for many of the various chemical changes which constitute food spoilage or decay. Other enzymes are present in the original cells of the food materials. Preservative processes are intended to render food less subject to the attacks of micro-organisms and enzymes. They retard and prevent the growth of these organisms and render the conditions unsuitable for the development and activity of enzymes. Preparatory processes are intended primarily to render food palatable, more nutritious and more easily digestible and attractive. Incidentally they may also be intended to prevent the formation and reactions of undesirable enzymes, or to assist in the development of desirable ones.

There are seven well-known methods of food preservation. These are *drying, salting, pickling, smoking, refrigeration, canning or preserving,* and *dehydration.* Drying, salting, and preserving have been practised

[1] The figures of the 1921 census are not available, this item is from the 1911 census.

almost from time immemorial. Refrigeration and dehydration are essentially modern developments. Many foods when subjected to some one of these processes for preservation purposes are also suitable for immediate consumption; usually a small amount of additional preparatory treatment is needed. Other processes used in food preparation are boiling, stewing, baking, roasting, and broiling, all being variations in methods of heat treatment. These are applied as experience and desires dictate.

These various processes and the effects they produce are not discussed in this report. Attention is given only to the various chemical products used in the preparation of foods either for preservation or for use. No attempt has been made to distinguish between chemicals used in factory operations only, those used only in the domestic circle, and those used in both places. The short paragraphs which are submitted on each substance are briefly explanatory of its origin and the purpose for which it is used. The series of paragraphs on these substances will, however, enable the reader to judge for himself as to the extent and importance of the market this industry offers for a number of chemical products. As far as possible only chemical products known to be used in Canada have been included in this enumeration, and a few substances of relatively minor importance have been omitted for lack of information.

Chemicals used in the preparation of food products must be free from deleterious substances of various kinds, many of which are poisonous. The use of certain chemicals for food preservation is limited by law in most countries, some products being completely banned, and some being permitted in quantities which do not exceed certain specified minima. The regulations controlling this use of chemicals in Canada and prescribing the degree of purity that may be safely used for food products are issued by the Department of Health, at Ottawa, under the Food and Drugs Act.[1]

Products used for Food Preparation

The principal products of chemical manufacture required for the preservation and preparation of foods are discussed briefly in the following paragraphs. The order of presentation is alphabetical, certain chemicals used in minor quantities as preservatives being noted under that caption.

Ammonium Bicarbonate. This substance is prepared from ammonia by treatment with excess of carbon dioxide. A small quantity is apparently used by some manufacturers of baking powders as a substitute for a portion of the sodium bicarbonate.

Baking Powders. These are mixtures of certain chemicals which are used to impart a spongy or porous texture to several varieties of breads, cakes, and pastries. They might be defined as substitutes for yeast in bread making. Yeast operates by the production of alcohol and carbon dioxide gas, both of which become entangled in the dough, producing a porous mass that later becomes fixed in the operation of baking. Baking powders when mixed evolve carbon dioxide which acts in the same way.

[1] These regulations can be procured in pamphlet form as "Regulations made by Order in Council" under the Food and Drugs Act. P.C. 2986, 1920, and P.C. 81, 1921.

When yeast is used the two products that promote the development of the spongy condition of the dough are produced by the chemical decomposition of some of the starches and sugars present. When baking powder is used the carbon dioxide resulting is produced by the chemical action of an acid on a carbonate.

Investigations made in the Food and Drug laboratory of the Department of Health in Ottawa show that from 12 to 16 per cent of gas (carbon dioxide) may be expected to be developed by any good baking powder. The standard of the United States Department of Agriculture[1] establishes a minimum gas production of 12 per cent by weight; the Canadian standard places the minimum gas at 10 per cent by weight.[2]

The highest grade baking powders consist of *sodium bicarbonate* and *cream of tartar* (potassium bitartrate) mixed in suitable proportions. To these is usually added a starch constituent such as wheat or rice flour, or prepared starch, partly to act as a dilutent, partly to prevent the premature development of the chemical reaction between the two substances due to the moisture of the atmosphere. Such a baking powder liberates its carbon dioxide slowly owing to the slow solubility of cream of tartar in cold water. To hasten the action and to provide a quantity of carbon dioxide at the beginning of the operation some baking powders contain a little *tartaric acid* replacing a part of the cream of tartar. *Sodium carbonate* also is used at least in part as a substitute for the bicarbonate; less frequently *magnesium carbonate* or *ammonium bicarbonate* are added.

Substitutes used in place of tartaric acid and cream of tartar are *acid phosphates* of *ammonium, potassium* or *calcium,* or *acid potassium sulphate.* It is stated that baking powders containing any one of these constituents will tend to darken the finished product.

Some baking powders contain dried *alum* which has the effect of whitening the flour. Soda alum appears to be the alum most frequently used. Ammonia alum and potassium alum are used occasionally. Many food specialists condemn the use of this material and in some countries its use is forbidden. *Sodium sulphate* and *potassium sodium tartrate* (Rochelle salts) are also found in some powders. Neither of these salts can serve any useful purpose in baking powders and their presence is undesirable.

The starch component of standard baking powder may be in part replaced by *milk powder.* In a few cases powdered *albumen* is added. While this latter constituent is harmless the amount added is so small that it has little food value and it is practically valueless as a constituent of baking powder.

Baking powders are manufactured simply by thoroughly drying the components and then mixing them in the proper proportions. Needless to say pure materials free from deleterious substances must be used to obtain the best results.

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[1] U. S. Dept. of Agriculture, Circular 136, June, 1919.
[2] Order in Council, Ottawa, Aug. 17, 1918, G. 1313.

A report on Baking Powder (Bulletin No. 439) issued by the Department of Health in 1920, mentions that 141 brands on sale in Canada had been collected and examined. Only nine of these brands were imported from the United States. The total number of manufacturers placing baking powders on the home market is not known, but it exceeds one hundred and twenty-five firms.

None of the chemicals mentioned in the foregoing statement as entering into the composition of baking powders are actually manufactured in Canada. One firm produces the crude carbonate of soda, known commercially as soda ash, but so far as information available shows, the refined carbonate and the bicarbonate are not produced. The farinaceous constituents and milk powder are made here. Albumen powder does not appear on any available production lists.

Baking Soda. Refer to sodium bicarbonate.

Calcium Lactate. This compound is used very rarely in small quantities to insure the stiffening of cream when whipped. It may also be present in preparations sold under trade names for the same purpose. Information on this point is not available. It is not made in Canada.

Citric Acid. This product is manufactured from the juice of lemons, limes, or other citrus fruits. It is used to acidify soft drinks, to make artificial lemonade, and in some effervescing medicinal salts. It is not made in Canada.

Cream of Tartar. Refer to potassium bitartrate.

Edible Fats and Oils.[1] Certain fats and oils of animal and vegetable origin possess high food values. They are used directly as foods and they also find wide applications in the preparation of many food products. The principal animal fats used are butter, beef tallow, mutton tallow, lard, and preparations made from these, such as oleo oil and stearine. They are prepared for consumption by the meat packing industry to which reference is made in another section. The principal vegetable oils used directly as foods are cocoanut oils, cocoanut butter, corn oil, cottonseed oil, olive oil, palm kernel oil, and peanut oil. A few other oils such as poppy seed oil, rape seed oil, soya bean oil, sesame oil, and sunflower oil, are used occasionally in smaller quantities. Mention should also be made of the essential or volatile oils which are used in flavouring and for making flavouring extracts. The principal oils used for this purpose are almond, anise, basil, cassia, celery seed, cinnamon, clove, geranium, lavender, lemon, marjoram, nutmeg, orange, orris, peppermint, rose, sandalwood, thyme, savory, spearmint, vanilla, and wintergreen. None of these oils are produced in Canada. Extracts of ginger and tonka bean may also be included here. These extracts are made in Canada from imported materials.

Some oils and fats are used directly as foods. Butter, beef tallow, and olive oil are cases in point. Some are used to preserve foods as in the case of meats packed in fats or sardines and ciscoes packed in olive oil. All the oils and fats mentioned find applications in the preparation of foods by

[1] Includes shortenings, which are edible oils or fats used in baking.

the processes of baking, roasting, frying, and broiling, and frequently some of them are used in canning and preserving meat products.

The principal use of the animal and vegetable oils in the first two lists given is as shortenings for the preparation of farinaceous foods. Shortenings are sometimes subjected to a preparatory treatment to render them odourless and tasteless and to effect purification. They may also be used in a natural condition. Those that are fluid at ordinary temperatures are sometimes subjected to a preparatory treatment to harden them. Vegetable oils, especially, can be converted into products of almost solid consistency by hydrogenation. Most of the so-called pure vegetable shortenings are prepared for marketing by this process. Another class of shortenings consists of animal and vegetable fats mixed in proportions which differ with the brand. Such products are often designated shortening compounds. Hydrogenated vegetable oils may be compounded with animal fats to produce shortening compounds. Oleomargarines are special blends of treated animal and vegetable fats and oils so compounded that in chemical composition, appearance, and taste they closely resemble butter. Compounds of this kind can be produced which are purer and better than butter, though they may be deficient in vitamins. The principal products used in their manufacture are oleo oil, neutral lard, cocoanut oil, earthnut oil, sesame oil, cottonseed oil, corn oil, sour milk or cream, and sometimes purified butter fat. In some brands casein and milk sugar are added, less often an extract obtained from egg yolks.

In the preparation of flavouring extracts and essences from the essential oils the principal solvents used are ethyl alcohol, water, and glycerine.

All the animal oils mentioned above are produced in Canada. Corn oil is the only edible vegetable oil produced here. All the others listed are imported as required. This also is true of essential oils for the production of flavouring extracts. Ethyl alcohol and glycerine are produced in Canada.

Ferments. Certain micro-organisms are capable of producing enzymes which cause the decomposition of certain complex natural organic compounds and the formation of water soluble simpler ones. These enzymes are utilized in the manufacture of certain food products. Some reference has already been made to them in the description of the Fermentation Industries when discussing the production of beverages containing alcohol, vinegars, casein, and lactic acid. Certain kinds of cheeses also owe their characteristic flavours to the use of definite ferments. Bread making by the use of yeast is also primarily a fermentation product. The factory use of these products is always under skilled technical control. The home use is usually empirical. Most of the ferments used in food preparation are developed when and where required. Malt, which contains the soluble ferment diastase, has a limited use as a food product, and is made in Canada. Compressed yeast, to which reference is made below, is also made here. No information is available with respect to the extent of the use of other ferments in Canada. One laboratory offers them for sale, but most of the products are made in the United States.

Flavouring Extracts. The bases of flavouring extracts, essences, and compounds are organic products naturally produced, or similar products made synthetically by controlled chemical processes. The extraction of flavours and perfumes from flowers and other natural products is an ancient industry whose commencement antedates historical records. The production of synthetic esters and ethers of like composition and their blending to reproduce natural odours and perfumes is one of the highest developments of modern chemistry. So far as is known none of these products are made in Canada. Some Canadian firms purchase prepared essential oils, synthetic perfumes, and flavouring materials and use them for the manufacture of flavouring extracts for distribution to the consumers. The principal flavours distributed in this way are almond, bergamot, cloves, lemon, rose, vanilla, and wintergreen. Other oils of this group, from which extracts or compounded extracts and flavours are made are listed in the paragraph on Edible Oils and Fats.

Lactic Acid. Commercial lactic acid is not used in the food industries directly except in the preparation of pectin. It is customary, however, to take advantage of the lactic fermentation process in domestic culinary operations. Milk is intentionally soured to cause the casein to be precipitated for recovery in some form as cheese. Milk is also soured and used with sodium bicarbonate (baking soda) as a substitute for baking powder in the production of certain kinds of pastry, cakes, and breads. In this case calcium lactate remains in the food and carbon dioxide is liberated and acts as the leavener. Lactic acid is not made commercially in Canada.

Pectin. This substance is the jelly-yielding compound found in apples, pears, and similar fleshy fruits. It is also found in carrots and turnips, and in the seeds of fruits as in oranges and grapefruit. Commercially soluble pectin is obtained from fruits like the apple by treatment with hot water. It is precipitated as a jelly on boiling or by acids. Apple pectin is used for thickening jams, especially when made of fruits that are devoid of pectin and will not set. Its use improves the quality of product and simplifies transportation and distribution problems. Soluble pectin is also used to advantage in home canning and preserving. One firm is producing this product in Canada for the home market.

Potassium Bitartrate. This compound, more familiar to the housekeeper as *cream of tartar* is used as the acid constituent of the best baking powders. It is also used within the domestic circle with baking soda as a leavener, instead of using a prepared baking powder. It serves as a mild acid for use in effervescent drinks and considerable quantities are used in the manufacture of candies. It is made from argol by extraction with water, argol being a byproduct of the wine industry. None is produced in Canada.

Preservatives. There are a number of substances that are used for the preservation of foods. This is accomplished either by preventing the growth of micro-organisms, including moulds, or by preventing oxidation. The principal compounds used are as follows:

Boracic Acid. This product is made from borax—sodium biborate. None is made in Canada. It is used chiefly for preserving dairy products. The Canadian regulations permit 1 part in 400 of cream, and 1 part in 200 of butter and other foods.

Carbon Dioxide. This product is an inert gas. If sterilized food packages are filled with carbon dioxide decay and oxidation are prevented. The gas is inserted by first exhausting the air and then introducing it under pressure. The method has been used for the preservation of chocolate, cocoa, coffee, crackers, partially dried fruits, dried milk, nuts, and numerous vegetables, as well as meats. Fats, when present, remain practically unchanged. The method is more successful than the use of a *vacuum,* since the pressure within the container may be kept equal to that outside. Evacuated containers have to be strong enough to resist external air pressure, whereas the use of carbon dioxide at atmospheric pressure makes it possible to use lighter packages. The method is not known to be in use in Canada.

Lime. Calcined calcium carbonate is slightly soluble in water. The aqueous solution of lime—lime water—is used for preserving eggs.

Potassium Nitrate. Saltpetre, the nitrate of potassium, is used in pickling solutions for the preservation of meats. The deep red colour imparted to corn meats is usually produced by the use of this chemical. None is made in Canada.

Sodium Benzoate. This substance is sometimes used to prevent the growth of fungi and micro-organisms. It is used as a preservative in pickles, catsups, jams, and preserves. Its application for this purpose is prohibited in many countries because its frequent use has been found to be associated with undesirable physiological effects. In Canada one part per thousand is permitted when used. It is produced in Canada by one firm.

Sodium Biborate. This salt is used in the same way as boracic acid, which see.

Sodium Nitrate. This compound is sometimes known as soda saltpetre or Chili saltpetre. It is used in some pickling brines for the preservation of meats. None is produced in Canada.

Sodium Salicylate. This product is used in much the same way as sodium benzoate and boric acid. Its use in food products is forbidden in most countries. The Canadian regulations permit one part in five thousand. None is produced in Canada.

Sulphurous Acid. This acid is produced by the combustion of sulphur. It is used as a bleaching agent and also as a preservative. Salts of this acid with sodium, potassium, or calcium can also be used as preservatives. The Canadian regulations permit one part in ten thousand in beverages and one part in two thousand in solid foods. The three salts mentioned are not made in Canada. The gas can be made by the combustion of imported sulphur.

General. It may be noted that the Canadian regulations forbid the use of the following chemicals for the preservation of foods:—formaldehyde, beta-naphthol, abrastol (asaprol), hydrofluoric acid, fluorides, fluoborates, fluo-silicates, and other fluorine compounds.

Salt. Common salt, sodium chloride, occurs in natural brines and also in the solid form as rock salt. Salt in brines is recovered by evaporation and crystallization. Rock salt is used directly as crushed rock salt, or it may be dissolved and recrystallized to effect purification. Salt is used as a food preservative both in the solid form and in solution in pickling brines. It is also used as a condiment. Rock salt is produced in Nova Scotia; salt obtained from brines is produced in Ontario; salt required in the western provinces of Canada is all imported as there is no commercial production as yet.

Sodium Bicarbonate. This compound of sodium is made from the carbonate by treatment with carbon dioxide. It is commonly called baking soda and finds many uses in the art of food preparation. Some of the principal applications are the preparation of effervescing salts of various kinds, including medicinal salts (effervescing magnesia, seidlitz powders, etc.), effervescing beverages, artificial mineral waters, baking powders. It is used directly in culinary operations for neutralizing fruit acids and thus destroying acidity. It is also used with lactic acid (in sour milk) as a substitute for baking powder. It is not made in Canada.

Sodium Carbonate. It is made from soda ash, the crude carbonate. Soda ash is made from sodium chloride by the use of ammonia gas and carbon dioxide (Solvay process). The carbonate of sodium is infrequently used as a substitute for the bicarbonate. Crude carbonate, commercially soda ash, is made in Canada by one firm. The recrystallized purified carbonate is not produced here.

Sugars (Sweetenings). Cane sugar is the best known and most widely used of a number of sweetening compounds applied to the preparation of food products. Other similar commodities used for the same purpose are cane syrups, sorghum syrups, cane molasses, glucoses (particularly as corn syrup), maltose, maple sugar, birch sugar (rare), and honey. All of these commodities are used in certain classes of factories on a large scale, and also within the domestic circle. Cane sugar especially is used also as a food preservative. Its application in the production of candied fruits, candied peels, jams, preserves, and canned products, is well known. Some one or more of the other sweetening compounds mentioned above are often substituted for cane sugar in some factory operations, particularly in the production of preserved and canned fruits, jams, and fruit jellies.

All of these products are used for the manufacture of candies, sweet biscuits, chocolate preparations, prepared jellies, soft drinks, and other similar products.

Mention should also be made of saccharine, a synthetic chemical product, not made in Canada, which is used as a substitute for sugar medicinally, and is also used in factory operations for sweetening syrups, oils, soft drinks, and wines. Its relative sweetening capacity is stated to be 500 times that of an equal quantity of cane sugar. The Canadian regulations permit the use of saccharine for sweetening only but it may not take the place of sugar in any food in which sugar is employed as a source of nutriment. One part in 1500 is permitted in beverages, and one part in 700 in solid foods.

The Sugar Manufacturing industry is discussed more fully in another section.

Tartaric Acid. This product is usually manufactured from wine-lees or from crude cream of tartar (argol). It is used as a substitute for cream of tartar in certain baking powders, and also in the manufacture of effervescing beverages and in some medicinal preparations. It is not made in Canada.

Vinegar. This product is an impure and dilute acetic acid prepared by a fermentation process. The production of vinegar has been discussed in the section on Fermentation Industries. It is used as a condiment and food preservative, particularly in the preparation of the numerous varieties and brands of pickles, and in food flavouring extracts and sauces.

Yeast. The commercial product sold as yeast consists of a yellowish white mass composed of the cells and spores of a unicellular plant, commonly called the yeast plant (technically Saccharomyces cerevisae) of which there are several varieties. Prepared yeast comes in nearly dry cakes, in soft cheese-like masses, or even in a semi-liquid or viscous form. Under suitable conditions of food supply and temperature yeasts grow rapidly. When growing the plant liberates carbon dioxide gas and forms alcohol. If entangled in a mass of dough and slightly warmed to a suitable temperature these products cause the dough to become spongy or porous. The porous character can be fixed by further heating to a higher temperature, which at the same time kills the yeast plant, vaporizes the alcohol, causes the carbon dioxide to pass away and produces those changes in the flour components of dough which are characteristic of the several processes of cooking, such as baking, boiling, or toasting.

The scientific cultivation of the several varieties of yeast most suitable for the purposes of the fermentation industries and for baking is the basis of an important industry. Yeast prepared in convenient packages for distribution to the domestic market for bread and pastry making is a well-known commercial commodity. More recently it has been finding wide application as a source of vitamin B, a product that appears to be essential to the maintenance of vitality. The other varieties of yeast are less well known and are usually cultivated at the point of consumption. Yeast is produced for commercial purposes at a number of points in Canada.

Containers. The preservation of foods necessitates the provision of suitable containers. The food preserving industries therefore afford a large market for a variety of products used in making these necessary articles. Dried, salted, smoked, and dehydrated products are commonly packed in wooden, pasteboard, or fibreboard containers, which may have been treated with paraffin or with certain varnishes or lacquers. Sheet metal containers are sometimes used. Pickled products are packed in wooden, fibreboard, or glass containers. Canned and preserved products are packed in wooden, glass, or sheet metal containers. Metal containers are usually made from sheet steel or sheet iron plate coated with tin. The annual consumption of tin plate of various kinds suitable for this purpose is very large. All of these products are made in Canada, but large quantities of the materials from which containers are made are imported. Collected statistical data are not available. Some information can be obtained indirectly by a study of the published records of the Department of Customs.

The production of containers also involves the use of waxes, especially paraffin, lacquers, varnishes, and rubber products. Glass containers are usually sealed by the use of sheet rubber rings and metal fitted tops. Cans are usually held together by the use of solder, which is also used for the final sealing. Solder is usually an alloy of tin and lead with a low fusion point.

Statistical Notes

This group of industries must be classed as consumers of chemical products only and not as producers of chemicals. The factory consumer purchases the required chemicals in bulk; the quantities needed, especially of some products, must be large, but there is no one compilation of statistical data available covering this group. The domestic consumer purchases in small lots, and pays relatively high prices for the products used, partly because distribution costs are necessarily high. The total consumption of some of the products mentioned in the preceding paragraphs must be very large, but in most cases there are no statistical studies available to indicate the requirements of this market for many of the chemicals used. The Dominion Bureau of Statistics issues the following publications which contain some statistical data bearing on phases of this subject; these publications refer only to the factory operations and do not include the larger market offered by the individual householder: Cocoa and chocolate, coffee and spices, fruit and vegetable canning, evaporated fruits and vegetables, jams and jellies, vinegar, pickles, and relishes, flour and grist mills, bread and other bakery products, biscuits and confectionery, liquors distilled, liquors malt, liquors vinous, starch and glucose, sugar refining, fish curing and packing, slaughtering and meat packing, tallow and animal oils. Unfortunately much of the statistical data available is incomplete in that important chemicals are grouped together so that data with respect to each cannot be obtained. In other cases the field has been inadequately surveyed, and the published returns are correspondingly inaccurate. The circular on the Baking Powder and Flavouring Extract Industry, 1919, issued in March, 1921, covers the operations of only 22 individual plants, located 12 in Quebec, 8 in Ontario, and one each in Nova

Scotia and Manitoba. This circular shows the consumption of these 22 plants of the following chemicals:—

Table 23.—Consumption of Chemicals in Twenty-Two Plants

	Lbs.		Lbs.
Ammonium bicarbonate..	12,550	Starch..	1,639,800
Sodium bicarbonate..	1,468,555	Flour..	31,441
Cream of tartar crystals.. ..	62,047	Sugar..	1,429,572
Salt..	95,381	Essences, essential oils, etc.. ..	29,934
Tartaric acid..	14,100	Alcohol, in proof gallons..	35,746
Calcium acid phosphate..	1,820,289	Unspecified materials, including containers valued at..	$1,210,350

It will be noted that essences are lumped with essential oils and a quantity given in pounds, whereas most essences contain only a very small percentage of essential oils. The number of brands of baking powder on the Canadian market, as reported in Bulletin No. 439, Department of Health, is 141, only five of which are imported. The 136 brands sold in Canada are manufactured by more than 125 different firms. While the statistical data quoted above probably represent the consumption of the larger firms, it is obvious that they cannot give a correct view of the size of the home market for the commodities mentioned.

General Notes

The preparation and preservation of food products are the bases of a number of manufacturing industries all of which are consumers of mineral and chemical products, nearly all of which use chemical processes, and many of which also produce important chemical byproducts. The principal manufacturing industries concerned are the following: Meat packing, fish packing, dairy produce, edible oils and fats, milling, sugar refining, starch products, fermentation products, canning and preserving, baking powder, fruit extracts and essences, effervescing beverages, and soft drinks. Some reference is made to these various industries in other sections of this report, special reference being made to the mineral and chemical products consumed or produced by them. Some reference has also been made to the extent of the development of these industries in Canada. A further and more extended reference to the inter-relations of these industries and to their requirements is beyond the scope of this report.

PART VII

ALLIED INDUSTRIES

GENERAL MANUFACTURING

INTRODUCTORY

The allied industries which are discussed in this part of this report have at least one feature in common, chemical processes are used either in the preparation of the final products of the industry or such processes are used to prepare materials for fabrication into these industrial products. The preceding part of this report discusses those industries engaged in the production and preservation of foods. The present part discusses sixteen other industries, under the title of General Manufacturing.

The first chapter describes the colour, paint, and varnish industry which provides materials for preserving and decorating our homes. The six following chapters deal with industries that have to do with products required for personal welfare or adornment, or with cleanliness and sanitary living. The subjects discussed are soap manufacture, textile manufacture, bleaching, staining, mordanting, dyeing and colour printing, laundering, and the manufacture of leather and rubber. The eighth chapter deals with the photographic industry in its broader features only, since this industry comprises a number of important subsidiary industries which contribute the numerous necessary products. The art of electro-plating and the manufacture of dry cells and storage batteries are discussed in the ninth and tenth chapters respectively. The remaining five chapters are devoted to brief discussions of a number of miscellaneous products of more or less complex composition which are required to meet the needs of nearly every community. The products discussed in these chapters are glue and gelatine, adhesives and cements, polishes and dressings, friction matches, abrasives, and sweeping compounds.

CHAPTER I

COLOUR, PAINT, AND VARNISH INDUSTRY

The paint and varnish industry is one of the more important of the expanding industries of this country. It provides one of the most essential of all building materials for both inside and outside work, important because its products not only protect and preserve the structural materials to which they are applied, but because they also serve to decorate and beautify these surfaces. The products of this industry find numerous other important applications in addition to their general use in the painting of wood, concrete, and metal products. Products of this industry are used in making printing inks of various kinds, oilcloths for floor and table use, and linoleums, patent leather and harness leather dressings, wall papers, window shades, rubber goods, and cement products.

Products

General

The products of the industry can be classified roughly as:

(1) *Pigments* and *Colours* which are used in making.

(2) *Paints,* which are used for covering, protecting, and decorating surfaces, inside and outside of buildings and other structures.

(3) *Varnishes, Enamels,* and *Stains,* which are used chiefly on interior surfaces of numerous kinds, and occasionally for exterior work, or which are used for technical purposes in manufacturing.

(4) *Miscellaneous products* which find various applications.

Paints themselves comprise two general classes, those in which the constituent ingredients have been ground together and thoroughly incorporated by special machinery in a factory, constituting mixed paints (including pastes), and those which are compounded by the painter from various dry ingredients or pastes, vehicles, and driers supplied by colour manufacturers. Varnishes are transparent or translucent liquids which, by oxidation, form a thin elastic coating free from cracks, upon surfaces to which they have been applied, this coating being colourless or nearly so. Enamels or varnish paints are paints which dry with a surface similar to that of a varnish, but which also impart a definite colour or tone to the finished surface. Stains are similar to oil or varnish paints, except that only enough colour or pigment is added to colour the wood or other surface to which they are to be applied, but not enough to obscure the grain or structure. If the product does not obscure the surface to which it is applied at all, it is termed a lacquer. (This term is also applied to solutions of shellac in alcohol and to solutions of pyroxylin.)

Paints

Paints conceal the surface to which they are applied and develop a new surface coloured or tinted and finished in accord with the composition of the particular paint used. They consist essentially of a liquid vehicle carrying solid pigments in suspension. Several classes of paints may be distinguished.

Oil paints are made ready mixed, usually made with linseed oil, pigments, and drier.

Paste paints are usually oil paints that must be thinned down for use.

Dry colours are pigments already compounded, or are pigments and bases which must be mixed with a suitable vehicle by the user.

Oil colours are usually coloured pigments of various kinds ground in oil (linseed usually) to a stiff paste, used for colouring, tinting, and toning.

Coach colours (Japans) are similar to oil colours, but the vehicle used is a quick drying Japan varnish. When used they are thinned with turpentine.

Enamels or *varnish paints* are essentially paints in which the vehicle is a varnish or varnish and oil.

Distemper colours are products in which water is used as the vehicle instead of oil or varnish.

Floor and deck paints are paints containing a quick hard drying varnish.

Varnishes and Enamels

Varnishes are named either from the principal purpose to which they are applied, or from some characteristic ingredient. The chief classes of varnishes on the market are:—

Asphaltum varnishes, made from natural asphaltum and a cement.

Carriage varnishes, which contain a large quantity of oil and will withstand outside exposure.

Copal varnishes, which are made from fossil resin (gum copal) and linseed oil.

Dammar varnishes, made from gum dammar and a solvent. These are white, not very hard, soften under heat, and are used for making white enamels and for coating pictures.

Gloss oil is a cheap product used as an adulterant and in the production of cheap paints that dry with a glossy surface.

Hard oil finish is a special type of furniture varnish.

Lacquers are special types of transparent varnishes made usually by dissolving gum shellac in alcohol and adding a colouring compound.

Pyroxylin lacquers are made from nitrated cellulose dissolved in a solvent, usually amyl acetate.

Shellac varnishes are quick drying hard varnishes, containing gum shellac in a solvent, but no oil.

Spar varnishes are similar to carriage varnishes, but contain less gum in solution and more oil.

Stains

Stains are made in great variety. They are named on the basis of their composition or application, for example, oil stains, spirit stains, varnish stains, creosote stains (shingle stains). Their chief characteristic is that they only partly obscure the surface to which they are applied. When used on wood the natural grain is still preserved.

Miscellaneous Products

Paint manufacturers also produce a number of miscellaneous products, such as wood fillers, crack and crevice fillers, liquid and paste cements, and various kinds of putty.

Uses

Paints and varnishes find numerous applications in the arts and in industry. Different uses naturally require paints or varnishes of different compositions, each paint or varnish being adapted to its own special applications. The number of materials available for the production of these products is also very large. The character and properties of the finished product are naturally dependent upon the selection of proper raw materials and the proper blending or mixing of these materials. The modern paint manufacturer therefore finds it necessary to organize and maintain a complete chemical laboratory as an essential part of his plant. The laboratory has charge of all raw materials which enter into the composition of the products of the factory. These materials must conform to certain definite standards as to chemical composition and physical character, standards established by experience and practice. The laboratory must also supervise the operations necessary to make the finished products, and these products must be examined to insure that they possess the characteristics proper to a paint or varnish suitable for the use to which this product is to be applied. The manufacture of paints and varnishes is an industry in which chemical and physical control over the raw materials, over the mechanical and chemical operations, and over the finished product is essential to the successful production of articles of uniform character and grade.

Raw Materials

General

In preparing the subjoined list of raw materials used in this industry it has been necessary to take cognizance of the fact that some factories purchase raw products in their natural state and perform in their own works the chemical and physical operations necessary to prepare products that enter directly into the paint or varnish mixture. For example, many dry colours are compounds produced through chemical reactions, chiefly salts of the metals chromium, iron, lead, potassium, and sodium. Some colours are made from organic compounds such as aniline or other hydrocarbon compounds in combination with sodium or potassium. In the production of such a colour as chrome yellow, lead is oxidized to litharge, litharge is dissolved in diluted acetic acid, and subsequently treated with potassium bichromate dissolved in water. Potassium bichromate is prepared from sodium bichromate and potassium chloride, a natural salt. Sodium bichromate is made by treating chrome iron ore (a natural product) in a reverberatory furnace with lime and soda, leaching and acidifying with sulphuric acid. Now it is obvious that the primary raw materials necessary to produce chrome yellow are lead ore, chrome iron ore, sodium chloride, potassium chloride, and sulphur, in addition to acetic acid which is obtained as a byproduct of hardwood distillation, or which can be made synthetically from coke, lime, and air as raw materials. Certain intermediate chemical products, such as litharge, lead acetate, sodium bichromate, and potassium bichromate, are made from these primary natural products. These again are brought together under proper conditions to produce the final product, the chrome yellow, which is to enter the finished product of the paint manufacturer.

Only a very few paint manufacturers make any of their own colours or pigments. A number make a few colours or other products required, and a number purchase all ingredients ready made, and devote their attention to grinding, blending, and mixing, and to the treatment of the different vehicles used.

The paint manufacturer uses three classes of materials: (1) the vehicle, which is usually some vegetable or mineral oil, or occasionally water, and including certain prepared chemical products that hasten the drying of the finished paint or varnish, (2) a base usually of mineral origin, or produced from minerals, to impart body to the paint, (3) pigments or colours to impart the desired colours, shades, and tones to the finished articles.

Sources of Supplies

The supplies of raw materials used in this country come from all parts of the world. Many of the oils are obtained in tropical and subtropical countries. Many of the gums and resins used in varnishes and some enamel paints come from Australia, Manila, Africa, Asia, and South America. The minerals used are obtained from many different sources, manganese dioxide, for example, comes from Brazil, Russia, and the Caucasus. A number of the chemicals were formerly obtained from Germany, which was also the source of many colours, or of the products from which colours were made. Some of these are not now procurable and some can be obtained in Great Britain or the United States.

Native Materials

The Canadian paint industry imports a large proportion of its raw materials, in some cases in the natural condition, and in many cases in a completely manufactured condition ready for grinding and mixing. Many of these materials are not produced in Canada. On the other hand it is probable that some of the intermediate operations in the preparation of mineral and chemical pigments might be performed profitably on imported raw materials. The development of this phase of the industry depends upon the local demand and, to a large extent, is a question of quantity production, as obviously it would not be profitable to carry on operations intermittently or on too small a scale. There are certain classes of products now imported that could probably be made from home materials not now utilized, or at least not utilized to their maximum capacity. These matters will require further extensive inquiry and investigation because the suitability of native materials has in many cases yet to be demonstrated. The demand for these materials will normally be one of slow growth because it is always difficult to supplant a material with an established reputation and known properties, even if more costly, by a less well known product, even though the latter may be of equal or even higher value. At the present time an officer of this department is making inquiries into the availability of Canadian ochres, both as to quantity, quality, and colours, having in view the fact that some of these are equal and in some cases superior to imported foreign ochres. The development of a Canadian chemical industry will make it possible to produce certain chemical salts of the metals from native minerals for use in this industry in the future.

In a few instances the production of native materials suitable for the paint industry is irregular and spasmodic. As a direct result the paint manufacturer is forced to import foreign material because he cannot depend upon the home producer for a stable production. Manganese dioxide, for example, in every respect suitable for the manufacture of driers and varnishes, is produced in Canada at irregular intervals. Still Canadian paint and varnish manufacturers find it necessary to secure most of their supplies through established foreign supply houses. It is even probable that they have purchased Canadian manganese dioxide through these sources. This and other similar cases are due to conditions of demand, supply, and marketing and at present cannot be avoided, although we may expect improvements in this regard in the future as the industry develops.

Classification of Raw Materials

The classified list of materials used in the Paint and Varnish industry which follows includes the principal raw materials used in the industry. Certain chemical salts used as colours have been included by name as well as the principal raw materials from which they are made. As explained in a previous paragraph this has been done because some manufacturers make their own chemical colours from the primary raw materials, others purchase intermediate products and make their colours, while still others purchase the finished colour and mix or grind only. Certain raw materials such as ochres should be mentioned both in lists of imported materials and in lists of native materials because native materials are not necessarily suitable for all purposes, and both native and imported materials find similar but different applications.

Table 24.—Materials of the Colour, Paint and Varnish Industry[1]

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

LIQUID VEHICLES, SOLVENTS, AND THINNERS: *Acetone*; alcohol (*amyl, ethyl, methyl*); *benzol; creosote; driers; naphtha;* oils [*corn*, hempseed, *linseed* (*boiled, raw*), menhaden, perilla, rosin, *shark*, soya bean, sunflower, *tar*, tung]; *turpentine*.

ASPHALTS, GUMS, RESINS, AND WAXES: Asphalts (asphaltum, gilsonite, manjak, pitches); gums (acacia, benzoin, camphor, carnauba wax, copaiba, copals, dammar, elemi, guaiacum, manila, mastic, sandarac, shellac, thus); resins (*Canada balsam*, dragon's blood, gamboge, pine resin); waxes (*beeswax*, ceresin).

MINERALS USED IN THE COLOUR INDUSTRY: *Asbestine;* asphaltums; *barytes;* chalk; chromite; *clay, china;* cobalt glance; *feldspar* (*ground*); *fluorspar;* fuller's earth; *graphite; gypsum; hematite;* kaolin; *limonite; marble flour;* ochres (*red, yellow*); pumice stone (pulverized); pyrolusite; rotten stone (pulverized); siennas; *silica;* slate (mineral black); *sodium chloride*; *talc*; umbers.

NATURAL ORGANIC SOURCES OF COLOURS (LAKES CHIEFLY): Annatto; blackthorn berries; cochineal; fustic chips; gamboge; logwood; madder; quercitron bark; sepia; turmeric.

CHEMICALLY PREPARED COLOURS: Anilines (numerous colours); blacks (bone, drop, lamp); blues [cobalt blue (cobalt oxide and alumina); cobalt potassium silicate (smalt); copper sulphate (copper blue); *ferric ferrocyanide* (Chinese or Prussian blue); sodium aluminium silicate (ultramarine blue)]; greens [Brunswick green (copper arsenite, copper hydroxide, and gypsum); chrome green (mixture of chrome yellow and Prussian blue); chromic oxide (chrome green, Guignet's green); copper acetate (Copper green); *copper arsenite* (Scheel's green); sodium aluminium silicate (ultramarine green)]; lakes (a variety of colours); oranges [arsenic monosulphide (realgar); chrome orange (neutral and basic lead chromates)]; reds [antimony trisulphide (antimony red, vermilion); ferric oxide (Indian red); lead chromate, basic (American vermilion, chrome red); *lead oxide, red* (red lead); mercuric sulphide, red (carmine)]; whites [aluminium hydroxide; barium sulphate (blanc fixe); calcium sulphate (mineral white, *calcined gypsum* (plaster of Paris)); lead, white (*basic carbonate*, basic sulphate); lead-zinc white (lead sulphate and zinc oxide); lithopone (barium sulphate and zinc sulphide); satin white (aluminium hydroxide and calcium sulphate); zinc oxide (zinc white)]; yellows [arsenic trisulphide (orpiment); barium chromate (barium yellow); cadmium sulphide (cadmium yellow); calcium chromate (calcium chrome yellow); cobalt potassium nitrite (Indian yellow); *lead chromate, neutral* (*chrome yellow*); stannic sulphide (mosaic gold); tungstic oxide (tungsten yellow); zinc chromate (zinc yellow)].

CHEMICALS USED IN THE MANUFACTURE OF MINERAL PIGMENTS AND LAKES: Acids (*acetic, carbonic, hydrochloric,* lactic, *nitric,* oxalic, *sulphuric,*

[1] NOTE.—Aniline colours and other colours derived from coal tar products are omitted from this list.

tartaric); alums (ammonia, chrome, potassium, soda); aluminium hydroxide and *sulphate; ammonia, aqua;* ammonium salts (*chloride, sulphide,* vanadate); antimony compounds (oxychloride, trioxide, trisulphide); arsenious oxide; auric chloride; barium chloride and sulphate; bismuth nitrate; cadmium salts; calcium compounds (*carbonate, hydroxide, hypochlorite, oxide, phosphate, sulphate*); carbon; *casein*; chromium compounds (arsenate, oxide, others); cobalt compounds (*chloride, linoleate, nitrate, oxide,* resinate); copper salts (acetate, nitrate, *sulphate*); ferric chloride and sulphide; ferrous chloride and sulphate; lead compounds [acetate (basic, neutral), chloride, linoleate, nitrate, oxides, resinate, sulphate]; magnesium carbonate and chloride; manganese compounds (borate, linoleate, oxide, resinate); mercuric compounds [chloride, nitrate, sulphate, sulphide (black, red)]; mercurous chloride and nitrate; potassium compounds [bichromate, bitartrate, carbonate, *chlorate*, ferricyanide, ferrocyanide, hydroxide, nitrate, oxalate, sulphate (acid, neutral), tartrate]; silver nitrate; sodium compounds (bichromate, bitartrate, carbonate, chromate, ferricyanide, ferrocyanide, *hydroxide,* hyposulphite, *linoleate,* nitrite, phosphate, resinate, *sulphate,* tungstate); stannic chloride; stannous chloride and sulphide; tungstic oxide; zinc oxide and sulphate.

Statistical Data

Statistical data are not available to show the quantities of individual products required by this industry. Many of the materials required are not produced in this country at all, and of many others the quantity used is so small that obviously they could not be profitably produced here. There are a number of products, however, chiefly made from minerals, that are now imported, that could be produced from Canadian sources. The subject will require careful statistical studies of the industry and its requirements before the extent of the market which it offers for these products can be ascertained. In the absence of such data the author is not in a position to discuss the subject further.

Imports and Exports. The tabulated statement of imports and exports of paints, pigments, colours, and varnishes given on another page classifies some of the materials used in this industry under twenty-three sub-heads. Unfortunately the published data group a number of separate products in single tariff items and it is not possible to ascertain the imports and exports of each particular commodity. Certain other chemical products used in this industry have been segregated under their proper sub-titles in the group of Chemicals and Dyes.

Canadian Situation

Available records show at least thirty-eight firms in Canada engaged in some phase of the Colour and Paint, Varnish and Stain industry. Several of the larger firms produce a number of pigments and colours, and purchase a large number of others of which the quantity of each required is not large. Many firms are mixers and grinders only, all supplies being purchased. A number of firms do not require colours or pigments in making such products as stains and wood preservatives.

CHAPTER II

SOAP MANUFACTURING

Soap manufacturing is essentially a chemical industry for the production of certain classes of chemical compounds, called soaps, which are required in the industrial arts and for domestic use. Soap is a compound of any fatty acid with some base. These compounds are usually prepared by treating an oil or fat with the hydroxide or the carbonate of potassium, sodium, or ammonium. All of these produce soluble compounds which are the principal soaps of commerce. Soaps for special purposes, all of which are insoluble, are occasionally made by the use of soluble compounds of certain metals, such as calcium, magnesium, aluminium, iron, chromium, mercury, lead, or zinc.

Raw Materials

The raw materials of the soap industry are very numerous. The materials used naturally vary with the purpose for which the soap is intended. As in all industry the costs of raw products are also important controlling factors in determining the selection of materials to be used. The principal products from which all soaps are made can be classified in two groups—the *Oils* (including fats and waxes) and the *Alkaline base*. In addition certain accessory materials are added to certain soaps to make products suitable for special purposes (e.g., medicated soaps, antiseptic soap, tooth soaps).

It is not desirable to enter upon a discussion of the classification and character of oils, fats, and waxes. There are certain features, however, that may be briefly reviewed. The difference between oil and fat is primarily one of liquidity and temperature, that is, a fat which is solid becomes an oil when warmed to liquefaction. Oils are definite mixtures of two or more glycerides. Glycerides are colourless, odourless, tasteless compounds of glycerine with a fatty acid. Glycerine is a compound of carbon, hydrogen, and oxygen of a definite constitution, which acts as a base in the formation of chemical compounds. The fatty acids are a group of organic compounds found in fats and oils. There are five principal series recognized, which are named respectively, stearic, oleic, linolic, linolinic, and clupanodonic acid series. Each series of acids contains a number of distinctive compounds with special characteristics. The stearic acid series, for example, includes butyric acid which occurs in cow butter fat, lauric acid which occurs in laurel oil, palmitic acid which occurs in most fats, but notably in palm oils, and many others. The total number of organic acids belonging to these five series is very large.

Oils may be grouped as fatty (or fixed oils), mineral oils, and essential (volatile) oils. The fatty oils are vegetable or animal products, which are not capable of distillation without decomposition (hence the name "fixed oils"). All of these oils are compounds of glycerine with some one of the fatty acids, such as oleic, stearic, palmitic; that is they are glycerides. When heated with an alkali they are decomposed, glycerine being liberated and an alkali salt of the fatty acid, which constitutes soap, is produced. Mineral oils are obtained from natural deposits of petroleum, or by distillation from oil shales. They consist of hydrogen and carbon only and can be distilled without decomposition. When boiled with alkali they are not decomposed, and are therefore not used directly in soap manufacture. Essential oils are volatile oils found in certain parts of plants (leaves, flowers, wood, fruit, roots, etc.). They are not capable of saponification, but are used for imparting a characteristic odour to special products. Waxes derived from animal or vegetable sources resemble fats very closely in most of their properties, but contain no glycerides, and therefore do not yield glycerine when treated with alkali.

In the manufacture of soaps the high grade and more expensive oils and fats are used almost wholly in the production of toilet soaps. Cheaper oils and fats are used for making household and some grades of laundry soaps, while the lowest grades and cheapest kinds of greases are used in the production of cleaning and scouring soaps for mill and factory use. As a general rule soft soaps are made with potash as the alkali, and hard soaps with soda. Ammonia soaps are unstable and are made only for special purposes. The shortage of potash salts during the war period resulted in the successful development of processes of making soft soap by using soda salts.

The most important fats used in soap making are mutton and beef tallows, lard, bone fat, skin grease, and other oils (menhaden, shark, shark liver, seal, porpoise, whale, etc.). Pure tallow soaps are hard and difficultly soluble, and it is customary to blend a softer oil with the tallow. Usually a vegetable oil is used for this purpose. Suitable oils are cocoanut, castor, cottonseed, corn (or maize), and other similar oils, or rosin. Other vegetable oils used in soap making are palm kernel, olive, peanut (otherwise named arachis, earth nut or ground nut), rice, soya bean, linseed, and Chinese vegetable tallow.

A process was developed some years ago for converting liquid oils into harder substances suitable for use as substitutes for tallows. The process consists in subjecting the oil to the action of hydrogen under a pressure of about 18 atmospheres and a temperature of 180° C. in the presence of finely divided metallic nickel or palladium. The process is under accurate control and an oil can be hardened to almost any degree from the consistency of lard to that of the harder waxes. An oil so treated is said to have been *hydrogenized.* The oils more frequently treated by this process in soap making are whale, cottonseed, corn, and linseed.

The alkali materials used by the soap manufacturer are chiefly compounds of sodium and potassium, ammonium compounds being of less importance. The principal sodium compounds are caustic soda, soda ash, the carbonate, bicarbonate, sesquicarbonate, silicate (water glass), chloride, and oxide. The principal potassium compounds used by the soap maker are caustic potash and potassium carbonate. Other potassium salts similar to the sodium series are occasionally used, the silicate and the chloride being the most important. Potassium carbonate, under the trade name of pearl ash, and "potash" prepared from wood ashes by leaching are purchased by the soap trade. The ammonium salt usually employed is the carbonate. Aqua ammonia (the hydroxide) and the sulphate or chloride are also used occasionally.

Soaps are perfumed by the use of essential oils, natural products obtained from various parts of plants, or by synthetic perfumes which are produced in the chemical laboratory.

Other accessory materials used in the soap industry for special purposes are sulphuric acid, calcium oxide, sodium oxide, lead oxide, lead acetate, ferrous sulphate, carbon tetrachloride, naphtha solvent, phenol, glycerine, methyl alcohol, formaldehyde, and starch. Certain inert substances, such as china clay, talcum, chalk, bentonite, barytes, asbestos, magnesium oxide, and some salts, and also seed husks are used as fillers. Colloidal clay (bentonite) acts as a detergent as well as a filler. Starch, potato flour, infusorial earth (kieselguhr), powdered pumice, silica powder, Irish moss, and sugar are used for making special kinds of soaps.

Table 25.—Materials used in the Soap Industry

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

CHEMICALS: *Aluminium sulphate; calcium hydroxide;* ferric persulphide; ferrous sulphate; *lead oxides; magnesium hydroxide;* potassium compounds (bicarbonate, carbonate, chloride, hydroxide, silicate, sulphate); sodium compounds (bicarbonate, borate, *carbonate, chloride, hydroxide,* sesquicarbonate, silicate, *sulphate*).

FILLERS: *Asbestos; barytes; bentonite* (*colloidal clay*); chalk; *clay, china;* magnesia; *potato flour;* seed husks; silica powder; *starch; talcum.*

ANIMAL OILS AND FATS: Acids (*oleic, palmitic, stearic*); *calcium stearate; fat, bone; grease, skin; lard;* oils (*fish, lard,* porpoise, seal, shark liver, *whale*); *tallow* (*beef, mutton*).

VEGETABLE OILS AND RESINS: Cottonseed (to make oil); foots; Irish moss; oils (castor, cocoanut, *corn* (maize), cottonseed, essential, *linseed,* olive, palm, palm kernel, rice, rosin, sesame, soya bean); rosin (pine); wax, Chinese vegetable.

OTHER MATERIALS: *Alcohol; carbon tetrachloride; formaldehyde; hydrogen peroxide; infusorial earth* (*kieselguhr*); *sugar.*

Principal Products of the Soap Industry

Soaps may be classed as hard soaps and soft soaps. These in turn may be designated by some name indicating the purpose to which each is best adapted. Hard soaps include household, harness, laundry, polishing, scouring, soap powders and chips, shaving soaps and creams, toilet and soap powders. Soft soaps are prepared particularly for use in the textile and leather dressing industries.

One of the most important byproducts of the soap industry is glycerine. In the ordinary processes of soap making, where the fatty substance is treated directly with the alkali, the glycerine byproduct is unavoidably mixed with impurities and other materials introduced during the process. It is separated from these with difficulty, and in some cases cannot be recovered. A process has been developed for separating the fatty acid from the glycerine before the addition of the alkali which is to make soap by reactions with the fatty acid. Fatty acids made from animal and vegetable fats and oils are produced at some abattoirs and other plants, and form an important intermediate product in the soap industry. The principal acids thus produced are stearic, palmitic, and oleic. Many other acids can be produced in this way, the nature of the product being determined by the oil used.

The miscellaneous products marketed by this industry include such products as candles, crude and refined glycerine, hydrogenated oils, lye, oleic acid, palmitic acid, stearic acid, refined tallow, and washing powders.

Statistical Data

No statistical data are yet available as to the extent of the development of the industry in Canada, and as to the quantities of raw materials consumed annually. A reference to the accompanying statistical tables of imports and exports will show that large quantities of certain soaps, such as laundry, castile, soft soap, soap powders, and toilet soaps, are imported to a value of nearly one and a quarter million dollars annually.

Canadian Situation

The Canadian position with respect to supplies of the raw materials required for this industry is shown concisely in the preceding lists, which show both native products and the foreign products which must be imported if used. It is to be noted that some of the native products suitable for use in this industry are exported in an unmanufactured or partially manufactured condition. On the other hand additional supplies of some materials also produced in Canada are imported. Large quantities of the finished products of this industry are also imported. (See statistical tables.)

Available records show that there are at least sixty-nine factories in Canada engaged in the manufacture of various kinds of soaps. The soap works are fairly well distributed throughout the area to be served; there is one plant in Nova Scotia; two in New Brunswick; sixteen in Quebec, all but two in the city of Montreal; forty-three in Ontario distributed through fifteen towns and cities; two in Manitoba; two in Saskatchewan; two in Alberta; and two in British Columbia.

Many of the factories included in the above enumeration are engaged in the production of specialties. A few of the larger organizations produce a variety of soaps for various uses.

The principal soaps manufactured in Canada are laundry and toilet, but various soaps for industrial use in the textile and leather trades, and for other special purposes are also produced.

The principal byproduct of the soap industry is glycerine. Crude glycerine is produced in Canada at about sixteen plants; refined glycerine is made at three.

Notes

It is obvious that most of the imported soaps could be replaced by similar home products to the advantage of Canadian trade. It would, however, be necessary to import increased quantities of fats and oils, but the other basic materials required could be produced in this country.

Large quantities of vegetable oils (particularly cottonseed, corn, olive, palm, and soya bean) are imported for use chiefly in the manufacture of soaps, but also for the preparation of food products such as margarines and vegetable shortenings. The desirability of using home products for the Canadian trade would suggest the necessity of agricultural research to develop varieties of oil-bearing plants that would thrive under Canadian climatic conditions and would furnish suitable substitute oils. One substitute having excellent properties would be sunflower seed oil. The oil cake from sunflower seeds would make a valuable stock food, and the stalks would produce a fibre suitable for use in straw board and possibly in other pulp products. At the present time the only important oil-bearing plant grown is flax from which flaxseed, flaxseed meal, and linseed oil are obtained. When the seed, from which the oil is obtained, is allowed to ripen, the flax straw is not serviceable as a source of linen, though it can be used to make an excellent chemical pulp for making paper.

The additional basic chemical products that would be required are all made from minerals and could nearly all be supplied from home products, if the market demand developed.

CHAPTER III

TEXTILE MANUFACTURING

The textile industry is primarily concerned with the production of woven or knitted fabrics invented to meet numerous human requirements, the most important of which is probably clothing. These products are made from a great variety of materials, which in turn have been subjected to preparatory treatment of some kind, spun into threads, cords, or yarns, and finally woven, knitted, or felted into fabrics. When the final product is a thin sheet of considerable length and breadth it is usually designated cloth. Woven, knitted, or felted fabrics may, however, be produced in a great variety of forms and shapes.

Raw Materials

The principal materials of the textile industry are organic fibres of natural or artificial origin. Only one natural mineral fibre (asbestos) is used in this industry, this use being limited to special fire-proof products. Certain other special kinds of textile fabrics are also made from artificial materials derived from mineral products.

The principal fibres of animal origin are wools and silks. Wool, of which there are many commercial grades, ordinarily refers to the hair fibre of sheep. Hair from many other animals, such as beaver, camel, cat, cow, dog, goat (mohair, cashmere), horse, llama (alpaca), and vicuna, is also utilized for making fabrics. Silk is obtained from the cocoon fibre of the cultivated mulberry silk worm. Wild silk or tussah is obtained from cocoons made by the larvae of other moths, usually uncultivated.

The principal vegetable fibre used in the textile industry is cotton, of which there are several varieties. Other fibres that are used for making special yarns and fabrics comprise aloes, barks (various), coir, Cuba bast, grasses (China, various), hemp, jute, linen, manila, New Zealand flax, osier (willow), palmetto, palm leaves (split), paper, paper mulberry, pineapple, ramie, rushes, seaweed, sisal, splints, straw (barley, oats, rice, rye, wheat), Tampico, vegetable silk, wood pulp, yucca. Mention might also be made of viscose, cellulose acetate, and cellulose silks made from cotton or wood cellulose by chemical processes and utilized as artificial silks.

The most important mineral fibre used in the textile industry is asbestos. Spun glass, glass wool, and fine wires of metals, all of which are made artificially from mineral products, are also used in this industry for special purposes. Probably about 85 per cent of the world's supply of asbestos fibre is produced in the province of Quebec. Spun glass and glass wool are not made in this country. Some grades of wire are made in Canada and others could be made if required.

Some of the products mentioned in the foregoing paragraphs are used for the manufacture of cordage, ropes, wire cloths, and braided or woven fabrics of many varieties. These products are not usually included with textile fabrics although the processes of manufacture are similar to those used in making textiles.

All the fibres used in the textile industry are subjected to certain preliminary preparatory processes, including cleansing, before being spun into yarns for weaving.

The preparation of wool involves a scouring process which yields two valuable byproducts, wool grease and suint. Wool grease is a crude fatty product which in refined form is termed "lanoline." Lanoline is a pure animal fat used in medicine, in pharmacy, and in the manufacture of cosmetics. "Suint" is essentially the dried organic salts of potash and soda deposited in the wool by the evaporation of the perspiration of the sheep. In localities where it is possible to treat large quantities of wool these products can be recovered profitably from the scouring solutions. The Canadian practice of washing the sheep before shearing results in the loss of much valuable material. These byproducts are not recovered in Canada at present, and it would not be practicable to do so unless provision were made for the treatment of large numbers of unwashed fleeces at central points before distribution. At present lanoline is imported, but there are no data showing the quantities required annually.

The preparation of cotton yields two important byproducts. Short and broken fibre is used as a source of pure cellulose for the manufacture of nitro-cellulose and other cellulose compounds. The seeds also yield a valuable oil, to which reference is made in another section, and cottonseed cake—valuable as a stock food. Cotton is not produced in Canada, but large quantities of fibre cotton, cotton for nitro-cellulose manufacture, and cottonseed are imported, as well as cottonseed oil and cottonseed cake.

Flax for the production of linen fibre has been successfully raised in Canada for many years and linen is produced on hand looms in Quebec. Large scale production of flax was attempted during the last years of the war, but at present many producers have been unable to dispose of their crops of flax. Large quantities of linen products are imported annually, and linen goods are woven in this country.

Many grades of wool, other animal hairs, silk, cotton, and other vegetable fibres are imported in prepared form when required by Canadian textile industries. Cellulose acetate has been made but not in fibre form.

The principal auxiliary raw materials used by the industry for the preparation of fibres in Canada are given in the subjoined lists, without reference to the particular application that may be made of each product.

The yarns or the finished fabrics made by the textile industry are subjected during the process of manufacture to bleaching, dyeing, and finishing processes. Each of these processes involves the use of chemical preparations to produce the desired effects. The principal chemical products used for these purposes in the Canadian textile industry are listed below, but no attempt has been made to list the great variety of artificial dyestuffs employed, all of which are imported. These lists, however, indicate the great dependence of this very important industry upon foreign chemical manufactures.

Table 26.—Principal Materials used in Textile Industries

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

PREPARATION OF FIBRES: Acids (*hydrochloric, sulphuric*); aluminium chloride; *ammonia*; ammonium chloride; *gasoline;* oils (*lard,* olive); potassium hydroxide; soaps (*linseed, resin, soft*); sodium compounds (*carbonate, hydroxide*).

BLEACHING: Acids (*acetic, sulphurous,* tartaric); *alcohol;* carbon bisulphide; *chlorine; chlorinated lime; hydrogen peroxide; lime water;* potassium permanganate; *resin soap*; sodium compounds (*hydroxide,* hypochlorite, peroxide); sulphur.

DYEING AND PRINTING: Acids (*acetic, hydrochloric,* monosulphonic, *nitric, oleic,* oxalic, phosphoric, *stearic, sulphuric,* tannic,[1] tartaric); *albumen*; *ammonia*; ammonium compounds (chloride, sulphocyanide); aluminium compounds (*acetate,* hydroxide, *sulphate,* sulphocyanide); antimony potassium tartrate;*calcium acetate;* castor oil (crude, sulphonated); chrome acetate; *copper sulphate*; dyestuffs (numerous organic, inorganic, and natural); ferric chloride; *ferrous sulphate; formaldehyde;* lead acetate; lime juice (crude); *methyl alcohol;* olein; resin; sodium compounds (*acetate,* arsenate, biborate, bichromate, *bisulphite, carbonate, cyanide, hydrous sulphate,* nitrite, phosphate); stannic oxalate; stannous chloride; tallow (beef); turpentine; whiting; zinc (dust); zinc oxide.

DRESSING AND WEIGHTING: Acids (phosphoric, salicylic, tannic), *albumen;* ammonium phosphate; barium sulphate; *calcium sulphate; casein; china clay; cresol; dextrine;* fats (*tallow, stearine*); *flour* (*wheat*); ferric compounds (acetate, chloride, *sulphate*); *gelatine; glucose; glue; gluten; glycerine*; gums (arabic, tragacanth); lead compounds (acetate, sulphate); magnesium compounds (chloride, *sulphate*); *paraffin*; potassium hydroxide; sodium compounds (biborate, *hydroxide,* silicate, tungstate); stannic chloride; starches (*corn, potato,* rice, *sago,* tapioca, *wheat*); *sugar;* wax; zinc compounds (chloride, sulphate).

Statistical Data

Silk, linen, cotton, and woollen textiles are made in this country, largely from imported raw materials. The Dominion Bureau of Statistics has not yet issued data with respect to the first two of these. The Canadian Trade Index only mentions three firms manufacturing silk goods of certain kinds, and four firms producing linens. Statistics for 1918 on the woollen textile industry show 75 mills reporting (Ontario 58, Quebec 11, Maritime 6), which consumed $582,392 worth of chemicals and dyestuffs, and $359,-735 worth of unclassified miscellaneous materials, which, it is to be presumed, includes dressing and finishing materials. Hosiery and knit goods in 1918 were reported from 108 plants (Ontario 80, Quebec 17, British Columbia 3, Prairies 5, Maritime 3), and the consumption of miscellaneous

[1] Includes natural products containing this acid, such as bark extracts, gall nuts, myrabolans, and sumach.

unclassified materials is placed at $2,136,782, which item must include all the secondary raw materials used in this branch of the industry. Statistics for 1920 on the cotton textile trade report 26 plants (Ontario 10, Quebec 12, Maritime 4), consuming $1,280,083 worth of chemicals and dyestuffs and $3,550,156 worth of miscellaneous unclassified products, which it is presumed includes dressing and finishing materials.

The total reported values for chemicals and dyestuffs is $1,862,475, and the total of unclassified materials is $6,046,673, adding 1918 statistics for woollens and 1920 statistics for cottons. Since these returns do not show even the principal items which enter into these totals no conclusions can be drawn as to the nature of this market for chemicals and products of chemical manufacture.

While it is impossible to ascertain from the published statistics even the actual size of the home market which this great group of industries offers for chemical products other than dyestuffs, it is obvious that the annual requirements amount to a considerable sum, and that among the products imported there must be a number that could be made in this country easily and profitably from native raw materials. This market for chemical products needs further investigation.

Canadian Situation

No special investigation has yet been made of the various textile industries established in Canada. Such a survey would disclose all the various products made in this country and the nature of the raw materials required. It would also make it possible to ascertain what additional products could be made here for the Canadian market, provided adequate data with respect to imports were also made available.

Asbestos yarns and textiles are not at present made in Canada, although the best fibre for this purpose is produced in the province of Quebec. Hitherto all of this fibre has been exported and such woven goods as were required were imported. One producing firm is reported to be planning for the erection of a spinning and weaving plant in Canada.

CHAPTER IV

BLEACHING, STAINING, MORDANTING, DYEING, AND COLOUR PRINTING

These industrial arts are very closely associated in practice and may be considered together. They have already been mentioned as processes employed in the manufacturing and finishing of textiles. Artistic and aesthetic effects in the colouring of fabrics and many objects of art or utility are obtained by the use of some one or more of these processes. Some of them are applied not only to textiles and textile fibres, but also to woods, leather, wood-pulp, bone, ivory, straws, grasses, and other materials to improve their appearance. All the operations in applying these arts involve chemical processes and most of them also necessitate the use of chemicals.

Bleaching is the art of removing the natural colours or accidental stains from any material. It is accomplished by the use of certain chemicals and also by direct sunlight. In the latter case the chemical changes which result in decolouring are promoted by the so-called actinic rays of the sunlight. Bleaching processes are used in the manufacture of textile fabrics from cotton, wool, linen, jute, manila, silk, hair, wood-pulp, and other materials. They may be applied to the raw product, to yarns, or to the woven textile itself as circumstances require or experience dictates. Other articles made of materials of animal or vegetable origin are also sometimes bleached.

Staining is the art of applying colour to such materials as wood, bone, ivory, celluloid, and similar products. The material acting as the stain and producing the colour effect is absorbed within the substance of the object to which it is applied in contradistinction to painting where the colour for the most part remains upon the surface.

Mordanting. This is the process of depositing certain chemicals, termed mordants, upon fabrics in such a way that they may subsequently become united with special dyestuffs to form insoluble coloured compounds *in situ*. Mordants themselves are chemical compounds used in dyeing, which are capable of combining with certain dye materials to form insoluble coloured compounds. They are usually applied to fabrics by using soluble salts from which the mordant may be deposited upon the fabric. The soluble salt used in this way has been termed a mordanting principal while the material which causes the mordant to be deposited has been termed a mordanting assistant. Mordants may be fixed upon the fabric by the use of chemicals which cause the formation of insoluble precipitates. Mordants may also be fixed to the fabric by the use of materials and as gums and starches which are capable of holding the mordant in place. The colour may be produced by the use of developing agents after mordanting, much as in photography, or by the addition of a dyestuff which forms an insoluble compound with the mordant. To assist in the even or uniform distribution of the dyestuff some chemical compounds such as hydrous sodium sulphate may be used as leveling agents. Mordants are as essential as the dyestuffs in certain methods of colouring fabrics. Metallic mordants are nearly always salts of some one of the metals aluminium, chromium, copper, iron, or tin because these metals will form desirable coloured compounds with certain dyestuffs. Sulphur is used in mordanting in a few cases. Tannic acid and some extracts which contain tannin are also ordinarily used as mordants. The principal chemicals used for this purpose directly, or to assist in the operations are listed below.

Dyeing is the art of applying colours to fibres, textiles, leather, and other porous materials. The ideal process would bring the dye in soluble form into contact with the material to be coloured and would then render it insoluble while in direct contact with the absorbent. Materials to be dyed are usually subjected to preparatory treatment such as washing or bleaching before beginning the dyeing process. If the colour solution is applied by brushing or other similar means the process would commonly be designated staining. This applies especially when dyes are applied to such materials as leather, feathers, straw, grasses and paper products. On the other hand, if the colour is applied by dipping into a bath of the dye or into several baths in succession the operation would more properly be called dyeing. In both cases the colour is absorbed by the fibre of the material subjected to treatment and does not remain as a new coating upon the outer surface. Only a few of the many materials used as dyes are listed separately below.

Colour Printing as applied to textiles, papers, leather, and other materials, refers to processes where colour applications are made to definite portions of the fabric under treatment. The colours and mordanting materials used are the same as those used in staining and dyeing, but the method of application is different. Frequently a somewhat different range of supplementary materials is required since it is usually necessary to thicken the solutions used to form printing pastes which will not spread or run. The body of these pastes is made with starch, dextrine, or some variety of gum. The pattern to be printed is cut upon a die or block. The prepared pastes are spread upon the higher portions of the cut blocks with rollers, or brushes, and the dressed block is then pressed upon the goods by hand power or by the use of machinery. The printing pastes are thus transferred from the block to selected portions of the fabrics as desired. There are many modifications in the detail of the operation of printing processes to meet special conditions of fabrics, dyes, and mordanting materials.

Raw Materials

The principal chemicals used in the practice of these arts are listed herewith in three groups. The first group includes those materials that are used in cleaning and preparatory operations, including bleaching; the second group includes materials used in mordanting; the third group includes the principal materials used in applying colours, as stains, dyes, or in colour printing. Limits of space make it impossible to add explanatory data as to the purpose for which each chemical is used.

Table 27.—Materials used in Bleaching and Colouring

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

(*a*) Bleaching Chemicals: Acids (*sulphuric, hydrochloric, acetic,* and *aqua regia*); aluminium chloride; barium peroxide; calcium compounds [chloride, *hypochlorite* (*bleaching powder*)]; *hydrogen peroxide*; magnesium chloride; potassium compounds (carbonate, permanganate); sodium compounds [carbonate (*soda ash* and *washing soda*), *hydroxide,* peroxide]; sulphur (as sulphur dioxide); *neutral soaps* made from olive oil, resin, or tallow.

(*b*) Mordanting Chemicals: Acids (*acetic, hydrochloric, nitric,* oxalic, *sulphuric,* tartaric, tannic); alum (chrome); aluminium compounds (acetate, chloride, hyposulphite, nitrate, oxalate, *sulphate,* sulpho-acetate); *ammonia;* ammonium vanadate; antimonial potassium fluoride; antimonial potassium tartrate (tartar emetic); antimonial sodium fluoride; antimony oxychloride; calcium acetate; chromium compounds (acetate, nitrate); copper compounds (acetate, nitrate, *sulphate,* sulphide); *glycerine;* iron compounds (acetate, nitrate, nitro-sulphate, *sulphate*); lead acetate; potassium bichromate; sodium compounds [bichromate, *sulphate* (*Glauber's salt*), stannate]; stannic compounds (acetate, chloride; stannous chloride; tannin extracts and barks (cutch, divi-divi, kino, myrobalans, nutgalls, sumach).

(*c*) Products used in Staining, Dyeing, or Colour Printing: Acids (*acetic,* citric, *hydrochloric, sulphuric, tartaric*); aluminium acetate; arsenious oxide; calcium compounds [hydroxide, *hypochlorite* (*bleaching powder*)]; coal tar colours (about 1,500 varieties are available); ferrous salts (acetate, nitrate, sulphate); mineral colours [barium chromate, cadmium sulphate, carbon black, chromic oxide, lampblack, lead chromate, *ochres* (*brown, red, yellow*), Prussian blue, ultramarine, vermilion]; paste bases (*blood albumen, beeswax, cornstarch, dextrine, flour,* gum arabic, gum tragacanth, olive oil, pipe clay, *wheat starch*); potassium compounds (bichromate, ferrocyanide, permanganate); stannous chloride; sodium compounds (carbonate, citrate, hydroxide, hyposulphite, sulphate); tannin solutions; zinc powder.

Accessory Equipment

In addition to the various raw materials required in the application of these arts the factory equipment comprises many articles made of wood or metals. Large and small vats, tanks, cisterns or kettles may be made of wood, stone or a suitable metal. Copper is the metal most frequently used for this purpose; lead also is sometimes employed. Some kinds of work can be carried out in enameled ware vessels. Copper or lead are also used for pipes, valves, and pumps. Where machinery is used ordinary steel or iron construction is employed except in those portions which come into contact with liquids containing chemicals in solution. At these points it is necessary to use materials that will not affect the chemicals. Wood, copper, or bronze is generally employed.

Statistical Data

No statistical data covering the annual consumption of chemicals and dyestuffs by this industry have been compiled. Incomplete data obtained from several textile mills and carpet factories indicated that the several branches of this industry offer a good market for a number of chemicals not now made in Canada in quantity sufficient to meet our own needs. This field requires fuller and more careful surveying before reliable information will be available. Most of the materials required by these industries in Canada are imported. Undoubtedly some of them could be made here profitably from native raw materials. The absence of accurate statistical data showing the requirements of these industries, in respect to the leading chemicals, makes it impossible to even name products for which they would offer a market.

Canadian Situation

Bleacheries and dye houses are usually established in connection with textile plants engaged in the production of yarns, cloths of all kinds, tapestries, and carpets. Occasionally dye houses also form an important part of the plant of a tannery making special grades of leather, or preparing furs. Equipment of this kind is maintained at a number of the Canadian textile mills, carpet factories, and tanneries. Several independent dye houses are also in operation. The author has been unable to secure any statistical data on this subject, and, so far as he is aware, no such studies have been made. The Canadian Trade Index lists 19 firms engaged in various phases of textile dyeing and 7 firms engaged in fur dyeing and dressing. These lists do not include textile mills and tanneries. It is believed that there are a number of other independent operators whose names have not been included in available directories. The same directory lists only 5 firms dealing in dyestuffs and dyers' supplies, while it is known that many of the necessary supplies are obtainable from firms dealing in chemicals or paints.

CHAPTER V

LAUNDRY INDUSTRY

The modern commercial laundry is a highly organized factory equipped with elaborate mechanical appliances for the purpose of carrying on the chemical and physical operations required in the cleansing of fabrics. In all the larger centres of population laundering has become an important industry.

The function of laundering is to cleanse textile fabrics of various kinds and to produce various kinds of surface finishes on the cleansed articles. The principal textile fabrics treated in laundries are woven from wool, cotton, flax, ramie, silk or silk substitutes. These goods have usually been treated with dyestuffs, either natural stains, colours, or pigments, or with artificial dyestuffs. The materials to be removed from the textiles in the cleansing operations consist of various extraneous substances that have become attached to the surface of the fabric or absorbed within its structure. The principal substances to be removed are the miscellaneous products found in the dust and dirt of city streets, smoke dust and soot, starch from previous treatments, waste epithelial tissue and other body excretions, waxes, greases, fats, and oils of various kinds, fruit stains or vegetable dyes, acid or alkali stains and discolorations, albuminous materials such as egg stains or blood stains, solid, mineral, or chemical substances derived from different sources.

Materials used in Laundering

The cleansing operations in laundering are accomplished by the use of pure soft water, both cold and hot, to which has been added certain chemicals, which collectively are termed detergents. It is obvious that the detergent used in any particular case must be one which will injure neither the textile fibre nor the dyestuff. Different classes of goods therefore not only require the use of different detergents, but often necessitate special mechanical treatment.

The most important chemical compound required for laundry work is pure soft water. Brown coloured waters will tend to produce vegetable stains on delicate fabrics. Hard waters cause the precipitation of insoluble calcium or magnesium soaps within the body of the fabrics subjected to treatment, tending to retard the cleansing and producing a harsh feel to the finished article. Where pure water is not available it is necessary to provide special purification equipment and treatment to obtain the best results.

The principal chemical products used in the laundry industry, either as detergents or for other purposes, are as follows:—

Soaps. Various kinds of soaps are used. The best laundry soap is one made from pure oleic acid. Soaps made from vegetable or animal fats, or resin are not so efficient.

Alkalies. The principal alkalies used are the carbonate or bicarbonate of soda. Corresponding salts of potash are used only occasionally.

Sodium hydroxide may be used, and sodium biborate is also employed. Various mixtures of these substances are sold under special trade names as washing compounds. Some of these washing compounds also contain soap powders and bleaching powders.

Acids. It is customary to use small quantities of some acid to counteract the alkalinity after treatment with alkalies or washing compounds. The principal acids used are acetic and lactic acid. Oxalic acid is also used especially where it is necessary to remove stains due to iron rust.

Bleaches. Discoloured white goods are treated with a bleaching liquor such as sodium hypochlorite. Javelle water which is used for this purpose is essentially a solution of sodium hypochlorite made by adding sodium carbonate (soda ash) to a solution of calcium hypochlorite. Bleaching powder could also be used but this is less frequently employed.

Other products used. Certain basic aniline dyes of a blue colour are used as blueing to counteract the slightly yellowish tint of stained cellulose fibre present in many uncoloured fabrics. The use of blue in limited amount imparts a clear white colour. Thin boiling wheat or corn starches are also employed to stiffen certain fabrics and to improve the finish. The running of some colours during laundering is sometimes retarded or prevented by the use of mordanting chemicals, such as acetic acid, alum (sodium or potassium), or sodium chloride. Mention should also be made of the use of indelible marking inks, some of which contain carbon black, and some of which cause the liberation of free carbon within the cellulose fibre of the fabric.

Canadian Situation

No statistical data are at present available showing the number and capacity of the various commercial laundries in Canada. It is probable that there are in the neighbourhood of 500. The application of scientific control to this industry in the purchase and use of the necessary chemical products required is a modern development of the business. The best methods of treating fabrics with detergents for cleansing purposes without injuring either the fabric or the dyes require chemical knowledge and skill. This knowledge and skill are obviously lacking in many establishments, and there appears to be opportunity for much improvement. Improved processes will not only lengthen the life of the article treated in these establishments and therefore reduce the national annual replacement costs, but will also effect a saving in the consumption of the materials used in the processes.

In addition to the chemicals consumed in commercial establishments the individual domestic laundry work must absorb a large quantity of soaps, washing compounds and other detergents, as well as blueing and starches. No data are available to show the annual consumption of the various chemicals required by the commercial and domestic laundry industry in this country.

Many of the products required in this industry are imported either as finished products or in a form suitable for compounding into the product required by the ultimate consumer. The manufacture of nearly all the principal products enumerated above is discussed in other sections of this report.

CHAPTER VI

LEATHER MANUFACTURE

General

The principal product of the tanning industry is leather. The basis of this industry is the hides, skins, and pelts of animals. The principal supplies of these materials are obtained from cattle, sheep, and goats. The hides and skins of many other mammalia are also utilized in this industry. Certain grades of leathers are obtained from the skins of other animals, such as seals, alligators, porpoise, sharks and some other fish.

Leather may be described as an imputrescible material prepared from the hide or skin of any animal. Hides and skins in their natural state are liable to decomposition and decay. The process of tanning preserves the hide and develops in the resultant leather certain desirable properties not possessed by the original material.

Tanning is essentially a complicated chemical process. Many of the reactions in the various tanning processes are only imperfectly understood from the chemical point of view, although the results are known empirically.

Tanning was the term originally applied to the treatment of hides and skins with some vegetable product containing tannic acid. Similar results can be obtained by treatment with certain chemicals and the term is now extended to include all chemical methods for the preservation of hides. It therefore includes treatment with mineral salts, oils, and anhydrides, as well as treatment with materials containing tannic acid.

The processes of bating, puering, and drenching are worthy of more extensive scientific study and investigation. In connection with these processes it is customary practice to use fermenting infusions of bird manure (pigeon or hen), animal manure (chiefly dog), and bran to accomplish certain ends. It is understood that the effects produced are due to the action of enzymes and bacteria. Certain chemical methods have already been developed to supplant these more primitive methods. The whole subject of tanning, however, is one which offers a very wide field to the research chemist with the object of developing logically scientific processes which can be accurately controlled, and which will invariably produce the same desired results.

Raw Materials

The materials used in the tanning industry other than hides and skins may be grouped, according to their origin, as vegetable tanning materials (containing tannic acids), organic compounds (including oils, fats, and waxes), and chemicals (including dyes). In the subjoined lists are included a number of materials that are used only for special processes. It is not intended to imply that all of these materials are in demand by the tanning industry as it is at present developed in Canada.

Table 28.—Materials used in the Tanning Industry

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

Vegetable Tanning Products: Barks (hemlock, mangrove, oak, others); *bran;* dyes (berries, extracts, wood chips); extracts (chestnut, palmetto, quebracho, sumach, others); *flour;* myrobalans; *sawdust;* valonia.

Organic Compounds: Albumen (*blood, egg*); *dextrine;* egg yolks; *gelatine;* oils (*cod,* cottonseed, *linseed, neatsfoot,* olive, *whale*); shellac.

Chemicals (including prepared minerals): Acids (boric, formic, *hydrochloric,* lactic, oxalic, *sulphuric, sulphurous*); *alcohol, absolute;* alums (chrome, potassium); *ammonia;* ammonium butyrate; aniline dyes; arazym;[1] arsenic sulphide, red; borax; *calcium oxide* (*lime*); chalk; *copper sulphate;* cropon;[1] dermiforma;[1] *formaldehyde; graphite; guncotton; iron sulphate;* lampblack; *naphtha;* phenolthalein; puerine;[1] potassium compounds (bicarbonate, carbonate); pumice stone, powdered; pyroxylin; *soaps;* sodium compounds (bicarbonate, bichromate, *carbonate, chloride, hydroxide,* sulphide, thiosulphate); *talc;* tin salts; *wood ashes.*

Vegetable tanning materials are valuable for their tannic acid content. The parts of the plant used vary with the species, the tannin being apparently concentrated in different parts of the plant in different species. Tanning materials include bark, leaves, twigs, roots, fruits, and excrescences. There are about twenty different products on the market, most of which come from tropical or sub-tropical areas. In addition to the natural vegetable materials, extracts of these materials which contain the active principles in concentrated form are prepared at the points of origin. Hemlock bark is the only vegetable tanning material produced in Canada and the production is irregular. Oak bark was formerly produced, but the production has almost entirely ceased. Owing to the non-production of essential tanning materials it is necessary to import these to a value of about one quarter of a million dollars annually.

Products

The principal products of Canadian tanneries are sole, belting, and harness leathers, sheep skins, chrome tanned leathers, upper and patent leathers, and dressed furs.

Statistical Data

Statistical studies of the annual requirements of the industry have not been made. It is therefore impossible to determine at present the quantities of the different chemicals (with one exception) required by this industry annually. Customs returns indicate that about 40,000 pounds of sodium hyposulphite are imported annually by tanners. The annual

[1] Arazym, a patent bate, consisting of tryptase in alkaline solution.
Cropon, a patent bate.
Dermiforma, a patent bate, consisting of wood fibre and dry pancreas mixed with ammonium chloride.
Puerine, a patent bate.

imports of hides and skins have a value in excess of five million dollars; the imports of unmanufactured leathers amount to nearly eight million dollars; manufactured leather goods imported are valued in excess of three and a half million annually. It is obvious that there is room for expansion of this industry to provide for home needs alone, and incidentally such expansion would provide a larger market for certain chemical products which could be made from native mineral products.

Canadian Situation

Available records show thirty-three tanneries in Canada, one being located in New Brunswick, two in Nova Scotia, fourteen in Quebec, fifteen in Ontario, and one in Alberta.

CHAPTER VII

RUBBER MANUFACTURING

General

A number of species of plants secrete a viscous milky juice (termed latex) within certain lactiferous vessels present in the bark. Plants of this type are very widely distributed throughout the world, but those species whose latex is of commercial importance grow in tropical and sub-tropical climates. Latex will flow from fresh cuts or wounds in the bark and is systematically collected from certain species. Rubber is prepared from this latex by suitable treatment, usually by heating and smoking, by natural drying, or, under special circumstances, by treatment with water or with acids. Gutta percha and balata are very closely related to rubber and are made in a similar manner from the latex of certain species of plants. They possess physical properties slightly different from rubber. In a few species of plants rubber is deposited in the wood of the stems or roots, and is recovered by grinding and special mechanical treatment, or by the use of solvents.

Natural rubber prepared from latex contains in addition a number of other substances derived from the parent plants or accumulated during the processes of preparation. Such substances include resins, nitrogenous materials derived from the plant, carbohydrates, vegetable colouring compounds, bark, inorganic matter such as sand or other dirt, and free acid or other material derived from the coagulating agents used.

Crude rubber is subjected to certain mechanical and chemical treatment to free it from impurities and to fit it for manufacturing processes. Raw rubber does not possess elasticity to a high degree; if stretched it will only return very slowly, if at all, to the original form, the elasticity varying with the kind of rubber and with the preliminary treatment to which it has been subjected. Some raw rubbers are soft and gummy at ordinary temperatures and all become hard on cooling. Raw rubber is soluble in hydrocarbon solvents. The principal solvents used commercially are acetone, alcohol, fusel oil, benzene, camphene, carbon bisulphide, carbon tetrachloride, ether, naphtha, naphthalene, petroleum solvents, pine oil, resin oil, toluol, turpentine and turpentine oil, and a number of other related compounds and artificial mixtures.

Raw rubber must be subjected to a preparatory process termed vulcanizing before it is suitable for industrial use. Vulcanizing has the effect of increasing the strength and elasticity of the product and otherwise alters the physical properties, and renders the material suitable for numerous industrial applications. Vulcanizing is usually accomplished by mixing sulphur or certain sulphur compounds with the raw rubber, shaping the product into the desired form, and then subjecting the mass to a pre-

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determined high temperature for a certain interval of time. Similar results can also be obtained by other methods, but vulcanization by sulphur is by far the most important process, and vulcanized rubber articles made by this method find the widest applications. The amount of sulphur used in vulcanizing rubber has certain effects on the physical properties of the finished products, hard rubbers being made by using proportionally larger quantities of sulphur.

Manufactured articles of commerce made of rubber almost invariably contain many other materials than rubber and sulphur. These materials include rubber substitutes and certain compounding materials which impart definite properties to the finished product. The rubber manufacturer uses a very great variety of materials other than raw rubber and sulphur in the compounding of the numerous mixtures that are used for producing the great variety of rubber articles used in industry.

Raw Materials

The principal materials used in the rubber industry are mentioned in the following list. The list could be almost indefinitely extended. Many of these materials are not produced in Canada and must be imported if used. Some of these materials could be produced from native products. This list has been printed in such a way that domestic products are distinguished from materials at present imported. With respect to Canadian products it may be noted that quantities of some of these materials are also imported for various reasons. All the materials mentioned in these lists are not necessarily used in any one factory. In the majority of cases factories limit their output to certain definite lines of products, and consume only those raw materials essential to the production of their special lines.

Table 29.—Principal Materials used in the Rubber Industry

(Names of products produced in Canada are in italics. A portion or all of the consumption may nevertheless, be imported.)

Natural Gums and Resins: Camphor; copal; resins (numerous kinds); rubbers (many varieties); shellac.

Minerals: Agalmatolite; anhydrite (powdered); *asbestic; asbestos;* asphalts; *barytes;* calamine; ceresin; chalk; clays (*china, fire, others*); *coal (powdered)*; *corundum;* elaterite; emery; *feldspar;* fuller's earth; gilsonite; *graphite (plumbago)*; *gypsum, kieselguhr;* manganese dioxide; *marble (flour)*; *mica;* ozokerite; pumice; rotten stone; *sand; shale (argillaceous, red)*; *silica (powder)*; *slate;* sulphur; *talc;* whiting (and Paris white).

Metals and Chemicals: *Acetone;* acids (*acetic,* tartaric); alcohol (*ethyl, methyl*); alum; alumina; aluminite; aluminium (flake); *alundum;* ammonium salts (borate, carbonate); aniline; antimony (powder); antimony sulphides; arsenic salts; atmido; barium salts [carbonate, sulphate (blanc fixe), sulphide]; *benzine;* Brunswick green; calcium salts [carbonate, phosphate (bone ash)]; calomel; carbon black; carbon bisulphide and tetrachloride; casein; *cellulose* (*wood*); charcoal (*animal, vegetable*); chloroform; *chrome yellow; dextrine; dextrose;* dyes; *ether; farina (potato flour); formalin;* glass (flour); *glucose; glue;* gluten; lampblack; lead (powder); lead compounds [acetate, *carbonate* (*white lead*), oleate, *oxides* (*litharge, red lead*), oxychloride, peroxide, sulphate, sulphide, sulphurets]; *lime; magnesia* (*calcined*); magnesium carbonate; mineral wool; *naphtha; ochres;* oils (aniline, pine, resin, tar, *turpentine*); *oleates;* organic accelerators (30 or more); *paraffin waxes; petroleum greases* and *residues; phenol;* pigments (many kinds); pitch (*coal,* stearine); *plaster of Paris;* Prussian blue; sienna, burnt; *sodium hydroxide;* sulphur chloride; tar (*coal*); *toluol; turpentine;* ultramarine; umbers (raw, burnt); vermilion; Venetian red; zinc (powder); zinc compounds (oxide, sulphide).

OTHER PRODUCTS: Cork; *cotton fabrics;* gelatine; *grease, wool; leather waste;* oils, vegetable (*corn* cottonseed, hemp, *linseed,* mustard, palm, peanut, poppyseed, rape, soya); *sawdust; starch; varnish; wheat flour.*

Products of the Rubber Industry

Rubber is a material whose applications in the industrial arts are extraordinarily widespread. There are probably about 50,000 separate articles manufactured which contain rubber as an essential constituent. The principal lines of manufacture are boots and shoes, automobile and bicycle tires, belting, sporting goods, clothing, hose, insulated wires and cables, water bottles, syringe bulbs, tubing, moulded goods of various kinds, hard rubber goods, sheet rubber, rubberized fabrics, and numerous articles made from these last two products.

Statistical Data

No statistical studies are available to show the amounts of the different materials required annually by the rubber industry in Canada. In the statistical tables given in part I of this report, which were compiled from the returns issued by the Department of Customs, some data are given with respect to the imports and exports of manufactured rubber goods. These data indicate that there are certain additional lines of goods needed in Canada that could probably be made in this country. The producer of minerals and the manufacturer of chemicals seeking for a broader market for their products in the Canadian rubber industries will be unable to obtain useful information with respect to the home market from these tables which are the best that can be compiled from the information available. In addition to rubber itself, which must be imported, the industry consumes large quantities of compounding materials, both minerals and chemicals, and many square yards of fabrics, particularly cottons, much of which might be supplied by home industries.

Canadian Situation

Available records show twenty-two firms in Canada engaged in the rubber industry exclusive of those producing insulated wires and cables. Four of these are located in Quebec, seventeen in Ontario, and one in British Columbia.

The Canadian rubber industries import the greater portion of their raw materials. They produce all the important lines of goods demanded by the home market, and in addition export in excess of six million dollars' worth of merchandise, particularly tires, boots, and shoes.

CHAPTER VIII

PHOTOGRAPHIC INDUSTRIES

General

Photography is defined as the art of producing images of objects by the action of light on certain chemicals. The processes now in use have been developed largely during the last fifty years, although the first scientific observations on the chemical effects of light on silver chloride were made nearly a century and a half ago. The practice of this art is now almost universal and many of its numerous applications are well known to everyone. By far the most important of these, commercially, is the Moving Picture industry.

The making of plates and films, and the production of chemicals for developing and fixing photographic images on these has become one of the largest and most important of chemical industries requiring much capital and consuming large quantities of certain commodities. The industry also gives employment to many persons. It is not possible to discuss the whole subject of the materials of the photographic industry in a short article. Reference can be made only to the principal products which are required for the manufacture of films and plates, and for the production of photographic pictures of the kinds most frequently seen.

Plates and films used in this industry are made by coating a sheet of glass, celluloid, or similar material with a sensitive emulsion of bromide of silver. This sensitized emulsion is usually made by adding silver nitrate to a solution containing bromide of potash and gelatine. A little iodide of potassium is often added to the bromide emulsion. The method of preparation of the emulsion and the operating conditions exert an important influence upon the final product.

After a prepared plate or film has been exposed to the action of light under conditions suitable for the affecting of the sensitized emulsion it is subjected to the action of certain chemicals to develop the image to the desired degree of intensity. When development is completed further changes are prevented by fixing the image by removing the unaltered silver salts present. This is done by the use of hyposulphite of soda. The action of both developing reagents and fixing solutions is tempered more or less by the presence of large or small amounts of other chemicals, which may effect the development and fixing of the image, or which may be present to protect and preserve the gelatine film containing both the emulsion and the image.

Silver bromide, as ordinarily used in sensitive emulsions, is affected chiefly by light rays from the blue end of the spectrum, and not at all by the red rays. Some kinds of plates and films are rendered sensitive to red and yellow rays by the addition of certain dyes in the emulsion. Such plates if made sensitive to red and yellow rays are called orthochromatic while if they are equally sensitive to all spectral colours they are called panchromatic.

Ordinary photographs are produced from negatives by the use of sensitized papers. Photographic papers are prepared much in the same way as films and plates with a sensitized coating on one side. Gelatine emulsions may be used for coating photographic papers, but other bases than gelatine, such as albumen, collodion, or casein are also employed. The emulsion used on printing out papers and on positive films is usually slower in action than that used on plates and films intended for making negatives, and is not sensitive to the red end of the spectrum.

Another group of chemical products is required for staining, colouring, toning, or otherwise altering the characters of images, especially those produced on certain kinds of sensitized photographic papers. Both negatives and prints are frequently protected and preserved by the use of various more or less transparent varnishes. Artificial lights of various kinds are frequently required and the production of flashlights and time lights consumes considerable quantities of certain chemicals.

Lastly, the manufacture of the various instruments and appliances of many kinds used in the industry, such as cameras, projection lanterns, and accessories, consumes large quantities of high-grade products supplied by various other industries.

Materials and Products

PLATES: Plates are usually made of the best quality of *sheet glass* similar to window glass, but thinner and of a greater degree of clearness.

FILMS: Films were formerly made entirely of celluloid, a compound made from nitro-cellulose and gum camphor. Owing to the inflammable nature of this product cellulose acetate, to which some camphor has been added, is now being widely used as a substitute. Celluloid sheets for negative films, from which, after exposure and development, are printed the positive or picture films used in moving picture machines, are made in long rolled sheets, about 40 inches in width and 2,500 feet in length. These sheets are coated with sensitive emulsion, and are then cut into strips, 1·375 inches in width and the full length of the roll. The strips are perforated in a special machine capable of very accurate work, and are then cut into such lengths as are required and wound on reels, preparatory to use in the special cameras used for making the exposures. Negative films are orthochromatic. Where negative films are required for the ordinary rolls used by the amateur, or for film packs, they are cut into strips or sheets of the desired size, wound on spools, or otherwise arranged in suitable packages for transportation and storage until they are required. Positive films for the moving picture industry are made much in the same way as the negative, but the celluloid base is made stronger and tougher as these films are subject to more or less rough usage when in use. Positive films are not orthochromatic, and can therefore be handled in a yellow or orange light.

Emulsion coatings are commonly made with albumen, gelatine, or collodion. The latter is a solution of nitro-cellulose in ether and alcohol. The sensitizing of the emulsion is accomplished by using silver nitrate and the bromide and iodide of potassium.

DEVELOPERS: Developers are chemicals which have the property of reducing to metallic silver that portion of the bromide and iodide of silver in the sensitive emulsion which has been altered by the action of light during the period of exposure. They are of two types, inorganic and organic. The principal inorganic developer used is ferrous oxalate. This is usually made by mixing *ferrous sulphate* with potassium oxalate in the proper proportions, the mixture being slightly acidified with citric acid. Organic developers are nearly all derivatives of phenol (carbolic acid) and many of the developers used contain mixtures of two or more of these compounds. These substances are sold under special or trade names which do not necessarily give any indication of their chemical composition. The same product, sold by different makers, may be marketed under two or more different trade names. The names of the more common of these developers are adurol, amidol, azol, diphenol, edinol, elon, glycin, hydroquinone, kachin, metol, ortol, pyrogallol, rodinol, rytol, satrapol, scalol, unal. They are all complex organic compounds derived from phenol, to which appropriate amounts of the carbonates and sulphites of sodium or potassium are added to make up a developing solution. "Eikonogen," another organic developer with very powerful action, is the sodium salt of amido-beta-naphthol-beta-sulphonic acid, and "diogen" is sodium amidonaphthol disulphonate. Probably pyrogallol, more commonly known as pyrogallic acid, a triphenol, $C_6H_3(OH)_3$, is the best known and most widely used developer. Sulphite of soda is generally used with this developer to diminish as much as possible the staining of the gelatine of the emulsion due to the decomposition of the pyrogallol in light. Carbonate of ammonia, carbonate of soda, or carbonate of potash is also used with this developer.

RETARDERS: Most developers also contain small amounts of soluble haloid salts (chloride, bromide, or iodide), which have the effect of hindering or slowing the reduction of the silver salts. They are usually termed retarders or restrainers and their effect is to prevent the image from appearing too rapidly, and thus becoming too dense or opaque before the process can be stopped. Acetone bisulphite and acetone sulphite are also used as a restrainer for rapid developers.

FIXERS: Fixing is the process of completely dissolving and removing the unaltered silver bromide that is present in the sensitive emulsion of the plate or film. This is usually accomplished by using a solution of sodium thiosulphate, more commonly known as hyposulphite of soda, or "hypo." Potassium cyanide can also be used for this purpose.

HARDENERS: Under some conditions, in warm weather, the gelatine film which contains the completed image has a tendency to frill, particularly along the edges. This is prevented by rendering it insoluble with formaldehyde or acetone, or hardening with chrome alum.

REDUCERS: Sometimes the completed image is too dense. It may be reduced by the use of a perchloride, that of iron being the one commonly used. The effect is to convert metallic silver of the image with silver chloride. If thiosulphate of soda is also present the chloride of silver will go into solution. The same effect is produced by using potassium ferricyanide and sodium thiosulphate. Other chemicals used for this purpose are chromic acid, ceric salts, ferric salts, manganic salts, titanic salts, mercuric nitrate, persulphate of soda.

INTENSIFIERS: Sometimes the completed image is too thin to give satisfactory prints. It then becomes necessary to intensify it if possible. This is accomplished by the use of perchloride of mercury and a developer such as ferrous oxalate or metol. Other salts used in intensification by various methods are potassium permanganate, sodium sulphite, silver nitrate, pyrogallol, lead nitrate, uranium nitrate, and potassium ferricyanide. Acids, hydrochloric, sulphuric, acetic, and citric, are also used in small quantities.

POSITIVES: The preparation of positive prints from negative images on films or plates involves the manufacture of positive films, to which reference has already been made, printing out papers, and developing papers. Positive films are usually celluloid coated with a gelatine emulsion of bromide of silver. Photographic papers are made from high-grade paper stock of several different kinds, the emulsions used varying considerably. The mounting of finished photographic prints necessarily creates a market for various other kinds of paper mill products and also for adhesives.

PHOTOGRAPHIC PAPERS: Photographic papers are coated with sensitized emulsions much in the same way as films or plates. The emulsions are not usually made sensitive to yellow and red light, and they are usually slower in action than those used on negatives. Printing out papers are those on which the image is printed by direct exposure under a negative and afterwards toned and fixed. Gelatine emulsions sensitized with silver chloride are used for this purpose, as well as albumen, collodion, and casein. Albumen to make such an emulsion is derived from the whites of eggs to which ammonium chloride and alcohol have been added. It is sensitized by treating with a solution of silver nitrate, the ammonium chloride present in the emulsion causing the formation of silver chloride. The silver nitrate also forms an insoluble compound with the albumen. Collodion and casein papers are sensitized with silver chloride. Developing papers are sensitized with an emulsion so constituted that the image formed on exposure has to be developed much as a negative is developed. Emulsions similar to those used on printing out papers are used, but the sensitizing salt is silver bromide, the chlorobromide or the phosphate. So-called platinum papers are surfaced without the use of gelatine. Pigment papers are coated with gelatine made sensitive to the action of light and containing certain pigment colours.

Printing out papers are subjected to toning operations after exposure, to improve the image. Gold chloride solutions containing ammonium sulphocyanide and other salts are used for this operation. Platinum chloride can be used in place of gold chloride to obtain certain different effects. Salts of other metals, such as palladium, uranium, or lead, have also been used for this purpose.

SENSITIZERS: Emulsions used on plates and films are made orthochromatic or panchromatic by the use of certain organic compounds classed as sensitizing dyes, that either affect the light or are affected by it. Erythrosine and eosine are used to make silver bromide plates sensitive to green and yellow rays (orthochromatic plates). Other sensitizers of this class are certain rosaniline and azo dyes, and monobromfluorescein. Some akridin and alizarin dyes are occasionally employed. Cyanine causes silver bromide to become sensitive to yellow, orange, and red rays. Ethyl red (quinaldin-quinolin-ethyl-cyanine) is sensitive to nearly all rays except the deeper reds. Other organic compounds even more sensitive to red light are orthochrome, pinachrome, pinacyanol, and pinaverdol. These are very complex organic salts derived from isocyanine, the names used here being trade names. Other sensitizers are also available.

FILTERS: Colour filters are made for filtering the light during the exposure of orthochromatic and panchromatic plates. These filters are usually made with a film of gelatine or collodion coloured with special dyes which intercept certain groups of light rays and permit others to pass. Auramine intercepts violet and blue rays, and transmits yellow, green, and red. Tartrazine and certain other aniline dyes can be used to transmit red rays. Methylene blue, naphthol green, naphthol yellow, erythrosine, and others are also used. Colour filters are used in making negatives for the reproduction of pictures in natural colours by the three-colour photographic process.

BLUEPRINT PAPERS: Blueprint papers are widely used for reproducing plans, engineering drawings, and similar purposes. The sensitive characteristic of these papers depends upon the fact that ferric salts are reduced to ferrous salts by the action of light. For example, ferric oxalate, $Fe_2(C_2O_4)_3$, on exposure to light is converted into FeC_2O_4. If this latter salt is treated with potassium *ferricyanide* it becomes converted to Prussian blue which is insoluble, while any unaltered ferric oxalate remains soluble and practically colourless. If *ferrocyanide* of potassium is used, the reverse action takes place, the ferrous oxalate remains unaltered, while insoluble Prussian blue is formed with the unaltered ferric oxalate. Printing papers of this kind are made by directly coating one side of the sheets of paper to be sensitized with a solution containing ammoniacal citrate of iron and potassium ferricyanide, a soluble gum being also present in the solution to act as an adhesive. When dry this coating is sensitive to light, Prussian blue being produced. When the paper is used for printing the blue image that will be formed is fixed by simply washing out the unaltered portions of the coating which remain water soluble. A similar paper that must be subjected to a developing operation is made by using a ferric salt only, such as ammoniacal citrate of iron, and then developing in potassium ferricyanide solution. Papers are made on which the images are reversed, whereby whites are reproduced as whites and dark parts are reproduced in shaded blues, by using ferric chloride and ammoniacal citrate of iron, in proper proportions and developing with ferrocyanide of potassium. The blue colours of all these prints can be changed to other colours by using certain reagents that produce characteristically coloured insoluble salts of iron. Tannic acid will turn the blue colours and shades to black and greys, sulphocyanide of potash will produce reds.

OTHER PRODUCTS: Printing papers of other kinds have also been developed by the use of a number of other chemicals. A number of these depend upon the use of potassium bichromate ($K_2Cr_2O_7$) and the effects that light produces on this salt in the presence of an organic colloid such as gelatine.

Gelatine or albumen containing bichromate of potash will harden if exposed to the action of light. If such a sensitized film is spread upon a plate, dried out in the dark, and then exposed to light through a negative, the exposed parts become hardened and insoluble in water, while the unexposed parts remain water soluble and can be removed. This property forms the basis of most of the modern methods for reproducing line drawings, etchings, and pictures of various kinds by printing processes such as heliotype, stannotype, albertype, photogravure, heliogravure, gillotype, zincography. The other principal materials used in these processes are nitric acid or ferric perchloride for etching, asphaltum, graphite, gutta percha, electrolytic copper, electrolytic steel, lead, and plates of zinc or copper. The details of the various processes are too complicated to discuss here.

Line engravings may be made by etching processes from negatives by utilizing the fact that asphaltum is sensitive to light, exposed portions becoming insoluble in turpentine or benzene.

LIGHTS: The making of negatives and positives necessitates the use of artificial lights. The commonest source of light, apart from natural sunlight is electricity, both arc and incandescent forms of lighting being employed. Such lights are also used in projection lanterns for throwing positive images on screens, whether moving pictures or lantern slides are used. Flashlights are frequently used in circumstances where the natural light is not sufficient to affect the sensitive emulsion satisfactorily.

Flashlights usually consist of powdered magnesium metal mixed with some oxidizing agent such as nitrates of rare earths, permanganate of potash or manganese dioxide, strontium nitrate, barium nitrate, barium peroxide, and others. Aluminium powder may be used with or as a substitute for magnesium. Red phosphorus or sulphide of antimony may also be used with metallic magnesium or aluminium in some flashlight powders.

Time lights are made to burn slowly. Their basis is metallic magnesium or aluminium to which some substance which has the effect of retarding the combustion is added, such as strontium carbonate, magnesium carbonate, magnesium silicate, sodium tungstate, or cerium nitrate.

ACCESSORIES: Finally the making of photographic apparatus and appliances creates a market for large quantities of numerous manufactured products, among which may be mentioned lenses of optical glass, coloured glasses, sheet metals, especially brass and aluminium, metal rods and wires, screws, nails, leather and artificial leather, veneers, glues and cements, dyes, lacquers and varnishes.

BYPRODUCTS: Mention should be made of the fact that in localities where large quantities of sensitive films and papers are used it is customary to save the spent solutions containing salts of silver, gold, and other precious metals for the purpose of recovering the valuable metal. By-product metals recovered in this way are again utilized for producing additional quantities of the original chemicals from which they were derived. The manufacturers of films and plates are probably the largest consumers of silver for the production of the silver salts used in sensitized emulsions.

The following classified list of materials used in the production, reproduction, and preservation of images by photography includes not only the various materials mentioned in the foregoing cursory descriptions, but also many others which are not included because of more limited applications.

Table 30.—Principal Materials used in the Photographic Industries

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

ACIDS: *Acetic;* boric; *carbolic; carbonic;* chromic; citric; formic; gallic; *hydriodic; hydrobromic; hydrochloric; hyposulphurous; nitric; nitrous;* oxalic; phosphoric; pyrogallic; *sulphuric; sulphurous;* tannic; tartaric.

COLOURS: Akridin dyes; alizarin blue; auramine; azo dyes; cyanine; dahlia violet; dicyanine; eosine; erythrosine; ethyl red; ethyl violet; methylene blue; monobromfluorescein; naphthol green; naphthol yellow; orthochrome; pinachrome; pinacyanol; pinaverdol; rosanilines; tartrazine.

DEVELOPERS: Diamidoresorcin; diamidophenol sulphate; diamidoxydiphenyl; ferric oxalate; hydroquinone; methylorthoamidophenol; monobromhydroquinone; monochlorhydroquinone; monomethylparamidophenol; monomethylparamidophenol sulphate; paramidosaligenin; paramidosaligenin hydrochloride; paramidophenol; para-oxyphenylglycocoll; pyrocatechol; pyrogallol; sodium compounds (amidoacetate, alpha-amido-beta-naphthol sulphonate, amidonaphthol disulphonate); thiocarbamide; thiosinamine; triamido-resorcin.

GUMS AND RESINS: Amber; *Canada balsam;* caoutchouc; colophony; copal; dammar; dragon's blood; elemi; gutta percha; mastic; sandarac; shellac.

EMULSIONS: *Albumen; collodion; gelatine;* silver salts such as albumenate, bromide, chloride, cyanide, iodide, nitrate, oleate, phosphate.

ELEMENTS: *Aluminium;* antimony; bromine; iodine; magnesium; phosphorus; sulphur.

PLATES AND FILMS: Sheet glass (selected); celluloid; cellite (cellulose acetate); viscose.

SOLVENTS: *Acetone;* alcohol (*ethyl, methyl, methylated*); aldehyde (methyl); *benzene; benzine;* carbon bisulphide; chloroform; ethers (methylated, sulphuric).

OTHER CHEMICALS: Alums (ammonium, chromium, potassium, sodium); *ammonia;* ammonium compounds (bichromate, bromide, carbonate, chloride, ferrous-sulphate, *hydroxide,* iodide, nitrate, oxalate, persulphate, sulphide, sulphocyanide); antimony sulphide; barium compounds (bromide, chloride, hydroxide, iodide, peroxide); cadmium compounds (bromide, chloride, iodide); calcium compounds (bromide, *carbonate, chloride, hydroxide, hypochlorite,* iodide, *oxide*); cerium nitrate; copper compounds (acetate, *ammonium sulphate,* bromide, chloride, *sulphate*); ferric chloride and hydroxide; ferrous chloride, hydroxide, oxide, and *sulphate;* gold chloride; lead nitrate; lithium compounds (carbonate, chloride); manganese dioxide; mercuric chloride; mercurous chloride; palladium chloride; platinum chloride; potassium compounds (bicarbonate, bichromate, bromide, carbonate, chloride, chloroplatinite, chromate, cyanide, ferricyanide, ferrocyanide, hydroxide, metabisulphide, permanganate); sodium compounds (biborate, bicarbonate, bromide, carbonates, chloride, *hydroxide,* hypochlorite, hypophosphite, iodide, sulph-antimoniate, sulphate, sulphite, thiosulphate); strontium nitrate; uranium nitrate; zinc compounds (bromide, chloride, iodide).

MISCELLANEOUS PRODUCTS: *Adhesives;* asphaltum; catechu; cellulose products; glass (optical, coloured); leather (*real, artificial*); metal products (such as *wires, rods, sheets,* and *castings of aluminium, brass, copper, zinc,* and *iron* or fabricated products such *as nails, screws, rivets* and *others*); *rubber products;* soaps (*castile*); *woven fabrics* (*cotton, linen silk*).

Statistical Data

The foregoing discussion on this industry has shown that it requires supplies of a very great variety of fine chemicals and other products, derived from many other industries. Products used in large quantities, such as films, plates, sensitizing emulsions, and developers are made only by a very few manufacturers. In a less degree this is also true of the numerous fine chemicals used for special purposes in the production of photographic images under various conditions. A few of the chemicals are widely employed in other industries, the photographic industry being one of the markets for the producers of these products (such as sodium carbonate, sulphide and thiosulphate, potassium salts, or salts of gold, silver, and platinum). The photographic industry is one of the largest consumers of silver salts, and therefore indirectly of metallic silver. Owing to the variety and nature of the products required by this industry, and to the small number of the manufacturers engaged therein, it is not surprising to find that there are no basic statistical data available showing its requirements. It would be a relatively simple matter to obtain statistical data with respect to those products that are used by this industry in common with other consumers, such as sodium and potassium salts, and silver salts. The consumption of films and plates is in part covered by import statistics, but additional classified statistical data could be obtained. Such information would be of value to manufacturers of these products.

The only available data relate to imports and exports, the items being based on the tariff classification. The following table showing average imports and exports for the three fiscal years prior to the war, and for a corresponding period after the armistice, has been compiled from the reports of the Department of Customs. Quantities and unit values are not given in these records, except the total length in feet of positive cinematograph films.

Table 31.—Table of Imports of Photographic Materials

Items as listed in Customs Tariff	Imports	
	Average 3 years 1912-13-14 Value in $	Average 3 years 1920-21-22 Value in $
Photographic dry plates	60,504	26,498
Cinematograph or moving picture films, positives, 1⅜" in width and over	....	1,594,103
Paper, photographic, plain basic, baryta coated, adapted exclusively for use in the manufacture of albumenized or sensitized paper	93,782	198,181
Albumenized or other papers and films chemically prepared for photographers' use	208,825	227,383

The average value of the glass plates imported for the manufacture of dry plates was $13,535 in each of the three years prior to the war, and $42,935 in each of the three years following the armistice. No separate records are available showing the importations of celluloid or cellite in sheets for the same purpose during these periods. The item appears to be included with the celluloid in sheets and other forms used in various manufacturing processes.

The only item of export recorded separately is that of films for photographers' use, which averaged $33,805 in the period 1912-13-14. In the years 1920-21-22 this item was extended to include films for moving pictures, and reached an average of $2,368,885 annually.

The imports of cinematograph positive films are not recorded for the three years prior to the war; importations for the three years immediately following the armistice have averaged 20,173,833 feet annually.

There are no records showing the importations of chemicals exclusively for the use of this industry. A classified list showing the salts of sodium and the organic developers imported would be of value to a manufacturer of chemicals.

Canadian Situation

All the film supports, all the paper stock for making photographic papers, all the important fine chemicals, many of the heavier chemicals, most of the plates, and many of the accessory products used in this industry are imported from other countries, chiefly from the United States and the United Kingdom, and, to a limited extent, from Germany, France, and other European countries. Lenses are not made here, but cameras and projection lanterns of certain kinds are made by two or three manufacturers.

Photographic negatives and positives are made in almost every Canadian city, town, village, or settlement. Photographic processes for preparing plates for printing purposes are used in every city and in many towns of importance. The total annual consumption of various chemicals for developing and printing must be fairly large. The requirements of this market are met by local distributors at all important centres. No statistical data are available showing the number of firms engaged professionally in photography or in manufacture of phototype plates for printing. The major portion of the manufacturing in Canada is in the hands of one firm. Blue print paper and similar products are made by a number of different firms, some consumers making their own papers. Projection lanterns of several kinds are made by a number of firms, the lenses being imported.

CHAPTER IX

ELECTRO-PLATING INDUSTRIES

The art of electro-plating consists in the depositing of a thin film or coating of a metal upon the surface of any body by the electrolytic decomposition of a salt of the metal so deposited. Metallic coatings are deposited upon many products by this method for various purposes. Objects made of iron or steel are preserved from corrosion by plating with copper, nickel, cobalt, platinum, or other less easily corroded metals. The protective coating may, at the same time, possess an artistic or ornamental value. Silver, gold, nickel, cobalt, and copper plating are often employed for this purpose.

Applications of the Art

Electro-plating methods are employed for the production of metals in very thin sheets. This is accomplished by taking precautions to prevent too close an adherence of the deposited metal to the surface on which it is deposited. It can then be stripped from that surface when the deposit has reached the requisite thickness. Gold foil made in this way is so thin that the sheet is nearly transparent and of a pale green colour. Foils or thin sheets of silver, copper, nickel, tin, and other metals can also be prepared by this process.

If the conditions of deposition are suitably adjusted metal in a finely powdered condition is produced in place of the thin coherent coating film or sheet. Finely powdered metals, such as lead, copper, or tin, are thus produced for industrial purposes.

Apparatus has been devised for coating wires of various metals with protective or artistic coating of various other metals by the electrolytic process. Wires to be coated with a metal are passed continuously through a suitable bath by mechanical means, the rate of travel being so adjusted that each portion of the wire is in the bath long enough to receive the desired thickness of deposited metal. Copper, silver, nickel, and gold plated wires are produced in this way.

This method of depositing metals has also been employed for making tubes, rods, or wires of certain metals, particularly copper, and occasionally iron. Such articles made by this process are usually subjected to a drawing process for finishing purposes. The material, being very pure, is usually tougher than that made by other processes Modifications of the process have also been developed for the production of tubes, hollow vessels of various kinds, parabolic mirrors, locomotive headlights, and other articles of special shapes and forms.

One of the most important applications of the process is in the art of galvanoplasty, which is the reproduction of the forms of objects by means of electro-deposited metals. In brief any object whose form it is desired to reproduce (such as a plaster cast, or other art object) is coated

77921—9

with a proper conducting medium. It may then be plated with a suitable metal, such as copper, in the usual way. If this coating is made dense and thick enough it can be removed from the object on which it was deposited, and will form an exact mould of the surfaces of the object with which it was in contact. This negative, suitably strengthened, can be used as a mould for the reproduction of exact replicas of the original object. This art probably finds its widest applications in the reproduction of woodcuts, electrotypes, autotypes, halftone plates, and other forms of plates used in the printing and publishing business. It is also used for producing metal objects of special forms or shapes.

A closely related process for reproducing drawings and designs upon metal surfaces should also be mentioned in this connection. When surfaces of metals are exposed to the action of certain chemicals in solutions, with which they form part of an electric circuit, these metals will be corroded by the solutions, and salts of the metal will be formed. If the surface of the metal is partly coated with a lacquer, varnish, wax, or other material not subject to the action of the corrosive liquid, solution will take place only on the uncoated portions of the surface of the sheet of metal. Any drawing or design can be etched upon a metallic surface in this way. The process is used to etch art designs upon the surfaces of metal objects, and also for the production of plates of various kinds for the use of the printing trade.

Selective corrosion of metal surfaces by the electrolytic process is also used by the metal engraver in the production of engraved plates.

Ornamental coatings in many tones of colour can be produced upon iron, copper, brass, silver, or nickel surfaces by subjecting objects made of these metals, or deposited coatings of the metals to the corrosive action of certain chemicals. Iron surfaces can be made silvery, brown, blue, or black in several tones; copper can be coloured from red to terra cotta or orange, and iridescent effects can also be produced; brass can be coloured olive green or several tones of colour between orange and yellow; nickel surfaces can be made iridescent, or yellowish to blue tones imparted; silver may be coloured several shades of grey; and blue to almost black. These processes are used very extensively for producing artistic colour effects on the surfaces of numerous manufactural products, particularly objects made from stamped sheet metal.

Electrolytes

In all branches of this art the solutions used are termed electrolytes. An electrolyte may be defined as a solution of chemical compounds some of which can be decomposed by the passage of an electric current. The composition of electrolytes naturally varies greatly, depending upon the purpose for which they are required. When used for metal plating they invariably contain salts of the metal to be deposited. In addition sheets, bars, rods, or other shaped masses of the same metal are suspended in the electrolyte and are connected with the positive terminal of the source of electric current These bodies are termed anodes, and they serve as a source of supply of metal to replace that deposited on the object being plated, during the period the current is passing. The objects to be plated are connected with the negative terminal of the source of current and are termed cathodes. When the current is passing through the electrolyte from the anode to the cathode, metal from the salt in solution will be deposited on the objects at the cathode, and at the same time the anodes will be slowly corroded, the metal passing into solution and replacing that deposited.

Where the object of the operation is to produce an etched surface of any kind the electrolyte usually consists of an acid or alkaline solution capable of conducting electric current and capable of forming salts with the metal to be etched. An inert material not subject to corrosion by the solution is used as the negative terminal dipping into the electrolyte, and the metal to be etched is placed in the electrolyte and connected with the positive terminal.

It may be mentioned that in certain cases electro-plating can be accomplished by the use of certain metallic salts without the use of anodes of the same metal. In such operations the electrolytes are rapidly exhausted and it is necessary to renew them by the addition of more salt. Such methods are not generally employed for continuous operations.

A number of different formulae are available for the composition of electrolytic baths for nearly every metal that is plated upon other surfaces by this process. The particular formula best suited to each class of operation is naturally determined by experiment and experience. No attempt is made here to discuss formulae for individual baths. The subjoined statements list only the different chemicals that are used most frequently in commercial practice in electro-plating, without discussing the technique of operations. This subject has been treated very exhaustively in a number of technical textbooks on this art.

The following metals (and alloys) can be deposited electrolytically from certain of their salts upon other metals or upon suitably prepared surfaces. Anodes of these metals should be as free from impurities as possible. In some cases cast anodes are employed, but for many operations rolled anodes are preferred: Brass, bronze, cobalt, copper, gold, iron, lead, nickel, palladium, platinum, silver, tin, and zinc.

Table 32.—Chemical Compounds used in Electrolytes

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

A. Metallic Salts or Oxides: Antimony compounds (persulphide, potassium tartrate); *arsenious oxide;* auric chloride; cobalt compounds (*chloride, nitrate, oxide, sulphate*); copper compounds [acetate, *carbonate, cyanide,* oxide (ous), potassium cyanide, *sulphate*]; *ferrous sulphate* and *basic sulphate;* lead compounds (acetate, basic carbonate, *yellow oxide*); nickel compounds (*ammonium chloride, chloride,* citrate, nitrate, *sulphate,* tartrate); palladium chloride; platinum compounds (ammonium chloride, chloride); silver nitrate; sodium compounds (*arsenate, chloride*); stannous chloride; zinc compounds (*chloride, sulphate*).

B. Conducting Chemicals: Acids (*acetic, benzoic,* boric, citric, *hydrochloric,* hydrocyanic, *hydrofluoric, nitric, sulphuric,* tartaric); ammonium compounds (*carbonate, chloride,* cyanide, phosphate); magnesium compounds (carbonate, chloride); mercury nitrate; potassium compounds (carbonate, chloride, cyanide, ferrocyanide, hydroxide, mercuric cyanide, sodium tartrate); sodium compounds (biborate, *carbonate, chloride,* citrate, cyanide, *hydroxide,* hyposulphite, phosphate, pyrophosphate, *sulphate, acid sulphate,* sulphocyanide, sulphite, acid sulphite, tartrate); *zinc cyanide.*

C. Chemicals used for Pickling: Acids (*hydrochloric, hydrofluoric, nitric, sulphuric*); *benzine*; *calcium oxide*; *petroleum oils*; potassium compounds (bitartrate, cyanide, dichromate, hydroxide); sodium compounds (*carbonate, chloride,* dichromate, *hydroxide,* nitrate, *sulphate, acid sulphate*).

D. Colloids used in Electrolytes: Acid, tannic; aluminium hydroxide; *gelatine*; *glue*; tin hydroxide.

E. Reducing agents used in Electrolytes: Acid, pyrogallic; hydroxylamine; *molasses; sugar.*

F. Miscellaneous Products: Alcohols (*ethyl, methyl*); asphaltum carbon bisulphide; chloroform; *collodion;* emery; ethyl sulphate; *graphite; gutta percha;* iodine; lampblack; pumice, resin; shellac; sulphur; whiting.

Statistical Data

Statistical data with respect to the development of this industry and its requirements are not available. Many of the materials required by this industry are not produced in this country and some of the materials produced are not available in a form suitable for use in this industry. Anodes are made in Canada, but in some cases at least imported metals are used for this purpose. The value of imported anodes as reported by the Department of Customs is usually less than ten thousand dollars annually. Metals imported in other forms for the production of anodes would not be classified in a separate tariff item and therefore cannot be identified. The principal acids and salts required by the industry are made in Canada, but many special products, required from time to time, are also imported.

Canadian Situation

The present status of the electro-plating and associated industries in Canada has not been specially investigated. The more common operations of plating with brass, bronze, copper, nickel, silver, and gold are carried out at a number of plants in association with other manufacturing processes. There are in addition at least fifty other firms engaged primarily in the electro-plating industry. Electrotypes for the use of the printing industry are also made in a number of establishments in the principal cities and some towns. Artistic plating, colouring, and etching are performed only in a few establishments, and many articles ornamented by these methods are imported. Etching is also employed as one of the steps in the production of engraved plates for bank notes, bond certificates, and similar products of the engraver's art. Apart from the preparation of electrotypes there is no information available at present showing that other forms of galvanoplasty are employed by Canadian firms in ordinary commercial practice.

CHAPTER X

DRY CELLS AND STORAGE BATTERIES

Numerous forms of electric batteries have been developed and many kinds are still in use for different purposes. The manufacture of batteries creates a limited demand for certain metals, mineral salts, acids, and the various forms of containers that are used in their construction. The extent of this industry has not been specially investigated for this report. The demand for dry cells for flashlights, house bells, telephones, and other purposes, and the storage battery requirements of automobiles, motor boats, and farm lighting indicate that the Canadian market for these products must be of large dimensions. A brief résumé of the various raw materials that enter into the construction of these two kinds of batteries is therefore given. Wet batteries are not discussed because the market is very limited for any given variety and the chemicals and other materials used in their construction, if made in Canada, are mentioned in other sections of this report.

Dry Cells

The modern dry cell as used for flashlights, house bells, and telephone service is a modification of Leclanché's wet battery. The negative pole is made of sheet zinc rolled into a hollow cylinder that is provided with a sheet zinc bottom. The sizes of the cylinders differ, according as the batteries are to be used for flashlights or for bell ringing and other purposes. A common size for bell ringing batteries is 2·5 inches in diameter and 6 inches in depth. Flashlight batteries are usually about 1·25 inches in diameter and 2·25 inches in depth, one, two, or three being used together in each holder, according to the style and voltage of the lamp used. The positive pole is a carbon rod, either smoothly cylindrical, or grooved to provide increased surface. A cylindrical wall of absorbent material (wood pulp, blotting paper, cheese cloth, starch, paste) saturated with electrolyte (ammonium chloride solution) is packed within the zinc cylinder. The carbon rod is placed centrally in the cylinder of absorbent material and the space between is packed with a mixture of coarsely granular carbon and manganese dioxide. The top of the cylindrical container is sealed with a preparation of bitumen or pitch. The outside of the zinc cell is often covered with a paper label or a thin pasteboard container. These batteries when new have an electromotive force that lies between 1·5 and 1·6 volts.

Storage Batteries

Storage batteries are of two principal types. The best known is probably the lead battery used in automobiles. The other variety, the Edison nickel-iron alkaline type, is also widely used for automobile and other services.

The lead type of storage battery consists of finely cast grids of antimonial lead, suitably prepared, mounted, and connected. The negative plates for a battery are made by filling the grids with a paste made of litharge (PbO) mixed with dilute sulphuric acid. The positive grids are filled with a paste of red lead (Pb_3O_4) and ammonium sulphate. Certain other ingredients are used as binders to make the pastes coherent. The kind of material used for a binder differs with different manufacturers. These materials include asbestos fibre, ammonium sulphate, anthracene, glycerine, graphite, and sodium or potassium silicate. The plates are prepared for use by special treatment in forming cells. This latter contains dilute sulphuric acid. The terminals are connected with a source of direct current at suitable amperage and voltage. Positive plates are made by placing the antimonial lead grids, charged with red lead paste, in a forming cell and connecting them as anodes. The passage of the current in the presence of dilute sulphuric acid converts the red lead of the paste into lead peroxide (PbO_2). The negative plates, charged with litharge paste, are treated in a similar manner, but are connected as cathodes by sending the current in the opposite direction. The litharge paste is reduced to metallic lead in a spongy condition. Formed plates are drained and dried and are then ready for marketing for use as units in assembling batteries. Insulation is accomplished by using rubber or wooden separators. Containers may be glass, hard rubber, bakelite, or some similar material.

The best known of the alkaline storage batteries is the Edison nickel-iron battery. The positive plate of this type consists of a series of perforated steel tubes nickel plated and filled with a mixture of flaked nickel and nickel hydroxide $Ni(OH)_2$. The negative plate consists of a cold rolled steel plate pressed into rectangular pockets, the whole being nickel plated. The walls of the pockets are finely perforated and the space is packed with ferric oxide (Fe_2O_3). In an assembled battery the plates are separated by narrow strips of hard rubber. As the battery is mounted in a steel container grooved side insulators of hard rubber are also required. Rubber insulation is also provided at the ends and bottom of the cell. The electrolyte is a 20 per cent solution of potassium hydroxide. After preparation of the plates as outlined above the positive plates are treated in an electrolytic cell to oxidize the nickel hydroxide, a compound corresponding to nickel dioxide (NiO_2) probably being formed. The negative plates are similarly treated in an electrolytic cell, the powdered ferric oxide being reduced to finely divided metallic iron. The two plates thus prepared are known respectively as the nickel and the iron plates. Special steel containers with special attachments are used for these cells.

There are many variations in the details of construction of the various kinds of storage batteries. It is unnecessary to touch upon these modifications in this brief description since they are not relevant to this report.

Storage batteries find numerous applications, a few of which are listed herewith: gas engine ignition, operation of various kinds of vehicles, passenger car and automobile lighting, railway signalling, telephone and telegraph operation, ringing call bells and alarm bells of many kinds, electro-plating, surgical and dental work, regulating work in the operation of transmission lines, in central electric power station operation as reserves, for voltage regulation, and other purposes. Occasionally they are used to operate various kinds of mechanisms, especially where they can store off peak power and deliver it later as required. They can also be used to operate railway switches at long distance for the control stations, for farm lighting, making 24-hour service possible without continuous operation of the generator.

Raw Materials

The principal components of dry cells and storage batteries have already been mentioned in the foregoing concise descriptions of the construction of the more common types. These materials may be recapitulated without comment.

Table 33.—Materials used in Dry Cells or Storage Batteries

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

CHEMICALS: *Acid, sulphuric;* ammonium compounds (chloride, *sulphate*); anthracene; *glycerine; graphite; iron oxide (ferric); lead oxides [red, yellow (litharge)]; manganese dioxide; nickel hydroxide;* potassium compounds (hydroxide, silicate); sodium silicate.

MISCELLANEOUS: *Asbestos fibre;* asphalt; carbon (plates, rods); resin; shellac; *starch; wood pulp; lead, antimonial;* nickel flake; steel, special (plates, tubes); zinc sheet; separators (wood, rubber); containers (glass, rubber, bakelite, lead lined wooden boxes).

Canadian Situation

Statistical data with respect to this industry have not been compiled. The number of firms engaged in the manufacture of the various kinds of batteries has not been ascertained. The number of retail distributors is very great. A reference to the customs statistics shows the importation of large numbers of the various types of batteries discussed in the foregoing paragraphs.

CHAPTER XI

GLUE AND GELATINE

Glue is a decomposition product obtained from certain nitrogenous tissues of animals by treatment with water raised to a suitable temperature. These tissues swell up on treatment, the organic structure is lost, and water soluble compounds pass into solution. When cold the solutions, unless very dilute, form jellies. The jelly when dried forms a horn-like more or less translucent (or even opaque) material to which the name glue is given. Glue can be readily dissolved by the use of hot water. The primary solution and the intermediate jelly do not possess the cementing properties which are characteristic of the solution made from the dry glue. The most conspicuous characteristic of glue, its ahhesive property, is notably affected by the temperature to which it has been subjected during extraction. The use of too high a temperature reduces the adhesives.

Gelatines are identical with glues. They are usually made from clearer, and preferably fresh stock under sanitary conditions. The product is therefore fit for use as a food or for other purposes where purity is necessary or desirable.

Raw Materials

The principal raw materials used in the manufacture of glues are skins or hides, bones, sinews, and fish stock, all of which are byproducts of other industries.

Skins and hides are usually valuable for the manufacture of leather, or for use as fur. Scrap and trimmings are usually sent to the glue factory. Fleshings—the scrapings from the flesh side—and skivings—the parings from the hair side—are utilized in glue manufacture. Glue is not obtained either from the epidermis nor from the fat tissue which underlies the skin of an animal, but only from the coriaceous portion. Leather may be used as glue stock, but it is necessary to subject it to preliminary treatment to remove the tannin. Otherwise the corium will not yield water soluble constituents. Hides yield some of the best grades of glue. Hide scrap available for the manufacture of glue consists largely of material derived from cattle, sheep, and pigs. Smaller amounts of material are derived from the fur dressing industry. Plucked rabbit, cat, and other skins obtained from felt factories are also used. Leather scrap from tanneries, shoe and belt factories is sometimes employed.

Bones used in the glue industry come from two sources. Fresh, green, or packer's bone consists of material obtained in fresh condition directly from abattoirs. The long bones, particularly the shin bones, are sent to factories where handles for knives, tooth brush shapes, buttons, and similar articles are made, the scrap only being then sent to the glue factory. Heads, ribs, feet and other parts too small to be of any other use go to the glue factory. A particularly good grade of glue or gelatine is made from the cores of the horns of cattle. The other kind of bone available is sometimes termed country bone. It is derived from butchers' shops and junk collectors. This material does not produce as good a grade of glue as fresh clean bone. Bones are usually subjected to degreasing treatment by the use of solvents such as benzene or carbon bisulphide or the grease may be recovered during the boiling operations.

Closely related to bone is a product made from it by treatment with hydrochloric acid after the removal of the grease with a solvent. The cartilaginous residue after treatment with acid is called *ossein*. It may be used fresh or may be dried for transport or storage. The mineral matter of the bones thus treated goes into solution and is recovered for marketing as bone phosphate. Bone phosphate thus prepared is used for making *"bone china"* and also in the manufacture of *phosphoric acid* and *acid phosphates* for use in the production of baking powders.

Sinews yield a product similar to that obtained from bone. If fresh and clean the extracted material will be used as gelatine. Dried sinews are obtainable for use in the manufacture of glues and gelatines.

Fish stock consists of the heads, bones, and skins of fish. They are usually available at canneries where the edible portions of fish are packed. The swimming bladders of certain kinds of fish contain, on the inside, an almost pure product of this class, which when dried is named isinglass. It is obtained by splitting the bladder, drying it on a surface with the skin (or outside) down, and then stripping off the inside material, which is completely water soluble.

Kinds of Glue

The following classes of glues are made and marketed:—

Animal glue—made from abattoir and tannery refuse of suitable kinds and from country bone. Glue stick is a low grade product made by evaporating and drying packing house waste liquors.

Fish glue—made from fish scrap. It has rather weak gelatinizing properties and is often prepared as a liquid glue. Objectionable odours are usually masked by using some strongly odoriferous oil such as sassafras.

Liquid glue—a prepared product in which the jelly-making property of glue or gelatine has been destroyed by the use of acetic, hydrochloric or nitric acid without affecting the adhesive properties. Either animal or fish glues may be prepared in liquid form.

Vegetable glue—made by treating starch with cold caustic soda. The name is also sometimes applied to algin obtained from certain species of marine algæ. Agar-agar, a product prepared in the orient from certain marine algæ, is also sometimes termed vegetable glue. This last material is variously designated as Japanese gelatine, Chinese isinglass, Ceylon gelatine, or some similar name according to the place of origin.

Manufacturing Processes

The methods of preparing glues and gelatines are alike. Dried material must first be soaked in water to soften it, and all materials must be cleaned as thoroughly as possible by washing. Most material is subjected to treatment with lime to soften it and cause it to swell. The period of treatment varies from a few hours to as much as sixty or ninety days, or even longer, according to circumstances. After suitable lime treatment the surplus lime is washed away and the absorbed portion is neutralized with hydrochloric or sulphuric acid. The former tends to give a clear product as calcium chloride is readily water soluble and can be removed, while the latter gives a more or less opaque product due to the presence of insoluble calcium sulphate. In one process sulphurous acid is used in the preliminary treatment instead of lime.

The prepared stock is next subjected to treatment with water in special kettles, usually steam heated. If open tanks are used the pressures must of necessity be atmospheric; if closed kettles are used the pressures may be varied to suit conditions. Usually several runs are made at different temperatures, or different pressures, or both, each run being kept separate. The amount of glue obtained from the stock in the final run is usually small. If the final run liquors are too dilute to be concentrated profitably they may be used on the first run of the next batch.

The liquors from the runs containing the jelly in solution are clarified by adding certain chemicals. Antiseptics may be added to prevent the growth of micro-organisms, and if it is desired to make a white glue, zinc oxide or some other white mineral pigment is added. The clarified liquors are evaporated to a certain point and then run into galvanized cooling pans where they solidify into a jelly. The jelly is cut into sheets by wire cutters manipulated by hand or power. The sheets are placed upon galvanized nets or linen sheets, stacked on trucks and placed in a dry room where they come in contact with a current of warm dry air. When thoroughly dried the material is broken or ground and packed for shipment into barrels, boxes, bags, or cartons.

The residues left in the tanks after the extraction of the glue by the hot water treatments are dried and sold as glue manure or tankage.

Accessory Materials

The principal accessory materials required by the industry, apart from the various vessels and appliances used in the factory, are as follows:

Calcium oxide for "liming;" *hydrochloric* or *sulphuric acid* for neutralizing; alum, phosphoric acid, *sulphurous acid, lime water,* albumen (blood or egg), and bone charcoal for clarifying; zinc oxide for whitening; formaldehyde or some other antiseptic to prevent the growth of micro-organisms; sulphur for bleaching with sulphur dioxide.

Uses of Glue and Gelatine

Hide glues are especially desirable for making wood joints. Paper boxes are best made with quick setting hide glues, but where coverings are added slower setting bone glues are used. Leather goods and belting require high grade glues or gelatine, and occasionally glycerine is added to prevent complete hardening. Bookbinders prefer good hide glues. Glues and gelatines are also used for sizing textiles, in the manufacture of felt hats, and for making certain plastics. Sand paper and other abrasive and polishing papers and cloths are made with glue. Vegetable glues are used for sizing textiles and for veneering wooden furniture.

Gelatine, which is merely a high grade sweet glue made from clean selected stock, is used in the manufacture of marshmallow confectionery because of its property of preventing crystallization of sugar. It will also prevent the curdling of casein. Gelatines are used for clarifying various liquids including spirituous liquors. They form important foodstuffs, are used in confectionery, form the basis of some leather finishing compounds, and are used in medicine, especially for coating pills or for making capsules and other containers. A very important application is in producing the emulsion used for the sensitized layer on photographic films and plates. It may also be used as an adhesive. When treated with formaldehyde gelatine is rendered insoluble in water.

The colloidal properties of glue are utilized in a number of factory processes. The most important of these, is in metallurgical operations for the recovery of such metals as copper, nickel, lead, zinc, and silver by electrolytic processes. It is also used as a colloid in electro-plating work.

Isinglass is used as a silk size, for making a cement for use on broken glass or pottery, and with pyroxylin to make a waterproofing compound for use in textile manufacture.

Canadian Situation

It has not been possible to ascertain the exact number of firms engaged in the manufacture of glues and gelatines in Canada. The Directory of Chemical Industries lists 18 manufacturers of adhesives and 20 manufacturers of glue stock. Very few of the makers of adhesives listed are producers of glues directly from raw materials, and some of the second group mentioned do not make glue. The Canadian Trade Index lists 16 glue makers, three makers of liquid and fish glues, one maker each of marine, millinery, and vegetable glue. One maker of gelatine is also listed.

Reliable statistical data with respect to the glue and gelatine industry and its requirements of raw materials are not available. The published records of the Department of Customs show the importation of considerable quantities of glues, gelatine, isinglass, glue stock, and fish offal. Quantities are not always given and gelatine and isinglass are combined.

CHAPTER XII

ADHESIVES AND CEMENTS

General

Cements may be defined as mixtures or compositions which are plastic under certain conditions, and which are hard and tenacious under other conditions. Those cementing compositions which exhibit sticky or tenacious characteristics to a marked degree at ordinary temperatures are sometimes termed adhesives. Both cements and adhesives are used for reuniting dismembered parts of broken articles, and also for uniting materials of the same kind or of different kinds. Cements are also used for filling joints, cracks, open spaces, or for forming smooth and impervious surfaces or coatings. Adhesives then may be regarded as a specialized group of products which form part of the larger cement group. Cements used for sealing joints or cracks in industrial apparatus are sometimes called lutes. These cements do not necessarily possess sufficient adhesive power to be classed as adhesives, but they must be both coherent and tenacious. There are some compositions which may serve as adhesives, as cements, or in both capacities; the term to be applied would be determined by the functions performed.

The term *cement* in its broadest application includes gums, glues, mucilages, papier-maché, mortars, and numerous mixtures of oils, varnishes, water, chemical products, and natural materials, which under certain conditions as to capacity for chemical reactions, or under suitable conditions of temperature, or of moisture, are capable of assuming sticky, tenacious, or stone-like characteristics. Hydraulic cements, limes, and mortars have already been discussed in another section. This section will be confined to cements used for other purposes, usually in small quantities, and including adhesives and lutes.

Cements proper will include cementing compositions used industrially for many purposes, such as coatings on containers, walls, or floors to protect them from acids or alkalies; leak-proofing casks, barrels, or other containers for liquids; crack and joint fillers; dental cements and fillings; cements for various mechanical uses, such as repairing leather or rubber goods, sticking glass to glass, metal to metal, metal to glass, glass or metal to leather or rubber, and similar operations; jewelers' cements; and others. On the basis of their composition cements may be classified as alcohol soluble, water soluble, oil cements, rubber cements, fusible cements, casein cement, celluloid cement, and others, each group having its own particular field of usefulness.

Adhesives include materials and compositions in which the property of adhesiveness is developed to a high degree. They are used primarily to cause two bodies to adhere together; they are also used in the composition of cements, the body of which is made of an inert material used as a filler. Common adhesives are dextrine (or British gum), starch and flour pastes of various kinds, glue, gelatine, solutions of soluble gums, such as arabic or tragacanth, and casein glues. Less common are adhesives made from isinglass, celluloid, collodion, gum mastic, gum sandarac, elemi, shellac, linseed and other oils, glutinous products derived from marine algae, albumen, sugar, and other products. The name mucilage is primarily applied to a number of sticky or gummy adhesives which are solutions of natural vegetable gums in water, such as gum arabic or gum tragacanth. Solutions of dextrine, glue, or other water soluble adhesive substance, to which other chemicals may or may not have been added, are also marketed as mucilages.

Lutes are compositions used for stopping joints between vessels and connecting tubes, pipes, or other vessels, to prevent the escape of gases or liquids during chemical and other industrial operations; they are also used to protect vessels and apparatus from the direct action of hot gases. In composition they resemble cements, but their industrial value is dependent upon their coherence as well as upon their tenacity. They consist of a menstruum in which solids are dissolved or suspended. They are usually made plastic with water or by heating or by the use of a solvent, depending upon the menstruum used. The solidifying or setting of a lute is dependent upon drying, hydration, or oxidation. Clay with water, or clay mixed with molasses or linseed oil is a common form of lute. Other lutes are made with hydraulic cement, plaster of Paris, lime, red lead, sulphur and sand, sodium silicate and sand, whiting, zinc oxide, and similar products. Glue and other adhesives mixed with sand, sawdust, papier-maché, or other inert materials might also be used as lutes.

Sealing wax and similar compositions were primarily developed to function both as adhesives and as temporarily plastic bodies upon which desired symbols would be retained after impression. They also function as cements and as lutes. The basis of nearly all good sealing wax is gum shellac. Other components of some waxes are pine rosin, colophony, beeswax, Venice turpentine, paraffin, tallow, and a number of inert products designed to give body to the product, or to colour it.

Grafting wax and similar compositions were primarily developed to function as lutes for special uses in agriculture. Their foundation is pitch, resin, or beeswax, to which tallow, lard, or some other oil or fat has been added, and occasionally a solvent, such as turpentine or denatured alcohol.

Closely allied products are modeling clays, plasticine, and similar products used for modeling or preparing moulds and casts.

A few cements, nearly all adhesives, and a few lutes are prepared in factories and marketed as such. A great many cements and lutes are made from materials purchased locally as required; most of the ingredients are products of the chemical industries or natural raw products. In previous sections reference has been made to the production of glue, gelatine, dextrine, starch, starch pastes, boiled linseed oil, varnishes, and other products that form the basis of cements and adhesives. The manufacturer of cements and adhesives is concerned with the blending of the various materials to make the compositions he desires, and not with the production of the primary products. Both operations may, of course, be carried out in the same works. The subjoined lists include the names of many products that enter into compositions used for cementing, but these compositions are so varied and numerous that the lists are not to be considered exhaustive.

Table 34.—Materials used in Cementing Compositions

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

Cements

MENSTRUA: *Albumen; casein; dextrine; gelatine; glue; glycerine;* isinglass; *lard; linseed oil (boiled); tallow;* thymol.

SOLVENTS: Acetones; alcohol (*denatured*); amyl acetate; *benzine; benzol;* carbon bisulphide; chloroform; ethers (acetic, nitric, sulphuric); *naphtha; turpentine; water.*

GUMS AND RESINS: Ammoniac; *beeswax;* Burgundy pitch; balata; camphor; *Canada balsam;* caoutchouc; copal; dammar; elemi; gutta percha; rubbers; mastic; pitch (*coal tar,* pine); rosin, sandarac; shellac; tar *(coal);* tolu; Venice turpentine; yellow wax.

CHEMICALS: Acids (*acetic, hydrochloric*); alum (soda); ammonium compounds (chloride, hydroxide); calcium compounds (acid chromate, *chloride, hydroxide,* nitrate); mercurous chloride; potassium compounds (bichromate, carbonate); sodium compounds (biborate, *chloride, hydroxide,* silicate); sulphur; zinc compounds (chloride, *sulphate*).

FILLERS: *Asbestos* (*ground*); barium sulphate; barytes (ground); brick dust; chalk (ground, levigated); clays (*ball, china,* pipe); *fluorspar (pulverized);* glass (pulverized); *graphite; gypsum (ground) iron (filings, borings); kaolin; kieselguhr; lead, red* and *white; litharge; magnesium oxide; manganese dioxide; ochres; plaster of Paris;* pumice (pulverized); *quartz* (*pulverized*); *quicklime; rouge; sand;* whiting; *wood ashes;* zinc oxide.

Adhesives

MENSTRUA: *Casein; dextrine; gelatine; glucose; glue; glycerine;* gums, (arabic, tragacanth); isinglass; *molasses; mucilage* (from carrageen moss, *flaxseed, kelp*); *pastes* (*flours*—rice, *rye, potato, wheat*); starches (arrowroot, *corn, potato*); sodium silicate; sugars (*brown, white*).

SOLVENTS: *Alcohol, water.*

ODORIZERS AND DISINFECTANTS: Acids (*carbolic,* salicylic); *formaldehyde;* gum camphor; oils (cloves, sassafras, *wintergreen);* thymol.

CHEMICALS: Acids (*acetic, nitric, sulphuric*); alum; aluminium sulphate; lead acetate; potassium carbonate; sodium silicate.

Lutes

Menstrua: *Albumen; casein; glue; linseed oil; molasses;* solutions containing a chemical, such as chromic acid, *cuprammonium sulphate,* magnesium oxychloride, *sodium hydroxide,* sodium silicate, or *sulphuric acid.*

Gums and Resins: Asphalt; gutta percha; *paraffin;* rosin; rubber; shellac.

Starch Products: Almond meal; *flours; linseed meal; starches.*

Fillers: *Aluminium* oxide; *cellulose (paper pulp, papier-maché)*; clays *(ball, china, kaolin); hydraulic cement;* glass (pulverized); *graphite; gypsum; iron oxide;* lead compounds *(carbonate, tetroxide)*; *lime; magnesium oxide; plaster of Paris; sand;* zinc oxide.

Wax Compositions

Menstrua: *Beeswax;* colophony; mastic; *paraffin; pitch;* resin; rosin (pine); shellac (bleached, orange, yellow); *tallow; turpentine; vaseline;* Venice turpentine; yellow wax.

Fillers: *Chalk; calcium carbonate (precipitated); gypsum; lead oxides; magnesium oxide; mica (pulverized); ochres; plaster of Paris;* Venetian red.

Colours: Berlin blue; blacks (carbon, *lamp*); cinnabar; *chrome yellow;* numerous other *pigments.*

Statistical Data

Cements, including adhesives and lutes, are minor products or by-products of several important industrial groups of manufactures. The Rubber industry, the Paint and Varnish industry, Meat Packing industry, Leather industry, Starch industry, and several others may each contribute certain varieties of cementing or adhesive materials, and there are also a number of independent operators producing primary products who obtain their raw materials from various sources. It would therefore require careful detailed investigation before reliable statistical data concerning the various raw materials which are consumed by this industry could be obtained. It is not a matter of surprise to be unable to obtain any statistical data relating to the requirements of this small group of manufactures. The only published information is the statement by the Dominion Bureau of Statistics that the materials used in the manufacture of adhesives cost $1,004,325 in 1919, and $1,070,493 in 1920; they were valued at $1,917,046 and $2,202,059 in the respective years, and the values added by processes of manufacturing are stated to be $912,721 in 1919, and $1,131,566 in 1920. The following table has also been issued showing the various products whose total valuations are given above. It will be noted that more than one-quarter of the total production is listed under the unfortunate title "All other products and by-products" without any intimation as to the products which comprise this group.

Table 35.—Products, Miscellaneous Chemical Industries Group, 1919 and 1920

Kind	Unit of measure	1919		1920	
		Quantity	Selling value	Quantity	Selling value
			$		$
Adhesives—					
Glue	lbs.	3,650,094	872,470	3,794,098	1,048,436
Liquid fish glue	gals.	19,857	23,517	20,041	25,320
Gum, dextrine, mucilage, liquid glue and flour paste	....	....	196,981	....	183,930
Size, including rosin paper sizing	....	....	187,306	....	175,480
Rubber and other cements and sealing wax	....	....	99,109	....	91,700
All other products and by-products	....	....	537,663	....	677,193
Total	....	....	1,917,046	....	2,202,059

The imports and exports of products that belong to this group are recorded in part in the annual reports of the Department of Customs. Some data are given in the schedule printed in another section of this report. The following tables indicate the average valuations assigned to the various products mentioned for the three fiscal years prior to the war, and for the three corresponding years following the armistice. Quantities are given wherever available. Many of these importations are required by industries other than that under discussion in this section.

Table 36.—Imports and Exports of Adhesive Products

Imports

Product	Quantity Average 1912-13-14	Average value 1912-13-14	Quantity Average 1920-21-22	Average value 1920-21-22
	lbs.	$	lbs.	$
Casein	(Not given)	12,491	831,987	102,628
Dextrine (dry)	2,277,529	79,026	2,395,388	163,848
British gum, dry sizing cream and enamel sizing	1,587,167	58,535	980,419	65,415
Mucilage and adhesive paste	(Not given)	33,949	(Not given)	70,024
Gelatine and isinglass	608,382	144,392	945,225	626,965
Glue, powdered or sheet	3,101,987	241,623	2,151,108	352,781
Glue, liquid	(Not given)	63,552	(Not given)	136,809

Exports

Product	Quantity Average 1912-13-14	Average value 1912-13-14	Quantity Average 1920-21-22	Average value 1920-21-22
Casein	547,183	21,572	23,615 (1922, only)	1,413
Glue	(Not given)	(Not given)	101,000	9,792
Glue stock	(Not given)	21,537	4,000,700 (average 1921-22)	122,079

Canadian Situation

As stated in previous paragraphs, the products included within this group are often made by firms whose principal products cause them to be classified in other industrial groups. Complete lists of products of this group made in Canada are not available. In many cases available lists refer to producers of a primary product, and not the secondary producer who markets a finished product ready for retailing to the ultimate consumer. The Canadian Trade Index lists 28 firms making mucilages, glues, dextrine, and other adhesives, and seven producing casein.

The report on Chemicals and Allied Products, 1919 and 1920, issued by the Dominion Bureau of Statistics, lists 17 producers in 1920, distributed one each in Nova Scotia and New Brunswick, seven in Quebec, and eight in Ontario. The products made by these merchants are not clearly defined, but from the table of products given on another page it is assumed that they include glue, liquid fish glue, gum, dextrine, mucilage, liquid glue and flour paste, size, including rosin paper sizing, rubber and other cements and sealing wax, as well as other products not mentioned in detail. There are probably a number of local producers of adhesives, particularly flour pastes and mucilages, in many of the large Canadian communities which cannot be reached by ordinary methods of inquiry.

CHAPTER XIII

POLISHES AND DRESSINGS

Polishes are preparations used for improving and preserving the surface of numerous objects, made of a great variety of materials. Their number and variety are legion, and it is only advisable to refer to the characteristics of certain classes of preparations and to mention a few of the many components. These classes of polishes may be conveniently grouped as leather dressings, metal polishes, stove polishes, and wood polishes. The fact must be recognized that some kinds of polishes fall within two or more of these groups.

Leather Dressings

Dressings used on leather goods are intended to render the material soft and pliant, to preserve the surface, and to improve its appearance. Reference was made in the section on Tanning to the materials used in making patent leathers. The materials included here are those used for making the various polishing creams and dressings used especially on shoes, harness, bags, and similar products. Ordinary commercial dressings, of which there are numerous brands on the market, usually contain a colouring material, some kind of unguent or solvent, occasionally a chemical which has the effect of preserving the leather, or of altering the surface so that it becomes more resistant to wear and weather, and a gum or wax which fills the pores and protects the surface.

Table 37.—Materials used in the Manufacture of Leather Dressings

COLOUR MATERIALS: Annatto; asphalt lac; bismarck brown; blacks (aniline, bone, carbon, ivory, *lamp,* vine); indigo; logwood; nankin yellow; Prussian blue; shellac (white, yellow, orange, ruby). Gall nuts or gallic acid and iron sulphate yield an intense black, while potassium ferrocyanide and iron sulphate produce a blue.

UNGUENTS OR SOLVENTS: Alcohol (*denatured*); blubber; *formalin; glycerine; lard* (*fresh, rancid*); nitro-benzol; oils (cottonseed, fish, *linseed,* olive, *neat's foot,* rosin, sperm); *stearine; tallow* (*beef, mutton*); *turpentine;* wool fat.

CHEMICALS: Acids (*acetic,* chromic, gallic, *nitric, oleic,* oxalic, *sulphuric,* tannic); alum (soda); *ammonia;* ammonium chloride; *iron sulphate;* lead compounds (acetate, *oxides*); magnesium compounds (carbonate, oxide); potassium compounds (binoxalate, bitartrate, carbonate, ferrocyanide); sodium compounds (biborate, *carbonate, hydroxide*).

GUMS AND WAXES: Arabic; *beeswax;* camphor; carnauba wax; ceresin; colophony; copal; dragon's blood; *paraffin;* shellac; spermaceti; tragacanth; Venice turpentine.

MISCELLANEOUS: *Glue;* isinglass; *molasses; potatoes; starch;* sugars (*grape, cane*); *syrups.*

Metal Polishes

Metal surfaces are usually smoothed by grinding operations. These processes leave the surface covered with minute grooves or scratches. The surface left by grinding is further improved by polishing. The principal underlying use of polishing powders is that successively finer cuts or scratches are produced upon the surface under treatment by using successively finer grained abrasive powders until a stage is reached where the scratches are so minute that they are invisible to the eye. These final surfaces are produced by the use of fine-textured abrasives, such as have already been mentioned in the section on Abrasives. Finished metal surfaces are maintained by the use of lacquers or varnishes, or they are renewed by the use of polishing powders, or prepared polishes.

An unprotected polished metal surface slowly deteriorates on exposure to the air. A tarnished surface is due to the action of oxygen, sulphur dioxide, or other gases in the air. This tarnish may be removed mechanically by the use of metal polishes containing abrasives, chemically by the use of metal polishes containing chemicals that will dissolve the metallic oxide or sulphide that constitutes surface tarnish, electrolytically by using a process that restores the metal to its original condition, usually with a matte surface which must afterwards be repolished, or by a combination of these several methods.

Obviously the kind of metal to be polished will in many cases determine the kind of polish to be used. Polishes suitable for iron, nickel, or cobalt surfaces are not necessarily suitable for copper or brass; polishes suitable for copper or brass are not necessarily suitable for silverware. Many polishes can be used in common on all metals. No attempt is made to classify the materials used in the manufacture of polishes upon the basis of the metal for which they are best suited.

Mention is made in the section on Abrasives of the materials used in the manufacture of polishing powders, papers, and cloths. This need not be repeated.

Table 38.—Principal Chemicals used in Making Polishes

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

CHEMICALS: Acids (*acetic, hydrochloric, nitric*, oxalic, *sulphuric*, tartaric); alums (potash, soda); *ammonia;* ammonium compounds (carbonate, chloride); calcium compounds (*chloride, oxide*); *chlorine* in solution *(Javelle water); copper sulphate;* dyes (red, yellow); potassium compounds (bichromate, bitartrate, carbonate, cyanide, hydroxide); silver nitrate; sodium compounds (biborate, *carbonate, chloride, hydroxide,* hyposulphite, nitrate, *sulphate)*.

UNGUENTS USED FOR MIXING PASTES: Cottonseed oil, *glycerine; lard oil; linseed oils (raw, boiled); oleic acid;* palm oil, *petroleum oil,* and *vaseline.*

SOLVENTS: Alcohol (*denatured*); *acetone; coal oil; nitro-benzol; turpentine.*

MISCELLANEOUS PRODUCTS: *Soaps* of several kinds, *sawdust, clays,* gum arabic, and gum camphor.

The electrolytic method of cleansing tarnished surfaces involves the use of an aluminium or zinc plate and the solution of a salt which acts as an electrolyte. A solution of hydroxide or carbonate of sodium or of potassium can be used for this purpose; ammonium chloride is also used.

Stove Polishes

This class of polishes is made chiefly for dressing cast iron and sheet steel surfaces. Products of this class are also occasionally used for dressing wood, leather, or other surfaces. Nearly all contain *natural graphite* (black lead, plumbago); *artificial graphite* is also used. The black colour is intensified by the use of carbon black; *bone black* and *lampblack* are also used occasionally. Pastes are made by the use of sodium silicate, *sugar, molasses, linseed oil,* or *vaseline.* Some blackings contain *iron sulphate* in small amount; if tannic acid in proper amount is added an intense black is produced. A very little *sulphuric* or *hydrochloric* acid is sometimes used in pastes; some pastes contain ceresin, carnauba wax, or paraffin. Black varnishes are usually made with asphaltum and *turpentine.*

Wood Polishes

The preparation and finishing of wood surfaces, particularly as applied to the finer grades of furniture, interior decorating, and artistic work, involves a number of successive operations designed to produce the surface finish desired. The preliminary preparation of wood surfaces, following the application of cutting tools and scrapers, usually involves the use of abrasive papers and cloths of different degrees of fineness, the coarser kinds being used for preliminary smoothening, and the finer for finishing. A final polish may be given by using a piece of wood or metal, or even a smooth stone. Polishing powders of various kinds, with oil or other medium, are used for finishing the finer surfaces. It is customary, in many cases, to apply a wax, varnish, or oil dressing after the final abrasive. The use of fillers, stains, varnishes, lacquers, polishes, and paints has already been mentioned in another section. Very fine textured polishing powders with linseed or olive oil are also used for finishing varnished surfaces where a matte finish is desired.

Statistical Data

There are no statistical data available showing the quantities of different products required by the various manufacturers of polishes and dressings in Canada. A brief reference is made to this group of products in the report on Chemicals and Allied Products, issued by the Dominion Bureau of Statistics for the years 1919-20. The number of manufacturers is placed at 33 in 1919, and 32 in 1920. The value of the raw materials used is placed at $908,584 in 1919, and $1,130,377 in 1920.

The selling value of the products is given as $1,769,552 and $2,005,970 for the respective years; the increase in value due to the manufacturing processes is given as $860,968 and $875,593 respectively.

Some information will also be found in the trade statistics based upon the returns from the Department of Customs. The item "Blacking, shoe, and shoemaker's ink, shoe, harness, and leather dressing, n.o.p." shows imports valued at $133,047 in 1914, which had increased to an average value of $257,009 in the three fiscal years following the armistice. In 1914, "Polish or composition, knife or other, n.o.p." is credited with $229,517 importations, which had risen to an average valuation of $340,434 in the three years following the armistice.

Canadian Situation

A partial classification of the producers of the various kinds of polishes is given in the Canadian Trade Index. This list contains the addresses of 38 firms manufacturing leather dressings; 31 making metal polishes; 14 making stove polishes; and 22 producing wood polishes. The Dominion Bureau of Statistics gives an unclassified list of 30 producers of polishes in the report on Chemicals and Allied Products, 1919 and 1920. It is very doubtful if the number of producers included in these lists includes more than the larger manufacturers. Polishes of various kinds are made by numerous small vendors throughout Canada for local marketing, and it is doubtful if these producers are reached by ordinary trade inquiries.

CHAPTER XIV

FRICTION MATCHES

Early matches consisted of a woven or twisted fibre cord that had been dipped in a solution of sodium nitrate or other chemical designed to retard combustion and then dried. When ignited at one end such a product smouldered or burned slowly. A match of this type was used for discharging firearms and for fuses. Later the same name was applied to wooden splints tipped with a composition, usually containing sulphur, which would ignite easily. Modern usage applies the name chiefly to splints of wood or other materials having one end tipped with a composition which ignites under friction either on any slightly rough surface or upon a specially prepared surface. This type of match is sometimes called a friction match.

Raw Materials

Ordinary friction matches are prepared by dipping wood splints, previously prepared, in melted paraffin or stearine, and then into an igniting composition, followed by drying. All the manufacturing operations in modern factories, including the making of the splints, the various dipping and drying operations, and the final packing in boxes for distribution to the consumer, are performed by automatic machinery, only a very limited amount of hand work being required. Formerly, yellow phosphorus was used in making friction matches. The use of this material has now been forbidden by law in most countries of the world because of the dangerously poisonous nature of this variety of phosphorus. Red (amorphous) phosphorus or phosphorus sesquisulphide are now used as substitutes, both being relatively innocuous. Ordinary matches carry the igniting composition in the head. Safety matches are made without phosphorus in the heads. The phosphorus compound, together with a fine abrasive, is placed on a specially prepared surface, usually the side of the container, upon which the matches must be scratched before they will ignite. Matches with large oval tips, intended to develop a glowing head, and to remain ignited under unusual and unfavourable conditions, contain special compositions in the heads. They are called fusees or vesuvians. Where fabric wicks dipped in paraffin or stearine are tipped with match composition the product is called vestas. Other special kinds of matches are also produced and marketed. Hand dipped matches are sometimes made for special markets.

The chief component of the ignition compound used on most matches is phosphorus, or phosphorus sulphide. This is usually combined with sulphur, which ignites easily, and with some compounds which yield oxygen readily when heated slightly. Potassium or sodium chlorate, potassium nitrate, lead nitrate, lead oxide, manganese peroxide, or potassium bichromate are commonly used in this way. Sometimes a little benzoic acid is incorporated in the mixture to leave a pleasant odour in the air after the ignition of the match. The composition is usually made coherent by the use of glue or gum. The following lists include the chemicals commonly used in the match industry for making all kinds of matches, without regard to the special materials used at present in Canadian match factories. Different manufacturers naturally use various and different formulae in compounding their friction compositions, and most factories regard these compositions as trade secrets.

Table 39.—Materials used for Friction Matches

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

CHEMICALS: Acid, phosphoric; ammonium compounds (phosphate, sulphate); antimony compounds (oxysulphide, *sulphide,* trisulphide); lead compounds (cyanide, *peroxide,* sulpho-cyanide, thiosulphate, *tetroxide*); *phosphorus* (*red*); *phosphorus sulphide;* potassium compounds (bichromate, chlorate ferrocyanide, nitrate); sodium compounds (bichromate, chlorate, nitrate).

MINERALS: *Clays; iron oxide; iron pyrites; manganese dioxide;* sulphur.

COLOURS: Aniline colours; *lampblack; red lead; red ochres;* smalt; ultramarine; vermilion; whiting.

ADHESIVES: *Dextrine; glue;* gum arabic or tragacanth; sodium silicate.

ABRASIVES: Pulverized glass or pumice; *sand* (*fine*).

SPLINTS: *Basswood;* birch; cottonwood; *fir; maple; poplar; white pine;* wicks (cotton, linen, or other textile fibre, coated with paraffin or stearine).

MISCELLANEOUS: *Alcohol; benzine;* benzoic acid; *charcoal; paraffin;* shellac; *stearine; sugar.*

ACCESSORY MATERIALS: Large quantities of *paper mill products* are used by this industry in the preparation of packages and shipping cases. *Printing inks* in several colours are also used for preparing labels.

Statistical Data

The value of the production of Canadian match factories is given by the Dominion Bureau of Statistics for the years 1918, $1,545,680; 1919, $2,207,221; and 1920, $2,698,125. It is interesting to note that the excise tax on matches yielded $2,665,198 in 1919 and $2,757,754 in 1920. The Canadian consumer therefore paid both sums in each year to obtain the matches he required. The exports in 1919 were valued at $92,293, and at $107,792 in 1920; the imports were valued at $8,801, and $37,770 in the respective years.

The returns from the Department of Customs show an average annual importation of $73,647 worth of matches in the three fiscal years prior to the war; this has diminished to an average of $51,040 in the three fiscal years since the armistice. The exports are not recorded for the year 1912; they amounted to $1,113 in 1913 and $338 in 1914. In the three years since the armistice they have averaged $95,037 annually. Our exports also include match splints, valued at $9,876 in 1912, and $1,329 in 1914, increasing to $215,434 in 1921, and $745,064 in 1922. Match blocks were exported to the average value of $4,674 for each of the three years prior to the war. No exports of these blocks are recorded in 1920 and in 1921, but in 1922 the valuation had risen to $120,443.

There are no statistical returns available showing either the values or the quantities of the various individual chemicals, mineral products, and other raw materials required by this industry. Phosphorus is made in Canada, but nearly all the other ingredients required in manufacturing are imported.

Canadian Situation

There were four plants in operation in the years 1919 and 1920, two being located in Quebec, and two in Ontario. At the present time seven firms are engaged in the production of matches, one of the plants being described as experimental.

CHAPTER XV

MISCELLANEOUS INDUSTRIES

ABRASIVES

Abrasive materials are used for grinding metals, and for polishing metals, woods, bone, ivory, artificial solids, and other materials.

Natural Abrasives

The more common abrasives used for grinding and for preparing metal and wood polishes are the natural minerals, *corundum,* emery, *garnet, sandstone, quartz* and flint; artificial abrasives of which aluminium oxide is the most important; crushed glass, and fine textured products, such as bath brick, *bone char, chalks, charcoals,* crocus, cuttle bone, fuller's earth, *infusorial earth, iron oxide, iron peroxide, iron subcarbonate, lead carbonate, lead oxides,* magnesium carbonate, magnesium oxide, *ochres, Paris white, pipe clay,* pumice, putty powder, rotten stone, *rouge, silica,* tripoli, *volcanic ash,* whiting. Gems are polished with artificial abrasives or with fragments of other gem materials, such as tourmaline, topaz, and diamond bort (carbonade). Stones and wheels (grindstones) are cut from suitable natural stones, sandstone, quartzite, and other bedded rocks. Other products are subjected to preparatory treatment and are then made up into the desired forms.

Abrasives (except stones used in a natural state) are all prepared for use by crushing where necessary, care being taken to produce angular fragments. The crushed product is sized by screening into powders of different degrees of coarseness. The finer products are floated, usually by using water, less frequently in an air current or in oil. The prepared powders may be used directly in powdered form, may be made up into pastes with various bases, or the coarser varieties may be used for making abrasive wheels, stones and papers.

Artificial Products

Artificial wheels, and cutting and polishing stones are made by the use of certain materials for binders, ball clay, *kaolin, lime,* sodium silicate, shellac (fused), *rubber* (vulcanized), and less frequently other binders are used for this purpose. The various objects are shaped in moulds, and usually subjected to heavy pressure, followed by baking or vitrifying in special furnaces.

Abrasive cloths and papers are made by coating suitable woven fabrics, or paper stock with an adhesive, and then covering the fresh surface with a sized pulverized abrasive, followed by drying. The adhesive commonly used is fish glue; other glues and some gums are used occasionally. Abrasive papers (such as sand paper) and abrasive cloths (such as emery cloth) are usually made from crushed glass, garnet, corundum, carborun-

77921—11

dum, aluminium oxide, or quartz. Special papers are made from powdered pumice and cuttle bone, chiefly for dental work.

Polishing pastes and liquids are mentioned in describing wood and metal polishes.

Uses of Abrasive Products

Wheels and stones are used chiefly in the grinding and polishing of metal products. They are also used for cutting and grinding glass when making plate glass, spectacles, lenses, cut glass articles, and similar products. Polishing powders are used for finishing these articles. Buttons and similar products are made from shell, bone, vegetable ivory, natural ivory, rare woods, cellite, celluloid, and other artificial compounds by the use of cutting and polishing wheels, the final finish often being produced by using polishing powders on buffing wheels. Certain kinds of abrasive wheels are used to make buffed leathers. The finer powders are used for polishing metals, glass, wood, and other products.

Canadian Situation

There are no statistical data available with respect to the manufacture or consumption of abrasive wheels, stones, or powders in Canada. Some information with respect to the quarrying of sandstones for making wheels and stones, and with respect to the manufacture of artificial abrasives is published in the annual reports on mineral production, and some generalized data are given in the trade returns of the Department of Customs.

There are nine firms in Canada engaged in the manufacture of wheels and stones from abrasives, apart from those engaged in the quarrying of sandstones and the manufacture of grindstones. There are also two firms producing abrasive papers. There are no data available showing the number of firms preparing abrasive powders for polishing or other uses.

SWEEPING COMPOUNDS

A small quantity of certain chemical products is absorbed annually in the manufacture of sweeping compounds. These are designed primarily to collect dust and to prevent its rising in the air when distributed by a broom. In some cases they also act as antiseptics or insecticides.

Sweeping compounds for domestic use are valuable chiefly as dust collectors. They consist usually of a body material, such as sawdust, bran, silica sand, cement, or even tea leaves, to which some binding material, such as rosin oil, tar oil, or raw linseed oil, has been added. Coarse sodium chloride is sometimes added also. They are usually treated with a small quantity of cedar oil, eucalyptus oil, patchouli oil, or myrbane oil to give them a pleasant odour.

Sweeping compounds for factory use, for disinfecting public halls, office buildings, street cars or railway cars are usually applied in fluid form, although products similar to those primarily prepared for domestic use may also be employed. These fluid sweeping compounds may contain kerosene, paraffin oil, linseed oil, crude cresylic acid, tar oils, neat's foot oil, cottonseed oil, sodium carbonate solution, as well as an odoriferous oil, such as eucalyptus or patchouli.

The Dominion Bureau of Statistics reports six firms engaged in the production of sweeping compounds in 1920. The selling value of the products is given as $83,171 in 1919 and $124,913 in 1920. The value of the raw materials used in the industry is stated to have been $27,266 in 1919 and $54,729 in 1920.

INDEX