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

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PREFACE

Substantial new industries are not developed by chance. Their successful foundation almost invariably demands close and careful study of existing related industries, market requirements, sources of necessary raw materials, transportation facilities, and other interrelated controlling factors. This report has been planned and prepared to aid in the development of new industries in Canada by presenting in concise form general statements showing existing conditions in the fields of metallurgical or chemical manufacturing. The Canadian situation in a number of other industries or groups of industries which utilize mineral or chemical products has also been reviewed. The field that had to be covered is very broad and the various discussions have necessarily been limited to essential facts, so far as these facts could be ascertained with the facilities that were available while the report was in preparation.

The information included in this report represents only a small portion of the results of the investigations on which it is based. The preparatory work involved numerous studies concerning the raw materials of industry, the sources of supply, processes of preparation, methods of utilization, and both technical and commercial requirements.

The review of Canadian industries presented in this report was first planned early in 1916, but special war work prevented the initiation of necessary field investigations until 1917. These were continued during parts of 1918, 1919, and 1920. Almost all of the information contained in this report has been available to those entitled to it ever since it was obtained, provided they applied for it. It did not appear desirable to publish any results of the investigation in report form until after the close of the war. Pressure of other duties and the preparation of certain special reports have delayed the completion of this report until the present.

The investigations upon which the report is based were primarily undertaken to supply information for war purposes. It was also realized that when peace came, it would be very desirable to have accurate information available with respect to the present development of the Metallurgical and Chemical arts in Canada. The initiation of new lines of endeavour and the expansion of old would assuredly depend upon a knowledge of what had been already accomplished.

The mineral industry is our most important basic industry through which raw materials are supplied not only to the two allied industries here under discussion, but also to all other industries. It is doubtful if any other industry, even agriculture, offers so great opportunities for immediate expansion and development of our commerce through the initiation of new enterprises based upon its raw materials. This is particularly true where new industries are designed to produce products which will displace foreign products now imported.

Metallurgical industries are based wholly upon the mineral industry. Those manufacturing industries which fabricate metallic products are therefore all dependent upon mineral products. So also are those which require appliances made with metals.

Chemical industries draw at least seventy-five per cent of their raw materials from mineral resources. Probably less than one-quarter of our chemical manufacturing industries obtain their principal raw materials from the other basic sources of supply. Even in these industries it will be found that certain materials, required in minor quantities but none the less essential, are either minerals or chemical products derived from minerals. Because of this very intimate dependence of practically all chemical industry upon the mineral industry it has been considered desirable to include in this report references to a number of chemical industries whose principal raw materials are derived from basic sources other than natural minerals.

Many other industries, not ordinarily classed either as metallurgical or chemical, not infrequently employ chemical processes and invariably require as raw materials some products of either of these groups.

The various industries operating in Canada have been grouped, for purposes of discussion, according to basic relationships, as explained more fully in the introductory chapter. The extent of the development of each industry or industrial group is briefly stated. Then follow statements of the products made in Canada by that industry, of the raw materials required, and of the sources of these raw materials whether domestic or foreign. Markets, both domestic and foreign, are discussed whenever possible, and frequent reference is made to industrial statistics when such are available.

The several reviews were correct in all essential details at the time they were prepared. In a few cases some changes have taken place in the interval which has elapsed between the date of preparation and the date of publication. Where possible such changes have been noted and it is thought that no important factors have been overlooked. The report chiefly presents conditions as found between the years 1919 and 1922.

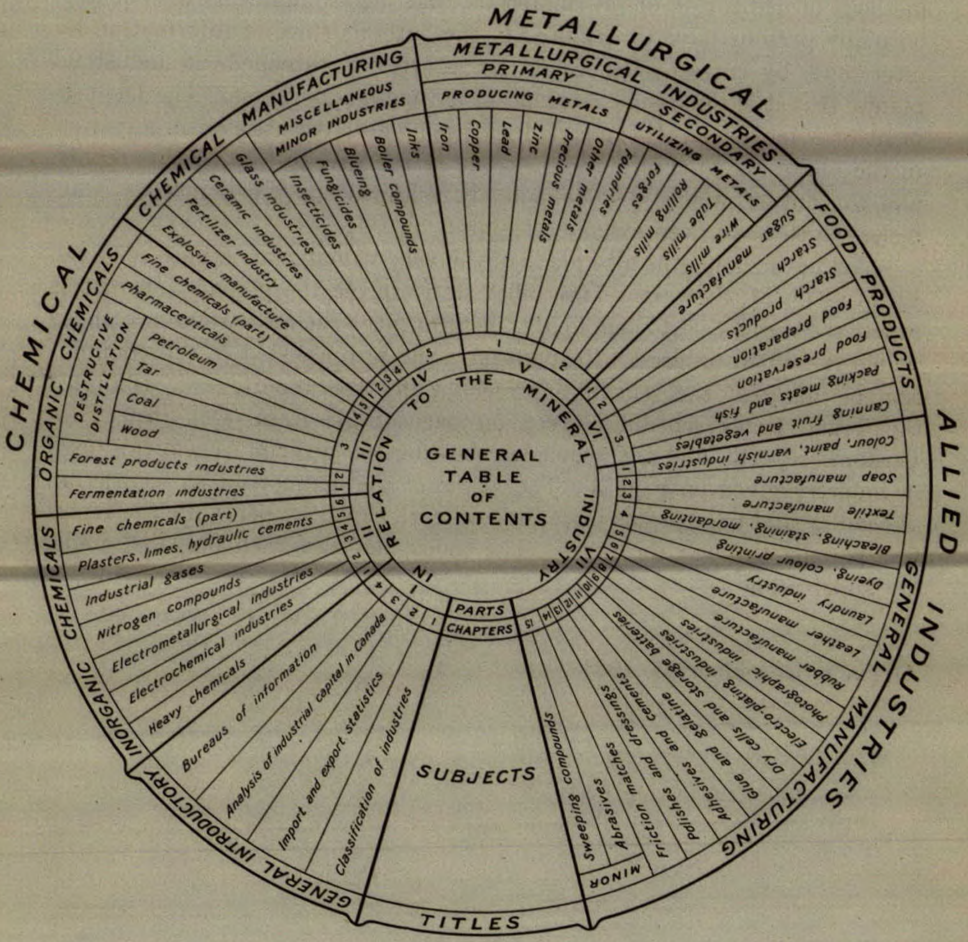
This report deals primarily with facts which are recorded impersonally. The ways and means necessary to promote industrial expansion or development necessarily involve the personal equations of the promoters and others. The opinions here introduced represent the author's personal views and are based upon carefully considered data.

The author is indebted to very many technical men throughout Canada, and at many points in the United States, for numerous courtesies extended to him personally. More than four hundred industrial establishments using metallurgical and chemical processes or utilizing raw materials of mineral origin have been visited to study organization, methods of utilization of raw materials, and the requirements of industry. So many persons have contributed to the author's store of information by interviews, by correspondence, or by courtesies extended at industrial plants, that it is impossible to mention individuals by name. The Department of Mines is greatly indebted to those who have assisted in any way in the obtaining of information for use in the preparation of this report, and the author wishes also to publicly acknowledge the numerous courtesies which have been extended to him.

Acknowledgment is also made of the very valuable assistance rendered by Miss D. M. Stewart, of my office staff, during the preparation of this report. Miss Stewart compiled a metallurgical-chemical reference index which is still in progress of expansion. She also assisted in the compilation of many of the schedules presented in this report, and compiled the Trade Index schedules given on pages 8-27 from Department of Customs reports, and the schedules showing the principal chemicals used in industry given on page 3. The whole of the manuscript as well as all the galley and page proofs have been critically read by her while the report was passing through the press. The index has also been prepared under her supervision.

ALFRED W. G. WILSON.

OTTAWA, December 15, 1923.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PART I

GENERAL INTRODUCTORY

CHAPTER I

CLASSIFICATION OF INDUSTRIES

The first problem that presents itself in preparing a report of this kind is the evolving of a logical classification of industry. The Mineral industry as a source of raw materials, for utilization in other industries, has been adopted as the primary and guiding concept. The term Mining industry is sometimes used synonymously with Mineral industry, but common usage tends to limit the application of this term to the winning of the ores of metals and to the production of some of the commoner non-metallic minerals. The non-metallic mineral industry also embraces several sub-titles such as Quarrying, Sand and Gravel industry, Building Stone industry, and similar designations.

Raw mineral products are passed to Manufacturing industry for preparation or fabrication for use in the arts. A careful analysis will show that it is impossible to draw a hard-and-fast line between Mining on the one hand and Manufacturing on the other. Using the latter term in its most literal sense, manufacturing begins as soon as waste rock is separated from valuable ores, an operation that often takes place underground. On the other hand ore as such is valueless in the arts. The usefulness of its valuable content begins only after the metal or other desired constituent has been isolated from the useless material. From this point the isolated material is ready for fabrication into useful articles produced by industry. It therefore seems logical to limit the term Manufacturing industry to those industries which are concerned chiefly with the fabrication of final finished products, whether chemical elements such as metals, chemical compounds of the elements, or the more complex artificial products of industry and commerce.

Intermediate between the consuming industries on the one hand and the producing industries on the other are those groups concerned with the processes of preparation. In a few isolated instances valuable metals or mineral products in a form suitable for use in manufacturing are recovered direct through the application of processes dependent upon certain physical properties. The recovery of nugget gold and platinum are examples. Even in these cases it is usually necessary to subject the product to a final chemical process for refining before the material is suitable for use in the arts. In the great majority of cases the natural mineral products have to be subjected to chemical processes for the purpose of securing the desired products, giving rise to the group name Chemical industries.

Chemical industry in its broadest sense embraces all industries employing chemical processes for the production of materials useful in the arts. As applied to products of the mineral industry it is customary to segregate those industries concerned with the production of metals and their alloys from the general Chemical group under the designation Metallurgical industry. This usage has been followed here, and the term Chemical industry is used in the more limited sense to apply to those industries using chemical processes to prepare chemical compounds of the elements for use in the arts.

When consideration is given to the source of energy or to the conditions under which chemical reactions are promoted certain sub-group designations, indicative of the processes employed, may be used to name industrial groups. Thus the prefixes thermo, hydro, or electro, may be used to designate minor groups of metallurgical or chemical industries. Where the source of energy is electric power certain groups of industries employing chemical and metallurgical processes may be associated under the name of Electrochemical industries. These are sometimes subdivided into the Electrochemical group proper, and the Electrometallurgical group. These sub-groups are considered together in this report because it is unnecessary to introduce detailed differentiations or discussions.

A study of the utilization of raw material in industry shows that all substances between source and final disposal pass successively by stages through one or more processes before the desired final product is secured. A very few raw materials are utilized in their natural state, excepting foods. In some instances natural raw products pass through a single stage of manufacturing to a finished product ready for utilization in another industry. These might be designated primary manufactural products. Such materials as sulphuric acid or caustic soda might be so designated. Again raw materials and primary manufactural products are assembled

PRINCIPAL CHEMICALS USED IN INDUSTRY

	ACIDS					
	HYDROCHLORIC	HYDROFLUORIC	NITRIC	PHOSPHORIC	SULPHURIC	SULPHUROUS
BATTERIES			o		o	
CERAMICS	o	o			o	
COAL DISTILLATION					o	
DYEING, ETC.	o		o		o	o
ELECTRO-PLATING	o	o	o		o	
EXPLOSIVES	o		o		o	
FERMENTATION		o		o	o	o
FERTILIZERS				o	o	
FOOD PREPARATION						o
GLASS		o				
GLUES	o			o	o	o
INSECTICIDES, ETC.						
LAUNDERING						
MEAT PACKING						
PAINT AND VARNISH	o		o		o	
PETROLEUM REFINING	o				o	
PHOTOGRAPHY	o		o		o	
PULP AND PAPER					o	o
RUBBER						
SOAP					o	
STARCH	o	o	o		o	o
SUGAR				o		
TANNING	o				o	o
TEXTILES	o		o	o	o	o
WOOD DISTILLATION	o				o	

	INORGANIC CHEMICALS																										
	ALUM (POTASH)	ALUM (SODA)	ALUMINIUM (POWDER)	ALUMINIUM HYDROXIDE	ALUMINIUM SULPHATE	AMMONIA	AMMONIUM CHLORIDE	AMMONIUM NITRATE	AMMONIUM SULPHATE	ARSENIOUS OXIDE	BARIUM CHLORIDE	CALCIUM ACETATE	CALCIUM CARBONATE	CALCIUM CHLORIDE	CALCIUM HYDROXIDE	CALCIUM HYPOCHLORITE	CALCIUM OXIDE	CALCIUM PHOSPHATE ACID	CARBON TETRACHLORIDE	COPPER SULPHATE	FERROUS SULPHATE	HYDROGEN PEROXIDE	LEAD ACETATE	LEAD ARSENATE	LEAD CARBONATE	LEAD CHROMATE	LEAD NITRATE
BATTERIES							o		o											o							
CERAMICS							o						o												o		
COAL DISTILLATION															o		o										
DYEING, ETC.	o	o		o	o	o	o			o		o		o	o	o	o			o	o	o	o			o	o
ELECTRO-PLATING	o	o		o		o	o		o	o							o			o	o		o		o		
EXPLOSIVES	o	o	o		o	o	o	o	o				o														
FERMENTATION						o							o	o	o												
FERTILIZERS									o									o									
FOOD PREPARATION	o	o											o				o	o									
GLASS										o			o		o		o										
GLUES		o													o		o										
INSECTICIDES, ETC.										o	o				o		o			o				o			
LAUNDERING	o	o											o			o						o					
MEAT PACKING	o	o																									
PAINT AND VARNISH	o	o		o	o	o	o			o			o	o	o	o	o		o	o	o		o		o	o	o
PETROLEUM REFINING															o		o										
PHOTOGRAPHY	o	o				o															o						o
PULP AND PAPER	o	o			o								o			o	o									o	
RUBBER	o	o	o	o						o			o		o		o		o				o		o		
SOAP						o	o		o						o		o		o		o						
STARCH																											
SUGAR													o		o			o									
TANNING	o	o			o	o	o		o	o	o		o	o	o		o			o	o						
TEXTILES	o	o		o	o	o	o		o			o		o	o	o				o	o	o	o				
WOOD DISTILLATION														o	o		o										

	INORGANIC CHEMICALS																									
	LEAD OXIDES	MAGNESIUM SULPHATE	POTASSIUM BICHROMATE	POTASSIUM BITARTRATE	POTASSIUM CARBONATE	POTASSIUM CHLORATE	POTASSIUM CHLORIDE	POTASSIUM HYDROXIDE	POTASSIUM NITRATE	SILVER NITRATE	SODIUM ACETATE	SODIUM BICARBONATE	SODIUM BISULPHATE	SODIUM BISULPHITE	SODIUM CARBONATE	SODIUM CHLORATE	SODIUM CHLORIDE	SODIUM HYDROXIDE	SODIUM HYPOSULPHITE	SODIUM NITRATE	SODIUM PHOSPHATE	SODIUM SILICATE	SODIUM SULPHATE	ZINC (DUST)	ZINC CARBONATE	ZINC OXIDE
BATTERIES	o		o					o																		
CERAMICS	o				o				o						o		o			o			o			
COAL DISTILLATION																		o								
DYEING, ETC.			o		o	o		o			o		o	o	o		o	o	o			o	o	o		
ELECTRO-PLATING	o			o	o		o	o		o		o	o	o	o		o	o	o	o	o		o			
EXPLOSIVES			o			o	o		o			o			o	o	o	o		o			o			o
FERMENTATION				o								o		o	o		o					o				
FERTILIZERS					o		o		o				o							o						
FOOD PREPARATION				o					o			o		o	o		o			o	o	o	o			
GLASS	o				o				o	o			o		o					o			o			o
GLUES																										o
INSECTICIDES, ETC.																	o									
LAUNDERING					o							o			o		o	o	o							
MEAT PACKING									o								o			o						
PAINT AND VARNISH	o		o	o	o	o		o	o	o					o			o	o		o	o	o		o	o
PETROLEUM REFINING															o			o								
PHOTOGRAPHY			o		o					o					o				o							
PULP AND PAPER	o	o												o	o		o	o	o			o	o			
RUBBER	o																							o		o
SOAP	o				o		o	o				o			o		o	o				o	o			o
STARCH															o			o								
SUGAR																										
TANNING		o	o		o							o		o	o		o	o	o				o			
TEXTILES		o				o		o				o		o	o			o				o		o		o
WOOD DISTILLATION								o						o	o			o								

	COAL TAR PRODUCTS															
	ANILINE	BENZENE	CARBON BISULPHIDE	CRESOLS	GASOLINES	HYDROQUINONE	METOL	NAPHTHA SOLVENT	NAPHTHALENE	NAPHTHOLS	NITRANILINE, PARA	PETROLATUM	PHENOL	PICRIC ACID	SODIUM BENZOATE	TOLUOL
BATTERIES																
CERAMICS												o				
COAL DISTILLATION																
DYEING, ETC.	o			o							o			o		o
ELECTRO-PLATING		o	o													
EXPLOSIVES		o		o					o			o	o	o		o
FERMENTATION																
FERTILIZERS																
FOOD PREPARATION															o	
GLASS																
GLUES																
INSECTICIDES, ETC.			o	o	o				o							
LAUNDERING					o			o								
MEAT PACKING															o	
PAINT AND VARNISH	o	o	o		o			o	o	o	o					
PETROLEUM REFINING																
PHOTOGRAPHY				o		o	o		o							
PULP AND PAPER	o															
RUBBER	o	o	o		o			o		o			o			
SOAP								o					o			
STARCH																
SUGAR																
TANNING	o							o								
TEXTILES	o		o	o	o			o								
WOOD DISTILLATION																

	MISCELLANEOUS SUBSTANCES																									
	ACETIC ACID	ACETONE	ALCOHOL (ETHYL)	ALCOHOL (METHYL)	AMYL ACETATE	CHLORINE LIQUID	CORN SYRUP	DEXTRINE	ETHER, ACETIC	ETHER, SULPHURIC	FORMALDEHYDE	FUSEL OIL	GELATINE	GLYCERINE	LINSEED OIL	NEATSFOOT OIL	OLEIC ACID	OLEO OIL	OXALIC ACID	PYROGALLIC ACID	STARCH	STEARIC ACID	SUGARS	TALLOW	TANNIC ACID	WHALE OIL
BATTERIES																										
CERAMICS																										
COAL DISTILLATION																										
DYEING, ETC.	o			o		o		o			o			o					o		o				o	
ELECTRO-PLATING	o		o	o																					o	
EXPLOSIVES		o	o	o					o	o				o					o		o		o			
FERMENTATION	o		o					o			o														o	
FERTILIZERS																										
FOOD PREPARATION	o		o		o			o	o				o	o				o			o		o	o		
GLASS																										
GLUES											o															
INSECTICIDES, ETC.											o															
LAUNDERING	o					o													o		o					
MEAT PACKING													o													
PAINT AND VARNISH	o	o	o	o	o							o			o											
PETROLEUM REFINING																										
PHOTOGRAPHY			o								o									o						
PULP AND PAPER						o		o					o	o							o				o	
RUBBER	o	o	o	o				o		o	o		o								o					
SOAP			o	o							o			o	o	o	o				o	o	o	o		o
STARCH	o																		o							
SUGAR																										
TANNING			o					o			o		o		o	o			o					o	o	o
TEXTILES	o			o		o		o			o		o	o			o		o		o	o		o	o	
WOOD DISTILLATION																										

TABLE 1

in certain classes of manufacturing and converted into finished products which might be termed secondary manufactural products. Such a product is nitro-glycerine, made from glycerine, sulphuric and nitric acids. In the same way finished manufactural products of higher ranks than secondary are common. In some cases the intermediate processes are very complex, and raw materials are drawn from diverse sources, as in the textile industry or the soap industry.

Manufacturing in its literal and broadest sense may be made to include all industrial operations whereby certain products, regardless of origin, are fashioned by labour, manual or otherwise, into useful or desirable forms. Owing to the specialized character of certain operations essential to the preliminary preparation of raw materials for utilization for final manufacturing it has been deemed advisable to segregate these industries under appropriate titles and to limit the term Manufacturing to those industries not otherwise provided for. In the majority of cases those industries here grouped under the general designation Manufacturing will be found to require raw materials from diverse sources, many of which are manufactural products of greater complexity than secondary.

The foregoing statements will enable the reader to appreciate the difficulties of preparing a logical classification when dealing with so complex a subject as that presented in this report, and in part will serve to explain the classification here adopted. As far as possible the groups of industries discussed have been arranged in logical sequence, proceeding from the less complex to the more complex. In many instances the relative degrees of complexity are largely a matter of personal opinion, and another classification than that adopted here would serve the purpose equally well.

The classification of the Canadian chemical, metallurgical, and allied industries which has been adopted to determine the order of presentation of subjects in this report is as follows:—

Chemical industries, producing chemical products:—
    Those making primary inorganic products—
        Heavy chemicals
        Electrochemical and electrometallurgical products
        Nitrogen compounds
        Industrial gases (chiefly)
        Plasters, limes, and hydraulic cements
        Fine chemicals (in part)

    Those making primary organic products—
        Fermentation products, including industrial alcohol
        Forest products
        Destructive distillation products

- Those making primary organic products—*Concluded*
    - Industrial gases (in part)
    - Pharmaceuticals
    - Fine chemicals (in part)
- Industries making and using both organic and inorganic products—
    - Explosive manufacture, including fireworks
    - Fertilizer manufacture
- Industries engaged in secondary manufacture—
    - Ceramic products, including glasses
    - Insecticides and fungicides
    - Blueing
    - Boiler compounds
    - Inks

Metallurgical industries, producing and utilizing metals:—

- Primary, production of metals from ores—
    - Aluminium, antimony, arsenic, calcium, cobalt, copper, gold, iron, lead, magnesium, manganese, molybdenum, nickel, platinum, silver, zinc
- Secondary, utilizing metals—
    - Foundries
    - Forges
    - Rolling mills
    - Tube mills
    - Wire mills

Allied industries, using chemicals and chemical processes:—

- Products primarily intended for food—
    - Sugar manufacture
    - Starch and starch products
    - Food preparation and preservation, including
        - Meat and fish packing
        - Fruit and vegetable canning
- General manufacturing—
    - Colour, paint, and varnish products
    - Soap manufacture
    - Textile manufacture
    - Bleaching, staining, mordanting, dyeing, and colour printing
    - Laundering
    - Leather manufacture
    - Rubber manufacture
    - Photographic products
    - Electroplating
    - Dry cells and storage batteries
    - Abrasive products
    - Glue and gelatine
    - Adhesives and cements
    - Friction matches
    - Polishes
    - Sweeping compounds

The more important subjects presented in this report when discussing these industries are:—

1. Raw materials of the industries under review.
2. Sources of raw materials of the industries under review.
3. Uses of mineral products, including chemicals, in industry.
4. Chemical and metallurgical industries now established in Canada.
5. Chemical and metallurgical products now being produced in Canada.
6. Home markets and the export trade.

CHAPTER II

IMPORT AND EXPORT STATISTICS

References will be made in succeeding paragraphs to the importance of accurate statistical information. A manufacturer planning the development of a new industry needs to know the absorptive capacity of the home market and also requires as much data as possible about foreign markets for the specific product in which he is interested. Lists of the various raw materials or partially prepared products which enter into a number of lines of manufacture are given in the various sections of this report which describe certain industries developed in Canada. It has not been possible, however, to obtain accurate statistical data showing the market each of these industries offers for each of the materials mentioned. Statistical studies which have been made of Canada's home markets have, with very few exceptions, not considered specific products.

The best data at present available with respect to home markets relate to those commodities that are imported from abroad. Imports represent our requirements chiefly for the home market; they also include some commodities which enter into our export trade, usually after passing through manufacturing processes in Canada. It has not been considered necessary or desirable to introduce many statistical data in each section of the report. Such data as are available are compiled annually by the Dominion Bureau of Statistics and issued in separate reports. The latest available statistics relating both to production and importations can therefore be obtained by application to this bureau.

An attempt has been made to show the nature of the Canadian home market for chemical and metallurgical products by compiling a special table based on statistical data relating to imports and exports that have already been published. The tables which follow show the average annual imports and exports of named groups of commodities for the three-year period prior to the war. Corresponding data for the first complete fiscal year following the close of the war are also included for comparison. Later information can be obtained by consulting the annual reports issued by the Department of Trade and Commerce.

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Abrasive materials:						
Abrasives, artificial in bulk, crushed or ground, for the manufacture of abrasive wheels and polishing composition	.....	†12,033	.....	.....	127,631	.....
Diamond dust or bort, and black diamonds for borers	.....	30,855	.....	.....	95,246	.....
Emery, in bulk, crushed or ground	.....	46,227	.....	.....	85,038	.....
Emery and carborundum wheels and manufactures of emery or carborundum	.....	123,734	.....	.....	563,247	.....
Flint and ground flint stones	92,810 cwt.	52,589	.....	119,140 cwt.	113,913	.....
Iron sand or globules or iron shot and dry putty adapted for polishing glass or granite or for sawing stone	279,021 lbs.	10,609	.....	.....	57,809	.....
Pumice and pumice stone, lava, and calcareous tufa, not further manufactured than ground	.....	19,252	.....	.....	35,815	.....
Sand paper, glass, flint and emery paper or emery cloth	.....	175,940	.....	.....	310,901	.....
Albumen:						
Albumen, blood, egg albumen and egg yolk	.....	34,057	.....	.....	129,509	.....
Casein	.....	12,491	.....	.....	33,319	.....
Alloys and alloy products:						
Babbit metal in blocks, bars, plates, and sheets	.....	43,465	.....	.....	26,214	.....
Britannia metal in pigs, blocks, or bars	341 cwt.	14,719	.....	155 cwt.	10,876	.....
Britannia metal, manufactures of, not plated	.....	28,771	.....	.....	16,653	.....
Cobalt alloys	.....	.....	.....	.....	.....	.....
Composition metal and plated metal in bars, ingots, or cores for the manufacture of watch cases, jewellery, filled gold and silver seamless wire	.....	28,579	.....	.....	39,520	.....
Ferro-manganese, ferro-silicon, and spiegeleisen	23,266 tons	636,172	.....	.....	.....	
Ferro-manganese and spiegeleisen containing more than 15% manganese	.....	.....	.....	33,282 tons	3,806,242	
Ferro-manganese and spiegeleisen containing not more than 15% manganese, and other ferro-alloys, n.o.p	.....	.....	.....	15,667 cwt.	482,383	
Ferro-silicon, containing more than 15% silicon	.....	.....	.....	21 cwt.	450	
Ferro-silicon, containing not more than 15% silicon	.....	.....	.....	7,758 cwt.	23,436	
Nickel, nickel silver, and German silver, in bars, rods, strips, sheets or plates	541,258 lbs.	136,081	.....	557,579 lbs.	190,245	.....
Nickel, nickel silver, and German silver, in ingots or blocks, n.o.p	73,836 lbs.	21,802	.....	86,079 lbs.	35,218	.....
Nickel, German, and Nevada silver, manufactures of, not plated	.....	80,824	.....	.....	234,928	.....
Phosphor tin and phosphor bronze, in blocks, bars, plates, sheets, and wire	.....	24,488	.....	.....	46,769	.....

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*The same item may appear under two entries owing to differences in tariff rates.
†One entry only.

AND ALLIED PRODUCTS.*

2.

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	2,104,274	....	....	....	7,571
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
547,183 lbs.	21,572	9,110 lbs.	1,936	....	....	32,643 lbs.	6,936
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	57,068 lbs.	231,990	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	21,624 tons	2,620,923	....	....	34 tons	1,139
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Alloys and alloy products—Continued:						
Stereotypes, electrotypes, and celluloids of newspaper columns in any language other than English and French, and of books, and bases and matrices and copper shells for the same, whether composed wholly or in part of metal or celluloid	754,556sq.in	15,427	.....	828,307sq.in	26,985	
Stereotypes, electrotypes and celluloids for almanacs, calendars, illustrated pamphlets, newspaper or other advertisements, n.o.p., and matrices or copper shells for such stereotypes, electrotypes, and celluloids	1,158,788sq.in	65,962	.....	1,277,825sq.in	54,019	
Stereotypes, electrotypes, celluloids, and bases for the same composed wholly or partly of metal or celluloid, n.o.p., and copper shells for such stereotypes, electrotypes, and celluloids	476,741sq.in	24,469	.....	231,787sq.in	14,575	
Stereotypes, electrotypes, and celluloids, matrices for	574,512sq.in	6,405	.....	2,217,159sq.in	11,763	.....
Type for printing, including chases, quoins, and slugs of all kinds	.....	171,142	.....	.....	64,768	.....
Type metal in blocks, bars, plates, and sheets	.....	1,314	.....	.....	85	.....
Yellow metal, in bars, bolts, and sheets, for use in the construction or repair of vessels	972 cwt.	14,799	.....	248 cwt.	7,598	.....
Ashes pot and pearl, less than 25 lbs	19,994 lbs.	1,078	5·4	663 lbs.	582	87·8
" " " 25 lbs. and more	219,983 lbs.	9,210	4·2	12,611 lbs.	6,690	53·0
" other	.....	.....	.....	.....	.....	.....
Asphalt, not solid	.....	†33,357	.....	.....	15,725	.....
" or asphaltum, solid	912,669 cwt.	744,318	81·5	414,552 cwt.	424,997	$1.03
Asphaltum oil	.....	24,335	.....	.....	33,984	.....
Baking powders	647,747 lbs.	179,796	.....	6,393 lbs.	1,389	.....
Balsam	.....	.....	.....	.....	.....	.....
Blacking, shoe and shoemakers' ink, shoe, harness, and leather dressing, n.o.p	.....	121,652	.....	.....	220,627	.....
Blueing, laundry	.....	49,692	.....	.....	87,039	.....
Bones, crude	41,713 cwt.	50,528	$1.21	2,183 cwt.	10,548	$4.83
Candles, paraffine wax	301,459 lbs.	36,091	.....	281,831 lbs.	58,032	
" other, n.o.p	476,633 lbs.	56,901	.....	461,353 lbs.	101,176	
Cellulose, nitro-:						
Celluloid, moulded into blanks	.....	6,563	.....	.....	580	.....
Celluloid, xylonite, or xyolite, rolled, moulded, or pressed	.....	147,491	.....	.....	671,405	.....
Celluloid, manufactures of, n.o.p	.....	74,269	.....	.....	218,193	.....
Collodion for use in films, when imported by photo engravers and manufacturers of copper rollers	523 gals.	‡809	$1.55	493 gals.	1,165	$2.36
Pyroxylin and wood naphtha, preparations of, for coating imitation leather, and for the manufacture of leather belting	.....	13,649	.....	.....	50,173	.....
Cellulose, pulps:						
Fibre and manufactures of, n.o.p	.....	133,590	.....	.....	271,607	.....
Soda pulps	.....	.....	.....	1,745,540 lbs.	80,624	4·6
Sulphite pulp, bleached	.....	.....	.....	299.257 lbs.	13,000	4·3
Sulphite pulp, unbleached	.....	227,460	.....	18,875,030 lbs.	377,543	2·0
Wood pulp mechanically or chemically prepared, n.o.p	.....	.....	.....	2,769,631 lbs.	52,829	1·9
Wood pulp, chemically prepared	.....	.....	.....	.....	.....	.....
Wood pulp, mechanically ground	.....	.....	.....	.....	.....	.....
Chalk, prepared	.....	44,007	.....	.....	78,160	.....
Charcoal	.....	72,022	.....	.....	124,924	.....

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
Electrotypes and Stereotypes	6,768	....	8,420	....	3,125	....	21,349
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
579 bbl.	25,586	135 bbl.	25,485	....	....	....	....
....	36,371	....	39,128	....	†105	....	
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
64,733 lbs.	13,112	267,682 lbs.	44,048	†550 lbs.	†136	1,000 lbs.	95
....	12,330	....	7,370	....	†91	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
49,789 cwt.	70,788	115,860 cwt.	210,601	‡6,778 cwt.	‡7,325	....	....
1,222 lbs.	190	181,324 lbs.	24,123	640 lbs.	145	6,299 lbs.	881
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
1,154,443 cwt.	2,203,820	8,332,930 cwt.	30,226,856	....	....	4,300 cwt	21,662
4,863,152 cwt.	3,452,404	3,508,726 cwt.	4,479,915	....	....	....	....
....	....	....	....	....	....	....	....
....	7,547	....	9,522	....	....	....	100

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes:	(Additional chemicals are included in trade groups. See Fertilizers,					
Acetone and amyl acetate	....	8,217	......	....	3,420	......
Acids:—						
Acetic and pyroligneous, crude, of any strength, not exceeding 30%	18,612 gals.	2,494	......	4,029 gals.	1,620	......
Acetic and pyroligneous, above proof strength	2,507 gals.	2,638	......	3,720 gals.	21,524	......
Acetic, and pyroligneous, n.o.p., not exceeding proof strength	1,162 gals.	887	......	43 gals.	20	......
Boracic, in packages of 25 lbs. and over—	377,719 lbs.	21,554	5·7	354,852 lbs.	48,813	13·8
Hydrochloric	910,934 lbs.	10,286	1·13	95,618 lbs.	7,558	7·9
Hydro-fluo-silicic	680,282 lbs.	30,212	4·4	1,656 lbs.	148	8·9
Nitric	190,449 lbs.	10,379	5·4	128,722 lbs.	18,644	14·5
Oxalic	316,364 lbs.	16,805	5·3	107,246 lbs.	39,868	37·2
Stearic	324,270 lbs.	28,913	8·9	173,559 lbs.	39,202	22·6
Sulphuric	2,056,303 lbs.	16,567	·81	12,185,903 lbs.	206,691	1·7
Tannic	25,450 lbs.	7,646	30·0	33,181 lbs.	23,429	70·6
Tartaric crystals	311,246 lbs.	70,734	22·7	329,558 lbs.	239,501	72·7
Other, n.o.p.	846,102 lbs.	108,992	......	1,678,123 lbs.	327,007	......
Alcohols:—						
Amyl alcohol or fusel oil or any substance known as potato spirit or potato oil	62 gals.	65	$1·04	58 gals.	398	$6·86
Ethyl alcohol or the substance known as alcohol, hydrated oxide of ethyl, or spirits of wine	869 gals.	360	41·4	5,035 gals.	5,245	$1·04
Ethyl alcohol, when imported by the Department of Inland Revenue, or by a person licensed by the Minister of Inland Revenue, to be denatured for use in the arts and industries and for fuel, light and power	‡20,620 gals.	‡7,359	35·7	6,582 gals.	5,690	86·4
Methyl alcohol, wood alcohol, wood naphtha, pyroxylic spirits, or any substance known as wood spirits or methylated spirits	190 gals.	164 ..	......	.... 184 gals.	256	......
Wood alcohol	....	....	......	....	....	......
Aluminium acetate, crude (red liquor), prepared from pyroligneous acid and adapted for dyeing and calico printing	....	379	......	....	28	......
Aluminium chloride and chloralum	‡2,220 lbs.	‡435	....	152 lbs.	136	......
Aluminium sulphate—						
Alum, in bulk, ground or unground, but not calcined (K & Na alums)	3,990,922 lbs.	32,454	......	Included in next total		
Aluminium sulphate or alum cake	4,020,809 lbs.	23,283	......	" "	"	
Alum in bulk, ground or unground, but not calcined; and aluminium sulphate, or alum cake	11,255,109 lbs.	104,582	......	25,528,854 lbs.	460,840	......
Ammonium chloride (sal ammoniac)	939,469 lbs.	45,348	4·8	693,855 lbs.	91,235	13·1
" nitrate	1,611,037 lbs.	96,649	6·0	738,055 lbs.	85,822	11·6
" sulphate	397,097 lbs.	12,578	3·2	140,153 lbs.	6,949	5·0
Aniline dyes, in packages of less than 1 lb. weight	2,094 lbs.	652	31·2	3,412 lbs.	2,948	86·4
Aniline and coal tar dyes, soluble in water, in bulk or packages of not less than 1 lb. weight, including alizarine and artificial alizarine	2,284,613 lbs.	497,164	......	1,786,202 lbs.	2,025,697	......
Aniline oil, crude	69,380 lbs.	6,862	9·9	288,756 lbs.	77,662	26·9
" salts	212,833 lbs.	18,826	8·8	8,882 lbs.	3,344	37·6
Antimony salts for dyeing	†970 lbs.	†75	......	....	....	......
" " viz.: tartar emetic, chloride, and lactate (antimonine)	32,541 lbs.	3,999	......	36,647 lbs.	13,637	......

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†One entry only.

‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
Explosives, Paints, Tanning Materials, and other groups.)							
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
†6,245,086 lbs.	†37,413	5,463,000 lbs.	75,857	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
591,596 gals.	255,601	327,313 gals.	606,550	†40 gals.	†25	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	20,631,900 lbs.	1,231,524	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Arsenic sulphide	365,982 lbs.	13,515	3·7	219,175 lbs.	24,671	11·3
Arsenious oxide	34,212 lbs.	977	2·9	2,231 lbs.	678	30·4
Barium peroxide, non-alcoholic, imported by manufacturers of hydrogen peroxide	†66,162 lbs.	†4,529	.....	122,411 lbs.	31,424	.....
Bromides, crude	†1,401 lbs.	†368	.....	6 lbs.	10	$1·67
Bromine	217 lbs.	85	39·3	723 lbs.	988	$1·37
Calcium acetate	.....	.....	.....	.....	.....	.....
" carbide	.....	.....	.....	.....	.....	.....
" chloride and hypochlorite,* in packages of not less than 25 lbs	12,563,307 lbs.	117,579	.....	11,958,547 lbs.	174,362	.....
" chloride and hypochlorite,* in packages of less than 25 lbs	.....	.....	.....	178,423 lbs.	13,751	.....
" oxide (lime)	857,860 cwt.	210,579	24·5	103,799 cwt.	59,140	57·0
" phosphate, monobasic	1,888,277 lbs.	77,598	4·1	3,102,469 lbs.	307,891	9·9
" sulphate (See Gypsum.)						
Carbon bisulphide	.....	.....	.....	81,757 lbs.	6,047	7·4
" dioxide	.....	.....	.....	.....	1,732	.....
Cobalt oxide and cobalt salts	.....	.....	.....	.....	.....	.....
Cocaine	437 ozs.	693	$ 1·59	12,333 ozs.	142,123	$11·52
Copper acetate, basic, dry	1,923 lbs.	332	17·3	3,509 lbs.	1,571	44·8
" sulphate (blue vitriol)	1,975,597 lbs.	95,413	4·8	2,526,718 lbs.	220,607	8·7
Cyanamid (See Fertilizers.)						
Disinfectants and other liquid non-alcoholic preparations for dipping or spraying, n.o.p	.....	71,062	.....	.....	153,287	.....
Dyestuffs	.....	.....	.....	.....	.....	.....
Ether, nitrous, sweet spirits of nitre, and aromatic spirits of ammonia	819 gals.	3,291	.....	316 gals.	3,348	.....
Ether, sulphuric, chloroform, and solutions of hydrogen peroxide	.....	47,761	.....	.....	135,160	.....
Glycerine, crude, imported by refiners	1,073,929 lbs.	146,401	13·6	.....	.....	.....
" imported for explosives	5,061,876 lbs.	895,016	17·7	2,010,398 lbs.	1,179,313	58·7
" n.o.p	156,553 lbs.	29,728	19	21,157 lbs.	4,843	22·9
Indigo	56,518 lbs.	11,508	20·4	.....	.....	.....
" , paste and extract of	101,229 lbs.	16,103	.....	145,445 lbs.	81,953	.....
Iodine, crude	10,645 lbs.	19,673	$1·85	8,481 lbs.	28,332	$3·34
Iron acetate or nitrate liquor, for dyeing and calico printing	.....	3,558	.....	.....	7,767	.....
" sulphate (copperas)	711,195 lbs.	5,177	0·73	776,611 lbs.	15,673	2·0
Lead acetate and nitrate, not ground	580,689 lbs.	32,123	.....	123,031 lbs.	18,291	.....
Magnesium oxide (magnesia)	509,235 lbs.	18,527	3·6	140,527 lbs.	16,606	11·8
Manganese oxide	3,228,492 lbs.	32,375	1·0	3,629,307 lbs.	94,222	2·6
Medicinal, chemical, and pharmaceutical preparations, including proprietary preparations (dry)	.....	1,054,459	.....	.....	1,434,016	.....
Medicinal, chemical and pharmaceutical preparations, including proprietary preparations (all other) non-alcoholic	.....	89,709	.....	.....	92,153	.....
Medicinal, chemical, and pharmaceutical preparations, including proprietary preparations (all other)	.....	139,497	.....	.....	217,717	.....
Morphine	2,321 ozs.	4,965	$2·14	30,087 ozs.	179,195	$5·95
Nicotine sulphate	.....	.....	.....	18,428 lbs.	14,322	77·7
Nitraniline, Para	35,320 lbs.	5,227	14·8	87,298 lbs.	57,661	66·1
Phosphorus	16,454 lbs.	5,141	31·2	53,696 lbs.	26,226	48·8
Platinum and black oxide of copper for use in the manufacture of chlorate and colours	†1 lb.	†608	.....	.....	74	.....
Potassium bicarbonate and carbonate (See Ashes)	26,803 lbs.	508	.....	3,987 lbs.	3,951	.....

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*Chiefly "Bleaching Powder."
†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	....	....	....	....	....
3,603,662 lbs.	102,679	5,462,500 lbs.	358,145	†576 lbs.	†15	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
13,880,934 lbs.	282,045	4,328,600 lbs.	203,084	....	....	....	....
6,237,352 lbs.	186,703	118,376,200 lbs.	4,720,783	‡416 lbs.	‡18	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	33,649	155,877 cwt.	67,052	....	....	....	....
Includes sodium	phosphate.						
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	640,303 lbs.	908,659	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	8,688	....	17,225	....	7,745	....	20,995
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
589,677 lbs.	80,605	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Potassium bichromate	334,176 lbs.	22,458	6·7	21,143 lbs.	10,708	51·1
" bitartrate (cream of tartar), in crystals or argols	1,583,227 lbs.	282,702	......	473,703 lbs.	261,653	......
" chlorate, not further prepared than ground	829,758 lbs.	61,412	7·4	22,591 lbs.	9,848	43·6
" chloride and sulphate	10,736,284 lbs.	105,426	......	449,657 lbs.	65,423	......
" cyanide, sodium cyanide, cyanogen or compounds of bromine and potassium for reducing metals in mining operations	1,092,836 lbs.	165,005	......	1,501,437 lbs.	424,128	......
" ferro- and ferricyanides	174,128 lbs.	17,090	......	9,242 lbs.	13,020	......
" hydroxide, in packages of not less than 25 lbs. each	523,316 lbs.	26,967	5·2	22,855 lbs.	16,714	73·1
" hydroxide, in packages of less than 25 lbs. each	34,561 lbs.	1,803	5·2	819 lbs.	954	$1·16
" nitrate (saltpetre)	1,053,437 lbs.	93,975	4·8	883,761 lbs.	161,962	18·3
" sulphate (See Potassium chloride, etc.)						
Quinine salts	155,812 ozs.	27,046	17·4	184,991 ozs.	160,477	86·7
Radio-active salts	....	2,027	......	....	528	......
Sodium arsenate, biarsenate, and stannate	35,425 lbs.	1,411	......	857 lbs.	146	......
" bicarbonate	6,265,076 lbs.	59,338	0·95	7,109,060 lbs.	150,772	2·1
" bichromate	526,428 lbs.	28,667	5·4	1,134,486 lbs.	218,702	19·3
" bisulphite	850,848 lbs.	9,797	1·2	10,658,446 lbs.	47,587	0·45
" borate (borax), in bulk of not less than 25 lbs	3,004,653 lbs.	112,166	3·7	2,311,765 lbs.	181,092	7·8
" carbonate (sal soda)	9,656,176 lbs.	59,861	0·62	10,671,902 lbs.	171,346	1·6
" " crude (soda ash or barilla)	56,246,241 lbs.	432,598	0·77	86,260,061 lbs.	1,915,923	2·2
" chlorate	608,318 lbs.	31,481	5·2	582 lbs.	144	24·7
" chloride, imported for the United Kingdom, or any British possession; or imported for the use of the sea or gulf fisheries	2,201,758 cwt.	370,045	16·8	1,899,062 cwt.	755,301	39·8
" chloride, in bulk, n.o.p	415,412 cwt.	64,067	15·4	1,096,780 cwt.	315,148	28·7
" " n.o.p., in bags, barrels, and other coverings	166,025 cwt.	70,093	42·2	266,457 cwt.	152,110	57·1
" cyanide (See Potassium cyanide, etc.)						
" ferro- and ferricyanides, and sulphite	309,702 lbs.	11,231	......	1,013,801 lbs.	165,271	......
" hydroxide, in packages of 25 lbs. and over	14,853,707 lbs.	270,409	1·8	11,379,483 lbs.	522,124	4·0
" hydroxide, when in packages less than 25 lbs. each	148,484 lbs.	8,281	5·6	93,912 lbs.	9,260	9·9
" hyposulphite	....	4,886	......	....	9,734	......
" " imported by tanners	538,800 lbs.	6,487	1·2	360,200 lbs.	8,590	2·4
" nitrate (cubic nitre)	75,151,179 lbs.	1,372,578	1·8	84,033,351 lbs.	3,294,369	3·9
" nitrite	326,220 lbs.	8,871	2·7	18,615 lbs.	5,272	28·3
" peroxide	25,634 lbs.	8,063	31·5	60,339 lbs.	19,739	32·7
" phosphate (See Calcium phosphate monobasic.)						
" silicate, crystals or solution	11,674,517 lbs.	74,245	......	25,470,115 lbs.	287,361	......
" stannate (See Sodium arsenate, etc.)						
" sulphate (Glauber's salts)	1,448,510 lbs.	7,000	0·48	551,213 lbs.	10,080	1·8
" sulphate, crude (salt cake)	21,031,292 lbs.	112,112	0·53	67,617,762 lbs.	626,446	0·93
" sulphide	1,234,967 lbs.	18,727	1·5	2,062,938 lbs.	88,459	4·3
" sulphite (See Sodium ferro- and ferricyanide, etc.)						
Sulphur, crude, refined and sublimed	59,156,183 lbs.	615,297	......	194,634,613 lbs.	2,042,172	......
Thorium nitrate	....	....	......	....	152	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*.

Exports							
Domestic				Foreign			
1911–14		1918–19		1911–14		1918–19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
350,950 lbs.	3,636	1,594,400 lbs.	17,082	5,611,958 lbs.	19,993	11,778,900 lbs.	105,365
....	....	....	....	....	....	....	....
....	47,537	....	5,865	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Thorium nitrate and cerium nitrate on cotton thread imported by manufacturers of incandescent gas mantles, or of stockings for such mantles	.....	5,610	.....	.....	14,998	.....
Tin bichloride	25,164 lbs.	3,703	14·7	124 lbs.	106	85·5
Tin chloride (stannous chloride)	.....	6,337	.....	.....	9,253	.....
Zinc chloride and sulphate	673,652 lbs.	20,762	.....	428,179 lbs.	32,949	.....
Other drugs, dyes, chemicals and medicines	.....	1,844,768	.....	.....	6,604,467	.....
Clay, China, ground or unground	414,008 cwt.	142,716	.....	217,219 cwt.	127,227	.....
" pipe, ground or unground	.....	833	.....	.....	1,148	.....
Dextrine, dry	2,252,991 lbs.	78,625	3·5	1,694,894 lbs.	134,771	7·95
" British gum, dry, sizing cream, and enamel sizing	1,580,500 lbs.	58,085	.....	907,110 lbs.	70,271	.....
Explosives:						
Blasting and mining powder	752,016 lbs.	65,302	.....	3,125 lbs.	276	.....
Fireworks, firecrackers, and torpedoes, all kinds	.....	46,335	.....	.....	32,002	.....
Fuses, non-metallic	.....	127,487	.....	.....	141,762	.....
Giant powder, nitro, nitro-glycerine, and other explosives, n.o.p	1,101,611 lbs.	175,632	.....	224,769 lbs.	148,255	.....
Gun, rifle, sporting, cannon, musket, and cannister powder	184,834 lbs.	115,986	.....	62,790 lbs.	62,244	.....
Gun, rifle, and pistol cartridges, or other ammunition, n.o.p	.....	846,197	.....	.....	239,943	.....
Nitrate compounds, adapted for use in the manufacture of explosives	†4,800 lbs.	†300	.....	200 lbs.	200	.....
Toluol—binitro-, trinitro-, and ammonium perchlorate imported by explosive manufacturers	†591,941 lbs.	†63,884	.....	.....	.....	.....
Explosives and fulminates, n.o.p	.....	.....	.....	.....	.....	.....
Fertilizers:	.....	.....	.....	.....	.....	.....
Bone dust, charred bone, and bone ash	75,484 cwt.	129,301	.....	40,498 cwt.	78,519	.....
Cyanamid	.....	.....	.....	.....	.....	.....
Fertilizers compounded or manufactured	.....	529,143	.....	.....	984,808	.....
Fertilizers, unmanufactured, n.o.p	.....	1,710	.....	.....	105,361	.....
Guano and other animal manures	49,839 cwt.	53,040	.....	70,554 cwt.	170,350	.....
Kainite and other crude German potash salts for fertilizers	339,333 lbs.	3,096	.....	176,000 lbs.	8,852	.....
Manures, vegetable	930 cwt.	422	45·4	4,457 cwt.	13,980	$3·14
Phosphate rock	.....	27,900	.....	.....	87,524	.....
Slag, blast furnace	.....	92,866	.....	.....	18,666	.....
Glass and Glassware:	.....	.....	.....	.....	.....	.....
Balls, and cut, pressed or moulded crystal glass tableware, blown glass tableware, and other cut glass ware	.....	630,629	.....	.....	439,536	.....
Carboys or demijohns, bottles, decanters, flasks, jars, and phials	.....	539,432	.....	.....	715,769	.....
Common and colourless window sheet	49,848,522 sq. ft.	1,363,326	.....	17,785,624 sq. ft.	1,514,377	.....
Dry plate sheet, cut to size, imported by manufacturers	.....	13,535	.....	.....	63,229	.....
German looking glass (thin plate), unsilvered or for silvering	.....	513	.....	.....	.....	.....
Dry plates, photographic	.....	60,426	.....	.....	22,728	.....
Lamps, incandescent—bulbs and tubing for, also gas light mantle stockings	.....	133,016	.....	.....	199,245	.....
Lamp chimneys, glass shades or globes	.....	377,867	.....	.....	184,054	.....
Ornamental figured and enamelled coloured sheet and memorial or other ornamental window sheet, n.o.p	.....	44,820	.....	.....	14,599	.....

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† One entry only.
Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911–14		1918–19		1911–14		1918–19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	908,190	...	6,036,522	...	351,567	...	715,657
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	16,272	...	213,432,531	...	4,515	...	228,177
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	164,349	...	37,506,294	...	46,275	...	502,219
...	1,720,824	...	...	...	5,216	...	...
...	...	...	...	...	...	...	...
...	...	1,037,569 cwt.	2,857,446	...	...	...	...
...	...	...	232,067	...	...	...	2,211
...	...	...	669,712	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	26,120	...	36,145	...	14,491	...	11,822
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

	Imports					
	Averago 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Glass and glassware—Continued:						
Painted or vitrified, chipped, figured, enamelled, and obscured white	.....	30,605	.....	.....	2,949	.....
Plain, coloured, opaque, stained or tinted, or muffled sheet	.....	114,444	.....	.....	21,884	.....
Plate glass, not bevelled, in sheets or panes, not exceeding 7 sq. ft. each, n.o.p	1,756,053 sq.ft.	296,253	.....	954,310 sq. ft.	409,618	.....
Plato glass, not bevelled, in sheets or panes exceeding 7 sq. ft. each, and not exceeding 25 sq. ft. each, n.o.p	1,410,826 sq.ft.	264,300	.....	278,671 sq. ft.	166,731	.....
Plate glass, not bevelled, n.o.p	1,919,480 sq.ft.	430,381	.....	648,399 sq. ft.	406,523	.....
Plate glass, bevelled, n.o.p	12,426 sq. ft.	2,500	.....	8,075 sq. ft.	6,796	.....
Plates or discs, optical	.....	†11,520	.....	.....	40,374	.....
Sheet and bent plate, n.o.p	.....	114,861	.....	.....	138,486	.....
Silvered	.....	146,217	.....	.....	164,239	.....
Spectacles, eye-glasses, and lenses	.....	37,755	.....	.....	110,765	.....
Stained or ornamental windows	.....	22,058	.....	.....	7,319	.....
Other articles, unfinished, not plate or sheet, and manufactures of, n.o.p	.....	436,917	.....	.....	934,935	.....
Glucose or grape sugar, glucose syrup and corn syrup, or any syrups containing any admixture thereof	5,401,891 lbs.	125,070	.....	2,584,336 lbs.	151,866	.....
Glues, including gelatine:						
Fish offal or refuse	.....	16,061	.....	.....	34,463	.....
Gelatine and isinglass	600,704 lbs.	143,930	.....	679,219 lbs.	411,466	.....
Glue, liquid	.....	63,496	.....	.....	142,291	.....
Glue, powderd or sheet	3,109,905 lbs.	240,894	.....	906,202 lbs.	152,900	.....
Glue stock	.....	.....	.....	.....	.....	.....
Mucilage and adhesive paste	.....	33,917	.....	.....	60,013	.....
Grease:						
Axle grease	4,240,970 lbs.	206,007	4·9	5,150,420 lbs.	415,368	8·1
Foots (cotton seed or olive refuse)	632,800 lbs.	27,477	.....	44,300 lbs.	6,496	.....
Grease and degras for stuffing or dressing leather	2,452,026 lbs.	110,933	.....	1,945,850 lbs.	255,034	.....
Grease and grease scraps	.....	.....	.....	.....	.....	.....
Grease, rough, the refuse of animal fat, for the manufacture of soap and oils only	12,869,673 lbs.	831,496	6·5	17,253,689 lbs.	1,875,751 lbs.	10·9
Gums and resins:						
Amber, Arabic, Australian, copal, damar, elemi, kaurie, mastic, sandarac, senegal, tragacanth, geddn, barberry, pontianac and lac, crude, seed, button, stick, and shell	.....	459,091	.....	.....	1,144,257	.....
Burgundy pitch	152,297 lbs.	7,316	4·8	65,737 lbs.	3,691	5·6
Camphor	50,024 lbs.	18,265	36·5	69,925 lbs.	91,646	$1·31
Chicle or Sappato gum, crude	6,924,722 lbs.	2,200,349	31·8	1,967,521 lbs.	1,141,543	.58
Chicle gum	.....	.....	.....	.....	.....	.....
Dragon's blood	875 lbs.	702	80·2	850 lbs.	1,184	$1·39
Opium, crude	4,857 lbs.	24,477	$5·04	34,263 lbs.	534,555	$15·60
Opium, powdered	314 lbs.	1,811	$5·76	123 lbs.	2,247	$18·27
Resin, 100 lbs. and over	271,748 cwt.	672,327	$2·48	337,099 cwt.	1,216,508	$3·61
Other gums, n.o.p	12,733 lbs.	3,010	.....	35,857 lbs.	7,634	.....
Gypsum, crude	3,305 tons	16,195	$4·90	114 tons	2,071	$18·17
" ground, not calcined	70,873 cwt.	11,735	16·6	2,418 cwt.	3,152	$1·30
" calcined (Plaster of Paris), and prepared wall plaster	526,426 cwt.	187,935	.....	21,741 cwt.	18,607	.....
Horns and hoofs	.....	.....	.....	.....	.....	.....
Ink, printing	.....	102,939	.....	.....	157,571	.....
" writing	.....	52,725	.....	.....	50,337	.....

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
113,143 lbs.	3,955	......	......	†17,142	†397	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	21,537	......	93,147	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
3,514,369 lbs.	99,315	3,788,300 lbs.	194,695	28,307 lbs.	993	1,709,000 cwt.	153,738
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
†32,710 lbs.	†16,806	759,817 lbs.	699,333	5,415,386 lbs.	2,508,069	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
377,616 tons	447,591	69,034 tons	82,047	......	......	......	......
......	8,643	......	129,795	......	‡593	......	......
......	......	......	......	......	......	......	......
......	21,222	......	34,949	......	†206	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Oils—Animal:						
Cod oil	111,042 gals.	55,042	49·2	170,114 gals.	275,478	$1·62
Cod liver oil	23,456 gals.	16,715	71·3	288 gals.	952	$3·31
Seal oil	42,932 gals.	22,842	50·9	162,374 gals.	222,119	$1·41
Whale and spermaceti oil.	7,997 gals.	3,643	......	1,642 gals.	3,259	......
Other fish oil	62,912 gals.	25,478	......	34,036 gals.	40,143	......
Lard oil	63,306 gals.	26,024	41·0	25,546 gals.	35,866	$1·40
Neatsfoot oil	16,950 gals.	12,182	71·0	3,690 gals.	5,077	$1·38
Other animal oil, n.o.p.	18,887 gals.	9,595	......	238,777 gals.	375,156	......
Oils, creosote	......	......	......	......	......	......
Oils, Mineral:						
Aniline (See Chemicals.)						
Asphaltum (See Asphaltum oil.)						
Carbolic or heavy oil	844,882 gals.	112,467	13·3	130,878 gals.	33,712	25·8
Coal and kerosene, crude	......	......	......	......	......	......
" " distilled, purified or refined	16,363,699 gals.	1,040,692	......	3,901,449 gals.	433,796	......
Gasoline under ·725 specific gravity at 60° temperature	31,332,421 gals.	4,091,455	......	2,825,812 gals.	739,449	......
Gasoline and naphtha	......	......	......	......	......	......
Illuminating oils, composed wholly or in part of the products of petroleum, coal, shale or lignite, costing more than 30 cents per gallon	190,754 gals.	74,457	......	228,433 gals.	175,779	......
Lubricating oils, composed wholly or in part of petroleum, and costing less than 25 cents per gallon	5,276,766 gals.	687,756	......	2,339,785 gals.	463,888	......
Lubricating oils, n.o.p.	1,089,541 gals.	343,504	......	3,466,108 gals.	1,492,374	......
Petroleum, crude, fuel and gas oils (·8235 specific gravity or heavier) at 60° temperature	131,149,637 gals.	4,265,324	......	139,635,201 gals.	7,923,246	......
Petroleum, crude, gas oils other than naphtha, benzine, and gasoline, lighter than ·8235 but not less than ·775 specific gravity at 60°	23,034 gals.	2,301	......	47,135 gals.	5,824	......
Petroleum, crude, in its natural state, ·7900 specific gravity or heavier at 60°, imported by oil refiners	......	......	......	260,819,944 gals.	14,666,967	......
Petroleum imported by miners or mining companies	......	......	......	4,710 gals.	1,922	......
Petroleum products, n.o.p.	4,236,210 gals.	468,607	......	29,882,932 gals.	5,574,659	......
Vaseline and similar products	......	23,243	......	......	173,798	......
Oils—Vegetable:						
Castor	218,669 gals.	65,690	30·0	56,079 gals.	135,006	$2·41
Cocoa butter	†1,119,602 lbs.	318,651	28·5	4,032,783 lbs.	1,242,185	30·8
Cocoanut, palm, and palm kernel, not edible, peanut and soya bean for manufacture of soap	398,309 gals.	342,875	......	2,390,107 gals.	3,089,637	......
Cocoanut, n.o.p.	†29,548 gals.	†33,539	......	28,950 gals.	45,123	......
Cotton seed, crude, for the manufacture of refined cotton seed oil	‡2,548,306 gals.	‡1,210,494	......	4,596,811 gals.	7,403,369	......
Cotton seed, refined, edible, and peanut for canning fish	40,362 gals.	23,511	......	86,944 gals.	179,758	......
Cotton seed, n.o.p.	999,697 gals.	473,774	47·4	169,650 gals.	287,419	$1·69
Flax seed or linseed, raw or boiled	2,072,433 lbs.	190,945	......	70,299 lbs.	12,657	......
Olive, for manufacturing soap or tobacco or for canning fish	17,395 gals.	21,846	$1·26	2,896 gals.	11,824	$4·08
Olive, n.o.p.	177,219 gals.	246,014	$1·39	17,533 gals.	52,604	$3·00
Palm, bleached, and Shea butter	454,960 lbs.	58,504	......	1,654 lbs.	546	......
Rosin and Chinawood	......	234,897	......	......	806,496	......
Sesame seed	2,110 gals.	1,676	79·4	996 gals.	1,903	$1·91
Vegetable, n.o.p.	378,873 gals.	169,572	......	143,375 gals.	236,512	......
Oils, other, n.o.p., including essential oils	......	474,116	......	......	1,000,517	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
218,029 gals.	73,428	297,305 gals.	399,666	†11,338 gals.	†3,642	10,826 gals.	12,957
...	...	...	...	...	...	...	...
13,638 gals.	5,273	83,523 gals.	121,802	...	...	8,945 gals.	9,842
1,567,874 gals.	604,826	43,352 gals.	66,144	...	...	...	...
93,453 gals.	33,875	120,060 gals.	124,476	†44 gals.	†11	...	...
...	...	...	...	†20 gals.	†5	...	...
188,720 gals.	196,181	83,466 gals.	147,749	...	...	...	...
1,115,870gal.	63,523	1,744,858 gals.	203,780	12,307 gals.	‡3,248	...	...
...	...	...	...	...	...	...	...
‡11,075 gals.	‡2,172	221,336 gals.	24,011	†305 gals.	†67	54,782,951gals.	2,683,041
21,456 gals.	3,333	2,742,047 gals.	273,633	106,352 gals.	9,488	45,062 gals.	3,978
...	...	...	...	...	...	...	...
24,325 gals.	4,786	361,081 gals.	106,464	96,163 gals.	18,980	346,592 gals.	75,158
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	743,574 gals.	857,334	...	...	230,782 gals.	372,506
460,277 gals.	120,868	1,081,389 gals.	250,785	57,305 gals.	39,499	59,815 gals.	51,128

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Paints, Pigments, Colours and Varnishes:						
Blanc fixe and satin white	3,179,149 lbs.	34,936	.....	8,577,631 lbs.	114,554	.....
Brocade and bronze powders	.....	25,910	.....	.....	39,330	.....
Gold liquid paint	.....	11,401	.....	.....	6,765	.....
Lamp black, bone black, carbon black, and ivory black	2,416,046 lbs.	89,651	.....	3,217,286 lbs.	314,362	.....
Lead, red, dry and orange mineral (paint)	1,139,660 lbs.	51,976		1,074,249 lbs.	101,243	.....
" " " " " (colours)	1,084,207 lbs.	44,227				
" white, dry	1,626,294 lbs.	82,306	5·1	300,772 lbs.	25,420	8·5
" " ground in oil	927,750 lbs.	48,482	5·2	48,612 lbs.	5,169	10·6
Liquid fillers, anti-corrosive and anti-fouling paints, and ground and liquid paints, n.o.p.	5,112,044 lbs.	448,734	.....	3,472,288 lbs.	423,285	.....
Litharge	18,036 cwt.	78,025	$4.33	18,418 cwt.	163,156	$8.86
Ochres, ochrey earths, siennas and umbers	3,371,887 lbs.	39,805	.....	3,171,616 lbs.	71,979	.....
Oxide of cobalt, copper, and tin, n.o.p., (metallic colours)	347,898 lbs.	113,074	.....	125,514 lbs.	65,203	.....
Oxides, fire proofs, rough stuffs, fillers, and colours, dry, n.o.p.	9,646,644 lbs.	302,668	.....	4,999,708 lbs.	445,738	.....
Paints and colours, ground in spirits, and all spirit varnishes and lacquers	4,355 gals.	10,949	.....	13,910 gals.	41,193	.....
Paris green, dry	984,277 lbs.	144,291	14·7	73,622 lbs.	32,224	43·8
Putty	466,431 lbs.	10,199	2·2	341,777 lbs.	14,745	4·3
Ultramarine blue, dry or in pulp	458,703 lbs.	28,922	.....	398,269 lbs.	86,610	.....
Varnish, lacquers, japans, japan dryers, liquid dryers, and oil finish, n.o.p.	96,180 gals.	175,767	.....	39,537 gals.	78,030	.....
Whiting, gilders' whiting, and Paris white	278,910 cwt.	107,444	.....	197,298 cwt.	180,721	.....
Zinc white, dry, (colours)	1,293,247 lbs.	33,409	2·6	16,650,072 lbs.	1,393,513	.....
" in vehicle	9,614,011 lbs.	402,913	4·2			
Mineral pigment, iron oxides, ochres, etc.	.....	.....	.....	.....	.....	.....
Paints and varnishes of all kinds	.....	.....	.....	.....	.....	.....
Pitch, bone, crude	.....	3,367	.....	.....	3,223	.....
" coal and pine (See Tar.)						
Polish or composition, knife and other, n.o.p.	.....	194,586	.....	.....	273,381	.....
Rubber and rubber products:						
Balata, crude, unmanufactured	†208 lbs.	†172	82·7	1,110 lbs.	1,071	96·5
Belting	.....	98,510	.....	.....	188,299	.....
Boots and shoes	.....	101,089	.....	.....	194,576	.....
Clothing, and clothing made water-proof with India-rubber	.....	1,323,925	.....	.....	144,855	.....
Elastic, round or flat, including garter elastic	.....	175,343	.....	.....	252,895	.....
Fillets of cotton and rubber not exceeding 7" wide, imported by card clothing manufacturers	.....	‡283	.....	.....	2,877	.....
Rubber, recovered	.....	.....	.....	3,038,586 lbs.	599,997	.....
" substitute	.....	.....	.....	1,473,386 lbs.	178,544	.....
Hard rubber, in sheets, but not further manufactured, also hard rubber in strips or rods but not further manufactured, imported for use in Canadian manufactures	5,245,721 lbs.	853,811	.....	.....	.....	.....
	.....	.....	.....	31,683 lbs.	25,707	.....
Hard rubber, unfinished, in tubes for fountain pens	.....	7,460	.....	.....	30,983	.....
Hose, including cotton or linen lined with rubber	.....	131,079	.....	.....	135,145	.....
Mats and matting	.....	90,853	.....	.....	4,828	.....
Packing			.....		119,296	.....
Rubber and gutta-percha, crude caoutchouc or India-rubber unmanufactured	4,849,097 lbs.	4,205,456	.....	19,227,232 lbs.	7,794,260	.....

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911–14		1918–19		1911–14		1918–19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
4,773,980 lbs.	27,298	1,861,700 lbs.	23,666	…	…	…	…
…	111,945	…	1,776,359	…	13,309	…	89,876
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	23,850	…	14,332	…	3,304	…	5,751
…	142,590	…	2,058,715	…	1,857	…	3,829
…	3,883	…	13,784	…	254	…	24,777
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	8,627	…	195,556	…	893	…	6,481
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Rubber and rubber products—continued:						
Rubber thread, not covered	14,449 lbs.	25,688	......	44,150 lbs.	65,156	......
Tires of rubber for vehicles of all kinds	......	1,320,762	......	......	1,045,140	......
Waste or junk	1,844,688 lbs.	223,440	......	3,392,417 lbs.	337,358	......
Other manufactures of India-rubber and gutta-percha, n.o.p., and rubber cement	......	1,003,182	......	......	1,287,601	......
Soap:	......	......	......	......	......	......
Castile	2,968,526 lbs.	178,239	6·0	91,141 lbs.	17,711	19·4
Common or laundry	6,567,109 lbs.	365,148	......	4,765,079 lbs.	444,241	......
" soft, and liquid	402,468 lbs.	16,460	......	134,636 lbs.	11,556	......
Harness	12,115 lbs.	1,048	8·7	1,645 lbs.	338	20·5
Pearline and other soap powders	2,398,823 lbs.	123,581	......	577,784 lbs.	44,740	......
Toilet	......	390,412	......	......	594,516	......
Whale oil	57,378 lbs.	1,985	3·5	16,351 lbs.	1,549	9·5
Other soap, n.o.p., including pumice, silver and mineral soaps, sapolio, and like articles	......	182,889	......	......	153,217	......
Starch	2,696,813 lbs.	106,015	......	2,541,926 lbs.	142,902	......
Tallow	311,462 lbs.	27,005	8·7	1,155,688 lbs.	161,983	14·0
Tanning materials:						
Camwood and sumac, and extracts of	692,050 lbs.	14,695	......	206,770 lbs.	14,053	......
Hemlock bark, extract of	......	......	......	......	......	......
Logwood, fustic, oak, oak bark, and quebracho, extracts of	31,625,546 lbs.	840,926	......	36,721,785 lbs.	2,016,442	......
Nut galls, and extracts thereof	15,258 lbs.	1,024	......	8,791 lbs.	3,869	......
Terra japonica, gambier or cutch	3,148,888 lbs.	108,086	......	907,874 lbs.	94,201	......
Tanning or dyeing articles in a crude state n.o.p.	8,524,597 lbs.	165,575	......	1,766,304 lbs.	148,899	......
Tar, coal and pine, crude, 15 gallons and over	2,848,824 gals.	120,103	......	......	......	......
Pitch, coal and pine	1,512,732 gals.	88,502	......	......	......	......
Tar, coal, crude, 15 gallons and over, and coal pitch	......	......	......	2,035,249 gals.	117,033	......
Tar, pine, crude, 15 gallons and over, and pine pitch	......	......	......	167,426 gals.	57,430	......
Turpentine, raw or crude	74,538 lbs.	5,125	6·9	59,451 lbs.	4,284	7·2
Turpentine, spirits of	1,043,909 gals.	561,753	53·9	920,363 gals.	565,174	61·4
Vinegar above proof strength	15,623 gals.	3,168	......	34,010 gals.	3,850	
" proof strength and under	179,015 gals.	68,399	......	48,171 gals.	17,729	
Wax:						
Bees	107,254 lbs.	33,439	31·2	246,109 lbs.	106,030	43·1
Paraffine (*See* also Candles)	1,471,671 lbs.	72,532	4·9	1,505,538 lbs.	190,941	12·7
Sealing	......	18,858	......	......	16,526	......
Vegetable and mineral, n.o.p	783,755 lbs.	103,693	......	634,875 lbs.	163,402	......
Other	......	72,060	......	......	51,582	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
......	......	......	......	......	......	......	......
......	......	......	3,016,974	......	......	......	29,765
†5,061,919 lbs.	†413,956	1,436,500 lbs.	129,925	†63,982 lbs.	†8,924	......	......
......	92,758	......	200,304	......	262,376	......	1,853,514
516,891 lbs.	25,101	4,017,985 lbs.	560,025	9,436 lbs.	879	641 lbs.	140
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
107,603 lbs.	4,144	1,629,927 lbs.	148,224	‡2,243 lbs.	‡117	......	......
1,987,389 lbs.	130,292	1,379,153 lbs.	173,491	†700 lbs.	†68	169,830 lbs.	21,015
......	......	......	......	......	......	......	......
2,458 bbl.	27,993	......	12,965	†71 bbl.	†847	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
Tar	49,190	......	73,559	......	201	......	400
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
246 gals.	57	......	......	‡194 gals.	‡140	......	......
......	......	61,709 cwt.	620,960	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......

CHAPTER III

AN ANALYSIS OF INDUSTRIAL CAPITAL IN CANADA[1]

The statistical tables which follow are published to show the place which British and foreign industries and extra-Canadian capital have attained in Canadian industrial development. The figures given, which are for the fiscal year ending March, 1919, and have been prepared by the Dominion Bureau of Statistics, are exceedingly conservative, for during the calendar years 1919 and 1920 the influx of extra-Canadian industries became more pronounced than ever before. For example, during these years in Toronto alone there were established 46 additional United States industries, as compared with 18 Canadian and 4 British (Report of Toronto Harbour Commission, 1920). When the compilation of 1920 figures is complete it may be found that the 34 per cent shown in the first table as the proportion held by United States capitalists in Canadian industries has increased to nearly 50 per cent, and that the British percentage has increased little or not at all.

It seems hardly necessary to comment on this situation. If foreign capital is attracted to such a remarkable extent by Canadian resources and industrial opportunities, surely they are worth more careful consideration by the United Kingdom. To put it briefly, unless the share held by foreign capital in the control and exploitation of the majority of Canadian manufactures and raw materials is to be predominant, British enterprise and Empire capital must assume their share of both the responsibility and the reward.

Table 3.—Stocks, Bonds and Other Securities Held by Incorporated and Joint Stock Companies Engaged in the Manufacturing Industries of Canada in 1918—Par Values

Nature of Security	Owned by 8,130,368 individual holders in			
	Canada	Great Britain	United States	Other Countries
	$	$	$	$
Stocks	790,512,678	136,686,566	494,706,199	13,838,322
Bonds	144,246,283	15,104,859	60,961,360	2,614,200
Other securities	10,684,697	1,966,400	275,618	768,800
Totals	945,443,658	153,757,825	555,943,177	17,221,322
Approximate percentage	56	9	34	1

N.B.—There are in addition to the securities above mentioned "Bearer Bonds," to the value of $25,984,786, and "Bearer Stocks" to the value of $3,395,000, the location of which cannot be definitely stated.

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[1] Prepared by the Dominion Bureau of Statistics and issued by the Commercial Intelligence Service, Department of Trade and Commerce, in 1922.

Table 4.—Distribution of Ownership of Stocks, Bonds, and Other Securities held by Incorporated and Joint Stock Companies in specified manufacturing industries in Canada in 1919, at par valuation[1]

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Lumber	126,012,126 61%	22,359,270 11%	54,794,285 27%	1,596,702 1%	204,762,383 100%
Pulp and paper	135,783,020 68%	8,405,006 4%	48,696,870 24%	8,519,128 4%	201,404,024 100%
Agricultural implements	39,660,962 58%	7,135,900 9·8%	21,003,000 31%	819,100 1·2%	68,618,962 100%
Foundries and machine shops	47,934,478 70%	5,725,736 8·4%	14,703,711 21%	37,895 0·2%	68,401,820 100%
Building and construction	21,608,880 46·4%	20,988,800 45%	3,905,250 8·4%	93,700 0·2%	46,596,630 100%
Electrical apparatus	15,873,808 36%	5,492,016 12%	21,572,290 49%	1,167,500 3%	44,105,614 100%
Cotton textiles	35,717,100 88·7%	2,385,550 6%	2,044,920 5%	135,600 0·3%	40,283,170 100%
Meat packing	20,558,790 57%	57,300 0·2%	14,809,820 41·4%	501,300 1·4%	35,927,110 100%
Rubber	13,539,474 40%	735,550 2%	17,037,400 50%	2,632,200 8%	33,944,624 100%
Flour and cereal mills	30,950,044 91·5%	1,348,385 3·8%	1,079,550 3·2%	489,050 1·5%	33,867,029 100%
Patent or proprietary medicines	3,280,819 12%	488,797 1·8%	23,639,650 86%	38,691 0·2%	27,447,957 100%
Paints and varnishes	9,861,028 44%	340,600 1·5%	10,415,500 47%	1,848,100 7·5%	22,465,228 100%
Sugar refining	12,841,196 67·2%	1,594,824 8·4%	3,221,612 17·2%	1,345,000 7·2%	19,002,632 100%
Automobile manufacture	5,912,800 39%	....	9,410,200 61%	....	15,323,000 100%
Car construction (except railway car shops)	5,526,000 40·4%	....	8,100,000 59·6%	....	13,626,000 100%
Artificial abrasives	53,700 0·4%	50,500 0·4%	11,400,075 99·1%	2,500 0·1%	11,506,775 100%
Drug and chemical trade	3,680,869 36%	3,821,997 37%	2,707,100 27%	....	10,209,966 100%
Automobile accessories	645,580 6·44%	15,200 0·15%	9,369,400 93·41%	....	10,030,180 100%
Brass and copper foundries	5,446,420 55%	9,700 0·1%	4,434,900 44·9%	....	9,891,020 100%
Condensed milk	2,274,300 48·5%	89,400 0·5%	1,888,980 40%	552,870 11%	4,705,550 100%
Petroleum refining	2,079,400 46·7%	10,800 0·2%	2,353,295 53·1%	550	4,444,045 100%

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[1] Compiled from twenty-one separate tables prepared by the Dominion Bureau of Statistics in which Stocks, Bonds, and other Securities are listed separately at par valuation. Percentage distribution of ownership is given approximately.

The distribution of the ownership of the various kinds of securities issued by Chemical, Metallurgical, and Mining companies incorporated in Canada has also been investigated by the Dominion Bureau of Statistics. The following three tables (Nos. 4a, 4b, and 4c), presenting conditions as at December 15, 1921, have been adapted from information supplied by this Bureau. Much additional statistical information on these subjects will be found in the reports on Chemical and Allied Products in Canada for 1919, 1920, and 1921, and also in the Industrial Review section of the annual report of the Mineral Production of Canada during the calendar year 1921.

Table 4a.—Distribution of Ownership of Securities issued by Chemical and Allied Companies incorporated in Canada as at December 15, 1921

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Chemical and Allied Products—					
Coal tar and its products	235,250	926,549	733,000	...	1,894,799
Approximate percentage	12	49	39	...	100
Acids, alkalies, salts, and compressed gases	14,650,220	7,100,788	18,627,016	43,800	40,421,824
Approximate percentage	36	18	46	...	100
Explosives, ammunition, fireworks, and matches	3,810,989	7,761,044	7,483,946	104,391	19,160,370
Approximate percentage	20	40	39	1	100
Fertilizers	741,350	16,500	29,000	...	786,850
Approximate percentage	94	2	4	...	100
Medicinal and pharmaceutical preparations	4,223,484	252,685	20,920,525	724,325	26,121,019
Approximate percentage	16	1	80	3	100
Paints, pigments, and varnishes	12,184,900	379,400	8,959,175	18,200	21,541,675
Approximate percentage	56	2	42	...	100
Soaps, washing compounds, and toilet preparations	3,726,878	5,449,066	32,403,821	5,907	41,585,672
Approximate percentage	9	13	78	...	100
Inks, dyes, and colours	249,230	12,000	1,378,090	6,280	1,645,600
Approximate percentage	15	1	84	...	100
Wood distillates and extracts	1,879,450	4,321,383	...	...	6,200,833
Approximate percentage	30	70	...	...	100
Miscellaneous chemical industries	2,199,650	167,200	35,441,233	218,900	38,026,983
Approximate percentage	6	...	93	1	100
Total for chemicals and allied products	43,901,401	26,386,615	125,975,806	1,121,803	197,385,625
Approximate percentage	22	13	64	1	100

Table 4b.—Distribution of Ownership of Securities issued by Metallurgical Companies incorporated in Canada as at December 15, 1921

Security	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Nickel-Copper Smelters and Refineries—					
Stocks	1,211,686	24,021,606	45,049,700	2,868,610	73,151,602
Bonds	3,020,936	19,218,823	754	306,152	22,546,665
Other Securities	926,139	66	....	3,634,995	4,561,200
Total	5,158,761	43,240,495	45,050,454	6,809,757	100,259,467
Approximate percentage	5	43	45	7	100
Silver-Cobalt Smelters—					
Stocks	1,933,505	....	5,025	....	1,938,530
Bonds	194,900	....	20,100	....	215,000
Total	2,128,405	....	25,125	....	2,153,530
Approximate percentage	99	....	1	....	100
Copper, Lead, Zinc—					
Stocks	14,283,700	....	12,000,420	....	26,284,120
Bonds	3,000,000	....	3,991,400	....	6,991,400
Total	17,283,700	....	16,491,820	....	33,275,520
Approximate percentage	51	....	49	....	100
Total, All Metallurgical Plants—					
Stocks	17,428,891	24,021,606	57,555,145	2,868,610	101,874,252
Bonds	6,215,836	19,218,823	4,012,254	306,152	29,753,065
Other Securities	926,139	66	....	3,634,995	4,561,200
Total	24,570,866	43,240,495	61,567,399	6,809,757	136,188,517
Approximate percentage	18	32	45	5	100

Table 4c.—Distribution of Ownership of Securities issued by Mining Companies incorporated in Canada as at December 15, 1921

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Metal Mining—					
Copper-gold-silver mining and milling[1]	9,905,844	3,201,082	38,031,198	44,114	51,182,238
Gold quartz mining and milling[2]	114,520,383	3,960,862	51,268,921	213,356	169,963,522
Gold placer and hydraulic mining	153,247	11,766,154	17,573,188	28,885	29,521,474
Iron mining and briquetting[3]	6,885,270	3,974,733	4,794,447	31,540	15,685,990
Molybdenite mining and milling[4]	4,086,529	2,700	3,158,305	248,169	7,495,703
Nickel-copper mining and milling[5]	5,308,766	43,240,495	45,050,454	6,809,757	100,409,472
Silver-cobalt mining and milling[6]	52,867,834	6,092,631	14,789,731	673,691	74,423,887
Silver-lead-zinc mining and milling[7]	26,099,377	616,313	10,193,511	2,603,555	39,512,756
Total for Metal Mines and Mills	219,827,250	72,854,970	184,859,755	10,653,067	488,195,042
Approximate percentage	45	15	38	2	100
Non-Metal Mines—					
Asbestos mining and milling	19,724,969	1,467,300	7,927,280	82,500	29,202,049
Coal mining	86,727,930	18,721,941	25,879,964	7,656,638	138,986,473
Gypsum mining and milling	1,484,550	400	1,484,500	68,350	3,037,800
Natural gas	13,237,270	2,803,999	6,825,823	....	22,867,092
Petroleum	3,388,922	7,050	2,882,689	....	6,278,661
Salt	1,469,080	76,600	305,300	....	*2,593,980
All other non-metallics	5,721,154	171,479	2,250,402	580	8,143,615
Total for Non-Metal Mines	131,753,875	23,248,769	47,555,958	7,808,068	*211,109,670
Approximate percentage	62	11	23	4	100
Structural Materials and Clay Products—					
Cement	35,116,930	4,297,246	809,100	405,400	40,628,676
Clay products	19,505,891	563,688	1,580,780	....	21,650,359
Lime burning	1,924,434	43,600	1,203,450	....	3,171,484
All other structural materials	9,329,940	160,500	503,610	....	9,994,050
Total Structural Materials and Clay Products	65,877,195	5,065,034	4,096,940	405,400	75,444,569
Approximate percentage	87	7	5	1	100
Grand total	417,458,320	101,168,773	236,512,653	18,866,535	774,749,281
Approximate percentage	54	13	31	2	100

[1] This group was composed of 10 producing, 5 operating but not producing, and 49 idle companies. There was also included the value of the stocks, etc., issued by the Granby Consolidated Mining, Smelting and Power Co., because the most important department of that company was copper production. It might be pointed out that the stocks of this company which operated coal and other non-metallic properties have been excluded from other compilations dealing with those groups so that duplication has been avoided.

[2] Includes 32 producing, 25 operating but not producing, and 93 idle incorporated companies.

[3] Includes 1 producing, 11 idle companies. Stock of Algoma Steel Company which operates iron properties not included here.

[4] Includes 10 idle molybdenite and 2 idle tungsten incorporated mining companies.

[5] Includes all stocks of nickel-copper companies and refers to mining, smelting and refining.

[6] Includes all silver-cobalt mining, milling and reduction companies situated at Cobalt, Gowganda and South Lorrain, Ontario, 22 producing, 7 operating but not producing, and 26 idle incorporated companies. Excludes stock of 3 silver smelters operating in Ontario.

[7] Comprises 19 producing, 8 operating but not producing, and 34 idle incorporated mining companies. Includes stock of the Consolidated Mining and Smelting Co., Trail.

*Includes $743,000 distribution of which was unknown.

The capital actually invested in these various industries is not necessarily the same as that shown by the total par valuations of the various securities. This fact is shown by two additional tables relating to the Metallurgical industries also prepared by the Dominion Bureau of Statistics. Table 4d shows the capital actually invested in these industries on December 15, 1921, while Table 4e shows the investment by residents of certain named countries, this latter table being derived from the data given in Table 4d by applying the actual percentages of investment derived from Table 4b.

Table 4d.—Capital Actually Employed in the Metallurgical Plants of Canada, 1921

	Nickel-Copper Smelters and Refineries	Silver-Cobalt Smelters	Copper, Lead and Zinc Smelters and Refineries	Total
	$	$	$	$
Lands, buildings, plant machinery and tools...	22,303,585	1,433,442	31,823,524	55,560,551
Materials on hand, supplies, finished products and ore on dump..........................	10,467,385	2,105,786	9,234,445	21,807,616
Cash, trading and operating accounts and bills receivable................................	4,062,590	444,096	812,092	5,318,778
Total................................	36,833,560	3,983,324	41,870,061	82,686,945
Approximate percentage..............	44	5	51	100

Table 4e.—Actual Investment in the Metallurgical Industry in Canada by Residents of the Countries Indicated

	Canada	Great Britain	United States	Other Countries	Total
	$	$	$	$	$
Nickel-copper....................	1,895,087	15,885,578	16,550,423	2,502,472	36,833,560
Silver smelters..................	3,935,524	....	47,800	....	3,983,324
Copper-lead-zinc................	21,353,731	....	20,516,330	....	41,870,061
Total.......................	27,184,342	15,885,578	37,114,553	2,502,472	82,686,945
Approximate percentage......	33	19	45	3	100

Similar information has been compiled showing the capital invested in the chemical and allied group of industries and in mining. In 1919 the total par valuation assigned to the securities of the companies reporting under the chemical group was $175,979,843, while the total capital was $111,760,019.[1] Data for 1919 and 1920 are not available. The mining industry in 1921 was credited with a par valuation of securities of $774,749,281 as compared with a total investment of capital in these securities amounting to $559,514,154.[2] Parallel compilations covering the several industries tabulated in Table 3 are not at present available.

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[1] Chemicals and Allied Products, 1919 and 1920, pp. 10 and 11.

[2] Report on the Mineral Production of Canada for 1921, pp. 126 and 129.

CHAPTER IV

BUREAUS OF INFORMATION

Persons requiring information about Canada's resources, development, markets, or industries may find the following directory of Public Service bureaus of some assistance. Inquiries should be addressed to the Department or Branch most immediately concerned with the subject of inquiry. It should be noted that each of the provinces formulates its own laws regulating mining, workmen's compensation, and company incorporations of provincial status. The provinces of Nova Scotia, New Brunswick, Quebec, Ontario, and British Columbia also control both surface and mining rights on Crown lands. The Federal Government at Ottawa formulates laws regulating mining on Dominion lands, employment, or company incorporations having interprovincial or Dominion status. The mining rights of Crown lands in the provinces of Manitoba, Saskatchewan, and Alberta, and in Yukon, the Provisional Districts of Mackenzie, and Franklin (including the Arctic islands) are at present vested in the Dominion of Canada. Factory laws and regulations may be either Federal or Provincial.

Table 5

DOMINION OF CANADA.[1]

Geology, natural history and mining resources:
Geology and natural history.
Geological Survey Branch, Department of Mines.

Mineral resources and technology, or raw materials of industry.
Mines Branch, Department of Mines.

Mining laws and regulations relating to territory under Federal jurisdiction.
Mining Lands Branch, Department of the Interior.

Water-power resources and developments:
Dominion Water Power Branch, Department of the Interior.

Agricultural resources and investigations:
Department of Agriculture.

Forest resources and utilization:
Forestry Branch, Department of the Interior.

Fishery resources:
Department of Marine and Fisheries.

General information on natural resources:
Natural Resources Intelligence Service, Department of the Interior.

Commercial information:
Commercial Intelligence Service, Department of Trade and Commerce.

Statistical information of all Canadian activities:
Dominion Bureau of Statistics, Department of Trade and Commerce.

Customs and excise laws:
Department of Customs.

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[1] Address all inquiries to Ottawa, Canada.

Sanitary regulations, food regulations, stream pollution, etc.:
Department of Public Health.

Employment regulations and factory laws:
Department of Labour.

Incorporation and incorporations:
Under-Secretary of State.

Laws of Canada:
Department of Justice.

PROVINCES OF CANADA.[1]

Laws regulating incorporations, employment, workmen's compensation, etc.
Department of the Attorney-General for the particular province concerned.

Natural resources:
Manitoba—The Provincial Secretary, Winnipeg.
Saskatchewan—The Provincial Secretary, Regina.
Alberta—The Provincial Secretary, Edmonton.

Mining laws, regulations, and mineral resources:
Nova Scotia—Department of Mines, Halifax.
New Brunswick—Department of Lands and Mines, Fredericton.
Quebec—Department of Lands, Forests, and Mines, Quebec.
Ontario—Department of Mines, Toronto.
British Columbia—Department of Mines, Victoria.

It should also be noted that the Canadian railways have organized a number of information bureaus. These offices undertake to advise inquirers about land location and settlement, and to supply information concerning industrial opportunities and natural resources. The two principal railways maintain information offices at many points in the United States, in Europe, and in other parts of the world. The principal information offices in Canada are:—

Canadian National Railways, Department of Colonization and Development, Montreal, Quebec.

Canadian Pacific Railway, Department of Colonization and Development, Montreal, Quebec.

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[1] Address inquiries to the provincial capitals.

PART II

CHEMICAL INDUSTRIES

PRIMARY INORGANIC PRODUCTS

INTRODUCTORY

The industries grouped under this caption embrace all those which are engaged in the production of finished manufactural products through the controlled application of chemical forces to raw materials. A general survey of the field of industry shows that the number of different commercial products made by chemical processes is very great. No enumeration of the exact number of chemical products made for commercial purposes is possible. There are probably many thousands such, and new products are being added continually.

For purposes of study, however, it is possible to group the several industries making these products into a comparatively small number of classes. The order of arrangement selected has been more or less arbitrarily chosen for purposes of presentation. The industrial groups first described might be termed Primary Chemical Manufacturing Industries, because for the most part their products are made directly from natural raw materials, and most of these products are made primarily for use in other industries. The second group of chemical industries will include those making secondary finished chemical products from primary chemicals alone or in combination with natural raw materials. The third great group of industries comprises those that are usually termed General Manufacturing. In this group chemical processes play a most important part, but the principal raw materials are usually natural products, and chemicals and chemical processes play a minor though more or less essential part.

In the following discussions no specific reference is made to water as an essential commodity in nearly all chemical industry. The use of heat in chemical industry and the sources from which it is obtained are not considered.

Changes in matter brought about by agencies which do not affect the composition of the material concerned are termed physical changes. Changes in matter brought about by agencies which affect the composition of the material concerned are termed chemical changes. The science of chemistry, in its broadest application, is the science which deals with chemical changes. Finished products produced by manufactural operations from any kind of raw materials are the result of the application of forces which promote physical changes alone, chemical changes alone, or, more frequently, both physical and chemical changes in the raw materials.

Logically it would appear that Chemical Manufacturing consists of the production of finished manufactural products through the promotion and control of chemical changes in raw materials. Actually chemical and physical processes are so intimately related that no such distinction can be made. There are very few industries in which physical processes alone are predominant. The production of refined cane sugar from raw sugar by solution, filtration, and evaporation is a process in which a minimum of chemical change is employed, but even here the clarification of syrups is promoted by chemical means. In the manufacture of beet sugar an important percentage of the sugar is recovered by chemical means. In the majority of industrial processes chemical changes play a much more important part, but always in association with operation of physical processes. It is therefore not desirable, nor indeed feasible, to draw any sharp distinction between manufacturing processes in which chemical processes predominate and those in which physical processes are the more active. The term Chemical manufacturing, as here used, is thus intended to include all types of manufacturing in which both chemistry and physics play important parts, without regard to the relative predominance of either type of process.

In enumerating accessory products, or materials used in these industries, detailed references to materials used in the construction of apparatus, often requiring continuous replacement, are omitted.

In many places in this report explanatory references are made to processes that are employed in chemical manufacturing, but it has not been considered advisable to include any technical descriptions of processes that are in operation in Canadian plants. Technical discussions of the methods of utilizing minerals and other raw materials in the different industries are reserved for consideration in special bulletins dealing with specific subjects. Trade specifications for different raw materials and products have also of necessity been omitted in these discussions, since they can be more appropriately considered in special reports dealing with single products or industries.

This part of the report is confined to a discussion of the manufacture of primary inorganic chemicals; the third part discusses primary organic chemicals; the fourth part deals with secondary products and chemical manufacturing. The last two sections of the series, parts six and seven, deal with Allied Industries, in which chemicals and chemical processes play an important part.

ALKALI INDUSTRY

PRODUCTS, BY-PRODUCTS AND INDUSTRIAL USES

(AMMONIA-SODA PROCESS)

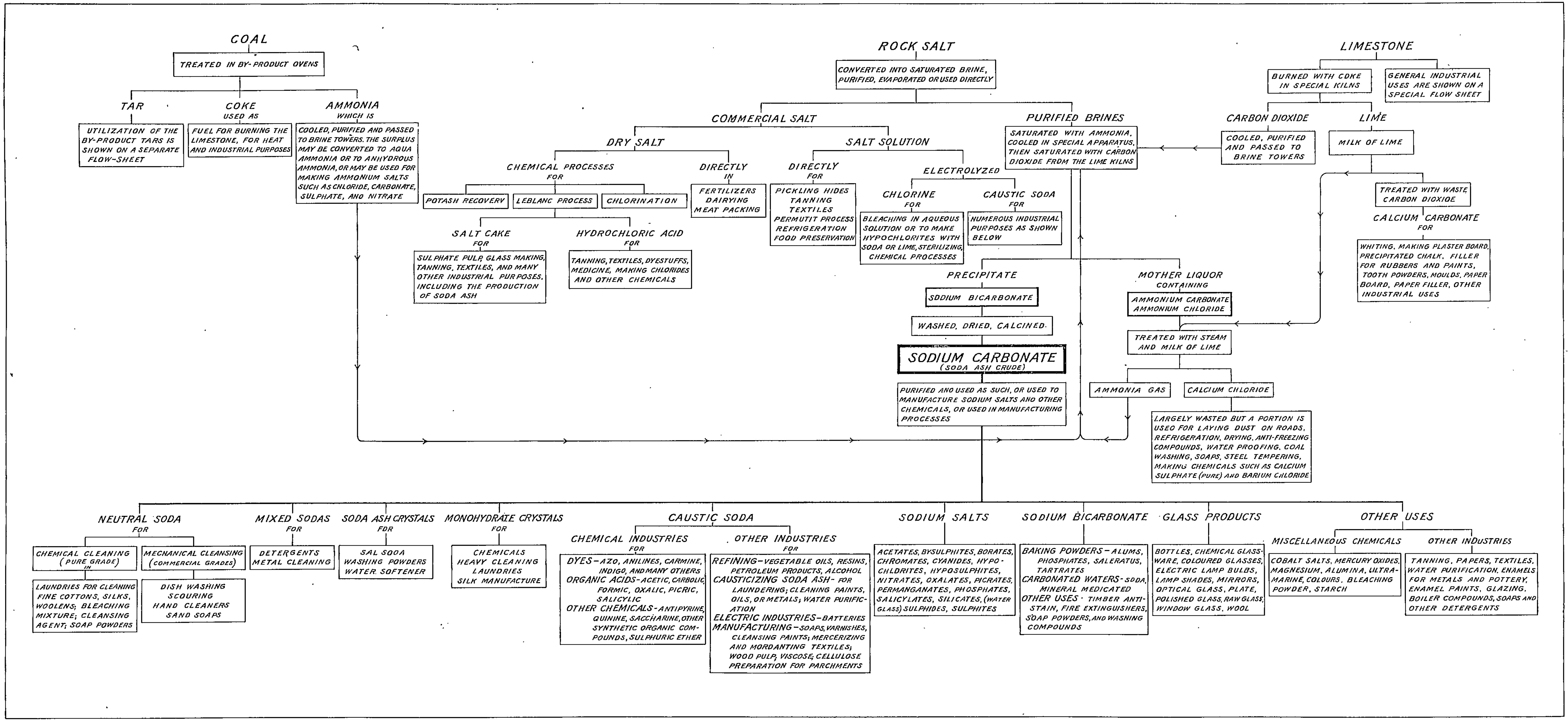

Diagram 2

CHAPTER I

HEAVY CHEMICALS

Chemical industry and industries using chemical products are, for the most part, founded upon the production of certain acids and alkalies. These products, directly or indirectly, are essential materials in the production of innumerable other products. Certain of these are usually made in large quantities from crude raw materials and, relatively to other chemicals, at a comparatively low unit cost. The products of this group of industries are termed heavy chemicals, and the industry is often referred to as the *Acid and Alkali Industry.*

The principal acids made are sulphuric, nitric, hydrochloric, and, occasionally, hydrofluoric. The principal alkali products are sodium sulphate, sodium carbonate, and sodium hydroxide; the principal byproducts are sodium thiosulphate and bleaching powder. Hydrochloric acid, also, is largely a byproduct of the alkali industry. The corresponding salts of potash are made by methods similar to those employed for making the sodium salts above enumerated, but their relatively higher cost tends to place them among the group of fine chemicals.

The principal raw materials of this group of industries are sulphur, Chili saltpetre, common salt, limestone, and coal or coke. The complete cycle of operations in an alkali works, using these raw materials, involves the production of sulphuric acid, sulphate of soda, hydrochloric acid, soda ash, caustic soda, and bleaching powder. All these products are not often made at the same works to-day owing to improved processes and to market conditions.

The following notes, largely non-technical in character, are intended only as a brief review of the Canadian situation with respect to these raw materials and products, and to the markets for the products.

SULPHURIC ACID

Pure sulphuric acid is a colourless odourless strongly corrosive liquid of an oily consistency, having a specific gravity of 1·8384 at 15° C. It begins to boil at 290° C. and the boiling point rises to 338° C. At about 400° C. the vapour dissociates into sulphur trioxide and water. At a higher temperature, about a red heat, there is still further dissociation with the production of sulphur dioxide and free oxygen. It freezes to a colourless crystalline solid at 10·5° C. The acid is extremely hygroscopic and can be mixed with water in all proportions; when strong acid is mixed with water there is a considerable amount of heat liberated and there is a decrease in volume.

Commercial sulphuric acid is frequently discoloured by impurities, so much so that the colour may become a deep brown. The common impurities are iron, arsenic, and lead sulphate.

There are a number of commercial grades of acid commonly produced and marketed. The industrial applications of this product are very numerous and probably every degree of dilution finds application in some process. Pure acid, 100 per cent H_2SO_4, is termed oleum. This product may contain varying amounts of sulphur trioxide in solution. "Contact acid" is made by the "contact process" and commonly contains 98 per cent H_2SO_4; "Oil of vitriol" or "66° acid" contains 93·19 per cent H_2SO_4 and is the grade commonly shipped in tank cars; "Tower acid" or "60° acid," and "Chamber acid" (or 50° to 55° acid) also find many industrial applications.

Raw Materials

The essential raw materials for the manufacture of sulphuric acid are water, oxygen, and sulphur. The two former are obtained from natural supplies, the oxygen of the atmosphere being utilized. Sulphur may be obtained as a natural mineral product, or it may be secured through the proper treatment of certain mineral sulphides, pyrites, the sulphide of iron, being the most important. All processes of manufacture involve the production of sulphur dioxide. This gas is a waste product in preliminary metallurgical operations for recovering metals from natural sulphides (particularly sulphides of copper, nickel, zinc, and lead) and this waste gas may also be utilized for the production of sulphuric acid.

Certain accessory materials are also required in the manufacture of this acid. Where the chamber process is employed natural nitrate of soda is used for the production of oxides of nitrogen which act as "oxygen carriers." In the contact process catalytic agents are required. The two commonly employed are ferric oxide and finely divided platinum. The finely divided platinum used for this purpose is specially prepared by soaking asbestos fibre, or magnesium sulphate, with a solution of chloride of platinum and then heating to a temperature high enough to drive off the chlorine. The resultant contact mass usually contains between seven and eight per cent of metallic platinum in a very fine state of division.

The accessory materials required for the construction of apparatus and for the operations of plants of different types are too extensive to be enumerated here.

Processes

The first step in every process is the production of sulphur dioxide by the oxidation of natural sulphur, or by oxidizing the sulphur present in certain metallic minerals, such as pyrites, blende, or galena. This gas is then treated in suitable equipment for the production of sulphuric acid by further oxidation and hydration. Two general types of processes are employed, known respectively as the chamber process and the contact process. Each of these processes is carried out in specially designed and constructed apparatus.

In the chamber process sulphur dioxide is brought into contact with oxygen (air) and water in the presence of nitrous oxides. These nitrous gases are made by the decomposition of sodium nitrate with strong sulphuric acid and function as "oxygen carriers" to promote the formation of the sulphuric acid from sulphur dioxide and atmospheric oxygen in the presence of water (as steam). Chamber acid, owing to the nature of the process, is always dilute. Where greater strengths are required it is necessary to employ some method of concentrating. This is usually done by heating in specially devised equipment constructed of acid resisting materials, such as sheet lead, platinum, acid proof alloys, chemical stoneware, acid proof brick, or fused silica products.

In the contact process sulphur dioxide and oxygen are combined, in the presence of a catalyzer, to produce sulphur trioxide. This product is then brought into contact with water to produce sulphuric acid. It is possible to make acid of any required strength directly by this method. In its operation it is essential that all gases employed be thoroughly cleaned by scrubbing and filtering before they come in contact with the catalyzing agent. Vapourized sulphur, flue dust, oxide of arsenic, and compounds of phosphorus or of mercury, which might be present in the gases produced by the roasting of pyrites, or other sulphide ores, would destroy the catalyzer if allowed to come in contact with it.

Where sulphur dioxide obtained from metallurgical operations is utilized the gases are first cleaned and then converted into sulphuric acid by the chamber process.

Industrial Uses

Sulphuric acid is probably the most important single chemical product manufactured. It enters into the manufacture of numerous other products and finds application, directly or indirectly, in almost every industry. Only a few of the principal industrial applications are listed here.

Oleum (sulphuric anhydride or Nordhausen fuming oil of vitriol) is used in the manufacture of certain explosives, and of certain products used in the dye industry (organo-sulphonic acids in the manufacture of alizarin, eosine, indigo, etc.); for purifying ozokerite; for making shoe-blacking; for raising the strength of weaker but concentrated acid as required.

Concentrated sulphuric acid is used in the explosives industry for producing many nitro-compounds, such as nitro-glycerine, pyroxylin, nitrobenzene, picric acid, and related products; for making nitric ether; for making organo-sulphonic acids; for manufacturing indigo; for drying air for laboratory purposes and for drying air or other gases in manufacturing processes; for purifying natural gas and petroleum products, such as benzene, coal oil, paraffin oil, and other mineral oils; for purifying colza oil; for the manufacture of fatty acids.

Dilute acid, chiefly chamber acid, is used in the manufacture of a great number of important products. The two principal applications are the making of artificial manures, and especially monobasic calcium phosphate (superphosphate fertilizers), and the manufacture of salt cake (sulphate of soda) and hydrochloric acid. Salt cake is a basic material from which are made such products as soda ash, bleaching powder, glass, soap, and many other articles. Chamber acid finds application in the manufacture of a number of acids such as acetic, boric, carbonic, chromic, citric, hydrochloric, hydrofluoric, nitric, phosphoric, stearic, sulphurous; in the making of fine chemicals such as bromine and iodine; for the production of sulphates of the metals aluminium, ammonium, barium, calcium, copper, iron, magnesium, mercury, zinc, and others; in the metallurgy of cobalt, copper, gold, nickel, platinum, silver, and zinc; in the tin plating and galvanizing industry for cleaning the surfaces of iron or steel articles; for cleaning other metal surfaces such as copper and silver; for the operation of galvanic batteries; in the preparation of electrolytes for plating; in the manufacture of various ethers; in the manufacture of many organic colour compounds; for making artificial parchment; for purifying mineral oils; in the manufacture of starch, syrups, and sugar; in the production of glucose; for the production of carbon dioxide, particularly in the manufacture of aerated waters; in the preparation of certain byproducts in the meat packing industry; for destroying fabric fibres in the reclaiming of rubber; in various processes connected with dyeing, in calico printing, tanning, and the textile trades; as a chemical reagent in both laboratory and factory; and in many other operations.

Imports and Exports

The average imports for the three years 1911-14 were 2,056,303 lbs., valued at $16,567, an average unit price of ·81 cent per pound. In the year 1918-19, 12,185,903 lbs. were imported, valued at $206,691, an average unit price of 1·7 cents per pound.

During one of the three years 1911-14 the export of 6,245,086 lbs. was reported, valued at $37,413. In 1918-19, 5,463,000 lbs., valued at $75,857, were exported.

None of the published returns indicate the strength of the acid imported or exported, and there is no intimation that the returns published are based on an acid of uniform strength.

The following tables show statistical data with respect to the Canadian annual production, imports, and exports:—[1]

Table 6. Sulphuric Acid in Canada, 1912-1919.

—		1912	1913	1914	1915	1916	1917	1918	1919
MATERIALS USED:									
Sulphur	Tons	4,773	4,281	2,227	4,716	20,566	25,994	25,552	2,245
Pyrites*	"	27,680	31,774	33,331	55,586	62,681	66,128	75,941	54,879
Production 66° Bé**	"	44,651	47,227	41,919	75,838	124,920	153,530	190,621	63,596
Imports	"	2,486	73	166	141	2,403	216	5,954	1,437
Exports	"	None	1,247	3,743	9,635	1,576	9,478	5,600	5,447

*Canadian pyrites as shipped contains on yearly averages 37—40% sulphur.

**Record includes a small production of oleum and other grades the strength of which is not specified. Production records of 50° Bé. and 60° Bé. acid have been reduced to 66° Bé. acid for statistical purposes.

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[1] Compiled by the Division of Mineral Resources and Statistics.

Canadian Situation

Native sulphur is not found in Canada in commercial quantities. Where this material is used it has to be imported. The supply for Nova Scotia points was formerly imported from Sicily, but at present it is secured from Louisiana or Texas. Quebec and central Ontario obtain supplies from Louisiana or Texas. British Columbia supplies come from Japan chiefly.

Pyrites, the principal metallic sulphide which is used as a source of sulphur for the manufacture of sulphuric acid, is available in Canada in large amounts. Before the war there was a large surplus production available for export. It was utilized in certain chemical works in central Ontario and in British Columbia. It was also available in Quebec, but in recent years it was not utilized for acid making in this province, imported sulphur proving more convenient. Newfoundland pyrites was formerly imported for acid making in Nova Scotia, but at present native sulphur alone is used. At present very little pyrites is being used in Canada for the production of sulphuric acid.

With respect to accessory materials required in the industry nitrate of soda is imported from Chili for use in the chamber process. The platinum, or the platinum product required for the contact process, is also imported. The life of a unit is long and the amount required is small but expensive owing to the high cost of platinum.

There are nine plants in Canada for the manufacture of sulphuric acid distributed as follows: one in Nova Scotia, one in Quebec, four in Ontario, and three in British Columbia. Three of these plants are producing acid for private use only; six plants, one in Quebec, three in Ontario, and two in British Columbia, produce acid for commercial distribution as such as well as for private use. The plant in Nova Scotia, three plants in Ontario, and two in British Columbia use the chamber process, and where necessary concentrate their acid. One plant in each of the provinces of Quebec, Ontario, and British Columbia uses the contact process, there being a total installation of six contact units.

The normal consumption of sulphuric acid in Canada prior to the war was between forty-five and fifty thousand tons of 66° Bé. acid or the equivalent. This consumption naturally increased greatly during the years 1915-16-17-18, but there was an apparent falling off in 1919, when the production was 63,596 tons. Only a very small quantity is exported. The imports are low and irregular.

Two Canadian plants are producing sulphuric acid for the manufacture of ammonium sulphate as a byproduct in connection with the operation of byproduct coke oven installations. Two firms operating coke ovens of this type at present purchase sulphuric acid as required. One plant in Ontario, formerly used in explosive manufacture, was reopened for a time; the acid produced was utilized in making fertilizers and certain other chemical products. One plant in British Columbia is making acid for use in the metallurgy of zinc.

Sulphuric acid is shipped in bottles, carboys, iron drums, and tank cars. Its corrosive character renders it somewhat dangerous to handle and freight rates are high. It is customary to manufacture this product in the vicinity of the absorbing market. The existing Canadian plants are able to provide for present demands and have considerable annual capacity in reserve.

It would be feasible to greatly increase our present output of sulphuric acid by utilizing the waste gases produced in the metallurgical operations of the copper-nickel plants in the Sudbury region were it possible to market the product. At present commercial conditions and the cost of marketing the product make this impracticable.

NITRIC ACID

Strong nitric acid free from impurities is an almost colourless liquid at ordinary temperatures, fuming when exposed to the air, and very strongly corrosive. Under the influence of strong light it may become pale amber yellow in colour, and the same effect is produced by heating slightly, or through the presence of small amounts of organic matter as impurities. The pure acid has a specific gravity of 1·53, its melting point is —41·3° C. and it boils at 86° C. It is soluble in water or in alcohol in any proportion. It is more mobile than sulphuric acid and nearly one-third lighter in weight.

This acid is sold as fuming nitric acid when it has a specific gravity of 1·48 (47·1° Bé.) or higher, corresponding to about 86 per cent pure acid. There are also a number of commercial grades with specific gravities ranging between 1·33 (36° Bé.) and 1·436 (44° Bé.). The first of these contains 52·30 per cent pure nitric acid (HNO_3) and the last 73·67 per cent. "Dynamite acid" is a name sometimes applied to acids of strength higher than 88 per cent, which are used for the production of the mixed acids (nitric 34 per cent, sulphuric 62 per cent) used in making nitroglycerine.

Raw Materials

Nitric acid is usually made from sodium nitrate (or Chili saltpetre) and sulphuric acid. Sodium nitrate is a natural salt found in certain arid regions, the world's supply coming chiefly from Chili. This salt frequently contains small amounts of sodium chloride which must be eliminated by purification before use, if it is desired to produce pure nitric acid.

This acid can also be produced by the fixation of atmospheric nitrogen. (See chapter III, page 74.)

A third process of manufacture is by the oxidation of ammonia gas (NH_3) obtained as a byproduct in coal tar distillation, or by one of the processes for fixing atmospheric nitrogen.

Processes

Commercial nitric acid is usually prepared by the action of sulphuric acid on sodium nitrate ($NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$). The operation is usually carried out in specially constructed cast iron retorts.

The retorts are heated before charging with sodium nitrate, the temperature being such that the whole charge is heated slightly above the boiling temperature of nitric acid. Sulphuric acid (about 92—95 per cent H_2SO_4) is then added, and the temperature is maintained for a time, and then gradually raised to promote a gradual and steady distillation of nitric acid. The acid distilled from the retorts is condensed in series of special earthenware or glass Woulfe bottles, or in condensers of special design. There are a number of types of apparatus in use for carrying out this process, the different designs having been developed to promote the efficiency of the operations in various ways and to increase the recoveries.

The processes for making nitric acid by the fixation of atmospheric nitrogen are described in the chapter on Production of Nitrogen Compounds (page 74).

Nitric acid can also be produced by the oxidation of ammonia (NH_3), as in the Haber process, or by modifications of this process. Further reference to this subject is made in the above mentioned chapter.

Industrial Uses

Nitric acid is strongly corrosive, this action being due to oxidation in part, and in part to the formation of certain nitrogen compounds. This fact makes it an important agent for the promotion of organic synthesis, and in the manufacture of certain dyestuffs and explosives. Nitrates or nitrogen compounds, made by the use of nitric acid, are essential to the production of almost every explosive. It is used for making synthetic dyestuffs, azo, diazo, and amido compounds, and pyroxylin (nitrated cellulose).

Nitrates of the metals are all soluble in water and are used in electroplating. Certain nitrates of the metals are used in the preparation of coloured fires and other forms of fireworks, owing to their high oxidizing power. Certain other salts, particularly nitrate of soda and nitrate of potash, but also nitrate of lime or nitrated lime, are important fertilizers. The nitrates of soda and potash are obtained chiefly from natural deposits; the nitrated lime products are artificial.

This acid also finds applications in metallurgy, in medicine, in engraving and etching, and in many minor industries.

Canadian Situation

Nitrate of soda has not been found in Canada in commercial quantities. The supplies used in this country are imported from Chili, either directly or through the United States. Deliveries are made both on the Atlantic and on the Pacific seaboard by boat and in the central provinces by rail. Sulphuric acid, as previously noted, is prepared in this country.

Nitric acid has not been made in Canada on a commercial scale, either directly from the nitrogen of the atmosphere or by the oxidation of ammonia.

Nitric acid is a dangerous material to handle or to transport. When shipped it is usually stored in glass bottles or carboys. As far as possible it is utilized as close to the points of production as possible. Nitrates of the metals, on the other hand, may usually be transported without serious danger when reasonable precautions are taken. Nitrates suitable for use as fertilizers can be readily transported. This fact is of considerable importance in relation to the possible expansion of this chemical industry in Canada.

The agricultural areas of Canada, where increased quantities of nitrate fertilizers will be in demand in the future, are for the most part located long distances from the regions where cheap hydro-electric power can be developed. Cheap hydro-electric power will, in the future, be the basis of a large air nitrate industry, and it is along this line that there appears to be opportunity of expanding this industry in Canada. It will be necessary, however, to manufacture products that can be distributed to the market without serious difficulty and at reasonable rates.

At the present time there are four nitric acid plants in Canada, two being located in Quebec, one in Ontario, and one in British Columbia.

No statistical data with respect to the normal annual production of this acid in Canada are available. The average importation for the three years prior to the war was 194,086 pounds. There is no record of any exports, and the strength of the acid imported is not given.

HYDROCHLORIC ACID

Hydrochloric acid is the name usually applied to the aqueous solution of hydrogen chloride. This solution is a clear colourless liquid, fuming when saturated, slightly yellow in colour when not absolutely pure, pungent and irritating to the mucous membranes. Anhydrous hydrogen chloride is a colourless gas at ordinary temperatures. When cooled under pressure it can be condensed into a liquid. The boiling point is $-83 \cdot 1°$ C., and the melting point $-112 \cdot 5°$ C. The solubility of anhydrous hydrogen chloride in water varies with the atmospheric temperature. Solutions containing more than 20·17 per cent of the anhydrous chloride lose both gas and water on heating. Solutions containing this percentage or less distil at 110° C. without change. A solution of this strength has a specific gravity of 1·10, corresponding to 13·3° on the Baumé scale. The commercial grade of this solution usually sold as "muriatic" acid, contains about 27·92 per cent anhydrous hydrogen chloride, corresponding to 18° Bé., or a specific gravity of 1·417. The stronger acid sold as C.P. grade (chemically pure) contains 34·26 per cent anhydrous hydrogen chloride, and has a specific gravity of 1·1745, corresponding to 21·5° Bé. Fuming acid may be of a higher specific gravity and contains more anhydrous hydrogen chloride. Acids of various degrees of dilution are required in industry.

Raw Materials

The principal raw materials used for the manufacture of this acid are common salt (sodium chloride, NaCl) and sulphuric acid. When these products are used the principal product of the operation is sodium sulphate (salt cake and Glauber's salt) and the resulting hydrochloric acid may be regarded as byproduct. One process uses sulphur dioxide gas, usually made from pyrites, in place of sulphuric acid.

Processes

Salt cake and anhydrous hydrogen chloride are produced by the decomposition of sodium chloride with sulphuric acid. The reaction takes place in two stages as shown by the equations, $NaCl + H_2SO_4 = NaHSO_4 + HCl$ and $NaCl + NaHSO_4 = Na_2SO_4 + HCl$. The first reaction takes place at ordinary temperatures, the second requires considerable heat to promote complete decomposition. The aqueous solutions of the anhydrous chloride are made by thoroughly cooling the gas and absorbing it in water by passing through a series of Woulfe bottles, coke towers, or both.

Hydrochloric acid can be made by causing hydrogen gas and chlorine to combine in the presence of a catalyst.

In some works the decomposition of sodium chloride for the production of sodium sulphate and hydrochloric acid is accomplished by the use of sulphur dioxide in the presence of atmospheric oxygen and steam under suitable conditions (Hargreaves process). The sulphur dioxide used is prepared by roasting pyrites, as in the manufacture of sulphuric acid. The anhydrous hydrogen chloride liberated by the reactions is recovered by cooling and absorption. The equation for the reaction is as follows:— $2NaCl+SO_2+O+H_2O=Na_2SO_4+2HCl$.

Industrial Uses

Hydrochloric acid is used for cleaning the surfaces of iron and steel products prior to tinning; in the manufacture of glue; in the preparation of fatty acids from lime soap; in organic synthesis and in the manufacture of dyes; for the production of the chlorides of the various metals; in the textile industry; in the production of certain kinds of leather; in medicine.

Imports

The average imports for the three fiscal years 1911-14 were 910,934 lbs., valued at $10,286, an average unit price of 1·13 cents per pound. In 1918-19 it was 95,618 lbs., valued at $7,558, an average unit price of 7·9 cents per pound. For the year ending March 31, 1920, the importations were 84,952 lbs., valued at $5,613, an average unit price of 6·6 cents per pound. These data published by the Department of Customs do not indicate the strength of the acid imported.

Canadian Situation

Natural deposits of the principal raw material, common salt, are found in Nova Scotia, Ontario, and Alberta. Commercial production takes place in the first two provinces named, and it is probable that salt will also soon be produced in Alberta. Brine springs have been reported from other provinces, but no commercial production of salt has developed. Salt for use in British Columbia is imported.

There are three firms in Canada equipped to produce hydrochloric acid. Two of these operate plants in Ontario, and one in British Columbia. Statistical data with respect to the annual production are not available.

Hydrochloric acid is a corrosive liquid and expensive to ship. It is usually shipped in carboys or in glass bottles, but it can be shipped in wooden tank cars. It is therefore desirable to manufacture as much as possible in proximity to the markets for the product. At the present time the existing Canadian works appear to be able to provide for all local demands.

SODIUM SULPHATE

Sodium sulphate is one of the principal products of the alkali industry. Technically artificial anhydrous sodium sulphate (Na_2SO_4) is generally called "salt cake." The hydrated salt ($Na_2SO_4 \cdot 10H_2O$) is named Glauber's salt.

Glauber's salt is found as a natural constituent of the waters of certain alkaline lakes, or in deposits of salts in the beds of these lakes. Such deposits occur in the lowest portions of many of the undrained topographic basins in the provinces of Manitoba, Saskatchewan, Alberta, and British Columbia, forming the so-called alkali lakes.

Processes

Artificial sodium sulphate (salt cake) is made from common salt (NaCl) by treatment with sulphuric acid. It can be made by treating common salt with pyrites or with such salts as magnesium sulphate, calcium sulphate, ferrous sulphate, or other metallic sulphates. It is also obtained as a byproduct in the manufacture of hydrochloric acid.

A large quantity of sodium sulphate is now made by the Hargreaves process in which sulphur dioxide (made from pyrites or sulphur) is used. The reaction takes place in the presence of moisture and atmospheric oxygen, when sodium chloride has been heated to a suitable temperature.

$$2NaCl+SO_2+O+H_2O=Na_2SO_4+2HCl.$$

Industrial Uses

Sodium sulphate is used for the production of sulphate pulp, and in the manufacture of plate glass, sheet glass, and bottle glass. Soda ash and Glauber's salt are both made from it. There are also a number of minor uses such as the manufacture of artificial indigo, and certain other chemicals, particularly salts of sodium such as sodium hypochlorite (used in photography and tanning), sodium thiosulphate, sodium acetate; it is also used occasionally as a fungicide.

Imports and Exports

The average importations during the three fiscal years, 1911-14, prior to the war were 21,031,292 lbs., valued at $112,112, an average unit price of 0·53 cent per pound. The imports in the fiscal year 1918-19 were 67,617,762 lbs., valued at $626,446, an average unit price of 0·93 cent per pound. In the year ending March 31, 1920, the imports were 53,920,065 lbs., valued at $409,642, an average unit price of 0·76 cent per pound. No exports of this commodity are reported by the Department of Customs.

The average importation of Glauber's salt during each of the three years prior to the war was 1,448,510 lbs., valued at $7,000, an average unit price of 0·48 cent per pound. In 1918-19, 551,213 lbs., valued at $10,080, were imported, at an average unit price of 1·80 cents per pound. In 1919-20 the imports were 710,177 lbs., valued at $8,871, an average unit price of 1·11 cents per pound.

At the present time the Canadian kraft pulp industries consume about 40,000 tons of anhydrous sodium sulphate annually and the demand is steadily increasing.

Canadian Situation

Natural sodium sulphate occurs as one of the constituents of the brines in certain alkaline lakes in the provinces of Manitoba, Saskatchewan, Alberta, and British Columbia. It also occurs in the beds of the lakes in layers, usually associated with other salts and with peaty material. A pure Glauber's salt can be obtained by evaporating the brines or by dissolving the soluble salts already deposited, and separating the sulphate of soda by differential crystallization. Glauber's salt contains 55·9 per cent water of crystallization. It will be necessary to develop processes of eliminating this water on account of the high freight rates to eastern markets, before it is commercially practicable to develop these deposits. Theoretically this appears easy, but there are a number of practical difficulties in the way of development which have not yet been overcome. Several attempts have been made to develop some of these deposits, but only one company appears to have attained any marked measure of success.

The principal raw material for the production of the artificial sulphate of soda is common salt. As already noted in discussing the raw materials for making hydrochloric acid, this material is available in the provinces of Nova Scotia, Ontario, and Alberta.

At the present time there are three firms equipped to produce anhydrous salt cake from sodium chloride, two plants being located in Ontario, and one in British Columbia. Canadian production has amounted to 6,000 tons per annum, but normally is much less than this, being largely dependent upon the ability of the home market to absorb hydrochloric acid.

SODA ASH

Crude commercial sodium carbonate is known as soda ash. It is a yellowish or greyish white material, in powder or lump form, containing 98—99 per cent sodium carbonate (Na_2CO_3) and slight quantities of sodium chloride, caustic soda, sodium sulphate, sodium sulphite, calcium or magnesium carbonate as impurities. The finished product is often ground before packing for shipment.

Processes

In the ammonia-soda (Solvay) process soda ash is made from common salt by treating a saturated solution with ammonium carbonate or with ammonia gas, and carbon dioxide under pressure. The resulting product is sodium bicarbonate, which is insoluble in the saturated brine and therefore is precipitated. The bicarbonate ($HNaCO_3$) is separated from the brine by filtration, washed and treated in special calcining furnaces to form the carbonate. In the operation of the Solvay process ammonia gas is usually obtained as a byproduct from coke ovens. The ammonia liquors, available as a waste product in municipal gas works, are also suitable for use in this process. The ammonia used in the process, which remains in the liquors as ammonium chloride, is recovered by treatment with lime. The final waste product is a solution of calcium chloride. Carbon dioxide is obtained by burning limestone with coke under careful control to obtain the maximum yield of gas. The lime obtained is used in the process of recovering ammonia from the waste liquors.

Soda Ash by the Ammonia-Soda Process

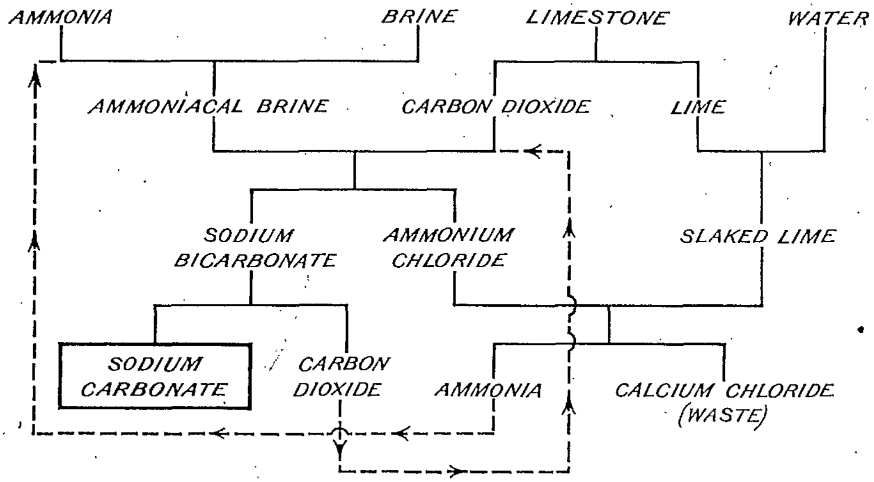


Diagram 3

Soda ash is also made by the Leblanc process. The raw products required are sodium sulphate, calcium carbonate (limestone), and coal. Mixed in proper proportions these materials are heated to fusion into a thick pasty mass, a special type of reverberatory furnace being employed. At this temperature reactions take place which result in the formation of sodium carbonate. When the reactions are completed the product is drawn from the furnace and cooled. In this stage the product is a more or less black porous mass, currently termed " black ash." The black ash is subjected to lixiviation with water, the resulting liquors after filtration contain sodium carbonate in solution, together with small amounts of sodium hydroxide and other sodium salts as impurities. The liquors are evaporated to a density sufficient to cause the sodium carbonate to crystallize.

The crystallized carbonate is then treated in a special calcining furnace, usually of the reverberatory type.

Incidentally the residues after lixiviation contain calcium sulphide. If these residues are treated with carbon dioxide the sulphide is decomposed with the formation of hydrogen sulphide and calcium carbonate. The hydrogen sulphide can be converted directly into sulphuric acid by oxidation, or can be treated to recover elemental sulphur.

Soda Ash by the Leblanc Process

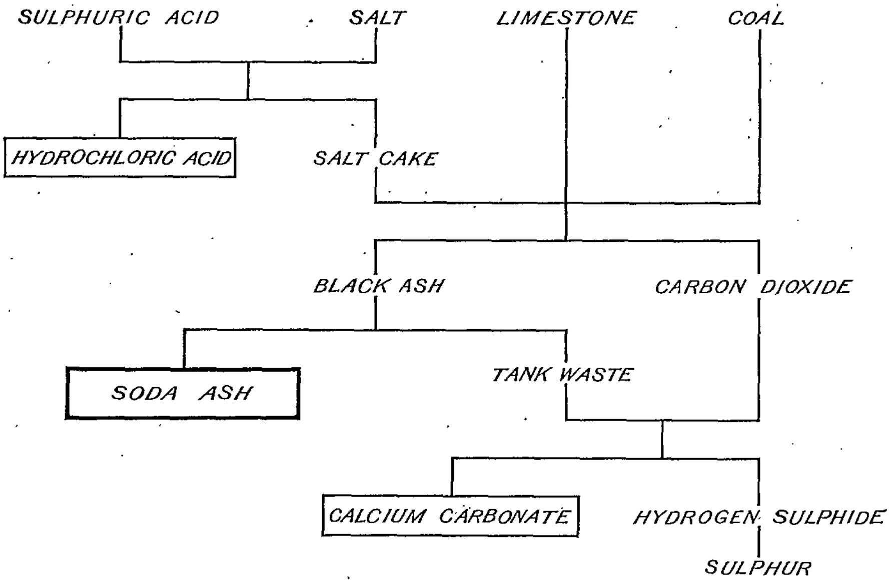


Diagram 4

It is sometimes necessary to subject crude soda ash to a further refining process to eliminate impurities that are objectionable in certain industries where pure soda ash is required. Refining is usually accomplished by dissolving the crude soda ash in hot water, precipitating the impurities where possible by treatment with bleaching powder, settling, decanting the clear solution, and concentrating the resulting clear liquor by evaporation.

Crystallized sodium carbonate ($Na_2CO_3 \cdot 10H_2O$) is marketed under the commercial name of washing soda.

Sodium bicarbonate ($HNaCO_3$) is made from the crystallized carbonate by special treatment with carbon dioxide.

Industrial Uses

Soda ash is one of the most important products of the Alkali industry, and is an essential material in many manufacturing processes. It enters into the composition of glasses; washing, laundering, and cleaning compounds may contain it; it is used in the manufacture of soaps, and certain grades of paper. It finds applications in paint manufacture, in the production of leather, in the dyeing of textiles, in the making of enameled metal products, in the refining of oils, and in metallurgy. It can also be used for the production of caustic soda, or for the production of numerous sodium salts. Washing soda and sodium bicarbonate are made from it.

Washing soda finds special applications in laundering, washing, and cleaning preparations, in the washing and bleaching of cotton, wool, linen, and other fabrics, in dyeing or printing fabrics, in the manufacture of certain grades of glass and soap. Some boiler compounds designed to prevent the formation of scale contain this product. It is also used in photographic work, in paper making, and for making fine chemicals of which sodium is the base.

Sodium bicarbonate finds its principal application in the compounding of baking powders, and in culinary operations. It is also used as the vehicle to supply carbon dioxide in the manufacture of numerous preparations for making aerated beverages. It finds applications in the tanning and textile industries, in electroplating with gold or platinum, and in the manufacture of fire extinguishers.

Imports

The average imports during the three fiscal years prior to the war, and the imports during the last two fiscal years are shown in table 7.

Table 7.—Imports of Soda Ash

—	1911-14		
	Quantity	Value	Unit price
	lbs.	$	cts.
Soda ash	56,246,241	432,598	0·77
Sal soda	9,656,176	59,861	0·62
Sodium bicarbonate	6,265,076	59,338	0·95

—	1918-19			1919-20		
	Quantity	Value	Unit price	Quantity	Value	Unit price
	lbs.	$	cts.	lbs.	$	cts.
Soda ash	86,260,061	1,915,923	2·2	52,016,313	1,075,084	2·1
Sal soda	10,671,902	171,346	1·6	10,619,962	158,059	1·5
Sodium bicarbonate	7,109,060	150,772	2·1	7,443,148	164,198	2·2

Canadian Situation

The basic raw material of the alkali industry is sodium chloride. This mineral, as already indicated, is available in Nova Scotia, Ontario, and Alberta. The ammonia-soda processes also require limestone and coke. The former is obtainable locally, but the latter is not so readily available. In Nova Scotia it could be obtained from coals produced in coal fields near the salt-producing locality; in Ontario none is available, and the supply must be imported or made from imported coal. In Alberta the prospective salt-producing areas are far from present markets and far from available supplies of coke. In the future, if the western markets for the alkali products expand, it may be feasible to assemble both raw products at some central point. Present commercial practice is to conduct operations in the vicinity of the salt-producing area, largely for reasons of economy in operation. It is only under exceptional circumstances that it would be profitable to depart from this practice.

Supplies of ammonia are obtainable from byproduct coal distillation plants and from the waste ammoniacal liquors of local gas plants producing illuminating gas from coal. Byproduct plants are located in the coal fields of Nova Scotia and in British Columbia, and additional plants will probably be erected in the future. At present the byproduct ammonia is converted into ammonium sulphate for the fertilizer trade. An alkali plant requiring some of this ammonia, unless self-contained, would have to compete with the fertilizer demand. The ammoniacal liquors could be used directly, or the ammonium sulphate, which is readily transportable, could be used as a source of ammonia. In Ontario, on the other hand, where there are a number of centres of population large enough to warrant the establishment of gas works, there is available a considerable amount of ammonia liquor suitable for this purpose, The alkali process would, however, have to compete with the demand for liquid ammonia for refrigeration and cold storage plants.

One large plant has been erected in the salt district of Ontario. This plant utilizes local salt and limestone, secures most of its ammonia from local gas works or purchases it in liquid form, and must of necessity depend upon imported coke.

No plant is built or contemplated in Canada using the Leblanc process. The raw materials required by this process, salt, sulphuric acid, limestone, and coal, while obtainable, are not available in juxtaposition except in Nova Scotia. Both salt and limestone are available locally in other provinces. Sulphuric acid capacity is available in certain localities only, and the production of this acid in part depends upon imported products (see section on Sulphuric Acid). With respect to coal the same remarks apply as in the ammonia-soda process.

Sodium carbonate is made in Canada in small amount by two firms, one being in Quebec and the other in British Columbia. Sodium bicarbonate is not known to be made in this country.

CAUSTIC SODA

Caustic soda (sodium hydrate, sodium hydroxide, NaOH) is a white, opaque, deliquescent solid. The specific gravity is 2·13, it melts at 318° C., boils at a white heat, and is readily soluble in cold or hot water.

Processes

The basic material used for its production is common salt. Modern plants all employ the electrolytic method, decomposing sodium chloride in aqueous solution, with the formation of the hydroxide and the liberation of chlorine. This latter is utilized for the manufacture of bleaching powder.

The older method of preparation was to heat soda ash with quicklime in special containers, which resulted in the formation of soluble caustic soda and insoluble calcium carbonate ($Na_2CO_3+Ca(OH)_2=2NaOH+CaCO_3$). This method is still employed in many soap works and in some paper mills where solutions of caustic soda are required.

Industrial Uses

Caustic soda is used in purifying and refining of vegetable oils, such as cottonseed oil or linseed oil; in the manufacture of soap; to purify petroleum products; in the textile industry; in organic synthesis, particularly the production of certain dyestuffs; and in the manufacture of non-coniferous softwood pulps. It is also used as the basis of a number of sodium salts, and finds applications in medicine.

Imports and Exports

The Canadian tariff subdivides importations of caustic soda under two items, importations in packages less than 25 pounds in weight, and importations 25 pounds and over. It is probable that the first mentioned group includes the finer grades of caustic not made in Canada. During the three years 1911-14 the average annual importations under the first group were 148,484 pounds, valued at $8,281, an average unit price of 5·6 cents per pound. In 1918-19 the importations of this grade were 93,912 pounds, valued at $9,260, an average unit price of 9·9 cents per pound. In 1919-20 the imports were 280,751 pounds, valued at $19,635, an average unit price of 7 cents per pound.

Imports classified under the second item for the same periods were as follows: 1911-14—14,853,707 pounds, valued at $270,409, an average unit price of 1·8 cents per pound; 1918-19—11,379,483 pounds, valued at $522,124, an average unit price of 4·6 cents per pound; 1919-20—6,097,654 pounds, valued at $224,888, an average unit price of 3·7 cents per pound.

The exports of lye (presumably caustic soda) for the years 1911-14 had an average valuation of $47,537; for 1918-19, $5,865; and for 1919-20, $60,148. The quantities exported are not recorded.

Information with respect to the present production and consumption is not available. An approximate idea of the extent of the demand not satisfied by domestic production is seen in the record of imports and exports.

Canadian Situation

There are five firms in Canada producing caustic soda. Four of these produce caustic for their own use to purify oils and fats, to manufacture soaps, and to make soda pulp. One firm produces caustic soda for commercial purposes. The refined and purer grades of caustic soda are not made in Canada.

All the raw materials necessary for the manufacture of this product by either process are available in Canada.

SODIUM THIOSULPHATE

Sodium thiosuphate ($Na_2S_2O_3 \cdot 5H_2O$), popularly known as hyposulphite of soda, or simply "Hypo," is a white solid occurring in translucent crystals. It has no odour; when tasted it appears cool, but leaves a bitter after-effect, slightly alkaline and sulphurous. The specific gravity is 1·729; it begins to melt in its own water of crystallization at 32°, and the fusion is complete at about 48° C. The fused salt remains liquid for some time after cooling. It loses its water of crystallization at 215°C., and if heated rapidly it decomposes at 233°C.

Processes

Sodium thiosulphate is usually obtained as a byproduct from the waste solutions (tank waste) available after sodium carbonate has been crystallized out. These liquors contain sodium carbonate or sodium sulphide, or both. By treatment with oxygen (air) and neutralizing with lime water a solution containing calcium and sodium sulphites and hyposulphites is formed. The calcium salts can be decomposed by treatment with sodium sulphate or carbonate, sodium thiosulphate being finally obtained by evaporation, cooling, and crystallization.

There are a number of other processes available for the production of this salt, but no one of them appears to be commercially practicable, except where tank liquors are available.

Industrial Uses

This material finds one of its chief uses in photography as a fixer for negatives. It serves as a convenient source for sulphur dioxide, and as such is useful in bleaching certain fabrics, wool, straw, oils, bone or ivory articles, hair, paper, and other materials. It is used in the manufacture of certain mineral colour pigments, especially red antimony sulphide (antimony vermilion); it finds application as a mordant in dyeing and printing on cotton, wool, or silk fabrics. It is used to a lesser degree in the metallurgy of silver, in the preparation of certain lacquers, as a fungicide or antifermenting compound in the preparation of certain foods, as a disinfectant. particularly in relation to domestic water supplies, and as a chemical reagent.

Imports

The average annual imports for general purposes for the years 1911-14 were valued at $4,886. In 1918-19 the value was $9,734, and in 1919-20 $23,713. The tanning industry imported an average quantity of 538,800 pounds, valued at $6,487, or 1·2 cents per pound, during the three-year period prior to the war. In 1918-19 the imports for use in this industry were 360,200 pounds, valued at $8,590, or 2·4 cents per pound. In 1919-20 the imports were 537,258 pounds, valued at $16,542, or 3·1 cents per pound.

Canadian Situation

The waste liquors ordinarily used for making sodium thiosulphate are obtained from the Leblanc soda process, and these are not at present available in Canada. It is a matter for investigation to ascertain if any other processes could be utilized profitably here. At present this salt is not made in Canada. All supplies are imported.

BLEACHING POWDER

Bleaching powder is a white powder which has the odour of chlorine. It is soluble in about 20 parts of water, but the commercial product always contains an insoluble residue consisting chiefly of calcium hydroxide. When treated with an acid chlorine is liberated and a calcium salt of the acid is formed. The formula is usually written $CaCl.OCl$, and the material is commonly called "chloride of lime." The commercial article commonly contains 38 to 40 per cent chlorine.

Processes

Bleaching powder is made by treating a high grade slacked lime with chlorine gas in specially designed chambers. The hydrated lime is prepared from limestone by burning and slacking. Chlorine gas is usually obtained as a byproduct in the manufacture of caustic soda by an electrolytic process.

Industrial Uses

The chief use of bleaching powder is, as the name indicates, for bleaching in the textile and paper industries. It is also used in certain metallurgical operations, as a disinfectant and deodorant, as an antiseptic, and for the purpose of preventing the decomposition of organic substances. Liquid chlorine appears to be displacing bleaching powder as an active bleaching agent in many industries, notably the sulphite pulp industry.

Imports

The statistical returns issued by the Department of Customs do not distinguish calcium chloride, which is imported for use in cold storage plants, from calcium hypochlorite or bleaching powder. The two items are lumped together, but it may be assumed that the importations of bleaching powder are much in excess of the importations of calcium chloride. It is not possible to obtain an average unit price. This item is subdivided into two parts, depending upon the weight of the packages, those below 25 pounds in weight being segregated from those which weigh 25 pounds or more.

In 1911-14 the bulk shipments averaged 12,563,307 lbs., valued at $117,579, annually. In 1918-19, 11,958,547 lbs., valued at $174,362, were imported.

There is no record for the small package shipments for the three years before the war. In 1918, 178,423 lbs., valued at $13,751, were imported.

In the fiscal year 1919-20 a variation was made in the method of recording these importations. The records for that year include two items as calcium chloride, and two items as chloride of lime and hypochlorite. It is to be assumed that the entries in this latter group refer to chlorinated lime.

Table 8.—Imports of Bleaching Powder

——	Pounds	Value
		$
Calcium chloride in packages of not less than 25 pounds	3,443,324	29,543
Calcium chloride in packages of less than 25 pounds	8,706	963
Chloride of lime and hypochlorite of lime in packages of not less than 25 pounds	20,443,025	368,737
Chloride of lime and hypochlorite of lime in packages of less than 25 pounds	188,579	13,911

Canadian Situation

Limestone suitable for the process is available in a number of localities. Chlorine gas is usually obtained by the decomposition of common salt. As already noted one Canadian firm is manufacturing caustic soda by the electrolysis of brine. The waste chlorine is utilized at the same works for the manufacture of bleaching powder.

CHAPTER II

ELECTROCHEMICAL AND ELECTROMETALLURGICAL INDUSTRIES

This group of industries comprises those which utilize the chemical and thermal effects of electric power for the production of various metallic and chemical products from raw materials of suitable character.

The process of decomposing chemical compounds by the passage of an electric current is called electrolysis. This phenomenon only takes place when the compound or its solution is an electric conductor, and such compound or solution would be termed an electrolyte. Electrolysis may take place in aqueous solution, or in an igneous solution of fused salts. Electrolysis then depends chiefly upon the chemical effects of electric current, the thermal effects being utilized to heat aqueous electrolytes, and to maintain the fusion of igneous electrolytes. Only direct current can be used for processes dependent upon electrolysis.

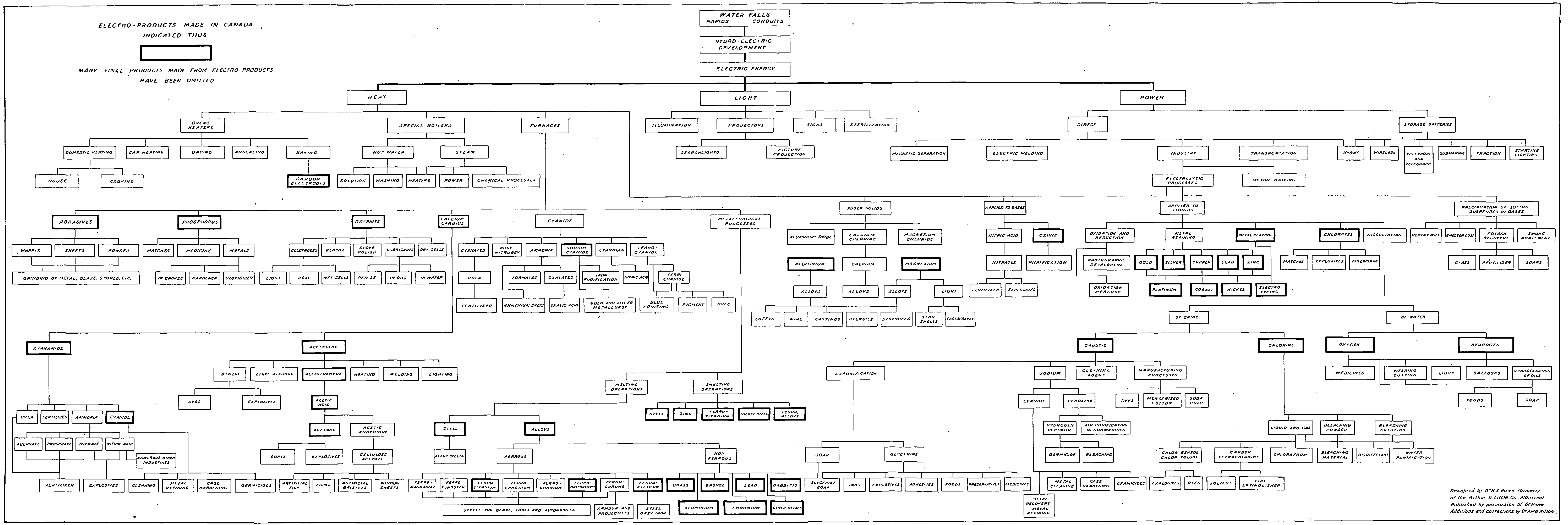
The art of recovering metals from compounds by utilizing either the chemical or the thermal effects of the electric current is termed electrometallurgy. The term includes processes for the separation of metals from their ores, for the production of metallic alloys, for electric deposition of metals, for electro-plating, and for the production of electrotype plates. Processes which involve the fusion of non-metallic products to promote chemical reactions that produce new compounds, as in the manufacture of carbides and abrasives, are sometimes classed as electrometallurgical, although strictly speaking they are electrochemical. Processes where metals are recovered or utilized by electrolysis require the use of direct current. Processes where the thermal effects of the current are utilized to promote high temperatures or fusion may use either an alternating or a direct current, the former being usually given the preference.

The accompanying diagram, showing the principal electro products and their uses, affords a general survey of the development of this industry, and its future possibilities. A better understanding of the immense development that has taken place in this group of industries in recent years, and of the opportunities available for research and expansion can be obtained by a perusal of the following paragraphs. No attempt has been made to give other than very brief explanatory notes. The data given are confined largely to statements of the products made by the use of the electric current from materials noted, without reference to the various special types of equipment that are required and without discussing practical operating difficulties and necessary precautions. Where raw materials mentioned are available from Canadian sources the names have been italicized.

PRODUCTS AND RAW MATERIALS

Electrochemical processes are utilized for the preparation of a very large number of products, both chemical compounds and elements. They are also used in a number of industrial arts. These numerous applications

ELECTRO-PRODUCTS AND SOME OF THEIR USES



ELECTRO-PRODUCTS MADE IN CANADA INDICATED THUS ▭

MANY FINAL PRODUCTS MADE FROM ELECTRO PRODUCTS HAVE BEEN OMITTED

Designed by Dr H. E. Howe, formerly
of the Arthur D. Little Co., Montreal
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Additions and corrections by Dr A. W. G. Wilson.

Diagram 5

can be best reviewed briefly by considering the product and the raw materials at the same time, rather than by listing each separately.

Aqueous Electrolytes

Electrolysis of aqueous solutions of salts results in the separation of the base from the acid portion of the salt, both of which may then be in a condition where they can be recovered separately, or where one or both will enter into new combinations. The simplest application of electrolysis is for the production of *hydrogen* and *oxygen* by the decomposition of water, either or both of which can be utilized industrially.

CAUSTIC SODA AND CHLORINE are prepared by the electrolysis of aqueous solution of *sodium chloride.* This method of preparing caustic soda has become one of the most important branches of the alkali industry. Caustic so prepared can be kept free from impurities, and is used as one of the bases from which to prepare the numerous sodium salts required by industry. Similar salts are also prepared from the carbonate produced by the soda ash process described elsewhere. The electrolytic cells used for this process have to be specially designed to facilitate the recovery of chlorine, and to prevent its escape into the atmosphere, on account of its irritating and poisonous effects. The chlorine produced by this process is cooled and condensed to liquid form for industrial use, or is brought into contact with fresh lime in special chambers to make *bleaching powder,* or *calcium hypochlorite,* a product which finds numerous industrial applications. Electrolytic chlorine can be used for making carbon tetrachloride, chloroform, chloral, chlorides of ethylene or acetylene, chloride of sulphur and certain organic chlorides used in the aniline dye industry. Chlorine can be liquefied under pressure when cooled. Liquid chlorine is stored in special steel containers or in storage tanks mounted on railway trucks for transportation in bulk. Large quantities are now shipped in this way to sulphite pulp mills where it is utilized in the preparation of solutions for bleaching wood pulp. Liquid chlorine is also used for purifying domestic water supplies. Chlorine is a byproduct of caustic soda manufacture and new methods of utilizing it are needed if the production of soda is to be increased to keep pace with the demand. Corresponding compounds of potassium can be made by the use of potassium chloride solution as an electrolyte. BROMINE and IODINE can be prepared from natural brines in much the same way as chlorine is recovered from sodium chloride brines.

CHLORATES and PERCHLORATES are made by the electrolysis of corresponding chlorides. When the temperature of the aqueous electrolyte is kept above 45° C. the chlorine liberated by the action of the current reacts with the alkali produced and a chlorate or a perchlorate results. In making chlorates the electrolyte is usually a 25 per cent solution of sodium chloride or of potassium chloride. Small amounts of sodium or potassium chromates respectively are added to the electrolyte in commercial practice to neutralize the action of nascent hydrogen which would otherwise appear at the cathode. Other substances used for a similar purpose are aluminium salts, clay, silicic acid, fluorides of the alkalies, or vanadium compounds. Perchlorates are produced by using a lower current density, lower temperature, and slower electrolytic action. The usual method of operation is to produce a chlorate in the electrolyte until a definite degree of saturation is reached; then the temperature of the electrolyte is lowered and the current density is decreased, and the chlorate is oxidized to the perchlorate. PERCHLORIC ACID is made by making the corresponding ammonium salt and then decomposing by chemical means. Corresponding salts of bromine and iodine can be made by much the same methods.

SODIUM HYPOCHLORITE in dilute solution can be made by electrolyzing sodium chloride in cold solutions. This method is used for producing a bleach to whiten wood pulp and other cellulose products, and sometimes as a disinfectant for laundry use.

There are a large number of other chemical compounds that can be prepared by electrolytic methods. These include many complex organic compounds where the electric current is used either to promote reduction or to facilitate oxidation. The following lists include many of these:—

INORGANIC COMPOUNDS: Acids (chromic, persulphuric); alum, chrome; aluminium chloride (anhydrous); chromates, bichromates, chromic oxide; copper hydroxide and cuprous oxide; hydrogen peroxide; lead compounds (arsenate, carbonate, peroxide, sulphate); perborates; permanganates; persulphates; potassium or sodium ferricyanides; zinc oxide.

ORGANIC COMPOUNDS: Anthraquinone; bromoform; chloral; formaldehyde; hexamethylenetetramine; iodiform; isopropyl alcohol; methyl acetone; paraformaldehyde; paraldehyde; saccharine; vanilla; electrolytic reduction or electrolytic oxidation products of nitro-benzene and its homologues.

The raw materials from which these products are made are largely natural mineral products such as *sodium chloride*, potassium chloride, *chrome ore;* compounds made from natural products, both mineral and organic; or metals obtained from ores.

SECONDARY CELLS, such as storage batteries and dry cells, are dependent on applications of chemical effects of the electric current. The construction and operation of these cells is discussed elsewhere.

Electrolytic processes are used in metallurgy for the recovery of certain metals from their ores, for the refining of these and other metals, and for electro-plating with metals and some alloys. The last group of processes is discussed more fully in the section dealing with the electro-plating industries. Brief references only are made to the two other applications of electrolysis.

COPPER can be recovered from an electrolyte made by leaching suitably prepared copper ore with *ferrous sulphate* solution. In another group of processes sulphur dioxide is used as a depolarizer during the decomposition of copper sulphate electrolytes. A very large proportion of the world's annual production of copper is refined by electrolysis, the electrolyte being *copper sulphate* solution containing a little free sulphuric acid. Copper is recovered by furnace processes directly from the ores. It is delivered to the refinery in cakes as blister copper, which are melted and cast into anodes. Both copper sulphate and copper cyanide are used in copper plating.

LEAD is refined electrolytically by the use of a *fluosilicate* electrolyte, impure anodes having first been prepared from the lead ores by furnace processes.

ZINC is recovered electrolytically from a *zinc sulphate* electrolyte, the latter being prepared from the zinc ore by a process which involves preliminary roasting, leaching, and purifying of the electrolyte. Zinc sulphate electrolytes are also used for coating surfaces with zinc electrolytically.

IRON is prepared from certain iron ores by using a solution of perchloride of iron as an electrolyte. Pure iron is sometimes prepared by electrolysis with ferrous ammonium sulphate solution as the electrolyte. Other salts have also been used for this purpose with more or less success.

The following metals are refined by electrolysis, aqueous solutions of certain salts being used as the electrolyte. The salt most frequently used in commercial practice is indicated although other electrolytes have been proposed and used in some cases.

ANTIMONY has been recovered by using sodium sulphide in a leaching solution. A solution of the fluoride has also been used, the electrolyte containing sodium and potassium fluorides and some free hydrofluoric acid.

BISMUTH has been refined from electrolytes containing sodium tartrates or oxalates. The fluosilicate has been used, and in laboratory determinations the nitrate. It is not prepared commercially by an electrolytic process.

CADMIUM has been refined by using the sulphate as the electrolyte, much the same way as in the refining of zinc. The metal is not in demand commercially.

COBALT could probably be refined by using sulphate solutions much the same way as nickel. Electro-plating with cobalt ammonium sulphate and certain other salts as the electrolyte finds commercial applications.

GOLD is refined by using a solution of the chloride containing free hydrochloric acid as the electrolyte. Complex electrolytes containing the cyanide are used for plating. Processes for recovering gold from its ores by leaching and subsequent electrolysis have been proposed but do not appear to have been commercially applied. An electrolyte so prepared could ordinarily contain gold as a chloride or a cyanide.

NICKEL is not recovered commercially from its ores by electrolysis although several processes have been proposed. Refined nickel can be produced commercially by electrolysis. The electrolytes used either contain sulphate of nickel with some copper sulphate and sulphuric acid, or nickel, iron, copper, and sodium chlorides. Anodes made from partly roasted nickel-copper matte are used in one process, and partly refined nickel anodes in the other. Electro-plating with nickel is an important industrial art.

The salts most frequently used in the electrolyte are nickel ammonium sulphate and nickel sulphate. Other salts have also been employed for this purpose.

Silver is not recovered from its ores by leaching and subsequent electrolysis. It is refined by the use of an electrolyte containing silver nitrate and free nitric acid. Silver plating is usually accomplished by the use of electrolytes containing silver cyanide and potassium cyanide. Other more complex baths are also used for plating where certain special results are required.

Tin is not recovered electrolytically from its ores, although both leaching and fusion processes have been proposed. Byproduct tin is recovered from scrap, using a caustic soda solution as an electrolyte. Sodium chloride, sodium stannate, stannic tetrachloride, and ferric chloride have also been used in various electrolytes that have been proposed and tried out. Plating with tin by electrolysis has also been tried. An alkaline electrolyte containing stannic chloride, caustic potash and potassium cyanide, and an acid electrolyte containing stannous chloride and sodium pyrophosphate have been used successfully. Electrolytes containing organic acids and salts in solution have also been used.

Igneous Electrolytes

A number of metals of industrial importance are recovered by the electrolysis of igneous solutions, the operations being conducted in such a way that the resulting metal is not subjected to oxidation by exposure to the air while hot. The igneous solution used as the electrolyte consists of a fused salt of the metal required, or of a fused salt in which the ore of the metal required can be dissolved, the salt being one which requires a higher potential for decomposition than the ore under treatment. Chlorides and fluorides are generally used in the formation of igneous electrolytic baths.

Aluminium is prepared by the electrolysis of aluminium oxide in a bath of fused cryolite, a natural sodium aluminium fluoride. The electrolyte sometimes contains additions of sodium fluoride, calcium fluoride, or aluminium fluoride. The oxide is prepared from the mineral bauxite by a preliminary purification. The electrolyte is prepared by mixing aluminium oxide, cryolite, and fluorspar in the proper proportions, and then subjecting them to the action of hydrofluoric acid. After treatment the product is dried and fused in the electric furnace. When the furnaces are in operation additions of aluminium oxide must be made to the bath to maintain the proper composition and to prevent a rise in voltage.

Magnesium is prepared by the electrolysis of the natural salt potassium magnesium chloride (carnallite). It can also be prepared from the fused chloride. During the operation of a cell anhydrous magnesium chloride is added from time to time to maintain the electrolyte.

CALCIUM is made from fused anhydrous calcium chloride. BARIUM and STRONTIUM can also be produced by the electrolysis of the fused chlorides.

SODIUM is prepared by the electrolysis of the fused hydroxide. The two principal processes employed are the Castner and the Griesheim. These differ in the design of the cell employed and in the method of collecting the metallic sodium. Both the nitrate and the chloride have also been used in processes for recovering sodium. Processes have been devised for using this latter salt as fused electrolyte, the sodium being collected indirectly in molten lead from which it was afterwards recovered. Modifications of these are now in use for the production of caustic soda. The metal has also been recovered successfully by the direct electrolysis of the fused chloride in a special type of furnace, but this process is not in general use.

POTASSIUM is prepared from the fused hydroxide much in the same way as sodium, but special care has to be taken to prevent the oxidation of the metal.

LEAD and ZINC have been prepared by the electrolysis of fused salts, but the methods are not commercially successful.

Some of the rare metals have been recovered by the electrolysis of aqueous solutions of selected salts. INDIUM may be recovered from the neutral sulphate; the nitrate and the chloride have also been used, the bath being slightly acidified with an organic acid such as formic, or with sulphuric acid in the presence of ammonium sulphate. THALLIUM has been recovered in the same way from an electrolyte containing ammonium thallium oxalate. LITHIUM has been recovered by the electrolysis of organic salts.

Other rare metals are prepared by the electrolysis of fused salts, the operation being carried out under conditions which prevent the oxidation of the metal. BORON has been prepared from boric acid dissolved in fused sodium biborate. CERIUM, LANTHANUM, LITHIUM, NEODYMIUM, PRASEODYMIUM, SAMARIUM, and URANIUM have been recovered by the electrolysis of the fused chloride of the corresponding metal. MANGANESE can be recovered by the electrolysis of the fused chloride or fluoride dissolved in a fused chloride of an alkali. TITANIUM has been recovered by the electrolysis of the dioxide in solution in fused calcium chloride. VANADIUM can be recovered by the electrolysis of the fused fluoride.

Electrothermal Processes

Electrothermal processes for the recovery of metals from their ores utilize the electric current only as a source of heat to promote fusion and to raise the temperature of the products treated to a point where desired chemical reactions will take place. The methods are commercially applied to the production of many of the rarer metals, or those which are difficult of reduction. The operation usually takes place in the presence of carbon (coke) and fluxes. CHROMIUM, MANGANESE, MOLYBDENUM, TITANIUM, TUNGSTEN, URANIUM, and VANADIUM can be recovered by this method.

SILICON and ZIRCONIUM are also reduced from the oxides by treatment in an electric furnace. PHOSPHORUS is obtained by the fusion of calcium phosphate (apatite, bone ash, or rock phosphate) in the presence of silica and carbon. ARSENIC has been obtained by heating mispickel in an electric furnace of special design (Westman process). TIN is not at present recovered by this process. Processes have also been developed for the production of the metals COPPER, NICKEL, and ZINC from their ores, especial attention having been given to zinc. These processes are not in successful commercial operation in America, but both nickel and zinc are being recovered in this way in small amount in foreign countries.

PIG IRON for industrial purposes is usually produced in blast furnaces, by smelting the ores with carbon in some form (coke, charcoal), limestone being used as a flux. The carbon content of the charge serves not alone to produce heat but also to reduce the oxides of iron present. Electrothermal methods of supplying the heat, the ore being reduced with carbon, have been in course of development during the last twenty-five years and they are now in successful operation in Europe, particularly in Sweden and Norway, where fuels are scarce and hydro-electric power is abundant and cheap.

GRAPHITE for industrial use is prepared from petroleum coke or anthracite coal in a special type of resistance furnace. Certain varieties of soft graphite made by the electrothermal process are the basis of important lubricants and paints. Graphitized carbon electrodes, made from petroleum coke or anthracite, are one of the essential requirements of many electrochemical industries. Anthracite for the making of electrodes is crushed and subjected to preparatory treatment in an electric furnace. The prepared anthracite is then mixed with a suitable binder, moulded into electrodes, and afterwards baked in special furnaces heated with electricity.

The electrothermal effects of the electric current are applied to the production of a number of alloys and chemical compounds of industrial importance.

STEEL is made from pig iron and scrap by fusion with fluxes in electric furnaces. ALLOY STEELS of all kinds are made in this way, the various alloying metals being added to the steel bath as ferro-alloys.

FERRO-ALLOYS are made in the electric furnace either directly from ores, or by the fusion of metals previously prepared. The more important ferro-alloys are those of *chromium, manganese, molybdenum, silicon, tungsten,* and *vanadium.* Alloys with *aluminium, boron, cerium, magnesium, titanium,* and *uranium* are also made.

NON-FERROUS ALLOYS of all kinds can be made in electrically heated furnaces. The method is commonly used for making *aluminium alloys, brasses, bronzes,* and *gun metal.* It is sometimes used for making *white metal alloys* and *bearing metals. Stellite,* an alloy of chromium, cobalt, and tungsten, is used for high speed cutting tools, and for making certain kinds of so-called "stainless steels." *Cuprovanadium, silicon-manganese,* and a number of other similar products are also made by electrothermic methods.

The thermal effects of the current are applied to promote the formation of new compounds or for refining and purifying products, both applications being of great industrial importance.

Carbon Bisulphide is made by fusing and vaporizing sulphur, and passing the vapour through red hot carbon, the operation taking place in a furnace of special design, and the heat being supplied by an electric current.

Calcium Carbide is made by fusing lime and coke in an electric furnace. The raw materials of this process are *coal* and *limestone.* The product finds many uses, and is made in large quantities. Other carbides could be made by a similar method if required.

Cyanamide is made from calcium carbide and pure *nitrogen* in special furnaces electrically heated.

Nitric acid, Nitrates, Nitrites, Ammonia, and Cyanides can be made from atmospheric nitrogen by processes which involve the use of electric power. These are discussed at more length in the section on Nitrogen.

Ozone is made by the use of a silent discharge of current at high potential between suitably arranged electrodes past which dry air at room temperature is forced. Ozone is used for bleaching, disinfecting, and other industrial purposes.

Artificial Abrasives, which find numerous applications in the grinding and polishing of metals, glasses, and other materials, form another important group of products produced by electric power.

Carborundum is made from coke, sand, and hardwood sawdust to which a little sodium chloride has been added. This mixture is heated in a furnace of special design. The intense heat that is generated in the centre of the mass, by the passage of the current, results in the formation of carbide of silica (SiC) in crystal form, this constituting the artificial abrasive known commercially as *carborundum.* In addition to the crystals a quantity of amorphous carbide of silica is produced at each heat, which is used industrially as a refractory. This is one of several closely related compounds of silicon and carbon which are formed during the operation, some of which are utilized (silicon monoxide, "siloxicon," "fibrox"). A modification of the process makes it possible to produce vessels or other articles which are essentially carborundum, by previously shaping or moulding the article in carbon, and then subjecting it to the action of vaporized silicon. Articles of this kind are marketed under trade names such as "silfrax," "silundum," and other designations. Carbide of silicon as an abrasive is marketed under several different trade names, *carborundum* being the first designation used. *"Carbolon," "carbosolite," "crystolon,"* and *"electrolon"* are essentially the same products, the different names being given by different producers. These products are also used as refractories where articles capable of withstanding high temperatures are needed in industrial operations.

Another important abrasive produced by applications of the thermal effect of the electric current is *artificial corundum.* Its discovery and development as an industrial product is due to the many attempts which have been made to develop methods for manufacturing artificial rubies and sapphires. The first artificial abrasive of this composition was made by heating crushed emery with charcoal or coke. The natural mineral contains iron and silica which were removed by the process, practically pure aluminium oxide being produced. Some of the iron is also recovered as ferrosilicon. Later methods employed aluminium oxide or materials containing the oxides in quantity. When the natural oxides are subjected to the intense heat of the electric furnace a dense fused product of essentially pure aluminium oxide is produced, and this constitutes the abrasive. Modern practice utilizes bauxite as the raw material. This is first calcined to drive off the combined water. A small amount of coke or charcoal and silica are mixed with the fused oxide, unless these are present in the original bauxite in sufficient quantity to remove the iron and other impurities. A low grade ferrosilicon is usually produced in commercial practice, which is marketed as a byproduct. The calcined material is charged to a special type of electric furnace and fused by the passage of the current. Artificial corundum is marketed under a variety of trade names, the chief of which are "*aloxite,*" "*alundum,*" "*coralox,*" "*boro-carbone,*" "*exolon,*" "*natite*" and "*artificial alumina.*" "*Oxalumina*" is made from aluminium bearing clay and ores; "*Adamite*" contains about 80 per cent aluminium oxide, and some silicates; "*Werlein's artificial abrasive*" is an aluminium-silicon compound.

ROUGE and CROCUS powders are made by calcining ferrous sulphate in crucibles. The heat is usually supplied by the combustion of a fuel, but electric heat could be used for the purpose.

CRUSHED STEEL, made by hardening special steels, and CRUSHED CAST IRON are also used as abrasives for special purposes. The metal for making these products can be prepared in an electric furnace, or furnaces heated by combustion could be used.

The heating effect of the electric current is used for a number of industrial operations. Electrodes made from petroleum coke or anthracite coal are baked with electric heat, a process which makes the electrochemical industries possible. Abrasives, shaped into wheels and sharpening stones by moulding and pressure, are held together by the use of special binding materials, the whole being solidified by drying or vitrifying in electric furnaces. Other similar operations performed in electric furnaces are the drying and baking of varnish enamels, the fusion and vitrifying of ceramic enamels, glasses, and other similar products.

ELECTRIC POWER is used for heating vessels, containers, and catalysts used in a number of chemical operations. Starting with coal and limestone as raw materials, calcium carbide is made. Calcium carbide and water yield acetylene gas. Treated in special electrically heated furnaces in the presence of suitable catalysts it is possible to produce a number of products by synthesis. *Acetaldehyde, acetic acid,* and *acetone* are made in this way in commercial quantities. Accessory materials required in these operations are mercury, sulphuric acid, caustic soda, and lime. The heating effect of the electric current is used for fusing quartz (pure silica sand) for the purpose of making tubes, evaporating dishes, and other articles required in the chemical industries.

ELECTRICAL PRECIPITATION of solid dust particles, carbon, and metallic salts contained in stack gases, smoke, and fumes discharged from industrial plants is now an important commercial process. Similar methods are used to prevent the dissemination of injurious dusts and fumes, and for the recovery of liquids disseminated in fine vapours. The static effects of an intermittent unidirectional current at high potential are used for this purpose.

Accessory Materials

The electrochemical industries naturally consume large quantities of accessory materials for the construction of apparatus and equipment. Electrolytic processes, where the electrolytes are aqueous solutions, may use containers made of glass, porcelain, lead, carbon, wood, cement, or cellulose products. Bitumen, tar, or bituminous paints, sulphur and sand mixtures, paraffin, and graphite mixtures are used as protective coatings. Wires, rods, bars, sheets, woven wire sheets, and plates of several different metals are used in different operations. Copper is the metal most in demand for conductors, but aluminium might be used in certain places; lead is used chiefly for lining tanks, and as electrodes in some operations; nickel is occasionally used for electrodes; silver or platinum is used only in certain special processes; other metals are only rarely required. Carbon is often used in making electrodes (either gas carbon or artificial graphite) and less frequently artificial magnetite. Porous diaphragms are made from ceramic materials, either baked clays or special porcelains. Carbon, carborundum, alundum, and other such materials are used occasionally.

Electrolysis of igneous solutions necessitates the use of materials insoluble in the electrolyte for containers and electrodes. Cast iron or nickel sheets are used in some cases. Other operations require the use of bricks or cements made from silica or calcined magnesite for lining the furnaces. Sometimes such materials as carborundum, alundum, or zirconium oxide are employed. Carbon or graphite electrodes are generally used especially at the higher temperatures.

Electrothermal operations necessitate the use of various refractories or carbon as furnace linings, and graphite, carbon, or anthracite electrodes. Furnaces may be constructed of bricks of several kinds, or of cement, bar iron tie rods or cast iron or sheet steel jackets being used where required. In some operations a portion of the charge itself (either in a natural condition or fused) serves as a refractory to protect the walls of the furnace, which is then of relatively simple construction. Conductors are almost invariably copper products, wires, rods, bars, plates, or castings. Aluminium wires and rods could be used at some points.

Furnaces for baking, vitrifying, and similar operations, are usually constructed of cement or brick, refractory linings being used where required.

When electric heat is used for promoting catalytic operations asbestos, magnesium oxide, glass wool, or diatomaceous earth may be used as heat insulators. Units of these kinds suffer little deterioration by use, and the actual consumption of replacement materials is necessarily small.

Electric power for use in these industries can be provided by steam plants or from hydro-electric generating stations. Power is usually transmitted at relatively high voltages, whereas electrochemical operations are usually carried on with currents at low pressure, therefore transformers are almost always required. Alternating current is usually delivered to transmission lines and therefore those electrochemical operations which require direct current at low voltage necessitate the installation both of transformers and converters.

Statistical Data

The general tables of statistical information given on another page include available data with respect to imports and exports of such electrochemical products as are mentioned in the Canadian tariff. Further generalized data will be found in the reports on Chemicals and Allied Products issued by the Dominion Bureau of Statistics. The latest available at the time of publication is the list for 1919 and 1920 and that for 1921. Statistical information with respect to the electrolytic production of metals, and with respect to the electrothermal production of steel, metals, alloys, abrasives, and carbide will be found in the annual reports on Mineral Production issued by the Dominion Bureau of Statistics.

The statistical data available are not prepared in such a way as to give information with respect to our annual requirements of many individual products. The annual production of many products is given and where the exports and imports are itemized it is possible to obtain an approximation as to the annual consumption of a few individual products. No data with respect to unabsorbed stocks of products at the time of preparing the statistical reports are issued.

As a rule, chemical products made by electrical processes are not distinguished in statistical reports from those made by other processes.

There are no segregated statistical data relating to the development of electrochemical industries in Canada. The total amount of available electric power devoted to these industries is not shown in any published statements.

Canadian Situation

A perusal of the preceding sections of this report has shown that a very wide range of commercial chemical products are manufactured from relatively common raw materials by electrochemical processes. All these processes require electric current; in some cases power is required in large blocks, in other cases the power requirements are relatively small. Most of the industries require continuous power deliveries, and very few operate with a variable load. The power factor for these industries is therefore high. While power requirements are not the only condition which will determine the location of any group of electrochemical industries, they are, nevertheless, important controlling factors; and where other conditions, especially with respect to labour, raw materials, and markets, are equal, or nearly so, a cheap source of power will be the determining factor in deciding on location. In view of this fact the following abstracts from a report issued by the Dominion Water Power Branch are of special importance and significance in their bearing upon the possible future developments of the electrochemical industries in Canada.[1]

"The water-wheels installed throughout the Dominion total 2,762,880 horse-power. A detailed analysis of the relationship between this installed power, taking into consideration local pondage and load factors, and the corresponding available water-power indicates that *at present recorded available water-powers* of the Dominion will permit of a turbine installation of *41,700,000 horse-power.* In other words, the present turbine installation represents only *6·6 per cent* utilization of the present recorded water-power resources. In support of this statement it may be said that the detailed analyses made of the water-power resources of the provinces of New Brunswick and Nova Scotia have disclosed most advantageous reservoir and pondage facilities for regulating stream flow, and it is estimated that, allowing for the diversity factor between installed power and customer's demands, the two provinces possess respectively 200,000 and 300,000 commercial horse-power as against the lower figures given in the table." "The total available and developed water-power resources of Canada are presented as follows:—

Table 9.—Available and Developed Water-power Resources of Canada

Province	Available 24-hr. power at 80 p.c. efficiency		Turbine installation h. p.
	At ordinary min. flow h.p.	At est. flow for max. dev. (dependable) for 6 mos. h.p.	
1	2	3	4
British Columbia	1,931,142	5,103,460	305,315
Alberta	475,281	1,137,505	33,187
Saskatchewan	513,481	1,087,756	....
Manitoba	3,270,491	5,769,444	104,147
Ontario	4,950,300	6,808,190	1,212,650
Quebec	6,915,244	11,640,052	1,105,385
New Brunswick	50,406	120,807	30,180
Nova Scotia	20,751	128,264	46,948
Prince Edward Island	3,000	5,270	1,869
Yukon and Northwest Territories	125,220	275,250	13,199
	18,255,316	32,075,998	2,762,880

"Practically every large industrial centre throughout the Dominion is now served with hydro-electric energy, and has within easy transmission distance ample reserves of water-power. *Over 90 per cent of the prime motive power of the central electric station industry of Canada is hydro power.*" * * * * * "With a water-power development of 315 horse-power per 1,000 population, Canada stands well to the fore in respect to availability and utilization of hydro-power resources, being surpassed on this basis by Norway alone. The enormous water-power reserves still untouched form a substantial foundation for the progressive exploitation and development of other natural resources." * * * * * * * "About 1·65 times as much electric

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[1] Central stations in Canada, 1920, published by Dominion Bureau of Statistics, Ottawa, 1923, p. 4, *et seq.* Consult also "Directory of Central Electric Stations in Canada," Dominion Water Power Branch, Ottawa.

> energy per capita was generated by central electric stations in Canada as in the United States" (in 1920). * * * "In Canada 97·2 per cent of the total electricity produced by central stations was generated by water-power and only 2·8 per cent by fuel, while in the United States only 37·1 per cent was generated by water-power, and 62·9 per cent by fuel stations." * * "The comparison of hydraulically developed electricity per capita was much more favourable to Canada, being 660 kilowatt hours, as against 153 kilowatt hours per capita in the United States."[1]

The capital invested in the central electric station industry in Canada is placed at $448,273,642, being much greater than that invested in any of the other basic industries of the country, except steam railways[2] (in 1920).

There are two electrochemical centres in Canada in the vicinity of large central power developments. One of these is in the vicinity of Niagara Falls, Ontario, and the other at Shawinigan Falls, Quebec. Electrochemical operations are also carried on at other points in Canada, but on a relatively smaller scale. Power from the Niagara district is used for municipal lighting, for street railway operation, and for general industrial purposes as well as for electrochemical industries. While the total amount of power available will be about 730,000 horse-power, the demands on this power for other purposes are so great that the amount available for electrochemical industries will be a relatively small proportion of the whole. The actual amount now in use in electrochemical industries has not been made public. In the basin of the St. Maurice river, Quebec, of which Shawinigan Falls is the industrial centre, there are potential and developed power resources in excess of one million horse-power, only about one half of which is now in use. This power also is used for municipal and general industrial purposes, but to a less extent than in the Niagara district. About one quarter of the power now available is used for electrochemical industries, and there are additional possible resources in excess of half a million horse-power that will be made available as required.

There are a number of other localities where large blocks of cheap power could be developed if required for industries of this type should commercial conditions ever make it desirable to do so.

The electrochemical industries established in Canada are briefly mentioned in the following sentences. Reference has been made in another section to the electro-plating industry. There are two electrolptic copper refineries in Canada with an annual rated capacity of 19,000 tons; one nickel refinery with a capacity of 7,500 tons; one lead refinery with a capacity of 50,000 tons; one zinc refinery with an annual capacity of 30,000 tons. Aluminium is made at one plant from imported bauxite ores; and magnesium was, at least for a time, made in another plant in the same district. Gold is refined electrically at the Royal Mint and at one small private plant; silver is refined electrolytically at one small private plant. Phosphorus is made at one plant, using local silica, imported calcium phosphate, and coke purchased from a manufacturer using either imported or domestic coal.

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[1] *Loc. cit.*, p. 12.

[2] *Loc. cit.*, p. 14.

Caustic soda is made at one plant by the electrolysis of sodium chlorine brines. The chlorine is absorbed by lime to make bleaching powder, or is liquefied for industrial use. One other plant also makes chlorine for its own use and another company makes hypochlorite bleaching solutions at two points for use in its own plants. One manufacturer produces chlorates and perchlorates of sodium or potassium, chiefly for the use of manufacturers of explosives. One plant produces acetaldehyde, acetic acid, and acetone by a synthetic process, using electric power as a source of heat.

Reference has been made in another section to the plants engaged in the production of electric iron, electric steels, and alloys. Ferrosilicon is produced in one plant from native silica, and is also obtained as a by-product in the manufacture of abrasives. Ferromolybdenum was produced for a time at two plants, but at present there is no production. Carborundum is made at four plants owned by three different firms; aluminium oxide abrasives are made at six plants owned by five firms. Graphite and graphite electrodes are made at one plant; anthracite electrodes are made at four plants by three firms, one of these manufacturing for its own use only. Calcium carbide is made commercially at three plants, and for use within the maker's works by one manufacturer. Cyanamide is made at one plant, which has an annual capacity of 60,000 tons. Some sodium cyanide is made at this works from a portion of the cyanamide, the balance being exported.

CHAPTER III

PRODUCTION OF NITROGEN COMPOUNDS

Nitrogen is an essential constituent of the foods required both by plants and by animals. It is also essential to the formation of numerous industrial products. In nature it forms about 79 per cent by volume of the atmosphere. It also occurs in nitre, Chili saltpetre, ammonium compounds, and in the tissues of animals and plants. It is invariably present in soils which support plant life, compounds being formed in the soil by the action of nitrifying bacteria.

Since nitrogenous compounds are essential constituents of both plant and animal tissues it follows that they must form important components of the foods of all living organisms. The chief importance of these compounds obviously depends upon the ability of living plants to assimilate them from the soils upon which their growth takes place. Since these compounds are essential to plant life, and since repeated cropping of any given area tends to exhaust the supply present in the soil, it becomes necessary to resort to artificial means to replace the amounts of nitrogenous compounds that are being abstracted from the soil by successive crops. It is for this reason that nitrogenous fertilizers are essential to the maintenance of a successful agricultural industry and this is the basis of the demand for commercial fertilizers.

Compounds of nitrogen constitute our most important explosives, whether for use in peace or war. Dynamite, blasting powders, and various other explosives that are used in all mining or quarrying operations, in road building and in railway construction, are nitrogen compounds. Nitrogen is essential to the manufacture of the numerous nitrocellulose products which constitute celluloid, artificial ivory, photographic films, artificial leather, many lacquers, and similar substances. It is present in dyes, and some of its compounds are used in making glass, sulphuric acid, and numerous other commercial products.

In combination with hydrogen, as ammonia, it is used in refrigeration plants, either for the production of artificial ice, or to operate cold storage plants. Ammonia is utilized in the manufacture of important chemicals and it also finds many applications within the household.

In combination with carbon and certain bases cyanides are formed. These are used in certain metallurgical processes for extracting gold and silver from their ores, and they have also found important agricultural uses as insecticides.

SOURCES OF NITROGEN

Organic Nitrogen Compounds

Organic nitrogen compounds are used principally as fertilizers for plant food or as nitrogenous feed for domestic animals. These materials consist of animal and plant refuse, such as decayed leaves, manure, abattoir tankage, dried blood, fish scrap, leather scrap, cottonseed meal, oil cake, and similar products. Some kinds of organic nitrogenous fertilizers have been used by agriculturalists for many centuries. The use of industrial waste products is of comparatively recent origin. These products have now come to be recognized to have greater value if used as animal foods. Their diversion in this direction in recent years has materially diminished the available supply of organic nitrates for use as agricultural fertilizers.

Inorganic Nitrogen Compounds

Inorganic nitrogen fertilizers are of constantly growing importance. They are derived from three principal sources.

Natural Nitrates. Nitrates of soda or potash are present in the soils of certain arid regions of the earth. These are extracted and used locally, or exported to the markets of the world. They have been used in small quantities for many centuries. The discovery of the deposits of sodium nitrate in Chili early in the last century marks the beginning of the world's trade in this commodity. They have been utilized on a constantly increasing scale for the last ninety years. At present they supply about one-third of the world's total requirements for nitrogenous fertilizers.

Byproduct Coke Ovens. The nitrogen content of bituminous coal is in part recovered among the byproducts of gas and coke ovens. It is commonly liberated as ammonia gas which is absorbed in water. The ammonia can be recovered from the aqueous solution as such or as a compound of ammonia with an acid. It is commonly converted into the sulphate, in which form it enters into many fertilizers. The recovery of byproduct ammonia and its utilization as a commercial fertilizer is a development of the last half century. Nearly one-third of the world's requirements of inorganic nitrogenous fertilizers are supplied from byproduct coke ovens.

Nitrogen Fixation Processes. The third important source of inorganic nitrogen is the atmosphere. Chemical and electrochemical processes have been developed during the last two decades by which nitrogen from the air can be combined with other elements to form useful compounds. These methods of producing nitrogen compounds are termed nitrogen-fixation processes. The plants now established are capable of producing more than one-third of the world's total annual requirements.

Reference is made in another section of this report to the Fertilizer industry and to the sources of its raw materials. In still other sections of the report references are also made to the occurrence of residual byproducts which are available for use in making fertilizers. The principal contributing industries of this kind are meat packing, industries preparing refined oils (of animal or vegetable origin), coal distillation, and coal tar distillation. Natural nitrates are not found in Canada in commercial quantities. A further discussion of the sources of supply of organic nitrogenous materials or of the recovery of ammonia produced during the distillation of coal or coal tar is unnecessary. Some reference, however, is made to the processes for the fixation of atmospheric nitrogen.

Nitrogen Fixation

In his presidential address before the British Association for the Advancement of Science, in 1900, Sir William Crookes pointed out that the nitrate fields of Chili would undoubtedly be exhausted within a measurably short time. Such exhaustion must inevitably result in a decrease of the world's food supply unless means were found to utilize the vast store of nitrogen available in the atmosphere. That nitrates could be made from the nitrogen of the air was known prior to 1900, but this address really marks the beginning of the investigations which led to commercial development of processes for fixing atmospheric nitrogen. The first successful commercial process was put in operation in 1905 at Notodden, Norway (Birkeland and Eyde process).

Many processes have been proposed for fixing atmospheric nitrogen. Some are in successful operation on a commercial scale, some are in process of development, and others have not got beyond the laboratory stage. Reference will be made here only to four types of processes, three of which have been operated commercially. These, in the order of their development, are the Arc process, the Cyanamide process, the Synthetic Ammonia process, and the Cyanide process.

Arc Process

This was the first method to be developed to the commercial stage of production. The raw materials are air and water, with abundance of electric power as another essential. The process depends upon the fact that nitrogen and oxygen of the air will unite to form oxides of nitrogen if heated to a high temperature in the electric arc. The phenomenon was known long before practical methods of applying it were suggested or developed. It is accomplished by passing a stream of air through an electric arc under suitable conditions to insure the heating of as large a volume of air as possible. Only a small portion of the gases present are combined while passing through the zone of high temperatures. The mixed gases must then be cooled rapidly to prevent the decomposition of the nitric oxide formed. When cooled quickly another portion of oxygen is absorbed from the mixture making the dioxide. The stream of gases is then brought into contact with a thin film of water or dilute nitric acid in special apparatus. Absorption takes place with the formation of nitrous and nitric acids. The nitrous acid present is converted into nitric acid by suitable means.

Several types of arc furnaces have been devised to promote the reactions upon which the process is based. These differ greatly in methods of construction and operation. The Birkeland and Eyde furnace, the first to be successfully operated commercially, maintains a broad thin disc of flame through which the stream of air passes. This is accomplished by drawing the arc between the flat poles of an electro magnet. A disc-like flame results, the arc being turned at right angles to its normal direction by the action of the magnetic poles. In commercial units a disc-like flame about 6·5 feet in diameter is maintained. The Schönherr furnace uses a long steady arc past which the air stream passes. In commercial units an arc over 20 feet in length may be maintained. In the Pauling furnace the electrodes are arranged at right angles to each other and the air stream under pressure is introduced between them in such a way that the arc is blown into a sheet of flame. These three types of furnaces are all in successful commercial operation on a large scale. Several other types have also been proposed, and some have been utilized commercially, but only on a small scale. Mention should be made of the Wielgolaski furnace, a modified form of the Schönherr type, since a small one was installed in British Columbia and operated experimentally for a short time.

The successful operation of furnaces using an electric arc is dependent upon the availability of very cheap electric power in large blocks. About 67,000 kilowatt hours of electric energy are required to fix one ton of nitrogen, the efficiency being only about three per cent and the heat losses enormous.

These processes yield an aqueous solution containing nitrous and nitric acids. The nitrous acid can readily be converted to nitric acid. A basic nitrate of calcium, suitable for use in fertilizers, is produced by treatment with milk of lime. It is also possible to make concentrated nitric acid and nitrate salts of other bases, as required.

Cyanamide Process

The raw materials used in this process are coal, limestone, air, and electric power. Coal is converted into coke, and the limestone is burned to lime. Lime and coke are converted into calcium carbide in electric furnaces. The carbide, after cooling, is ground fine and packed into ovens of a special form. Pure nitrogen, obtained from the air by compression and fractional distillation, is introduced to these ovens, all the air being expelled. Electric power is then applied to bring the mass to a yellow heat. The nitrogen combines with the calcium carbide to form calcium cyanamide. When the conversion is as complete as possible the ovens are cooled and the crude cyanamide is removed, crushed, and finely ground. It is then heated with water to remove any unaltered carbide. The power consumption of this process is about 15,000 kilowatt hours per ton of nitrogen fixed, and the efficiency is much higher than in the arc process.

Crude calcium cyanamide can only be used in limited quantities as a fertilizer material. This cyanamide, however, is a basic product from which a large series of other important products, some of which are more suitable for use as fertilizers, can be made. These products include ammonia, ammonium sulphate, and ammonium phosphate. The accompanying flow sheet shows the principal products that can be derived from calcium cyanamide. It also indicates, in a general way, the processes employed to make these products, and their industrial uses.

UTILIZATION OF ATMOSPHERIC NITROGEN

CHART SHOWING INDUSTRIAL POSSIBILITIES OF THE CYANAMIDE PROCESS

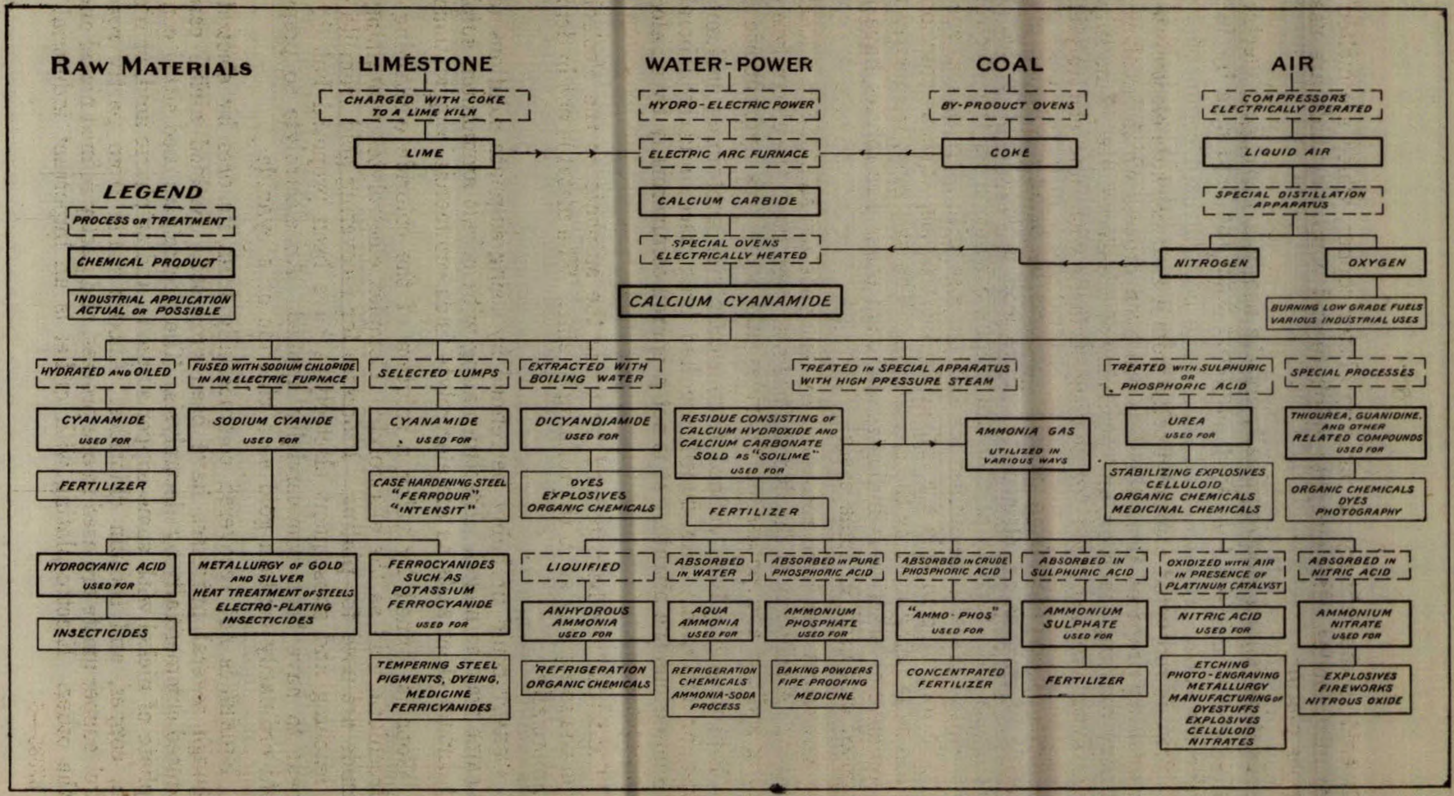

Diagram 6

Synthetic Ammonia Processes

Nitrogen and hydrogen in the presence of a catalytic substance capable of promoting a reaction between them will unite to form ammonia. This reaction is the basis of the direct synthetic ammonia process commonly known as the Haber process. The successful operation of the process is dependent upon the use of an effective catalyst. The original Haber process, which was developed in Germany prior to the war, operates under a pressure of about 200 atmospheres and at a temperature of about 500° C. The principles of operation had all been worked out prior to the war, but the plant in operation in 1914 was only a small commercial unit. During the war, when supplies of nitrates from Chili were shut off, the plant capacity was enormously enlarged. During the war similar processes were developed in France, Italy, and the United States, varying both in the temperatures and the pressures at which the operations were conducted and in the catalyst used. In England an experimental plant was erected to use the Haber process. In France a good deal of attention has been given to the Claude process in which ammonia is synthesized from nitrogen and hydrogen under a working pressure of 1,000 atmospheres. In the United States much work has been done under Government auspices upon a process which is a modification of the Haber process, and also upon the cyanamide process.[1]

Hydrogen for use in the Haber process is prepared from water gas by treatment with steam in the presence of a catalyst (Bosch process). It may also be made electrolytically by the decomposition of water. Nitrogen is obtained from the air either by admixture with the water gas or by the production of a pure producer gas. Nitrogen can also be obtained by fractional distillation from liquid air. When hydrogen is made from water gas, or when producer gas is used to introduce nitrogen, elaborate precautions must be taken to purify the mixed gases by eliminating carbon monoxide and carbon dioxide. These operations usually take place under pressure. The purified mixed gases should contain approximately three parts of hydrogen by volume to each part of nitrogen.

The synthesis of ammonia from the purified gases is accomplished in special apparatus through which the gases are circulated. The catalyst to be employed is so placed in a converting unit that a maximum amount of contact surfaces will be exposed to the gases, while the freedom of circulation will be reduced as little as possible. The best operating temperatures lie between 450° C. and 600° C. and the reaction is exothermic. Provision must be made to maintain the catalyst at a suitable temperature. The outgoing gases, containing the synthesized ammonia, are led through heat interchangers by which they lose heat to the incoming stream, the proper balance being maintained so that the catalyst becomes neither cooled nor overheated. The ammonia is removed from the circulating gases by absorption or liquefaction, the gases after stripping being returned to circulation. The yield varies to about 18 per cent under the best oper-

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[1] Consult Report on the Fixation and Utilization of Nitrogen, prepared by the Nitrate Division, Ordnance Office, War Department, Washington, 1922.

ating conditions. The apparatus used for this process is of very complicated design and a very high degree of operating skill is required.

Ammonia is obtained in anhydrous liquid form. It can be converted into nitric acid by oxidation in suitable apparatus. It can be used to make ammonium salts and for all other purposes to which this product is applied.

Cyanide Process

There are a number of methods by which crude cyanides can be obtained from certain raw materials. This process has not yet been developed to a commercial scale, but, since the raw materials are abundant and relatively cheap, and since there is a considerable demand for cyanides for use as insecticides and in metallurgical processes, this method of preparation may become industrially important. Ammonia can also be made from cyanides by treatment with steam, and since the demand for ammonia and products that can be made from it is greater than that for cyanides, the process may also offer some possibilities in this direction if it is ever able to compete with ammonia made by other methods.

The process depends upon the fact that a cyanide of the base is formed if a mixture of a carbonate of an alkali or an alkaline earth is heated with carbon in the presence of nitrogen. Experimental work has shown that the carbonates of sodium or of barium are best for use in the process. Bucher proposes to mix thoroughly pulverized soda ash and carbon with finely divided iron, the mixture being briquetted and charged into an externally heated retort. When heated to about 1,000° C. in the presence of nitrogen crude sodium cyanide is formed. Another method uses the same materials, in slightly different proportions, but omits the briquetting, and uses a revolving retort.

The raw materials most suited for use would be soda ash and metallurgical coke. Iron would be supplied as scale or as pulverized cast iron. Nitrogen would be obtained from the air.

Canadian Situation

Natural nitrates are not found in Canada in commercial quantities. Artificial nitrates are not at present made for domestic consumption. There are two air fixation plants in Canada, both belonging to United States firms, located here on account of power conditions. One of these, using the cyanamide process is located at Niagara Falls, Ontario. It has an annual capacity of 12,000 tons of fixed nitrogen. Almost the entire production is exported as cyanamide to the United States, where it is converted into ammo-phos, a high grade fertilizer constituent, urea, which is used largely in certain manufacturing industries, and smaller quantities of other chemicals. The other plant is located near Vancouver, British Columbia, and is at present idle. It is said to have a capacity of 800 tons of fixed nitrogen per annum.

No statistical studies have been made showing the annual nitrogen requirements even of the principal industries requiring compounds of this element. Undoubtedly agriculture is the largest consumer through fertilizers. Explosive manufacturing and acid production (sulphuric, nitric) also require considerable quantities of nitrates, and small quantities are required by other industries. The fertilizer industry obtains a portion of its requirements from organic wastes locally produced. It also obtains some ammonium sulphate from the byproduct coke plants. The balance of its requirements and some of the demands of other industries using nitrates are met by the importation of nitrate of soda from Chili. A small quantity of nitrate of potash is also imported from Europe. Some data with respect to these importations are given in the tabular statement of imports of chemicals on another page. The average importations of nitrate of soda from Chili for the three years prior to the war were equivalent to about 5,862 tons of fixed nitrogen annually. For the three years after the close of the war this average annual importation was reduced to 2,167 tons. The fixed nitrogen in imported nitrate of potash for each of the three years prior to the war averaged 135 tons per annum, while for the three years after the armistice the average was reduced to about 48 tons.

There are several byproduct coking plants in Canada producing ammonium sulphate much in excess of the home demand for this product. The annual production naturally varies with the demand for coke. Information with respect to plant capacity is given in the section on Coal Distillation and exports are given in the tabular statement already mentioned.

Summary

The foregoing very brief sketch of the present development of nitrogen fixation processes has been introduced to show the raw materials that are required by this group of industries in relation to Canada's position. It will have been noted that in addition to power requirements and equipment the principal raw materials are limestone, coal, air, water, and, for one group of processes, sodium chloride, this latter being the natural mineral product from which soda ash is made. All these materials of suitable grade are available in quantity in Canada at certain points. Canada, however, is at present lacking in one very essential and exceedingly important requirement. There are no trained technical experts available to design equipment and develop processes, none to supervise and direct, and there are no local opportunities to obtain experience in technical operations of this kind. It is true that there is a small production of fixed nitrogen from byproduct coke ovens. This production is, however, a byproduct of the coking industry, itself in turn dependent upon the demand for coke. It is unlikely that byproduct nitrogen can ever equal the demand. An independent source of supply is necessary.

The importance to Canada of self-contained essential industries is obvious. Nitrogen is essential to numerous industries and no native source capable of supplying our requirements has yet been developed. The demand made by agriculture for fertilizers must necessarily expand as the country develops. Our mining industry creates a demand for explosives which in the natural course of events will increase gradually. The building of roads, lumbering, clearing operations, development of water powers, and other activities also create a demand for explosives. During the great war the entire production of explosives in this country was dependent on imported nitrogen as well as imported sulphur.

In addition to fertilizers and explosives, other products are made by prosperous industries whose maintenance is directly dependent upon a supply of certain compounds of nitrogen. It is therefore unfortunate that almost the whole of the nitrogen requirements of all these industries must be imported. At the present time we do not know our exact annual requirements, in other words the size and value of the home market cannot be determined. No accurate data are available to enable us to determine the probable cost of producing our own nitrogen requirements. In fact it is probable that the imported materials can be purchased cheaper than one could make equivalent products. The time is not far distant, however, when these foreign purchases will be impossible, and they might at any time be discontinued under war conditions.

The natural importance of controlling an adequate supply of nitrogen cannot be exaggerated. Our present dependence on foreign sources for supplies of this important chemical is such that the question is worthy of attention from those responsible for the welfare of the nation.

In conclusion, attention is drawn to the fact that the entire British Empire is dependent upon foreign sources for a considerable quantity of its nitrogen. These nitrogen requirements and the sources of supply are worthy of further inquiry than has already been made, having in view the fact that the natural conditions in Canada would appear to offer favourable opportunity for the development of a nitrogen industry designed to supply the needs of the Empire. While the Canadian market alone may not be competent, at present, to support an air fixation market, the Empire market could undoubtedly do so.

CHAPTER IV

INDUSTRIAL GASES

Industrial applications are made of a number of products, which are in a gaseous state under ordinary conditions of temperature and pressure. These products include natural and artificial compounds, and chemical elements, the latter being very frequently prepared from natural substances by chemical and physical processes. In the brief discussion which follows the gaseous substances mentioned are those ordinarily used in industry. Gases used for military purposes are not included, except in so far as they may also be used industrially. Each important gas is mentioned separately in alphabetical order, regardless either of its relative importance, or of its technology.

ACETYLENE. Acetylene is a highly inflammable colourless gas, containing carbon and hydrogen. Pure acetylene is almost odourless, but the commercial gas possesses a distinctive odour due to the presence of impurities. When required for industrial or commercial purposes it is prepared by the interaction of water and calcium carbide. This gas is soluble in alcohol, acetone, and other organic liquids. Advantage is taken of this property to store the gas in convenient containers for distribution and commercial purposes.

Industrially, where large quantities of the gas are required it is generated at the point of application by the use of specially designed apparatus. When required in portable form it is absorbed in acetone and the solution is stored in special containers.

Acetylene gas is used for illuminating purposes, in private houses, in public buildings, in industrial plants, and for municipal lighting purposes. The total number of public and private installations of these several kinds in Canada has not been tabulated, but there are at least fifteen municipalities in which acetylene generating plants have been established for municipal lighting purposes.

Dissolved acetylene stored in convenient containers is employed for small lighting plants and for lighting railway coaches or boats. Formerly it was employed for lighting automobiles. The principal application of acetylene in this form is probably for high pressure oxy-acetylene welding.

Individual lamps of many varieties have been developed for the more or less automatic generation of acetylene from water and calcium carbide stored in suitable containers integrally attached to the lamp. Bicycle lights, and some motor car lights and carriage lamps are of this type. It is also used extensively in miner's lamps. The most important application is for lights, beacons, and other marine signals as aids to navigation. Acetylene lighted buoys and beacons have been developed in which the generation of the gas is automatically controlled. When the storage capacity is made large enough some of these signals will remain in continuous operation for about a year without attention.

Acetylene gas is also industrially important in chemical manufacturing as the basis of other chemical compounds. Acetic acid, acetone, and ethyl alcohol can all be made directly from this gas by special processes.

Calcium carbide is made by two firms in three plants in Canada. It is available in convenient containers at almost every important point in the country. There are at least eight plants engaged in the production of dissolved acetylene for distribution in containers for commercial purposes. There is one large plant in Quebec capable of producing acetic acid and acetone directly from acetylene. The requirements of this country for acetylene gas for all purposes can be amply supplied from internal sources, and there is a surplus available for export.

AIR. Natural air consists of a mixture of many gases. Nitrogen constitutes about 78 per cent of the whole, oxygen 21 per cent, and the balance is made up of small amounts of the rare gases—argon, neon, helium, krypton, and xenon—and gases derived from natural or industrial sources, such as hydrogen, carbon dioxide, carbon monoxide, marsh gas, ammonia, nitric acid, sulphur dioxide, water vapour, and other substances in minute quantities. Air can be liquefied at low temperatures under a pressure of about 40 atmospheres. Liquid air is a mobile pale blue coloured fluid. It boils at a temperature which varies with its composition, the average being about —190° C.

Liquid air is prepared by cooling and compressing atmospheric air. Several types of apparatus have been devised and are in commercial use for the manufacture of this product.

Liquid air is used chiefly for the manufacture of nitrogen and oxygen for industrial use. Liquid air containing about 60 per cent oxygen is used in mine rescue apparatus to resuscitate partially asphyxiated persons. It has also been used as an explosive and it finds a number of uses in chemical and physical laboratories, especially for the production of extremely low temperatures.

Liquid air is made in Canada at one plant incidentally in the manufacture of nitrogen required to produce cyanamide. Liquid air is also made by one firm to meet the limited local market demand for this product.

AIR GAS. Air gas consists of a mixture of air and hydrocarbon vapour derived from gasoline or benzol, or related volatile liquid hydrocarbons. In the manufacture of this gas care must be taken not to produce an explosive mixture. Air gas containing two per cent or slightly less of hydrocarbon vapour will burn with a non-luminous flame. Percentages between two and seven must be avoided owing to their explosive character. Above seven per cent the gas burns with a luminous flame. This gas is usually used with gas mantles for illuminating purposes. The units are usually small and suitable for domestic or hotel lighting systems.

This product is sometimes named *gasoline gas*. The name air gas is also sometimes applied to producer gas made with air only, without the use of steam.

No data are available with respect to the installations of air gas plants in Canada. It is believed that a number of these are in use for lighting large houses and some country hotels where electric light is not available.

AMMONIA. This compound is usually gaseous at ordinary atmospheric pressure. It is readily soluble in water, and it can easily be liquefied. Industrially either the hydrous solution (aqua ammonia) or the condensed liquid product (anhydrous ammonia) may be employed, each form having its own special applications.

Ammonia for industrial purposes is almost invariably obtained as a byproduct in the destructive distillation of bituminous coal, during the manufacture of metallurgical coke or coal gas. It is made in this way in Canada (see page 132). Ammonia can also be produced from atmospheric nitrogen by several different and rather complicated chemico-physical processes to which some reference is made in chapter III (page 77).

Ammonia for industrial uses is obtained in Canada only from the waste ammonia liquors of coal gas plants in some of the larger cities and towns. That produced incidentally during the manufacture of metallurgical coke in byproduct ovens is recovered as ammonium sulphate and marketed as such.

The aqueous solution of ammonia, chemically ammonium hydroxide, is used industrially in the manufacture of ammonium compounds. It also finds applications in the textile industry, in the manufacture of soaps, and in laundering.

Anhydrous ammonia is used in the manufacture of certain chemicals, but its principal industrial application is for refrigeration in cold storage plants and abattoirs.

Ammonia liquors are produced in Canada at five or six points. Aqua ammonia and anhydrous ammonia appear to be produced only by one firm in Toronto. A considerable quantity of anhydrous ammonia must be imported annually, but the customs returns are not compiled in a form to furnish information on this point.

ARGON. This is a colourless inert gas which is present in the atmosphere in the proportion of about 0·9 per cent by volume. It can be liquefied only under high pressure and at a temperature of —186° C. It is obtained from the atmosphere by a complex process of compression and cooling by which liquid air is first produced. Liquid air is then subjected to fractional distillation at low temperatures, argon being one of the fractions recovered. It may also be obtained by the use of a high tension electric current so arranged that sparks pass rapidly through a vessel containing air and a solution of caustic soda. The electric spark causes the nitrogen of the air to be oxidized to nitrous acid, which is absorbed by the caustic soda, forming sodium nitrite. The gaseous residue will be chiefly argon and oxygen. The latter can be removed by passing the residual mixture over red hot finely divided copper or by absorption with potassium pyrogallate. Where argon is required on a commercial scale it is usually made by the differential distillation of liquid air.

Argon is used industrially for filling incandescent lamp bulbs. Its use lengthens the life of the filaments employed in making the lamps and improves the quality of the light emitted.

This gas is not prepared commercially in Canada. The quantity used for the manufacture of incandescent lamps is small, and is usually imported in steel cylinders.

BLUE GAS. See Water Gas.

CARBON DIOXIDE. Carbon dioxide is a colourless gas which is easily liquefied and which is readily soluble in water, to which it imparts a slightly acid taste. The gas will not support combustion and for this reason is an important constituent of some fire extinguishers.

Carbon dioxide occurs in a natural condition in the neighbourhood of volcanic regions, and issues from fissures and springs. It also occurs in solution in spring waters in limestone regions and in certain mineral springs. Occasionally the natural gas is employed for aerating table waters. Commercial and industrial supplies of this gas are usually manufactured directly where required. There are a number of processes in use for preparing this product, but only brief references can be made to the more important of these in order to indicate the different raw materials that are required.

Natural carbonates such as dolomite, magnesite, or limestone, are easily decomposed by heating to a moderate temperature in suitable kilns. The reaction is promoted somewhat by the use of steam. Where large quantities of the gas are required, particularly in chemical manufacture, this method is usually employed. It is also employed in connection with the manufacture and refining of sugar. There are at least four plants of this type operating in Canada, three being used in sugar refining.

Carbon dioxide is also made from natural carbonates, particularly magnesite and limestone, by treatment with dilute hydrochloric or dilute sulphuric acid. Marble dust is very frequently employed for this purpose. Where magnesite and sulphuric acid are employed the residual liquor may be concentrated and magnesium sulphate can be recovered as a byproduct. As a substitute for sulphuric acid the residual nitre cake for the manufacture of sulphuric acid has been used.

Carbon dioxide is produced in large quantities by the fermentation processes in the manufacture of alcohol and beer. It is possible to collect this gas if the vats are covered and sealed against air leaks. If obtained in this way it can be compressed and liquefied. Gas so obtained is used for aerating beers. If required for other purposes it is necessary to subject it to a special deodorizing or purifying process.

Carbon dioxide is also prepared on a large scale by the use of coke or anthracite coal and heated copper oxide. In this process the monoxide is first made by passing air through the heated carbonaceous fuel in a retort. The resulting gas is passed through a second retort containing heated copper oxide, which converts it into carbon dioxide. The resulting dioxide is then divided into two parts, one of which may be utilized, the other of which is again passed through the heated coke or coal, being again converted into the monoxide. The products of the first cycle contain nitrogen from the original air, and they are therefore discarded until only pure carbon dioxide is obtained. Once the cycle is established, a continuous supply of carbon dioxide can be obtained, the copper oxide being regenerated by alternately passing air over it.

In another process coke is burned under a boiler, the air supply being controlled so as to promote the production of the maximum amount of carbon dioxide; the steam generated is used to drive the power plant. The flue gases are conducted to apparatus where carbon dioxide is absorbed in sodium carbonate solution, the waste gases being allowed to escape. The absorptive solution is then heated by exhaust steam to liberate pure carbon dioxide, which is cooled and compressed. The absorbing and cooling operations are cyclic and heat interchangers are employed.

This gas in a less pure condition can also be prepared by extraction from mixtures of other gases in which it is present, particularly from furnace gases and lime kiln gases. These methods are not discussed here.

In some works the gas is used directly without further treatment. Where the gas is intended for distribution to consumers it is usually cooled, compressed, and liquefied for storage in special steel containers. When it is to be used immediately and when the distance it has to be conveyed is small the expense of transferring may be reduced by omitting the containers and preparing it in solid form. In this form it is sometimes compressed in wooden moulds.

One of the principal commercial uses of carbon dioxide is in the manufacture of sodium carbonate and bicarbonate by the Solvay ammonia-soda process, and in the Claus-Chance process for the recovery of sulphur. The former process is in use at one plant in Canada, the latter has not been introduced.

Pure carbon dioxide gas is used for the manufacture of many brands of artificial mineral waters, aerated waters, soda waters, and beers. Many plants of this kind are distributed throughout this country.

This gas is also used in refrigeration plants, especially on ships. It is more advantageous than ammonia for this purpose. This use is, however, being superseded by a cooling system using cthyl chloride as the refrigerant.

There are also a number of miscellaneous minor uses such as in fire extinguishers, to compress fluid steel in ingots, to destroy insects and vermin in grain storage elevators. The liquid form has been used as a source of power for operating pneumatic railway signals and torpedoes. Beer is carbonated and clarified with the liquid gas. White lead and a number of other chemical products can be made by its use. It is also utilized in the refining of sugar, in the making of bread and cakes, and for the sterilizing of milk.

Some references have already been made to the use of this gas in a number of Canadian industries. The number of industrial establishments in which it is used in some form is very large and no attempt has been made to prepare tabulated lists of consumers. The liquid gas stored in containers for distribution to individual small consumers is prepared at four points in Canada by two firms. Very small quantities are also imported annually.

CARBON MONOXIDE. This gas is formed by the combustion of carbon (coal) in a limited supply of oxygen. It can also be made by passing carbon dioxide over incandescent carbon and by a number of other chemical reactions. When required for industrial purposes it is usually made in a gas producer. This gas is the principal important constituent of producer gas, and it is also an important constituent of water gas and other gaseous fuels.

Apart from the industrial uses of the various gaseous fuels which contain carbon monoxide, to which reference is made in other paragraphs, this gas has several other uses. The most important of these is probably in the refining of nickel by the Mond process. It can also be used for the formation of formic acid, oxalic acid, and acetic acid. In these operations the other principal chemicals required are caustic soda and methyl alcohol. Another chemical product made from carbon monoxide and chlorine, and used in the manufacture of certain dyestuffs, is carbonyl chloride, better known as phosgene. This gas may also be used as a reducing agent.

The Mond process for refining nickel is not operated in Canada, but nearly one quarter of the nickel recovered from Canadian ores is refined by this process in Great Britain. None of the other chemicals made from carbon monoxide and mentioned in a preceding paragraph are produced in Canada. No data are available to indicate our annual requirements of these chemicals.

CARBURETTED WATER GAS. See Water Gas.

CHLORINE. This gas is heavy and of a greenish yellow colour at ordinary temperatures. It is intensely irritating to the mucous membranes and is poisonous. Chlorine is prepared as a byproduct in the manufacture of caustic soda from common salt by electrolysis. There is a surplus production of byproduct chlorine and new industrial uses are being devised to absorb this surplus. It is also prepared industrially by the oxidation of hydrochloric acid, itself a byproduct, with manganese dioxide under suitable conditions.

Chlorine readily forms hypochlorites with caustic soda, slacked lime, or similar hydrates. These compounds are active bleaching agents and are made for use in the pulp and paper industry, and for bleaching textiles. Chlorinated lime is also used in many metallurgical operations. The aqueous solution of chlorine is also useful as a textile bleaching liquor.

Chlorine can be liquefied under a pressure of four atmospheres at 15° C. Liquefaction is accomplished by using specially designed pumps in which the compression piston head is lubricated with sulphuric acid. It is also liquefied by absorption processes, tin tetrachloride or carbon tetrachloride being used as absorbers. Liquid chlorine for industrial purposes is stored in steel containers of various sizes. Where large quantities are required special tanks, of 15 tons capacity, mounted on railway trucks, are used.

Liquid chlorine is now widely used to purify domestic water supplies; large quantities are also used for preparing sulphite pulp bleach, and the Canadian demand for this purpose is increasing. Chlorine in liquid form also finds a market in other industries, particularly textile bleaching and chemical manufacture.

The chlorine manufacturer not only produces bleaching powder and liquid chlorine, but also produces a number of other chemicals which find various industrial applications. These include carbon tetrachloride (important as a fire-extinguishing compound); chloroform; chlorides of aluminium, antimony, tin, or sulphur; hydrochloric acid; benzaldehyde; benzoic acid; chloracetic acids; chlorbenzols; and other products.

In Canada chlorine is made as a byproduct of caustic soda manufacture at one plant. A large proportion of the output is liquefied, stored in tank cars, and shipped to the sulphite pulp mills. A portion of the output is used for the manufacture of chlorinated lime. A considerable quantity of chlorinated lime is also imported into Canada. The annual amount and value of these importations cannot be determined because the records available do not separate this item from chloride of lime, an entirely different compound.

Hypochlorite bleaching solutions are also made directly at two sulphite pulp mills by an electrolytic process, to be used as a bleaching agent. Chlorine gas is not produced and recovered as such in these plants.

About forty thousand dollars worth of liquid chlorine was imported in 1920, chiefly for water purification and use as a bleaching agent. It is probable that the newsprint industry and the gradual improvements that are being made in municipal water supplies for domestic purposes will greatly expand the home market for this product.

COAL GAS. This is the name applied to the gaseous product formed when bituminous coal is subjected to destructive distillation in highly heated chambers or other closed containers. The ordinary commercial coal gas consists of mixtures of a number of gases and vapours, most of which are inflammable. The proportions in which the different constituents are present in the gas vary considerably with the conditions of production.

Coal gas may be made by treating bituminous coal in clay retorts heated externally by means of producer gas, coal, or coke. The majority of the gas plants used for municipal lighting and heating are of this type. Coal gas is also made by the treatment of soft coal in special kinds of retorts termed byproduct ovens, the heat being supplied by the combustion of a portion of the distillation products. Byproduct gas finds its chief application in the steel industry for heating purposes, and it is also used occasionally in other large industrial establishments.

Apart from the clay retorts, fire brick, structural steel, and other similar materials used in the construction of banks of retorts or byproduct coke ovens, the principal raw material of this industry is bituminous coal. Coal for this purpose should be high in volatile constituents, low as possible in ash, and free from sulphur. Usually a coking coal is preferred.

Gas retorts and fire brick could be made in some parts of Canada, but many of the plants now in operation were constructed almost entirely from imported materials. The reasons for these importations differ, but the principal factor is geographic location with respect to the best markets from which to purchase supplies, coupled with the fact that materials of established suitability are naturally preferred by purchasers. Such Canadian materials as are suitable are not yet well known. The available materials are also, in many cases, too far from the point where they are required, and the market demand is not such that quantity production can be attained.

The iron and steel equipment required is also, for the most part, imported because of limited demand, special design, and other conditions imposed by geographic location with respect to sources of supply. Local coals are used in retort plants in both eastern and western Canada. Retort plants in Ontario, and at some points in Quebec and Manitoba are dependent upon imported coals. Two of the byproduct plants use coals produced near the plants, and the other two use imported coals.

Retort gas is used industrially for small heating and annealing furnaces, for melting, for welding, and in similar operations in small plants. The principal use is for lighting and in culinary operations. It also finds a limited application in house heating. Coal gas is often mixed with inflammable gases made by other processes, water gas, carburetted water gas, or oil gas being used for this purpose.

Coal gas for municipal purposes is washed and purified to remove ammonia, cyanogen compounds, and sulphuretted hydrogen. The purification is usually accomplished by the use of ferric oxide. Some plants use a natural iron ore, limonite, for this purpose. In other plants the iron oxide required may be chemically prepared. No data are available showing the quantities of limonite ore and iron oxides used annually for this purpose. In nearly every plant native materials are used.

Retort plants have been erected in twenty-four Canadian towns and cities and in one city in Newfoundland. Fifteen of these plants are located in Ontario, two in Quebec, five in British Columbia, one in Nova Scotia, and one in New Brunswick. Coal gas alone is utilized only in eight of the municipalities. Carburetted water gas, oil gas, or water gas are added to the coal gas in sixteen plants. In some cases the supplementary equipment is of sufficient capacity to supply all the gas needed without the use of the retorts. In such cases the relative costs of coal and oil and the variations in the demand for gas may determine which plant to use.

Statistical data with respect to the capacities of these plants are not available. The total amount of soft coal used annually for the production of coal gas is approximately 425,000 tons. The municipal gas systems also absorb a small tonnage of anthracite coal, and in excess of nine million gallons of oil, nearly all of which is imported.

Coal gas made in byproduct ovens in Canada is used partly for coking operations, but chiefly in the open hearth furnaces and soaking pits of the steel works. There are four byproduct plants in Canada, one being located in Nova Scotia, two in Ontario, and one in British Columbia. Both plants in Ontario are operated on imported coals. The other two plants use coal from local mines. These plants are operated chiefly for the production of metallurgical coke, and a more extended reference is made to them in the section dealing with Coal Distillation (page 130).

HELIUM. This gas is next to hydrogen the lightest gas known. It is colourless and inert, and can be liquefied only at a very low temperature. It occurs in minute quantities in the atmosphere and is also present in certain minerals. Its presence in natural gases from certain localities has been known for some years. During the war it was proposed to use this gas as a substitute for hydrogen for inflating balloons and dirigible air ships. Its lightness, non-inflammability, and general inertness render it particularly adaptable for this purpose. Commercial methods for recovering this gas from natural gas were developed in Canada and in the United States, and a considerable quantity had been prepared at the time the armistice was declared. Further investigations are in progress to develop other industrial applications of this gas.

An investigation of helium sources within the British Empire, made under the direction of Dr. J. C. McLennan, head of the Department of Physics, University of Toronto, has shown that the largest available supply of this gas within the Empire is located in Alberta.[1] No commercial development has yet taken place in Canada, but the production of this gas on a large scale for use in the aeronautical service of the country is practicable.

HYDROGEN. This is a colourless, tasteless, odourless, highly inflammable gas which can only be liquefied with difficulty under high pressure and at a very low temperature. It is the lightest gas known. It can be generated by many different processes. Industrial hydrogen is usually made by the electrolysis of water, or by the use of ferrosilicon and caustic soda. It is stored under pressure in steel bottles. It is used with oxygen in the oxy-hydrogen blowpipe for welding, cutting metals, and it also finds other applications where a high temperature is required. Hydrogen is used for inflating balloons and airships of various kinds. It also finds applications in certain industrial chemical operations, including the hydrogenation of oils for the manufacture of certain food products.

Hydrogen for industrial purposes is made by at least two firms in Canada, one in Ontario and one in British Columbia. There are also several plants equipped to produce hydrogenated oils.

Available records do not indicate any importations of this gas.

ILLUMINATING GAS. There are a number of combustible gases that are used for illuminating purposes. Gases consisting chiefly of carbon monoxide or hydrogen are not self illuminating. When used for illuminating purposes it is necessary to employ some form of gas mantle which is heated to incandescence by the combustion of the gas. These gases can also be enriched by the addition of volatile hydrocarbons which will liberate free carbon in the flame. The carbon being heated to incandescence renders the flame luminous. Gases such as coal gas, oil gas, or natural gas, which are rich in hydrocarbons, are self luminous. These gases are also used with gas mantles, the complete combustion being promoted by the construction of the burner employed, which introduces additional air to consume the carbon. The various kinds of gases used for illuminating purposes are briefly discussed under the titles acetylene, coal gas, natural gas, oil gas, producer gas, and water gas.

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[1] See Mines Branch Bulletin, Publication No. 522.

NATURAL GAS. This name is commonly applied to a natural gaseous fuel which issues from strata containing petroleum. Accumulations of gas are found beneath impervious strata above the petroleum bearing strata, and these natural reservoirs are tapped by means of bore holes. Natural gas is also occasionally found escaping from fractures or through porous strata. The composition of this gas varies from place to place, and may even vary in the same well at different times. The principal constituent is usually methane, but there are also small amounts of other gases containing carbon and hydrogen. Recently certain natural gas areas have been found to produce a natural gas containing small amounts of helium—to which reference is made in another paragraph. Some natural gas wells produce nearly pure nitrogen, and less frequently carbon dioxide, both of which are useless as fuels.

Natural gas is used as a fuel for many types of industrial heating, such as the operation of reverberatory furnaces, retort furnaces, annealing furnaces, glass furnaces and pots, metallurgical furnaces. It is also used as a source of power and light in factory operation, and as a source of light and heat for domestic purposes. The calorific value of natural gas is usually much higher than that of any ordinary artificial gas and it is one of the best fuels known.

Natural gas rich in methane could be used for the manufacture of industrial alcohol, but no commercial developments of this kind are yet in operation. It is used in some localities, where there is a limited demand for other purposes, for the manufacture of carbon black, a product for which there is a large demand. No carbon black is at present made in Canada. Large quantities of this product are imported annually, but the exact amount cannot be determined from the published statistics which include four different kinds of black pigments in the one item.

Natural gas in commercial quantities is being obtained in the provinces of New Brunswick, Quebec (very small), Ontario, and Alberta. It also occurs in the Mackenzie River basin and probably in a number of other areas, particularly in the western provinces. Detailed statistical information with respect to this industry is published annually by the Dominion Bureau of Statistics.

NITROGEN. This is a colourless, odourless, tasteless, and inert gas which constitutes about 78 per cent of the atmosphere. It can be liquefied at —118° C. under heavy pressure. Liquid nitrogen is a colourless mobile fluid. The gas is prepared from air either by fractional distillation of liquid air, or by removing the oxygen by chemical means. Where nitrogen is required mixed with hydrogen it can be prepared from producer gas. Nitrogen as ordinarily prepared contains a small amount of other gases such as argon, carbon dioxide, and oxygen as impurities.

The principal industrial use of nitrogen gas is for the manufacture of certain chemical products by processes that are termed nitrogen fixation processes. Atmospheric nitrogen can be used for the manufacture of ammonia, nitric acid, nitrous acid, cyanides, and cyanamides, and a number of compounds derived from one or more of the above products. It is probable that future industrial developments on a large scale will utilize several of these processes for the manufacture of nitrogen fertilizers, explosives, and certain chemicals required for metallurgical industries. A further reference to this subject is made in the chapter on Production of Nitrogen Compounds.

Nitrogen does not support combustion and is inert. It is therefore sometimes used for protecting inflammable liquids during transfer and storage. It is also used for filling small incandescent lamp bulbs, though for this use argon is being increasingly employed.

There is one plant in Ontario engaged in the production of cyanamide and sodium cyanide, utilizing nitrogen derived from the air.

NITROUS OXIDE. This gaseous compound is colourless and of a sweetish taste. When cooled under pressure it can be liquefied. It is prepared industrially by heating ammonium nitrate or by heating a mixture of sodium nitrate and ammonium sulphate under suitable conditions. Its principal use is as an anesthetic in dentistry and in surgery. It may be used alone or mixed with oxygen and is popularly known as "laughing gas." Commercially the gas for use as an anesthetic is specially treated to free it from other oxides of nitrogen and from chlorine. It is stored in steel cylinders under pressure.

This gas is used in nearly every dental laboratory in the country and in many hospitals. There do not appear to be any records of importations, and, so far as the author is aware, the gas is not made in Canada. There are no statistical data showing the amount required annually.

OIL GAS. Gas made by the destructive distillation of petroleum is termed oil gas. The operation is similar to that for the production of coal gas, but it is possible to prepare this gas in small plants. The gas may also be compressed for storage without serious detriment. When coal gas is compressed a considerable portion is deposited as liquid hydrocarbons, and the residual gas when burned is found to have lost its luminous character. Oil gas when compressed loses less of the hydrocarbons and retains its luminous properties. Several systems have been invented for making this gas. The Pintsch process used for making Pintsch gas is one of these.

Oil gas is compressed and stored in portable iron containers under a pressure of 8 to 10 atmospheres. In this form it is used for lighting railway coaches, stations, vessels, lighthouses, and other marine signals.

There are several small plants of this type in operation in Canada, but no list of the installations is available.

Oil gas compressed to about 100 atmospheres pressure, so that the greater portion of it liquefies, is stored in steel bottles and utilized industrially as "Blau gas." Available information indicates only one plant of this type in Canada.

OXYGEN. This is a colourless, odourless, tasteless gas which can be liquefied under pressure at —190° C. Liquid oxygen is a slightly bluish liquid which can be solidified at —227° C. This gas constitutes about one-fifth of the air and is the substance that supports the combustion of all fuels. Pure oxygen can be made for industrial purposes by the fractional distillation of liquid air. It is also made by the electrolysis of water, being recovered at the same time as the hydrogen.

Industrial oxygen is compressed or liquefied and stored in steel drums or bottles. It is used with hydrogen or acetylene in the oxy-hydrogen or oxy-acetylene blow lamp for the production of high temperatures. These lamps are used for cutting and welding steel and other metals including platinum. Pure oxygen gas is administered in cases of asphyxia, due to noxious gases or drowning. It is also occasionally used in medical practice as a stimulant, especially in anaesthesia. In recent years a method of using liquid oxygen as an explosive has been devised.

Oxygen is essential for the promotion of combustion. Ordinarily all fuels are burned by the use of oxygen of the air. There is a large quantity of low grade coal, high in ash, available that cannot be economically burned under present conditions. On the other hand oxygen is a byproduct in the manufacture of air nitrates for fertilizer and other purposes. If the manufacture of air nitrates becomes a well established industry in the future there will be available a large supply of byproduct oxygen. It has been proposed to utilize this oxygen to burn these low grade fuels for the generation of heat, steam, and power. The development of a cheap method of making oxygen from the air or from water would also make it practicable to use lower grade fuels industrially.

Oxygen as a byproduct is produced in one plant where only the nitrogen is utilized, the oxygen being discarded. There are at least six plants which prepare bottled oxygen for industrial use. There are no records of importation, consumption, or production.

Ozone. This colourless gas is an allotropic form of oxygen possessing a very characteristic odour. It will support combustion more actively than oxygen, and is a very active oxidizing and bleaching agent. It can be liquefied under suitable conditions of temperature and pressure. Liquid ozone is an opaque blue liquid which boils at —119° C. It can be made electrically in a variety of ways, by the electrolysis of water, and by the use of high tension electric discharges. Chemically it can be prepared by heating barium peroxide with sulphuric acid under suitable conditions, or by passing oxygen over heated peroxides. When required for commercial purposes it is almost universally made electrically, by passing a current of air or oxygen between two specially formed high tension electrodes.

Ozone has the property of destroying the objectionable odours of organic origin arising from various industrial operations such as tanning, manufacture of glue, manufacture of certain organic chemicals, or odours arising from decaying vegetable or animal refuse. It is frequently used in certain factories for deodorizing, being generated at or near the place where it is required.

The most important commercial use of ozone is the sterilizing of local and domestic water supplies. The greater portion of the organic impurities in water can be removed by filtration, but the final purification is accomplished by introducing ozone in such a way that it will come into contact with as much of the water as possible. It will remove all objectionable tastes and odours due to organic materials and completely sterilizes it if it is properly applied.

Ozone is also beginning to find industrial applications in many technical operations. It is used for bleaching, deodorizing, or removing objectionable flavours from oils, fats, tallows, and waxes. It has the property of hardening raw flaxseed oil and it will cause other oils to thicken. Oils thus treated are used in the paint and varnish industry. As a bleaching agent it has been used in various textile industries for treating fine cotton and linen fabrics. It is not so suitable as chlorine for bleaching silk or wool, and the cost is higher. It has been used for clarifying sugar solutions. It is also used in the cold storage and brewing industries, and it has been proposed to use it for sterilizing sewage.

There is no information available with respect to the utilization of ozone industrially in Canada, though the abundance and relatively low cost of electric power in many localities should make it practicable to utilize ozone for sterilizing some water supplies. There are no records of any importations of ozone in compressed or liquid form.

PRODUCER GAS. Producer gas is a gaseous fuel made by blowing air, or air and steam through incandescent coal, coke, or other fuel such as charcoal or peat. It consists principally of a mixture of carbon monoxide and nitrogen, with small amounts of hydrogen and marsh gas. The reactions take place in a specially designed furnace. The calorific value of the gas prepared in ordinary producers is low—usually below 200 B. Th. U.

Producer gas is used industrially for many purposes where a cheap fuel easily controlled is required. Its principal use is probably for heating various types of melting furnaces, reverberatory furnaces, pottery furnaces, retorts, and other kinds of industrial furnaces, and in other metallurgical operations. This gas is also used for power purposes in gas engines.

There are a number of producer gas plants operated in Canadian manufacturing establishments, but no statistical data are available as to their number, distribution, or fuel requirements.

SULPHUR DIOXIDE. This is a colourless gas with a pungent and characteristic odour. When inhaled, even in very dilute mixtures with air, it has an irritating effect on the mucous membranes. It occurs naturally in volcanic regions and is present in the air of cities through the combustion of fuels containing sulphur. Very large quantities of this gas are also discharged into the air by smelting and refining plants treating sulphide copper or zinc ores. The gas is readily soluble in water forming sulphurous acid which oxidizes to sulphuric acid. It can be liquefied easily at a pressure of about three atmospheres when cooled to —10° C. The gas is prepared on a large scale for industrial purposes by the combustion of sulphur or of the sulphur content of pyrites in air. Extensive reference has already been made to the principal industrial applications of the products made from this gas in the sections on Heavy Chemicals and on the Pulp and Paper industry.

The liquid gas is stored in steel bottles or steel tanks for transportation purposes. Certain European countries require that these storage vessels shall be capable of withstanding an internal pressure of 30 atmospheres, but there are no regulations of this kind in force in Canada.

Sulphur dioxide in the gaseous form is used for the manufacture of sulphuric acid and sulphates, to make sulphite pulp, in certain metallurgical operations, in the manufacture of starch, in bleaching, and in numerous other industries. Its use in the different industries is discussed in other sections.

Liquid sulphur dioxide can be easily stored and transported. In this form it could be used in the sulphite pulp industry, and in many other industries much more conveniently than it can be made locally by burning sulphur. The liquid form is now used chiefly in refrigerator plants. It is also used as a solvent in the manufacture of glue, for bleaching delicate textile fabrics and straw, as a disinfectant, and in certain chemical manufacturing processes, such as refining of petroleum, tanning leather, or refining sugar. It is occasionally used in fire extinguisher liquids, and in the manufacture of certain chemicals.

Where the gas is required in manufacturing it is usually made locally. The industries requiring this gas in Canada all operate their own plants. Liquid sulphur dioxide is not made in Canada and there are no records of importations. Large quantities of this gas are discharged into the air at smelting plants, notably in the Sudbury region. It is probable that in the future it may be profitable to recover a portion of this gas in liquid form and utilize it in the manufacture of sulphite pulp. While this waste gas could also be used for making sulphuric acid, this product could not be marketed profitably under present conditions, and the quantity that could be produced would be much in excess of present requirements. There is a possibility of recovering elemental sulphur from waste sulphur dioxide gas in smelter stack gases by treatment with carbohydrates, or producer gas and steam. The subject is worthy of further and complete investigation.

WATER GAS. This is a mixture of hydrogen and carbon monoxide made by decomposing steam with incandescent carbon. This gas burns with a pale blue, non-luminous flame. It is used as a fuel, for developing power, and also for admixture with coal gas. The principal materials required are coke or anthracite coal and steam. There appears to be only one water gas plant in operation in Canada, and this is used as an auxiliary to a coal gas plant. All other plants produce carburetted water gas.

Water gas can be made luminous by the addition of hydrocarbons that will liberate free carbon in the flame as the gas burns. This is accomplished by vapourizing suitable petroleum oils in a heated carburetter, mixing the resultant oil gas with water gas, and heating the mixed gases. The final product is called carburetted water gas. There are a number of systems in use for the production of this gas. The systems used in Canadian plants are the Lowe, the Springer, and the Merrifield-Wescott-Pearson. There are twenty-five carburetted water gas plants in Canada, thirteen of which are used as auxiliaries to retort gas plants. Twelve plants are used for municipal purposes independently of other gas systems. Petroleum oils used for the manufacture of carburetted water gas in Canada are all imported. Anthracite coal is also imported. Coke used for this purpose may have been made from either domestic or imported coals in local retort plants.

CHAPTER V

PLASTERS, LIMES, AND HYDRAULIC CEMENTS

The production of structural materials from non-metallic mineral products constitutes one of our most important groups of industries. Among these materials plasters, limes, and cements are of first importance. All of these products are made by the suitable heat treatment of natural minerals, found in large deposits. This treatment promotes certain chemical changes which cause the final product to possess the property of hardening when subjected to certain well established conditions. This hardening property is due to a chemical change that can be promoted almost at will by the subsequent treatment. Heat to promote these chemical changes is obtained by the use of coal, petroleum, fuel oil, or natural gas. Plasters and limes are also made with wood fuel. Fuel and water are accessory raw materials required by this group of industries.

Raw Materials and Processes

Plasters: Plasters are made from gypsum, a mineral which occurs in large bedded deposits. Pure gypsum is a hydrous calcium sulphate containing 20.9% water ($CaSO_4.2H_2O$). Commercial gypsum, as mined, is rarely pure. It usually contains silica, anhydrite, calcite, and clayey products, the percentages varying locally. The presence of impurities naturally affects the character of the plasters that can be made from any given deposit of natural gypsum. For some varieties of plasters impurities amounting to 25% of the whole can be tolerated. When gypsum is burned by externally applied heat at a low temperature (150°—200° C.), most of the combined water is driven off, the residue constituting a partly dehydrated calcium sulphate. This product, when finely ground, constitutes the plaster of Paris of commerce. If certain impurities were present in the original gypsum, or if they were added, the finished product has somewhat different properties from plaster of Paris, and it is known commercially as cement plaster. Both plaster of Paris and cement plaster possess the property of re-absorbing water and setting or hardening. It is this property which makes these products of value commercially as structural materials. Certain variations in the method of manufacture and subsequent treatment give rise to closely related products which are marketed under such trade names as hard finish plaster and hard burned plaster.

Limes: Limes are oxides of calcium or magnesium obtained by subjecting the natural carbonates to heat. Limestone is the natural raw material from which calcium limes are made. Pure limestone is calcium carbonate, which contains 56 per cent calcium oxide and 44 per cent carbon dioxide. On heating to a temperature of about 900°—950° C. the carbon dioxide is driven off and the oxide of calcium, or lime, remains. This oxide has the property of setting or hardening if treated with water and then exposed to the air or any gas containing carbon dioxide. Pure limestone yields a pure lime when calcined. Such a product is called "quicklime." Natural limestones commonly contain some magnesium carbonate. Where the relative proportions of the two carbonates are nearly equal the natural rock is designated dolomite. At the other extreme we find deposits of almost pure magnesium carbonate, known as magnesite. Magnesium carbonate can also be decomposed on heating with the production of magnesium oxide. The intermediate rocks between limestone on the one hand and magnesite on the other give rise to different varieties of lime when calcined. Limes which carry less than 10 per cent of magnesium oxide are commercially rated as high calcium limes, while those that contain magnesium oxide in excess of this amount are designated magnesian limes.

When a lime is treated with water the oxides of calcium and magnesium present are converted into hydrates. This operation, known as "slaking," is accompanied by the evolution of heat. The hydrated lime, when exposed to the air, slowly absorbs carbon dioxide and reverts to the carbonate. Pure lime shrinks notably on drying. This is counteracted in practice by adding sand to the lime paste made in slaking, the product constituting lime mortar. Magnesian limes slake more slowly than pure limes. They also give off less heat, swell less, and set more rapidly. Magnesian limestones and dolomites which contain silica and clay materials as impurities, on burning yield a product that will set under water if the impurities are present in sufficient quantity. Such a product constitutes a hydraulic cement, to which further reference is made in a subsequent paragraph.

Magnesite, when burned, yields magnesium oxide. Pure magnesite contains 47·6 per cent magnesium oxide, and 52·4 per cent carbon dioxide. Magnesites are less widely distributed than limestones, particularly the purer varieties. The calcining operation is also more difficult to perform. The oxide is therefore more costly than lime, and its industrial applications are more specialized and limited. If the rock is burned at a light red heat the magnesium oxide formed has a relatively low specific gravity, absorbs water, and sets in air about the same way as lime does, and the paste can be moulded into shapes or otherwise applied. If the rock is calcined at a high temperature, the magnesium oxide produced has a higher specific gravity, does not form plaster like the low burned material, and does not absorb carbon dioxide from the air to form the carbonate. Magnesite bricks are usually made from mixtures of the heavy dead burned material and the lighter material burned at lower temperatures. The presence of 15 per cent to 20 per cent of the latter makes it possible to mould the bricks to the desired shapes. Such bricks harden slowly in the air, and, when sufficiently dry, are burned at a low red heat.

Magnesium oxide possesses the property of cementing or hardening when mixed with a solution of magnesium chloride, the product formed being oxychloride of magnesium. These materials are utilized as magnesia cement to make artificial stone, floors, floor tiles, and similar products from broken stones of various kinds and colours. The same material is used for cementing abrasive materials to make grindstones, emery wheels, and other kinds of polishing stones.

Hydraulic Cements: Hydraulic cements are mortars which have the property of setting under water. There are a number of different materials which will form cements having this property in common. An impure limestone, containing a certain amount of silica and clay material, and iron oxide, will, when calcined, yield a cement that will slake slowly and harden. Such a product is called a hydraulic lime. If the percentage of impurities present lies between 15 per cent and 40 per cent the lime present will practically all unite with the silica, alumina, and iron to form complex compounds, and there will be little or no free calcium oxide in the finished product. This material is not affected by water after burning as there is no free lime to slake. If it is ground into a fine powder this powder will harden rapidly if mixed with water, and will even set under water. A cement made from natural rock in this way is termed a natural cement.

It is possible to make mixtures of rocks containing lime (or lime and magnesia), silica, alumina, and iron oxide in suitable proportions to produce a product similar to natural cement. The raw materials used in commercial practice are limestones or marls to supply the lime, and clays or shales to supply the necessary silica, alumina, and iron oxide. The raw materials are dried, ground to fine powder separately, mixed in proper proportions to give the finished product desired, and charged into a special type of kiln. Modern practice uses long cylindrical rotary kilns, lined with fire brick, and fired with pulverized coal, natural gas, or oil. The mixture is calcined in the kiln at a temperature around 1,650° C. During the burning the lime unites with the silica, alumina, and iron oxide to form complex silicates and other compounds. The product as it leaves the kilns is in more or less nodular masses called "clinker." The clinker is then ground to an impalpable powder in special equipment. This fine powder has the property of hardening or setting when mixed with water in suitable proportions. In commerce it is known as Portland cement and it possesses the property of setting under water. In commercial practice it is customary to add a small quantity of gypsum to Portland cement clinker at the beginning of the final grinding. The finished product then contains a certain proportion of ground gypsum. This has the effect of retarding the rate of setting of the Portland cement, making it possible to shape and mould the material as desired. In structural work broken stone and sand are usually used with Portland cement, the latter serving chiefly to cement these materials together and to hold them in place.

Cement clinker is an artificial product consisting of silicates, aluminates, and ferrites of lime, or of lime and magnesia. Somewhat similar products are made incidentally as slags in iron blast furnaces, and they occur naturally in volcanic regions (as volcanic ashes). These products, if finely ground and mixed with water have the property of hardening much as does Portland cement, although the rate of hardening may be slower, and the hardened product may not be so strong. If slaked lime is added the hardening property may be improved. In some localities where volcanic ashes or blast furnace slags are available a cement is made by grinding these and adding a little slaked lime. This type of product is called Puzzolan cement.

Commercial Uses

Pure gypsum yields plaster of Paris on calcining. High grade plaster of Paris finds a large number of industrial applications which can be only briefly mentioned. The principal uses are as follows: Dental plaster modelling, moulds for many purposes, plate glass moulds for polishing, pottery moulds, hat moulds, foundry work, rubber stamp moulds, interior decoration for walls and ceilings, surgical casts, plaster ornaments, making match heads, in the construction of safes, in engraving or polishing jewels and jewelry, filler for paper, gypsum paint or whiting, in palaeontological and archaeological research.

Impure gypsum, or gypsum to which impurities have been added before or after calcining, yields a product called cement plaster if burned below 200° C. Cement plasters may be improved and strengthened by the addition of hair or wood fibre. A retarder is also added to delay the time of setting. Such plasters find many applications in interior work in dwelling houses and office buildings. The product is marketed under a number of trade names. If the calcining takes place at a red heat or over, and borax or alum is added and the mixture reheated, the product sets slower than ordinary plaster, but finally becomes much harder. Such plasters are termed hard finish plasters. Similar products are marketed under trade names such as Keene's cement, Mack's cement, Parian cement, and others. There are a number of other products made from calcined gypsums used principally for interior work. Such are alabastine, lieno plaster board, partition blocks, and similar materials.

The best known use of lime is undoubtedly for the production of lime mortars. Since lime shrinks on drying and hardening it is never used alone. In making mortar the lime is slaked with water and allowed to cool, forming lime paste. Mortar is made by adding from two to four parts of sand to this paste. When lime is slaked under ordinary conditions by ignorant workmen the product is not necessarily uniform or satisfactory. If properly slaked the lime will absorb about one-third of its own weight of water. The best results are obtained if this slaking is done under competent supervision with suitable machinery. Some producers are now marketing a scientifically slaked lime called "hydrated-lime." The product is a dry white powder, which is packed in sacks or bags for marketing. It makes an excellent lime paste when water is added.

Lime is used in the manufacture of sand-lime bricks. These are made by mixing sand or gravel with a small amount of slaked lime, forcing the mixture into a mould under heavy pressure and then drying and hardening the product.

Lime also finds a large number of applications in the arts and industries. To enumerate these alone would require a great deal of space. The accompanying schedule showing many of the uses of limes has been included, through the courtesy of the National Lime Association, to show many of these applications.

Hydraulic cements, and particularly Portland cement, are used in the construction of dams, buildings, floors, sidewalks, and roadways, bridge piers, bridges, and in many other ways. Dry cement powder is used occasionally as a mineral filler for insecticides.

CHART SHOWING SOME OF THE INDUSTRIAL APPLICATIONS OF LIMES

Prepared by the Chemistry Department National Lime Association Washington D.C.

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Diagram 7

Statistical Data

Statistics of the annual production in Canada of gypsum, ground gypsum, calcined gypsum, lime, sand-lime brick, and cements, are given annually in the reports on Mineral Production. No statistical data are available showing the annual requirements of the various other industries which use lime as a raw material. Data with respect to imports and exports of these commodities are also available in the annual reports of the Dominion Bureau of Statistics.

Canadian Situation

Natural deposits of gypsum occur in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, and British Columbia. Gypsum has been quarried in all the provinces mentioned, though the last available reports indicate that no work is now in progress in British Columbia. Available records show the existence of 20 producers in Canada, 10 of these being located in Nova Scotia, 5 in New Brunswick, 3 in Ontario, and 2 in British Columbia. Eight of these plants were idle during the last few years. Most of these firms are engaged only in quarrying gypsum and selling it in lump form, or as crushed, or as ground gypsum. There are five firms, operating six plants, engaged in the production of calcined gypsum products.

Natural deposits of limestone, or magnesian limestone, occur in all the provinces of Canada, and there are lime burning plants in each province. The latest available records show 1 plant in Nova Scotia, and 1 proposed, 6 in New Brunswick, 2 in Prince Edward Island, both of which were idle at last reports, 24 in Quebec (7 idle), 45 in Ontario (13 idle), 8 in Manitoba (3 idle), 1 idle in Saskatchewan, 5 in Alberta (2 idle), 5 in British Columbia (1 idle). The total number of plants, including those that are idle, is 97. No data are available showing the total number of kilns available, the types of kilns in use, and the annual capacity of the kilns. Ten of these plants are equipped for the production of hydrated lime.

In addition to the above there are four firms operating special lime kilns for the production of lime for use in the manufacture of soda ash and calcium carbide.

There are 18 plants in Canada for the manufacture of sand-lime brick, having a daily rated capacity of about 650,000 bricks. One of these is located in Quebec, 10 in Ontario, 3 in Manitoba, 2 in Saskatchewan, and 2 in Alberta.

Materials suitable for the manufacture of hydraulic cements occur in all the provinces of Canada. Portland cement plants have been established in the provinces of Quebec, Ontario, Manitoba, Alberta, and British Columbia. An additional plant is proposed for the eastern provinces, but none has yet been constructed. One plant, located in Nova Scotia, makes Puzzolan cement from blast furnace slag.

There are 9 corporations operating in Canada owning 21 mills for the production of cement. Omitting the mill making Puzzolan cement, one making natural cement in a vertical kiln, and one mill that has been idle for some years, there are 18 mills available, equipped with 109 cylindrical kilns, having a rated capacity of 46,000 barrels of cement per day. The sizes and capacities of the several kilns vary greatly; the shortest kiln reported is 60 feet in length, while the longest measures 185 feet over all. The number of kilns actually in operation varies with the demand. During the last few years many of the plants have been idle and the others have not been working to capacity.

CHAPTER VI

FINE CHEMICALS (INORGANIC)

General

Many chemical products are classified as fine chemicals, in contradistinction to those which have been described in the preceding chapters of this report as heavy chemicals. It is not possible to formulate a precise definition of the term " fine chemical " which will be of universal application. There are a number of chemical products, such as those used as developers in photography, or the synthetic drugs, which are universally regarded as fine chemicals. There are other products upon whose classification it is much more difficult to decide.

There seems to be a general consensus of opinion that chemical products which are made on a comparatively small scale under special conditions of manufacture by highly skilled labour working under competent technical supervision shall be called fine chemicals. Usually the products are of a high grade of purity and are correspondingly free from impurities; often they are rare products made only by a few manufacturers and the unit costs are comparatively high owing to the conditions of manufacture, complexity and cost of the operation of the processes, and rarity and relative costliness of the raw materials.

The Association of British Chemical Manufacturers classify fine chemicals in five groups, as follows: Analytical, Pharmaceutical, Photographic, Rare Earth, and Synthetic Essences and Perfumes.

The first four groups of fine chemicals can be further subdivided into inorganic and organic products. In this chapter brief reference is made to inorganic fine chemicals; the organic fine chemicals are considered in chapter V at the end of part III of this report.

Inorganic Fine Chemicals

The number of inorganic or fine chemicals made for analytical work is very large and no attempt is made to enumerate them. Most of those marketed are made chemically pure, but in some cases routine laboratory determinations may be made with products which while nearly pure are not absolutely so. Analytical chemicals are usually made from purified hydroxides or carbonates of the metals, and purified acids. The basis of both series of products is the natural minerals containing the elements desired.

Inorganic pharmaceutical chemicals for medicinal purposes are made in the same way as analytical chemicals and from the same raw materials. Since they are for human use and are often applied internally they must be pure, or at least free from deleterious substances. The pharmaceutical manufacturer of inorganic fine chemicals often purchases inorganic chemicals either crude or of a technical grade and submits them to a refining process instead of making the products directly from raw materials. A classification of the principal chemicals used as pharmaceuticals is given in part III, chapter IV.

Photographic fine chemicals of inorganic origin are made in the same way as those for analytical purposes or for the pharmacist.

Salts of the rare earths are made by complex chemical processes from the rare natural minerals in which these substances are found.

The fifth group of fine chemicals does not include any inorganic compounds.

Table 10.—Fine Chemicals made in Canada (inorganic)[1]

Acids (hydrobromic, hypophosphorous, phosphoric, sulphurous); ammonium compounds (bromide, chloride, hydrosulphide, iodide, magnesium phosphate, nitrate); antimony chloride; arsenic compounds (iodide, tribromide); bismuth compounds (iodide, oxychloride); calcium sulphide; copper compounds (bromide, carbonate, chloride, cyanide, nitrate, oxide); gold compounds (chloride, sodium chloride); iron compounds (arseniate, bromide, iodide, perchloride, phosphate, sulphide); lead compounds (iodide, peroxide); magnesium compounds (chloride, phosphate); mercuric compounds (cyanide, iodide, oxide); mercurous compounds (iodide, nitrate, sulphate); potassium compounds (carbonate, chloride, iodide, nitrate, sulphate, sulphide); silver compounds (chloride, nitrate, oxide); sodium compounds (amalgam, arseniate, bromide, iodide, nitrate); sulphur iodide; zinc compounds (bromide, carbonate, iodide, sulphate).

Canadian Situation

No systematic studies have yet been made of the fine chemical situation in Canada. The preceding list names many products that were made here at one time. During the war production of most of these compounds ceased, and it has not been possible to ascertain how far it has since been resumed.

No statistical studies have been made of this industry in Canada. These products were made only by two or three firms. How many firms are now engaged in producing such products is unknown. Canada, for the most part, imports all the chemicals used for analytical purposes, for pharmaceutical purposes, and for photography. Where salts of the rare earths are required they are always imported.

Trade statistics based on Customs returns do not present any reliable information with respect to the market for these products in Canada.

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[1] The products listed were all manufactured in Canada at one time. They are not all now being produced, but manufacture could be resumed if warranted by commercial conditions.

PART III

CHEMICAL INDUSTRIES

PRIMARY ORGANIC PRODUCTS

INTRODUCTORY

There are a number of important industries whose principal raw materials are natural products of organic origin. Most of the materials are derived from plant life, but in a few instances they may be of animal origin. Inorganic chemicals are required in many cases to carry out the necessary chemical processes in making the products of this group of industries, but they play a relatively minor part, although they are essential to the successful application of the processes in which they are used.

The industries discussed in this section have been classified into five groups. The first group comprises those which use ferments as essential to their processes. The most important product is Industrial Alcohol. The second group comprises those industries which are based upon forest products, especially timber. The principal subject discussed is the production and utilization of cellulose. Some reference has also been made to other industries which produce cellulose products, although the cellulose used may be obtained from other sources than timber, all cellulose utilized commercially being of vegetable origin. The third group comprises those industries which make products by the destructive distillation of raw organic materials. The destructive distillation of wood has been included in this section in preference to discussing the subject under the caption of Forest Products industries. This third group also includes the destructive distillation of coal, coal tar, and petroleum. The fourth group comprises the numerous preparations that are used in pharmacy and medicine, and the fifth group includes fine chemicals of organic origin that are used chiefly in photography, and to a less extent in medicine and in other industries.

The raw materials of the first two groups of industries are derived from living plants and animals. The principal raw materials of the third group, the destructive distillation industries, with the exception of woods and plants, are natural mineral products. Coal is considered to have originated from prehistoric plant life, while petroleum is generally considered to have been derived from animal remains. Shale oils, on the other hand, which are closely related to petroleums, are obtained by the destructive distillation of shales which are supposed to contain organic materials derived from plants. Pharmaceutical preparations are derived chiefly from vegetables, although numerous fine chemicals derived from mineral products are also included in every book on this subject. Fine chemicals of organic origin, other than those included in pharmaceuticals, are derived chiefly from the products obtained by the fractional distillation of coal tar.

In the industrial utilization of these materials many other minerals or products derived from minerals are required. The discussions in the text have been confined to brief reviews of the salient features of the industries mentioned, special references being made to the mineral products that are essential to these industries. The discussion of the last two groups of industries has necessarily been very brief.

CHAPTER I

FERMENTATION INDUSTRIES

Fermentation is defined as the chemical decomposition of an organic compound with the formation of less complex compounds, through the agency of a ferment. A ferment may be an unorganized complex organic compound capable of causing fermentation under suitable conditions—termed a chemical ferment or enzyme—or it may be a living organism—such as one of the many kinds of bacteria or yeasts. The fermentation industries then comprise that group of industries which employ ferments for the production of organic compounds of commercial importance by the decomposition of more complex organic products.

The fermentation industries form a group of very important chemical industries. The principal raw products utilized by these industries are of vegetable origin, and usually products of the agricultural industry, such as grains and cereals, potatoes, grapes, sugar cane, sugar beets, and other products containing natural sugars or starch which can be converted into sugars. These industries, for the most part, do not utilize minerals or chemicals made from minerals in their direct processes, though such materials may play a secondary part in some operations. They furnish a considerable market for manufactural products made from minerals and mineral chemicals, and a brief reference is therefore made to them and to their development in Canada. In another section of this report a more extended reference is made to the possibility of developing an Industrial Alcohol industry in this country.

The fermentation industries comprise such industrial operations as the production of wine, beer, alcohol, and vinegar; the souring of milk and cream for the production of casein; the preparation of coffee, cocoa, tea, and tobacco; the extraction of natural indigo; the retting of flax; the tanning of hides; and the preparation of many medicinal products. The most important of these is probably the production of industrial alcohol. Vinegar and lactic acid are also made in this way. In this section reference is made only to the production of alcohol, vinegar, and lactic acid. Commercial casein is usually made by the use of inorganic chemical precipitants and is therefore mentioned in a separate section.

Wine Production

Commercial wines are made from the juices of grapes, extracted by special processes, fermentation being promoted by pure cultures of wine yeasts. Similar products are made from the juices of many other fruits, but rarely on a commercial scale, except in the case of cider made from apple juice. Unfermented fruit juices are occasionally clarified, given a preliminary preservative treatment, and bottled.

The wine industry offers a limited market for certain types of coagulants such as egg albumen, ox blood, gelatine, isinglass, milk, or casein, which are used for "fining." Occasionally a soluble sodium compound of casein is used for this purpose. Excess acidity is corrected by the use of pulverized limestone or carbonate of lime, or by adding potassium tartrate. Gypsum has been used to assist in the improvement of the colour. The industry absorbs a considerable number of bottles annually, and it therefore offers a market for the products of the glass industry.

No statistical data are available with respect to the chemical requirements of this industry in Canada. The 1920 edition of the Canadian Trade Index contains the names of 13 firms making fermented wines, 37 firms making cider, and 12 firms making unfermented wines or grape juice, one firm making both fermented and unfermented wines.

Malting and Brewing

This industry produces beer from malt by the process of brewing. Beer is an alcoholic beverage containing less alcohol (3—6 per cent) than wines and larger quantities of vegetable extracts. The principal raw materials are certain grains (usually barley, but corn, rice, wheat, or oats can be used), hops, brewer's yeast, and water. Most grains contain large quantities of starch which is not subject to alcoholic fermentation. It is therefore necessary to cause the grain to germinate naturally under suitable conditions. This process, known as malting, results in the formation of diastase, an enzyme capable of decomposing starch into maltose and dextrine, the first of these being a sugar.

In practice the germinated grain or malt is ground or crushed in warm water to permit the diastase to come into contact with as much starch as possible. A certain proportion of the starch is converted into maltose and the mixture is then heated to decompose the diastase, the resulting liquid constituting the wort. After the wort has been cooled a certain amount of a pure yeast culture is added and this causes the maltose to be converted into a less complex sugar, dextrose, through the action of an enzyme, maltase, present in the malt and in the yeast. This dextrose is in turn converted into alcohol and carbon dioxide by the action of zymase, another enzyme present in the yeast. These operations require accurate temperature control to obtain the best results, and elaborate artificial heating and cooling equipment is usually employed.

This industry does not utilize inorganic products except indirectly. It offers a very large market for bottles. The cooling equipment requires either anhydrous ammonia or liquid carbonic acid to produce low temperatures, and brine solutions, either sodium chloride or calcium chloride for refrigeration. Carbonic acid gas is also used for charging. Isinglass or gelatine is used for clarifying. Certain special varnishes, made from shellac, are used for dressing the insides of wooden barrels, tanks or vats to prevent the wood becoming soaked with the various solutions. Resinous pitch is also employed for lining barrels and vats.

Statistical data with respect to the annual requirements of this industry, either for bottles or other products, are not available. The Canadian Trade Index for 1920 contains the names of 64 firms engaged in the production of beers of various kinds.

Distilled Liquors and Alcohol

Alcohol produced by the fermentation process in the manufacture of wines and beers is retained in association with the extracts and liquors in which it is produced, and the maximum conversion attainable is not usually desired. Where fermentation processes are used for the production of distilled liquors the maximum amount of alcohol possible is produced by the fermentation, and the liquid containing the alcohol is then subjected to fractional distillation. Where a pure product is required the distillation process may be repeated two or more times, the final product being "rectified spirit" which contains 94—96 per cent pure ethyl alcohol.

Raw materials for the production of distilled liquors consist of wines, materials containing sugars, and materials which contain starch. Alcohol can also be made from products convertible into glucose, or synthetically from ethylene (C_2H_4) or acetylene (C_2H_2).

The distillation of wines results in the production of brandy. Brandy is also made by the use of spirits made from starch products.

Sugar is made chiefly from the juice of the sugar cane and from sugar beets. Sugar itself is not used directly for the production of alcohol or distilled liquors. Cane molasses obtained after the raw sugar has been removed, sugar beets, and beet molasses are subjected to alcoholic fermentation and afterwards distilled. Cane "bagasse," which consists largely of fragments of sugar cane from which most of the juices have been expressed, is also allowed to ferment, and is then extracted, the resulting liquors being subject to distillation. Fruit juices containing sugars may be treated in the same way. The principal product of this phase of the industry is probably rum. Cherry brandy, plum spirit, and gin are closely related products made in a similar manner.

The larger part of the production of distilled liquors and alcohol is obtained from starch bearing materials. In America the grains—wheat, barley, rye, and corn—were formerly largely used for this purpose. In Germany potatoes are the principal source of starch. Rice can also be employed.

Grains are malted to produce diastase, or malt is added to prepared grains, the object being to convert the starch into a sugar, which is then fermented with yeast to produce alcohol. In the distilling industry the operations are carried on in such a way as to obtain the maximum conversion of the starch into sugar and then into alcohol. Potatoes are mashed and boiled under pressure, steam usually being employed for this purpose, and are so treated that the starch cells are broken and the starch itself is almost completely gelatinized. Corn is treated in a very similar manner. Starch prepared in this way, from potatoes or from corn, is then treated with finely ground malt, specially prepared for the purpose, in order to supply diastase for the conversion into sugar.

The liquors obtained by the treatment of starch with diastase constitute the distiller's wort. This wort is treated with pure yeast culture to promote fermentation. The resulting fermented mash is distilled for the production of spirits. In addition to spirits containing a high proportion of ethyl alcohol there are usually produced a considerable quantity of fusel oils which are subsequently separated by redistillation. This fusel oil consists largely of amyl alcohol, but also contains other members of the series. Aldehyde due to the oxidation of ethyl alcohol, amine bases, and formic acid are also present. The first of these byproducts is utilized industrially for the preparation of certain varnishes and lacquers. It is also used as a solvent for nitrocellulose, and for other purposes.

Redistillation is necessary for the production of spirits free from undesirable byproducts. Distilled liquors are sometimes designated "grain spirit" or "potato spirit," according to the source of the starch. Where pure ethyl alcohol for industrial purposes is required it is necessary to subject the product to a further distillation process termed rectification. Rectified spirits contain 94—96 per cent ethyl alcohol. Absolute alcohol is made by removing the balance of the water by special treatment.

The residues where grains or potatoes are used contain nitrogenous materials, and are utilized for the manufacture of special foods for cattle. The residues from molasses fermentation, after the alcohol and related products have been removed by distillation, contain some nitrogen and an important percentage of potash salts. They are usually dried and used directly as fertilizer materials, or they may be subjected to further treatment for the production of certain potash salts, ammonia, or compounds of cyanogen.

The production of alcohol from wood fibre, which is composed largely of cellulose, is a problem that has received a good deal of attention. The conversion of cellulose into dextrose, both by the use of strong sulphuric acid and strong hydrochloric acid, has been accomplished. Ethyl alcohol has been obtained in the usual manner by the fermentation of the dextrose and subsequent distillation. The spirit obtained from wood cellulose is apt to contain methyl as well as ethyl alcohol, but it can be used industrially as methylated spirits.

A process has been developed for the production of ethyl alcohol from acetylene. This gas is produced by the interaction of water and calcium carbide—electric power, coke, and limestone being the essential raw materials for industrial production on a large scale. The gas is converted into acetaldehyde in the presence of catalytic agents, such as sulphuric acid, glacial acetic acid with a salt of mercury, ferric-mercuric sulphate, or certain other chemicals. The acetaldehyde is then hydrogenated by reduced nickel into ethyl alcohol. The process is said to be in successful commercial operation in Switzerland. Alcohol can also be prepared synthetically from acetylene by an electrolytic process.

Ethylene can also be hydrated into alcohol. This has been successfully accomplished at the coke ovens of the Skinningrove Iron and Steel

Works, at Saltburn, England. A yield of 1·6 gallons of ethyl alcohol per ton of coal coked was obtained.

Distilled liquors are used largely for beverage purposes. Small quantities are also required for medicinal purposes, or find application in the industrial arts chiefly as solvents. The production of distilled liquors in Canada has been greatly curtailed during recent years and it is probable that most of the plants now engaged in this industry will be converted to the production of industrial alcohol if the prohibitive excise taxes which have hitherto prevailed are removed. There are thirteen firms engaged in the distillation industry. Six of these firms also produce alcohol for industrial purposes, and three other firms produce industrial alcohol only.

Industrial alcohol is undoubtedly the most important product of the fermentation industries. It forms the base from which more than two hundred products are made, and is also used very extensively as a solvent in many industries for the manufacture of numerous products. The development of an industrial alcohol industry in this country would materially reduce the costs of many products that are now imported, and would broaden the market for many industrial products.

The successful development of a commercial process that would make it possible to utilize the waste liquors from the sulphite pulp mills of this country would be of immense industrial importance. The immediate difficulties appear to be due to the low percentage conversion that can be obtained and the large volume of liquors that must be handled. These troubles together with certain technical difficulties of manipulation have hitherto retarded developments in this direction. The extraordinary high excise duties and the corresponding lack of demand for large quantities of industrial alcohol for manufacturing purposes all have combined to prevent the profitable utilization of these waste products in this way.

A more extended discussion of Industrial Alcohol and its commercial utilization is given on another page.

The manufacture of alcohol by distillation does not offer a market for any large quantity of minerals or mineral products. Small quantities of hydrofluoric acid or ammonium fluoride are used as an antiseptic to prevent secondary fermentation and to otherwise aid in the alcoholic fermentation. Some of the accessory products used in brewing are also used in this industry. The consumption of glass bottles was formerly very large. Alcohol for industrial purposes is handled in barrels, drums, and tank cars.

Vinegar

This product consists of weak aqueous solutions of acetic acid—between 4 and 10 per cent—in association with fruit flavours. It is made by the oxidation of alcohol through the agency of certain bacteria. These bacteria will only grow and develop in weak alcoholic solutions which contain other materials—nitrogenous products and mineral salts—suitable for food. Commercial vinegar is made from low grade wines, from dilute spirits (to which suitable foods for the acetic acid making bacteria have been added), from specially prepared malt, from fermented fruit juices (particularly apple and pear juice), and from sugar beets.

Where sugar containing materials are used alcohol is first produced by the addition of yeast to promote fermentation and to convert as much of the sugar as possible into alcohol. When the fermentation is complete the resulting liquor is decanted and clarified and then treated with the acetic acid bacteria in specially prepared vats or vessels, so constructed that air to supply oxygen has direct access to as large a surface of liquid as possible.

Vinegar made in this way is used chiefly as a condiment in the preparation of food, and as a preservative in pickling fruits, vegetables, and meats. Occasionally vinegar is used in the manufacture of white lead.

There are more than thirty-two firms in Canada engaged in the manufacture of vinegars. The principal vinegars manufactured are malt, cider, and spirit. There are no statistical data available showing the quantities produced annually. The average quantity of vinegar imported in the three fiscal years preceding the war was 15,623 gallons above proof strength, valued at $3,168, and 179,015 gallons of proof strength and under, valued at $68,399. In the fiscal year 1918-19, 34,010 gallons above proof strength, valued at $3,850, and 48,171 gallons of proof strength and under, valued at $17,729, were imported. In two years before the war 388 gallons of imported vinegar, valued at $280, were exported, and in the same period 492 gallons of domestic vinegar valued at $114 were exported. No exports are recorded in the first year after the armistice.

The vinegar manufacturing industry does not utilize inorganic chemicals or other products to any great extent. In one process of making spirit vinegar sulphuric acid is used to hydrolize starch to glucose previous to the fermentation of the glucose. In this process pulverized limestone is used to neutralize any free acid which may be present when the conversion is complete. So far as the writer is aware this process is not employed in Canada. The industry requires a limited number of containers. Glass bottles are used for this purpose, to a limited extent. Bulk shipments are usually handled in kegs or barrels.

Lactic Acid

This acid, as the name implies, is the acid that is produced by the souring of milk. Commercial lactic acid is prepared by heating a solution of glucose (grape sugar) with lactic acid bacteria under suitable conditions.

The solution of glucose is made from starch obtained from grains such as corn or from potatoes by treatment with malt as in the manufacture of alcohol. A nitrogenous food prepared from nitrites and other salts, or a prepared vegetable albumen is supplied to support the life of the bacteria. Pure cultures of the proper bacteria to produce lactic acid are added to the solution and the fermentation is carried out at a temperature not lower than 45°C. nor higher than 55°C. At this temperature the ferments which produce alcohol or those which produce butyric acid do not thrive. Since the lactic acid bacteria are themselves destroyed by the acid they make, if it exceeds one per cent, it is necessary to add small quantities of powdered limestone to neutralize the excess acid, calcium lactate being formed. The operation is a delicate one, since if more than half of one per cent of the acid is removed by neutralization at any one time there will be a tendency to form butyric acid, which is not desired. The operation is continued until all the sugar has been converted.

Calcium lactate obtained in this way is purified by crystallization, and lactic acid is obtained by treatment with sulphuric acid, and afterwards concentrating and purifying.

Commercial lactic acid is a clear syrup-like solution containing 22—24 per cent acid. It is used in the tanning and leather industries, in the textile industry, as a mordant in dyeing, and medicinally. It is also used for the production of certain metallic salts.

So far as the writer is aware this acid is not made commercially in Canada. The available records do not indicate how much is imported annually.

CASEIN MANUFACTURE

Casein is a complex organic compound found in the milk of mammals and in the juices and seeds of certain leguminous plants. It occurs in milk in combination with calcium, the compound being present in colloidal suspension. Technical casein is prepared from sweet milk. Since it must be free from fat the milk is first treated in a centrifugal separator to remove the cream, after which a small amount of caustic soda in solution (or sodium carbonate) is added. The mixture is then treated several times in the separator to remove all fat. After treatment in the centrifugal separators the resulting liquid is placed in a vat and mixed with dilute sulphuric or hydrochloric acid, the liquid being thoroughly agitated and the acid being added slowly until precipitation is complete. Under this treatment the lime-casein compound in the milk is decomposed and the casein is separated as a solid which is allowed to settle in the bottom of the treatment tank. The liquid is removed by decantation or siphoning, and the curd is washed repeatedly in cold water until all traces of acid have been removed.

Casein curd prepared in this way is drained, pressed between cloths to remove the excess water, broken into small pieces and thoroughly dried in vacuum drums.

Casein is insoluble in alcohol, ether, and water. Chemically it acts both as an acid and as a base, forming salts with members of either group. The salts formed with the alkali bases are soluble, as are many of the other salts.

Casein and casein preparations find a number of industrial applications. The principal uses are as a varnish preparation, as an adhesive, in the preparation of plastic materials which are used as substitutes for celluloid, horn, or ivory, as a sizing material in the manufacture of paper and in the textile industries, in food preparations, and in "fining" certain products of the fermentation industries. Casein glue which can be rendered waterproof is an important material in the manufacture of aeroplane propeller blades, veneer plywood, etc. "Galalith" is a hornlike substance prepared from casein by treatment with formaldehyde, which finds many applications in industry, particularly as an insulating material.

The principal accessory materials used in the production of technical casein and its products are sulphuric or hydrochloric acids. Acetic acid, citric acid, lactic acid, phosphoric acid, or tannic acid can also be used. Either caustic soda or sodium bicarbonate is used as the alkali. In addition the following products are required occasionally: alcohol; ammonium hydroxide; borax; calcium compounds (hydroxide, tannate); camphor; formaldehyde; magnesia; sodium compounds (arsenate, biborate, bicarbonate, silicate, tungstate).

The average value of imported casein for the three years prior to the war was $12,491. During the same period 547,183 lbs., produced in Canada, and valued at $21,572, were exported annually. In the fiscal year 1918-19 the imports were valued at $33,319, and the exports amounted to 9,110 lbs., valued at $1,936. In the fiscal year ending March 31, 1920, the imports amounted to 1,234,635 lbs., valued at $159,177. Of this quantity 1,187,183 lbs. came from the United States, and 3,360 lbs. from Great Britain, the balance 44,092 lbs. being credited to "other countries." No exports are recorded for the year 1919-20.

There are no statistical records available showing the quantity produced in Canada, nor the average annual requirements. The largest single consumer is probably the paper industry. The large quantity imported last year would indicate that there is available a large domestic market which could be supplied by home production. Casein is essentially a by-product of the dairy industry since it is prepared from milk from which the cream has been removed. Available records show only six firms in Canada who produce casein.

INDUSTRIAL ALCOHOL

There are a number of closely related chemical compounds, which are classed as alcohols. Some of these alcohols are not of commercial importance as yet, and some of them have only limited applications. There are two, however, ethyl alcohol (C_2H_5OH) and methanol (CH_3OH), which find numerous uses in the arts and industries and these are correspondingly important commercially. Ethyl alcohol is readily produced from a variety of substances, has a heating value of 12,700 B.Th.U., is relatively easier to make, is more valuable industrially, and is in greater demand than methanol. When alcohol is mentioned it is usually ethyl alcohol that is meant. Methanol, formerly known as wood alcohol because it is obtained from the destructive distillation of wood, has a heating value of 9,594 B.Th.U., is relatively less plentiful than ethyl alcohol, is made from a narrower range of raw materials, and has fewer industrial applications. The manufacture and commercial uses of methanol are described elsewhere in this report (see section on Wood Distillation).

Industrial alcohol is the commercial name applied to ethyl alcohol that has been prepared for industrial use. Alcohol can be produced by the fermentation of any organic substance which contains sugar or starch. It is a potable drug and is well known as an important constituent of numerous beverages. Owing to the physiological effects of alcohol when its use as a beverage is abused numerous legislative restrictions affecting its manufacture and sale have been brought into effect in recent years in nearly all countries. Alcohol, and beverages containing alcohol have also been subjected to exorbitant and indiscriminate taxation for many years in Canada particularly, in the United States to a less degree, and with more discrimination in other countries. Until very recent years there has been no distinction made in Canada between alcohol for industrial purposes and that contained in beverages. This circumstance has prevented the development in this country of the very large group of chemical industries which use alcohol as a basic material. Restrictive legislation which does not discriminate between the use of alcohol for beverage purposes and its use for manufacturing is retroactive and is not in the public interest. Public welfare demands the minimum of restrictions on both the manufacture and the use of ethyl alcohol in industrial operations. The more enlightened legislation contained in the Canadian Inland Revenue Act of July, 1920,[1] will tend to improve conditions in this respect. The development of several essential chemical industries and their profitable continuation depend primarily upon the wise control of the production, distribution, and uses of ethyl alcohol. A glance at the table listing industries using alcohol and at the names of the varieties of products made from it, will quickly demonstrate the immense importance of this product in promoting national development and progress.

Denatured Alcohol

Alcohol for industrial purposes must be kept separate and distinct from alcoholic beverages. It has been found possible to treat it with certain other products in such a way that it cannot be used as a beverage, while it is still suitable for certain manufacturing purposes. Alcohol so treated is termed " denatured " alcohol. Because it is possible to denature alcohol and to thus render it unfit for beverage purposes it becomes possible to modify restrictive legislation so as to restrain the use of alcoholic beverages without imposing undue handicaps on the development of chemical industries based on alcohol or the use of alcohol industrially.

There are a number of chemical products which can only be made from alcohol that has not been subjected to denaturing treatment. In such cases it is necessary to impose rigid restrictions on its use to prevent its misuse for beverage purposes. There are, however, numerous industrial operations in which denatured alcohol can be used. Rigid restrictions are not necessary in these cases, except in the supervision of the initial manufacturing and denaturing.

Denatured alcohol is prepared by adding to the pure product small quantities of one or more designated chemicals which render the resultant mixture unfit to drink, and which cannot be easily removed from the alcohol by distillation or other means. The substances used for this purpose are either poisonous or are repugnant to taste and smell. No one denaturant can be used for all purposes since the denaturant itself might injure the

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[1] An Act to amend the Inland Revenue Act, 10-11 George V., Chap. 52, Part X.

final products to be manufactured. The kind of denaturant used will thus depend in part upon the purpose for which the alcohol is required. Sometimes industrial alcohol is only partially denatured.

Denatured alcohol, as defined in the Inland Revenue Act,[1] means alcohol in suitable admixture with such denaturants as to render it, in the judgment of the minister, non-potable and to prevent recovery of the ethyl alcohol. The United States act defines denatured alcohol as ethyl alcohol to which has been added some material which prevents its use for internal administration.

The Canadian act further provides for "specially denatured alcohol" which is defined to mean alcohol in suitable admixture with such special denaturants as have been approved by the minister.

The United States act provides for completely denatured and specially denatured alcohols. The former is defined as alcohol which has been denatured by a limited number of fixed formulae, for sale to the general public with very little supervision. All of the products produced by these formulae are injurious to the human system. The latter is defined as alcohol which is not as completely denatured as the "completely," and can only be obtained under a heavy bond for use in manufacturing processes in which the alcohol is always protected by the bond.

Denaturing alcohol for industrial purposes appears to have been first legalized in Great Britain about 1855. A tax had been levied on alcohol for a number of years previously, but in this year the use of methylated spirits for industrial purposes was permitted. The denaturant was a 10 per cent addition of impure methanol containing acetone and other chemicals produced in the destructive distillation of wood. Alcohol so treated was not subject to the alcohol tax. Holland legalized denatured alcohol for industrial purposes in 1865, and still greater freedom was authorized in 1872. France recognized the importance of denatured alcohol in 1872, and in 1881 further modified the laws relating thereto. Germany allowed tax free industrial alcohol in 1879, followed in subsequent years by further legislation which tended to reduce the restrictions on the use of this chemical in manufacturing and increased the number of denaturants permitted. This legislation has been an exceedingly important factor in the development of many of the German chemical industries because for many years industrial alcohol was obtainable there more cheaply than in any other country. Tax free alcohol for industrial purposes was authorized in Austria in 1888, in Italy in 1889, in Sweden in 1890, in Norway in 1891, in Switzerland in 1893, in Belgium in 1896.

The history of alcohol legislation in the United States shows many changes and variations. The first tax on distilled spirits was levied as a revenue measure in 1791, fifteen years after the Declaration of Independence. Numerous modifications have taken place from time to time, tending chiefly to the imposition of closer restrictions and higher taxes. In 1917 the tax rate was $3.20 per proof gallon for spirits in beverages, and $2.20 per proof gallon for non-beverage purposes. At this rate 95 per cent pure alcohol for manufacturing purposes was taxed $4.18 per gallon.

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[1] 10-11 George V., Chap. 52, July, 1920, p. 6.

Restricted exemptions from the application of these taxes were provided from time to time for special purposes, and various provisions with respect to denaturants were also made at irregular intervals. The National Prohibition Act, passed in 1920, under sections 1 to 19, of Title III., provides for tax free alcohol for industrial purposes.[1] Six formulae for completely denatured alcohol and 58 formulae for specially denatured alcohol have already been allowed by the Commissioner of Internal Revenue. Additional formulae for tax free specially denatured alcohol may be allowed from time to time.

The Canadian Inland Revenue Act of 1906[2] provided for a tax of $1.90 on every gallon of proof, the equivalent of 49·28 per cent absolute alcohol, and proportionally for greater or less strength, and denaturing with wood spirits was permitted. This tax was raised to $2.40 by the amended act of August, 1914,[3] the equivalent of $4.63 per gallon of 95 per cent pure alcohol, or about twelve times the cost of manufacture. Under the legislation of July, 1920,[4] "denatured alcohol and specially denatured alcohol as defined in the next preceding section which is intended for use in the arts and industries, or for fuel, light, or power, or for any mechanical purpose, may be manufactured in Canada free from excise duty."* * * * * "Denatured alcohol shall be sold, delivered and transported without restriction to dealers, manufacturers, and other persons." * * * * "Specially denatured alcohol shall only be sold or delivered under a departmental permit to dealers and manufacturers to be used in the arts and industries in cases where denatured alcohol would be unsuitable, and shall only be moved or transported under such conditions as the Minister may by regulations prescribe." The Department of Inland Revenue is charged with the control of the actual manufacture of denatured alcohol for the purpose of ensuring the quality of the denaturants as well as the respective percentages employed in producing the different grades. Under departmental regulations the use of methanol, benzol, nitro-benzol, and pine oil for the production of completely denatured alcohol by prescribed formulae has been authorized. The use of iodine for the production of a specially denatured alcohol has also been authorized. Prescribed formulae for the use of these denaturants have been issued as departmental regulations. Provision has been made in the act for the authorization of additional formulae if suitable representations are made to the responsible administering department.

Raw Materials

Industrial alcohol can be made from three classes of raw organic materials, which may be designated sugars, starches, cellulose, and it can also be made from certain mineral products. The sugar group comprises such products as molasses from sugar cane, sugar beets, fruit juices, juices of certain palms, and similar products. The starch group comprises potatoes, yams, grains of all kinds (especially rice, wheat, barley, and Indian

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[1] See U. S. Treasury Department Regulations.

[2] Chapter 51, Revised Statutes of Canada, section 154.

[3] Chapter 6, 5 George V., section 154.

[4] Chapter 52, 10-11 George V., section 369.

corn), acorns, or chestnuts. The cellulose group comprises such materials as sawdust, waste sulphite liquors, straw, and cellulose fibres of certain plants or parts of plants. It is also possible to make alcohol synthetically from ethylene gas, a byproduct of coal carbonization as well as a constituent of some natural gases, or from acetylene gas, the primary materials in the latter case being coke, limestone, and electric power. These latter methods are still in the experimental stages and are not factors in the present industrial production. They offer especial opportunities for future industrial development in Canada because of the great available supplies of raw materials and potentially cheap electric power.

Processes of producing alcohol by fermentation from sugars and starches have already been briefly discussed in the section dealing with the Fermentation industries. Alcohol can be produced from cellulose products by first converting the cellulose content into glucose (hydrolizing) by special treatment, either with sulphuric or sulphurous acid, or by other means. The resulting sugar is subjected to alcoholic fermentation until the maximum conversion is obtained. On the completion of the fermentation the alcohol is recovered by distillation and rectification.

The list of organic substances, both natural and artificial, from which ethyl alcohol can be produced is very large. The subjoined tabulation includes only the more common materials that have been used for this purpose. Many of these products, however, are obviously unsuited for the production of cheap alcohol for industrial use. Many of the products are not available in sufficient quantities in any one locality to make it practicable to produce alcohol from them at a profit. This is particularly true of most fruits and of certain trade wastes such as sawdust. A number of processes have been patented and exploited to utilize sawdust, but the technical difficulties have not all been completely surmounted and the processes must be regarded as being still in the development stages. With respect to sulphite liquors as a source of cheap alcohol the outlook is more promising, especially for the larger mills. There are about 45 plants in Europe now producing industrial alcohol from this trade waste, 21 of these plants being in Sweden. There is also one plant in the United States producing sulphite alcohol. The most recent proposal is to further utilize the residue after the extraction of the alcohol as a fuel. It has been stated that the fuel recovered is more than sufficient to operate the alcohol plant.[1]

Table 11.—Sources of Ethyl Alcohol

GRAINS: Barley, buckwheat, maize (Indian corn), millet, oats, ragee, rice, rye, wheat.

BERRIES: Blackberry, blueberry, currant, gooseberry, huckleberry, mulberry, raspberry, strawberry.

FRUITS: Acorn, apple, apricot, banana, cactus fruit, cherry, date, fig, grape, horsechestnut, melon, orange, peach, pear, pineapple, plum, pomegranate, prune, watermelon.

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[1] Ethyl alcohol and coal from sulphite waste liquor, N. E. Clementson, Pulp and Paper Magazine, Mar. 24, 1921, pp. 317-322.

ROOTS: Carrot, cassava, mangel, sugar beet, turnip.

STEMS: (Leaves and underground stems included) Agave, artichoke, cactus, cocoanut palm, date palm, fern (bracken), grasstree, mahua, palms (nipa and sago), peat, potato, seaweed, sorghum, sotol, straw, sugar cane (and bagasse), sugar corn stems, zamia palm, other trees containing starch or cellulose.

TRADE WASTES: Beet molasses, cane molasses, corn cannery refuse, fruit cannery refuse, garbage (city refuse), gases (from coke plants), sawdust, sulphite liquor.

SYNTHETIC: Calcium carbide (coke, limestone, and electric power), ethylene (byproduct from coal or coke ovens, and also a constituent of some natural gases).

Uses of Industrial Alcohol

Industrial alcohol is utilized in so many industries and in such a great variety of ways that it is impossible to present a complete list of its applications here. The principal applications of this product may, however, be grouped under one or more of the three following heads: fuel, solvent, or raw material for the manufacture of chemicals.

As a *fuel* it may be used as a source of heat, light, or power. Its heating value, which is high, is rated at 12,700 British thermal units. It is now used in comparatively small units for each of the three purposes mentioned above. Its applications to these uses on a larger scale are dependent not only upon the cheapening of production, but also upon the relative cheapness and availability of supplies of competing fuels. It is probable that alcohol will form an important constituent of motor fuels in the future.

As a *solvent* alcohol finds numerous applications in many industries. It evaporates readily from its solutions and is thefore valuable where it is desired eventually to dispose of the solvent. Nitrocellulose is soluble in alcohol and solutions are utilized in the manufacture of photographic films, celluloid and celluloid products, collodion (liquid skin), smokeless powders, gas mantles, artificial silks and leathers, carbon lamp filaments, and other articles. Many dyes and flavouring extracts used in the preparation of foods are applied in liquid form by the use of alcohol as a solvent. Calico printing is accomplished by using dye solutions. It is used as a solvent for certain gums and resins in the manufacture of spirit varnishes, and as a vehicle for wood dyes, metal and wood polishes, wood lacquers, and fabric dopes. It is used as a solvent for numerous drugs and medicinals, in the manufacture of liniments and lotions, and for the production of flavouring extracts from essential oils such as lemon, peppermint, rose, vanilla, or wintergreen.

In *chemical manufacture* it is used for making such products as ether, ethyl acetate and many other ethyl compounds, acetic acid vinegar, chloroform, iodoform, mercury fulminate, antipyrine, sulphonal, and it also finds very wide application in the manufacture of aniline dyes.

The accompanying chart, published through the courtesy of the U.S. Industrial Alcohol Company of New York, shows only a few of the many uses of this very important chemical product.

There are at the present time nine firms licensed to produce industrial alcohol in Canada, five of these are located in Ontario, three in Quebec, and one in British Columbia. So far as records now available indicate there is only one Canadian firm now manufacturing chloroform, ethyl bromide, and ethyl chloride. This production is a comparatively recent development. Formerly chloroform and certain ethers were made in Canada for the home market, but production became unprofitable owing to the high alcohol tax of the acts of 1906 and 1914 and production ceased. Alcohol as a solvent is used by many Canadian industries, particularly the paint and varnish trade, and in the manufacture of drugs and pharmaceuticals. Its use as a fuel is both limited and local. A considerable quantity is used during the winter months in non-freezing solutions for automobile radiators.

Industrial alcohol produced in Canada at the present time is made either from grains or from molasses, the latter being obtained from sugar refineries in Canada, and also imported. One firm proposes to utilize potatoes, but there are no records available showing production of potato spirit.

The statistical tables in part I of this report show the imports and exports of alcohol and of a number of products in the manufacture of which alcohol is used as a solvent, or in which alcohol is required for manufacturing processes. The Dominion Bureau of Statistics reports the production of 1,777,289 proof gallons[1] valued at $893,528 in 1919, and 2,223,428 proof gallons valued at $1,595,584 in 1920.

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[1] A proof gallon contains 49·28 per cent pure alcohol by weight.

CHART SHOWING SOME OF THE MANY USES OF ALCOHOL

PREPARED BY

U.S. INDUSTRIAL ALCOHOL COMPANY

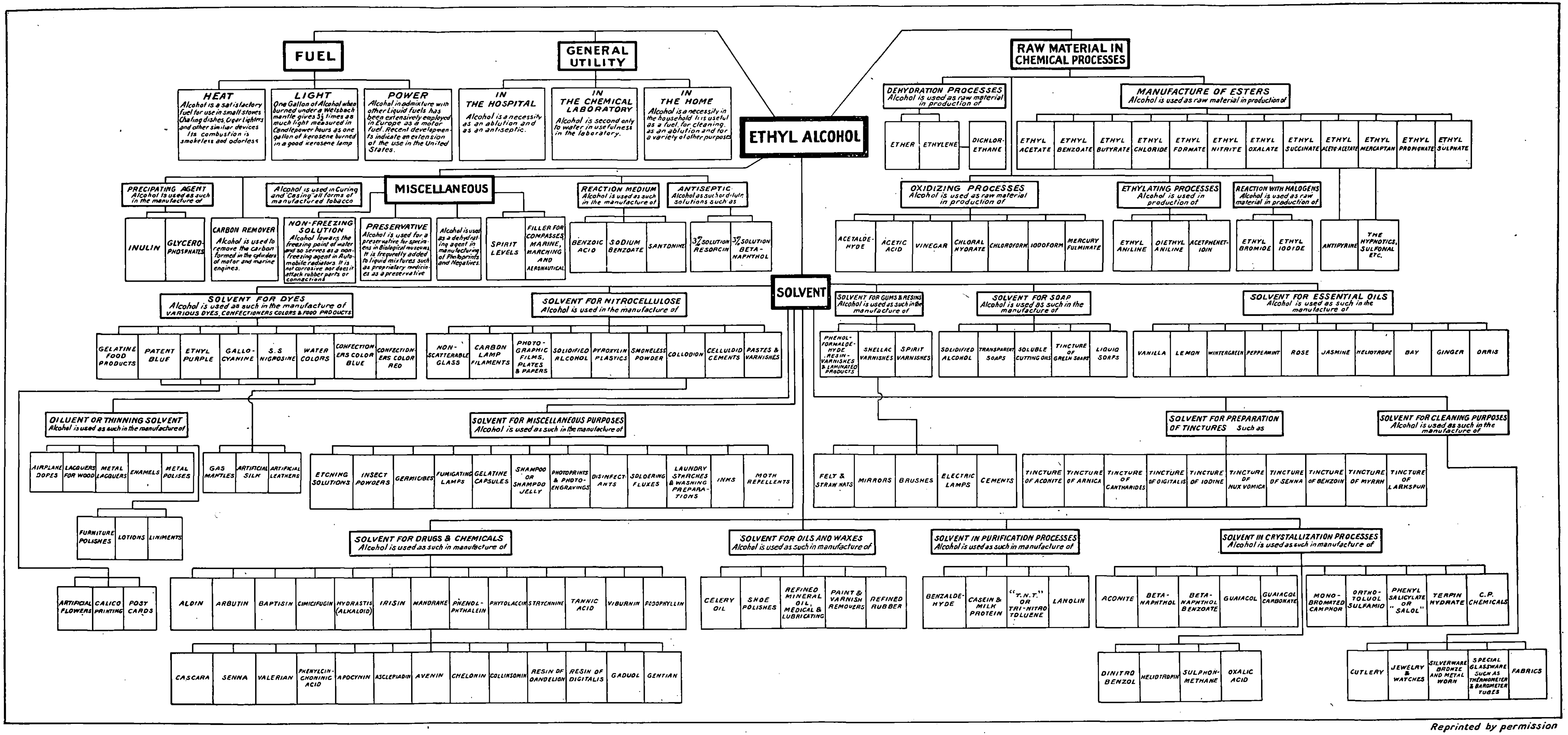

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Diagram 8

CHAPTER II

FOREST PRODUCTS INDUSTRIES

The arboreal products of forests furnish raw materials for a number of important groups of industries. The industries primarily dependent upon forest woods are the lumbering industry in all its branches, the wood cellulose industry (otherwise the pulp and paper industry), the wood distillation industry, and certain extracting operations. There are in addition a number of secondary industries making byproducts of commercial importance from the waste material of the primary groups. These byproducts are also occasionally made directly from fresh raw material gathered for the purpose.

The principal products of the lumber industry are firewood, poles, lagging, posts, rails, ties, lumber, lath, shingles, barrel staves and other cooperage stock, box shooks, and mine timber of all kinds. A discussion of the manufacture of these products in Canada does not come within the scope of this report.

The principal products of the wood cellulose industry and of the wood distillation industries are made by chemical and physical processes from wood as the principal raw material. Both these groups of industries have been extensively developed in Canada. The development of the wood cellulose industry is discussed in a following section; the wood distillation industry is discussed in the section on Destructive Distillation.

The principal products obtained by extraction from a limited variety of woods or barks are tannin extracts, turpentine, and rosin. Tannin products are also obtained as byproducts form certain kinds of bark where the tree trunks have been converted into lumber products. Oak bark for tanning was formerly produced in Canada, and there is still a small production of hemlock bark. So far as the writer is aware there is no Canadian production of tannin extracts from native forest products or from waste products. All tannin extracts required by the leather producing industries are imported. Turpentine and rosin are not produced in Canada by extraction processes.

The utilization of wood waste for the manufacture of byproducts is a very important subject which offers opportunities for further chemical investigation and possibly of extensive commercial development. Sawdust is already utilized in a small way in the composition of materials for the manufacture of moulded and pressed articles and plaster blocks; it is occasionally mixed with clays used for making tile or brick when it is desired to make these products light and porous; and sawdust, slabs, and other waste products of white pine, poplar, and fir are converted into wood flour which is used as an absorbent for nitro-glycerine in the production of dynamite. Sawdust and wood scrap have been used for the production of glucose, which may serve as a cattle food, or may be used for the manufacture of ethyl alcohol by fermentation. Oxalic acid has been made from sawdust. Refuse wood has also been used for the production of producer gas.

Cellulose also is a base for the manufacture of a number of important secondary products in addition to those which belong to the pulp and paper group. The most important of these are known as fibre products, including fibre boards, indurated ware, and insulating products. It also forms a base for the production of vulcanized fibre and artificial silks. The northern spruce, which possesses a compact structure and long fibre, seems particularly well adapted to the production of cellulose suitable for making artificial silk. These silks are usually made from cotton cellulose it is true, but wood cellulose has been used, more particularly for the manufacture of viscose. Ethyl alcohol can also be produced from the waste liquors obtained in the manufacture of wood cellulose. Fibre products and vulcanized fibre are made in Canada, but so far as the writer is aware no other cellulose byproducts are made in this country. It is not feasible to discuss these subjects further in this report.

Attention might be called to the possibility of developing a byproduct industry through the utilization of the now abandoned stumps and roots of some of the cut over pulpwood forests. Softwood distillation plants have not hitherto been successfully established in Canada. Still it might prove to be commercially feasible to combine softwood distillation with extraction and other processes in such a way as to develop a commercially successful enterprise in some localities where raw materials are abundant and cheaply available. Spruce stumps would yield turpentine and products closely related to turpentine, spruce oils similar to pine oils and suitable for ore concentration, spruce gum by extraction, creosote oils, tars and pitch by destructive distillation, a certain amount of chemically prepared cellulose fibre suitable for kraft or other papers, and possibly tannin extracts. In some localities the cleared land would have a market value as farm land; in other localities it would be suitable only for re-foresting. Undoubtedly the field operations would have to be carried on with portable equipment and crude apparatus. The crude products could be refined at suitable central plants.

At the present time one Candian plant is recovering turpentine as a byproduct in the manufacture of sulphate pulp from spruce and jack pine. During a certain stage of the digesting of the wood chips in the alkaline solutions used the gases liberated contain volatile turpentine oils which are recovered by condensation, and afterwards rectified in a special still. Another plant is employed experimentally in the production of turpentine and colophony directly from the viscous exudation obtained by tapping the bark of the Douglas fir. This product yields turpentine oil as the primary product of distillation. The residue consists of colophony or resin, which may be utilized as such, or which may be subjected to destructive distillation at a higher temperature, yielding rosin spirit, rosin oil, and pitch.

PULP AND PAPER INDUSTRY

The basis of paper manufacturing is cellulose of vegetable origin. Cellulose for paper making may be obtained from numerous trees and grasses. The principal sources of supply in America are the woods of red and black spruce, Canada balsam, and poplar. Cellulose is also obtained from cotton and linen rags, or may be made directly from cotton or flax straw. Wheat, oat, and rye straws are also used for producing certain grades of pulp used in making box board. A recent report is to the effect that an attempt is soon to be made to utilize waste straws in the Prairie Provinces of Canada for the production of pulp and newsprint.

The processes in use for preparing cellulose for paper making, except in the case of ground wood fibre, are entirely chemical. In the manufacture of paper from cellulose the paper maker requires a large number of prepared materials of mineral origin, and also quantities of chemical products as fillers and for the purpose of imparting certain physical properties to his finished product. The paper maker also employs a number of mineral and chemical products in the preparation of the equipment and appliances used in his plant. The principal mineral and chemical products used in the pulp and paper industry, are given in the following list.

Table 12.—Mineral and Chemical Products used in the Pulp and Paper Industry

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

MATERIALS USED IN EQUIPMENT: Asbestos; bricks (chemical, fire); *cement, Portland;* clays (*china*, fire, *local*); coal; *litharge; pitch; pulpstones;* rolls (granite, lava, sandstone); *silica sand; soapstone;* sodium silicate.

MATERIALS USED IN CELLULOSE PRODUCTION: *Acid, sulphuric; chlorine gas; dolomite; lime* (*burnt, chlorinated*); *limestone; magnesite;* sodium compounds (*carbonate, chloride, hydroxide, sulphate*); sulphur.

MATERIALS USED IN PAPER PRODUCTION: Acid, tannic; alums (potash, soda); alumina; aluminium sulphate (papermaker's alum, or alum cake); aniline colours and pigments; barytes (ground); blanc fixe; calcium sulphate (pearl hardening); *casein;* cellulose hydrate; *cement, Portland;* chrome colours; *clay, china;* dyes, natural; *gelatine; glycerine; gypsum* (*ground*); magnesia; mineral pigments (chromium oxide, *iron oxides,* lead chromate, *ochres* and *umbers,* organic pigments and lakes, smalt, ultramarine); Prussian blue; resins; satin white; *soaps;* sodium compounds [*carbonate* (*anhydrous, crude, crystals*), hyposulphite, silicate, *sulphate,* sulphite]; *starch; talc.*

Statistical Data

Statistical data showing the actual consumption of the different mineral and chemical products required by this industry are not available. The magnitude of the industry indicates that large quantities of certain products, such as sulphur, sodium sulphate, blanc fixe, and clays must be required annually. As most of these materials are imported, but could be produced in Canada, it is obvious that this industry offers a home market for these products. Before it can be stated that additional mineral and chemical products for the use of the pulp and paper industry can be profitably prepared in this country it will be necessary to carefully survey the market to ascertain the actual demand for each commodity that could be prepared from native resources.

Canadian Situation

The pulp and paper manufacturing industry in Canada is rapidly expanding. At present there are 109 mills in operation, four in construction and three temporarily idle. The milling capacity available at the end of 1920 provided for a daily output of approximately 4,000 tons of groundwood pulp; 2,600 tons of sulphite, about one-third being unbleached, and the balance bleached; 700 tons of sulphate; 15 tons of soda pulp; and 2,700 tons of newsprint paper. In addition to these principal products Canadian mills are producing a great variety of special papers, the chief of which are kraft, manila, tag, envelope, wrapping, poster, wall, writing, ledger, lithograph, book, wall board of various kinds, ship and fibre boards, bristol board, corrugated paper, egg case fillers, carpet paper, jute, felt, building papers, indurated fibre ware, toilet tissue, crepe, tissue, and a number of other specialties. The total daily capacity of Canadian mills producing miscellaneous papers is 480 tons, in addition to a capacity of 650 tons of various kinds of mill board and related products.

General Notes

The sulphur requirements of this industry alone are at present in the neighbourhood of 90,000 tons annually, all of which must be imported at a delivery cost probably not far from $25 per ton. Sulphur is essential for the manufacture of sulphite pulp, one of the constituents of newsprint paper, the largest single item of production made by this industry. The pulp and paper industry can never be self-contained until its dependence on foreign sources of sulphur has been eliminated. The author has elsewhere discussed the possibility of substituting native pyrites as a source of sulphur in the manufacture of sulphite pulp.[1] It may be stated that there are no insuperable obstacles to the introduction of pyrites burning plants into the sulphite mills, and the principal technical difficulties have already been overcome. A higher degree of technical skill is required to operate a pyrites burning plant than is needed by the ordinary sulphur burning equipment.

Another source of supply of sulphur from Canadian sources will undoubtedly be from the waste gases of the nickel industry at Sudbury. At present no commercial process has been developed whereby this waste product can be successfully utilized by the sulphite pulp manufacturer. The

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[1] Pyrites in Canada, Mines Branch Report 167. Pyrites in the Sulphite Mill, Pulp and Paper Magazine, Jan. 31st, 1918, p. 95.

great importance of an independent native source of sulphur not only for this industry, but also for other industries in which it figures as an essential raw material, warrants the inauguration of extensive scientific research in an attempt to develop a process by which the sulphur content of these waste gases may be made available for the use of industry.

Other Cellulose Industries

Cellulose is obtained from grasses and other plants as well as from woods. Plants which are cultivated as sources of cellulose are cotton, flax, hemp, jute, esparto, China grass, ramie, and others. The cellulose of cotton and linen and that in the pith of certain plants is nearly pure.

Cellulose is not soluble in water nor in other ordinary solvents. It will, however, hydrolyze in the presence of the salts of certain metals, and the hydrated cellulose forms a thick viscous solution. It may be oxidized to oxycellulose by the use of dilute nitric or chromic acids; if boiled with the dilute acids for some time it becomes converted into hydrocellulose. If heated with strong acetic acid it forms acetyl compounds, cellulose acetates, which are amorphous substances soluble in chloroform, glacial acetic acid, ethyl benzoate or nitrobenzene and insoluble in water or alcohol. If heated with strong sulphuric acid it swells and dissolves forming a paste-like substance as a precipitate when water is added. If the acid is diluted and heated to 120° C. the cellulose is converted into dextrose. Dextrose in turn can be converted into ethyl alcohol by the use of ferments and attempts have been made to make alcohol from wood waste by applying these chemical reactions commercially. If cellulose is heated with nitric acid under proper conditions cellulose nitrates are produced. Cellulose also forms compounds with sodium hydroxide, cupro-ammonium hydroxide, and zinc chloride. These products are homogeneous viscous solutions. These and other chemical products derived from cellulose are the basis of a number of cellulose industries to which only a very brief reference can be made.

Explosives. Cellulose is heated with sulphuric and nitric acids under suitable conditions to produce cellulose nitrates that are used as the basis of a number of explosives. The cellulose usually used for this purpose is cotton, although other celluloses have also been used, including those obtained from woods. Gun cotton is the best known product.

Collodion. Cotton wool which has been cleaned with sodium hydroxide is weakly nitrated to form gun cotton. This product is soluble in a mixture of alcohol and ether and the solution constitutes collodion. The product is known to many people through its sale in minute quantities at high prices as "artificial skin." It is used industrially in photography and in medicine. It is also used for coating mantles for incandescent lamps, films, and in certain kinds of varnishes. Collodion is formed into fine silk threads by a special process, and these are woven into fabrics either alone or in combination with other textile fibres. Large quantities of collodion silks have been made in France and Germany.

Cellulose Acetate. This product is made by heating cellulose with dilute acids to convert it into hydrocellulose. The hydrocellulose is then treated with anhydrous acetic acid. It can also be produced by the direct use of cellulose and acetic acid. The material finds many industrial uses, such as the manufacture of films, artificial silks, and varnishes, to which further reference is made below.

Cellulose Formate. This product is made by hydrolyzing cellulose with sulphuric acid and then treating with formic acid. The product is similar to cellulose acetate and has been used for artificial silks.

Pyroxylin. This product is made by heating cellulose with sulphuric and nitric acids under suitable conditions to produce a pure nitrated cellulose. This material is washed free from acids and allowed to dry and constitutes pyroxylin which has a number of industrial uses.

Celluloid. Cellulose is nitrated to pyroxylin. The pyroxylin in a suitable condition is mixed with camphor and the mixture is warmed and subjected to kneading and pressure. The two substances unite to form a transparent product which is not explosive, though it is highly inflammable, and which possesses characteristic properties. This material is marketed under the name of celluloid. The industrial applications of celluloid are very numerous, and cannot be discussed here. Other substances than camphor have been proposed as solvents for the pyroxylin, such as certain derivatives of phenol, cresol, or naphthol, and other coal tar products. There are also a number of synthetic products such as bakelite produced without the use of cellulose that are marketed as substitutes for celluloid, or which have found industrial applications of their own. Another celluloid substitute that has come on the market is cellulose acetate. These substitutes are mentioned to draw attention to them because it is not always possible for the layman to distinguish between true celluloid and these later products.

Artificial Silks. Collodion is made from cellulose by nitrating in the usual way and preparing the alcohol-ether solution. This solution is squirted into minute threads by suitable apparatus. The squirted threads are either received in water where they solidify and are drawn off as produced, or they pass into a warm air chamber where the solvents quickly vaporize and the threads can be drawn off. These threads are then spun together to make stouter threads which are used for textile production.

In another process a cuprammonium solution of cellulose is made and artificial silk threads are prepared from the resulting viscous solution.

Viscose is an artificial product prepared by treating cellulose with a concentrated solution of sodium hydroxide, squirting the product into threads which are received in a solution of ammonium chloride. This latter substance precipitates the cellulose, which retains its fibre form. These threads are twisted to form stronger threads, and are then used in textiles.

Cellulose acetate is dissolved in suitable solvent, squirted into fine threads which are received in alcohol or ammonium chloride to harden them. These fine silk-like fibres are then twisted into threads and the threads are used for making textile fabrics. Cellulose acetate silk is used for coating fine copper wires for electrical purposes, such as magnet wires and the wires used on induction coils.

Varnishes. Solutions of cellulose products are used for dopes and varnishes. The products chiefly used in this way are pyroxylin, viscose, cellulose acetate, and collodion with suitable solvents as vehicles.

Films. Photographic films and films for projection lanterns were formerly largely made from celluloid. Owing to the inflammable nature of this product and the consequent fire risk in moving picture theatres, many attempts were made to render the films slow burning by the addition of other chemicals. In recent years, however, the discovery of cellulose acetate and the possibility of making films of this material have changed the situation. "Cellite" films are made by mixing cellulose acetate with camphor or with some of the substitutes for camphor. Cellulose formate and certain other similar cellulose compounds can also be used in this way.

Conclusion. The foregoing review is intended to give the general reader some understanding of the very numerous industrial applications of cellulose. Most of the products mentioned here are made from cellulose derived from sources other than wood. It is within the limits of possibility, as noted elsewhere in this report, that the splendid long fibre spruce of Gaspé, northern Quebec, and Newfoundland will yield cellulose that could economically be used for some of these products. With the exception of certain explosives and collodion none of them are now made in Canada. Collodion films and silks are not produced here at present, but one plant has been projected and may be erected shortly. Some cellulose varnishes are on sale here but it is not known whether they were actually made in Canada or were imported in bulk and repacked for retailing.

CHAPTER III

DESTRUCTIVE DISTILLATION INDUSTRIES

There are a number of very important industries founded on the fact that many complex organic compounds, when subjected to heat treatment in closed vessels, can be decomposed and a new series of compounds produced. The process by which this change is brought about is designated dry distillation or destructive distillation, in contrast with other distillation processes where the products finally recovered have not been changed chemically during process of treatment. The principal materials subjected to destructive distillation are usually solids, less frequently liquids. The final products are either gases or liquids at ordinary temperatures. Many kinds of organic materials when submitted to destructive distillation will yield other products. The principal raw materials which are habitually subjected to destructive distillation processes on a large scale are woods, both hard and soft, bituminous coals, and petroleum. Each of these three classes of materials gives rise to a series of extremely important commercial products that find many uses in the industrial arts or which are in turn the basis of other products of importance and value.

These processes form the basis of the most important of the chemical industries of the world. In this report each of the three groups of raw materials is considered in turn. The discussion is necessarily confined to a very brief general statement with respect to the processes employed, the products obtained, and the industrial uses of the principal products. In each case the subject is viewed from the standpoint of the present development in Canada and the Canadian market. It is not possible to deal with the subject in its entirety in a report of this kind, and the possibility of future development and expansion cannot be dealt with here.

The subject is presented under four sub-titles: Distillation of Woods; Distillation of Coals; Distillation of Coal Tar; Distillation of Petroleum. While other substances than those covered by these designations yield decomposition products on distillation, the industries based on their treatment are relatively insignificant. So far as known they have not been developed in Canada, and all discussion is therefore omitted.

WOOD DISTILLATION

A number of industrially important commercial products are obtained from various woods by subjection to heat treatment under suitable conditions. All modern processes treat the woods within closed containers or retorts. The heat may be applied by introducing steam within the container, or externally by using coils in which steam or oil is circulated, or by direct firing. Where wood is treated by steam distillation to remove the more volatile constituents other constituents may, in some cases, be recovered by the use of solvents. Where heat is applied externally the wood substances (such as cellulose, lignin, resin or gums) are broken down into chemically simpler compounds which are volatile, the final product being charcoal, and the process being designated " destructive distillation."

Raw Materials

In general, woods used as raw materials for the distillation processes can be grouped in either of two classes, softwoods and hardwoods. The former include all the coniferous trees such as pines, firs, spruce, and cedar. The latter include such woods as maple, birch, beech, and oak.

Treatment Processes

Coniferous softwoods are sometimes subjected to steam distillation to remove the volatile turpentines and to increase the yield of these products, before being subjected to the charring heat necessary to bring about the destructive distillation. The principal final products of softwood distillation are methanol,[1] turpentine, turpentine oils, rosin, rosin spirits, rosin oils, pine oils, pine tar, wood pitch, and charcoal. Steam distillation may be followed by extraction with a mineral oil solvent to recover the resin. The treated chips are then available for the manufacture of wood cellulose in place of being decomposed by destructive distillation.

Destructive distillation of hardwoods usually proceeds without preliminary steam treatment. The series of final commercial products obtained is greater than in the case of softwoods. The principal final products are acetic acid, acetone, ketones, methanol, creosote oils, tar, pitch, and charcoal (see chart). Some of these products form the bases of other compounds, and the total number of chemical products, that can be prepared from the primary products of hardwood distillation for industrial purposes, is very large.

The destructive distillation of hardwoods has been successfully established in Canada for nearly twenty-five years. So far as the writer is aware indirect heating with steam or oil is not used in this country. Softwoods and hardwoods were formerly employed for the production of charcoal by the old processes, but no other products were recovered. At present softwood distillation with the recovery of the principal byproducts has not been developed to a successful commercial stage. The following notes therefore apply only to the hardwood distillation industry in so far as it has been developed in this country.

The woods used in Canada in the hardwood distillation industry are principally maple and birch, with small amounts of beech. The wood is prepared for distillation by cutting and piling for seasoning, followed by sawing into short lengths and splitting where necessary preparatory to charging into the special retorts. The retorts used are of the horizontal type into which charging cars, loaded with split wood in short lengths, can be run directly. The operation is usually completed in twenty-four hours.

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[1] Methyl alcohol or wood alcohol.

CHART OF THE HARDWOOD DISTILLATION INDUSTRY

MAPLE - BIRCH - BEECH

SPLIT OR SAWED BLOCKS - AIRTIGHT RETORT - HEAT

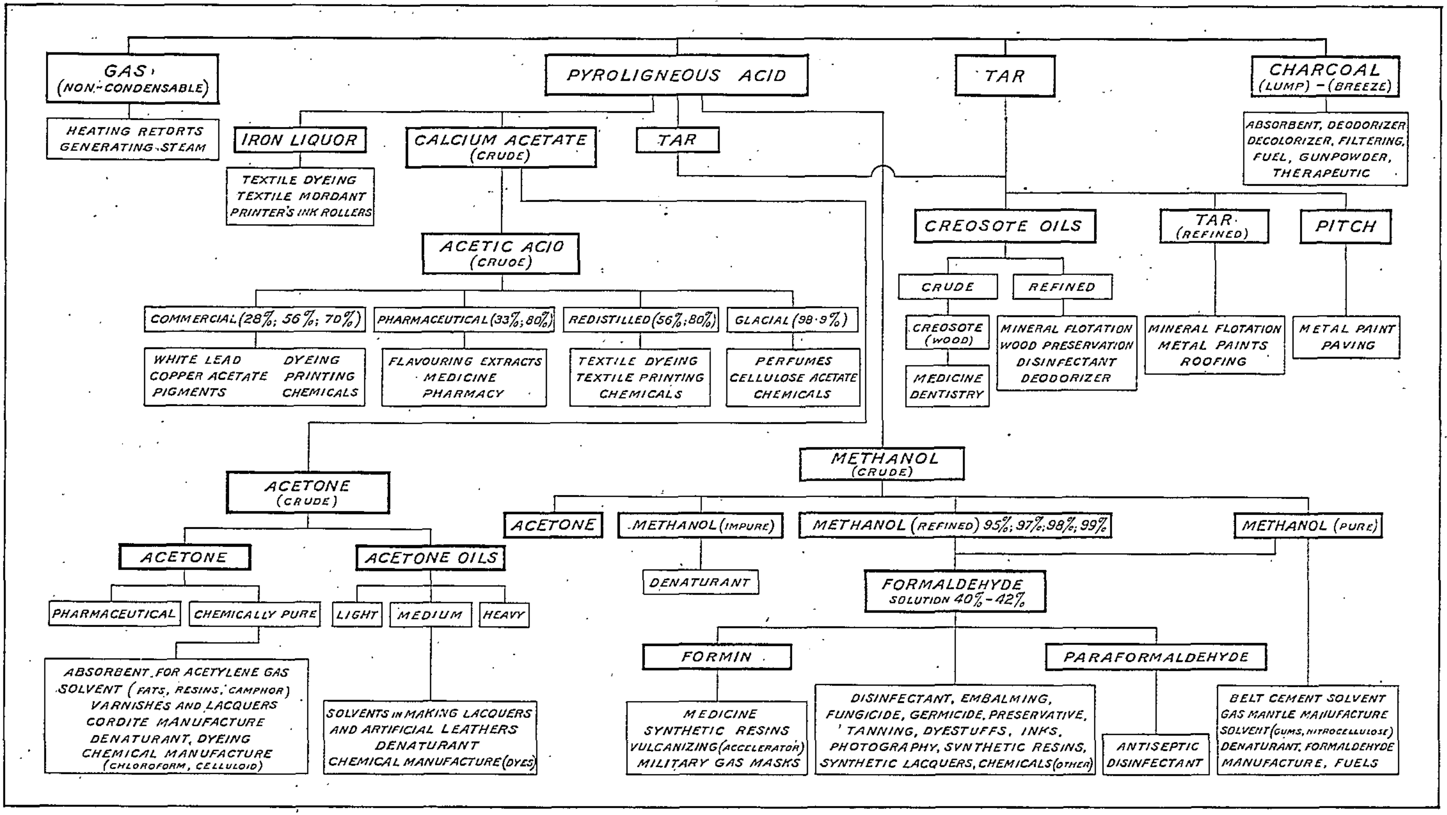

Diagram 9

Products of Wood Distillation

The total yields of byproducts obtained from woods depend upon the woods used and upon the treatment to which they are subjected. Rapid heating in small retorts to a high temperature increases the gas yield, decreases the amount of residual charcoal, and also diminishes the acetic acid and tar. Slow heating, usually accomplished in large retorts, results in relatively lower yields of gas, and greater yields of the condensable distillates (oils and acetic acid) and charcoal.

The principal primary products are non-condensable gases which are used for fuel, condensable liquors—pyroligneous acid and tars—and charcoal as a final product. The pyroligneous acid and the tar are usually recovered together and separated by decantation, each to be subjected to further treatment. Each of these liquids naturally contains small portions of the other.

The pyroligneous acid yields methanol, calcium acetate on treatment with lime, and a residual product from which flotation oils and iron acetate liquor are made. The latter product is used in the textile industry for dyeing and mordanting. Calcium acetate, on further treatment, yields acetic acid and acetone products of which there are several commercial grades, and from which many additional products can be made. Methanol as obtained from the pyroligneous acid liquors is subjected to further refining to produce the several commercial grades. This product finds very extensive uses in the arts and industries as a solvent, as a denaturant for ethyl alcohol, for industrial purposes, as a fuel, in the manufacture of formaldehyde, and as the base from which a number of other important products are prepared.

The tar portion of the condensable distillate is subjected to further refining by fractional distillation in special apparatus and yields a number of products. Those produced in Canada may be classed as creosote oils, refined tar, and hardwood pitch. Many other special compounds can be obtained if desired.

The final product charcoal is used principally as a fuel, though small amounts are employed for many other purposes.

The accompanying chart of the Hardwood Distillation industry will serve to show a few of the numerous products that are made by this industry, and it also shows the principal industrial uses of the more important final products. There are, however, many other products that can be recovered during the refining processes. The market for these products is limited and no attempt appears to have been made to produce them in this country.

The principal products marketed by the hardwood distillation industry, as now established in Canada, are charcoal, several grades of methanol, methanol acetate, calcium acetate, acetone, acetone oils, acetic acid, acetic anhydride, formaldehyde, and sodium acetate, tar and hardwood pitch, and some wood oils suitable for application in mineral flotation processes. The principal raw material required by the industry in addition to the wood is burnt lime for the manufacture of crude calcium acetate from which acetic acid, acetone, and related products are made. The refining operations require the use of a number of accessory chemical compounds for purifying byproducts. The principal chemicals used for this purpose are hydrochloric and sulphuric acids, fresh charcoal, calcium chloride, calcium oxide, iodine, manganese dioxide, potassium hydroxide, potassium bichromate or permanganate occasionally, phosphorus pentoxide, metallic sodium, and sodium bisulphite, carbonate or hydroxide less frequently.

Statistical Data

Available trade returns indicate a considerable export trade in some of the commodities produced by this industry. The corresponding records of importation show only comparatively light importations. It is therefore to be inferred that the Canadian market requirements for the principal products of this industry are well supplied by home production. If future trade conditions warrant further expansion there are still available suitable forest areas, particularly in the province of New Brunswick and in eastern Quebec, with some less extensive hardwood tracts in Ontario. Statistical data are not available to show the annual production and consumption of the various products made by this industry. Available records with respect to the imports and exports for certain years are given in the statistical tables under appropriate titles.

Canadian Situation

The present hardwood distillation industry in Canada is owned and operated by one corporation. There are nine plants available for the production of crude products, five of these being in Ontario, and four in Quebec. One of the Ontario plants also includes a refinery, and another refinery operates in Quebec. This firm also operates its own lime kilns in Ontario.

Reference should also be made to two closely related industries which exist in this country. In British Columbia one firm is experimenting in the preparation of turpentine products, flotation oils, resin and pitch from the resinous gum of the Douglas fir, the latter being obtained by tapping. In eastern Canada small quantities of hemlock oil and cedar oil are prepared at irregular intervals by individuals operating crude portable stills, the raw materials being the leaves and twigs of native hemlock or native cedar trees respectively. Spruce oil can be made in the same way. Hemlock and spruce oils are used in the manufacture of certain perfumes and liniments. Cedar oil is used extensively in the manufacture of polishes for furniture and floors, and also as an insecticide. The total quantity produced is small and the market available is limited.

COAL DISTILLATION

Coal may be defined as an amorphous mineral containing complex hydrocarbon compounds and some free carbon. It occurs in beds and has been derived from the remains of prehistoric vegetation. In colour it varies from brown to black, and in texture it may be either massive and compact or in layers. This mineral is our most important natural fuel. In nature all gradations are found from loose incoherent material like peat to compact and almost incombustible graphitic anthracite. For commercial purposes coals are frequently classified as anthracite, bituminous coals, and lignites. These differ chiefly in the amount of volatile constituents which are liberated on heating. Graphitic anthracites contain about 1 to 3 per cent volatile constituents, ordinary anthracites as used for domestic purposes from 3 to 10 per cent, semi-anthracites and semi-bituminous coals from 5 to 20 per cent, bituminous coals from 20 to 50 per cent. Lignites which often retain distinct traces of the old vegetable structure, are characterized by their loose structure, lamination, colour, and the presence of proportionally large amounts of water.

Raw Materials

Bituminous coals are almost wholly employed in the coal distillation industry. Anthracites are too low in volatile constituents to be of importance. Lignites yield too much moisture and only limited amounts of other products. Among the many varieties of bituminous coals that are available those which give the largest yield of volatile products are naturally in most demand.

Commercially it is customary to subdivide bituminous coals into two sub-classes on the basis of the coke yield. Those which yield a compact coke suitable for industrial uses are termed coking coals, while those which yield a loose incoherent coke product are termed non-coking coals. The coal distillation industries are dependent upon coking bituminous coals for their importance and success. In heating these coals by distillation processes the variety of chemical products that may be obtained greatly exceeds that which can be obtained from any other known material.

Treatment Processes

The treatment of bituminous coals by these processes was primarily based on the desire to obtain inflammable gases for lighting and heating or coke for metallurgical work. In the preparation of illuminating gases small quantities of coal were heated in closed retorts, the maximum quantity of gas was produced, a portion of the residual coke was used as a fuel to heat the retort, and the balance was sold as a domestic fuel because it was too weak and was otherwise unsuitable for metallurgical purposes. On the other hand, if metallurgical coke was required the gases and other volatile constituents were burned and coke only was recovered. It is only in comparatively recent years that plants have been designed to recover the maximum of products with the minimum of waste. Modern plants use the incondensable volatile constituents partly for heating the retorts in which the distillation takes place, and partly for industrial purposes; the condensable volatile constituents are recovered, and the residual coke is used for metallurgical purposes.

In a modern byproduct plant a series of gas-tight retorts or chambers are built side by side in such a way as to conserve heat as much as possible. The coal to be treated is placed within a retort, sealed from contact with the air, and then heated slowly to a suitable predetermined temperature. The volatile constituents, which are given off as the temperature rises, are collected in flues, so arranged that a portion of their heat is transferred to the incoming gaseous fuel. The partly cooled distillation products are conducted to suitable treating units for the separation and recovery of the desirable products. The principal products primarily recovered are benzol and related compounds, tar, and ammonia. The cleaned gases are then available for fuel. A portion is returned to the retorts to be used for heating, this portion being preheated as much as possible by the waste heat of the gases in the collecting flues. The other portion is available for any operations where a flexible fuel supply is needed for heating or lighting. Byproduct oven gas is used for heating various types of steel furnaces, for raising steam, illumination, and for domestic purposes. When the charge of coal placed in the retort ceases to discharge volatile constituents the connection with the collecting flue is closed, the retort is opened, and the residual coke is discharged and cooled by quenching with water. This coke is then available for metallurgical purposes or for heating. Most of the coke made in this way is used in iron blast furnaces, some of it is used in copper smelting and in the smelting of nickel ores. It is also used for lime burning and for many other purposes.

Products of Coal Distillation

The yields of different products obtained in coking ovens vary with the nature of the bituminous coal used, with the type of oven and with the temperature at which coking takes place. No general data as to the various yields can therefore be given. Nova Scotia coals, as treated at Sydney, are said to yield about 10 gallons of tar per ton of coal, 5 to 6 pounds of ammonia which is recovered as ammonium sulphate weighing 20 to 24 pounds. The gas yield per ton of coal coked is about 11,000 cubic feet, about half of which is required to heat the ovens, the other half being available for industrial purposes. The coke yield will vary from 65 to about 70 per cent of the weight of the coal charged.

Byproduct oven gas is usually washed with water to remove ammonia and other water-soluble constituents. These wash waters constitute the so called gas liquors and are one of the principal sources of ammonia and ammonium salts. The washed gases contain not only incondensable gases, which collectively are called fuel gases, but also a number of other highly volatile compounds that are liquids at ordinary temperatures. The principal components of this class are benzene, toluene, xylene, and carbon bisulphide. These are frequently removed by cooling and washing the gas with special oils, the different compounds being recovered subsequently by fractional distillation.

Tar is probably the most important of the byproducts obtained from coal distillation. It contains a large number of important compounds which are separated and recovered by fractional distillation. Coal tar distillation is discussed in the following section of this report.

PRODUCTS DERIVED FROM COAL

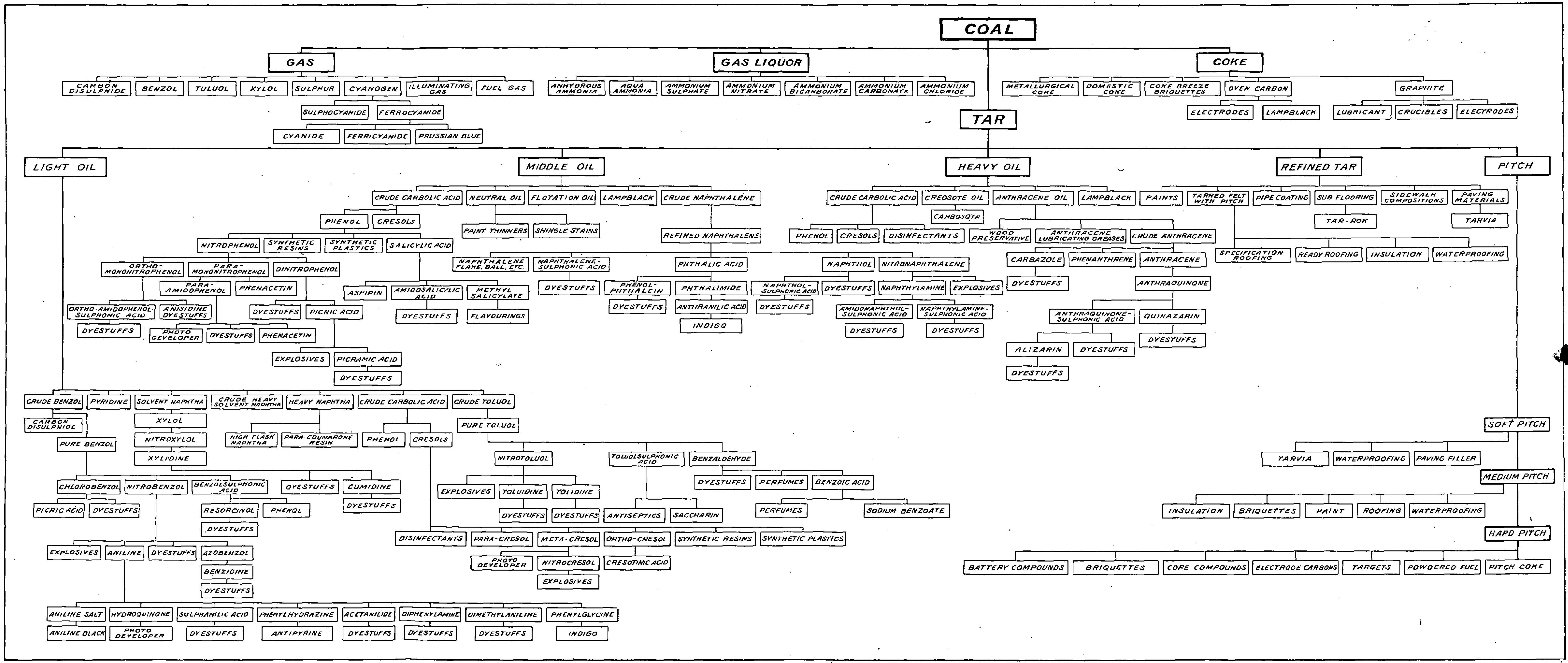

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Diagram 10

The destructive distillation of coal for the production of illuminating gas for domestic purposes is briefly discussed under the sub-title Coal Gas in the section dealing with Industrial Gases. Coal is also treated in beehive coke ovens for the production of metallurgical coke. All the other valuable products of the destructive distillation process are burned in the process, and this method of producing coke is therefore considered to be very wasteful of natural resources. It is not considered necessary to describe the process here.

Statistical Data

The quantity of coal used annually for the production of metallurgical coke naturally varies from year to year. In 1918 domestic coal mines supplied 1,348,232 tons of coal, and 635,010 tons were imported for the manufacture of coke. The average yield from all classes of ovens was 63·4 per cent of the coal charged. At the present time (1922) the consumption of coal in domestic coking plants is much below the capacity of available ovens owing to general business conditions.

There are, according to the Dominion Bureau of Statistics, about fifty plants in Canada making artificial illuminating gas from coal. The total amount of coal used in these plants is about 425,000 tons per annum, and the quantity of tar produced must be in excess of 3,500,000 imperial gallons. No statistical data have been prepared on this subject and the above figures are estimates only. A large proportion of the coal used is imported from the United States.

The question of the utilization of the tars and other byproducts obtained from the destructive distillation of coals is discussed in a following section of this report.

Canadian Situation

Coal is subjected to destructive distillation in Canadian plants for three different purposes—to produce metallurgical coke alone; to produce metallurgical coke and byproduct gases for industrial use; and to produce artificial gas for domestic purposes with or without the production of byproduct coke. When coke is produced some plants convert all their coke into carburetted water gas, which is mixed with the gases obtained by distillation.

Gases and tars are not recovered from between 26 and 30 per cent of the coal treated in distillation plants for the production of metallurgical coke. These plants use beehive ovens chiefly, though some retorts are also used. In these plants all products other than coke are consumed. The beehive ovens are all located in the Crowsnest Pass area; the retort ovens are located chiefly in Nova Scotia, there being also one plant in British Columbia that is at present idle.

Byproduct coke ovens are employed in the treatment of between 70 and 74 per cent of the coal used for the production of metallurgical coke. There are four plants of this kind in Canada, located as follows: Sydney, Nova Scotia; Hamilton, Ontario; Sault Ste. Marie, Ontario; and Anyox, British Columbia. At all of these plants the gases are stripped for the production of benzene, toluene, xylene, solvent naphtha, and naphthalene. Sulphate of ammonia is recovered in crude form, and the tars are also recovered. Two plants, one in Nova Scotia and one in Ontario, sell their tars in the crude state to treating works. The other plant in Ontario uses the tar for firing open hearth steel furnaces. At Anyox about one-third of the tar produced is burned under boilers and two-thirds is shipped to a treatment plant at Vancouver.

The byproduct plant at Sydney uses coal from Glace Bay, Nova Scotia. The plants at Hamilton and Sault Ste. Marie use coals imported from the United States. The plant at Anyox, B.C., uses coal mined at Cassidy, Vancouver Island. The average quantity of tar recovered at all of the plants is 5·8 imperial gallons per ton of coal treated.

COAL TAR DISTILLATION

General

Tar is a black to brown opaque, viscous, or oily liquid, obtained by the destructive distillation of organic substances. It is heavier than water and not miscible with it. There are great differences between tars obtained from different sources and between tars obtained from the same source by different processes. The principal constituents of wood tars are phenols and their derivatives; the principal constituents of tars obtained from peat, lignite, and bituminous shales are hydrocarbons of the paraffin series or others closely related to them; the principal constituents of tars obtained from coal are aromatic hydrocarbons, of which the simplest compound is benzene. All tars contain a large number of other constituents, as well as the principal components. They also usually contain other compounds derived from primary constituents by their decomposition by heat during the process of production. Tar therefore varies in composition according to the amount of heat used in its preparation, according to the process employed, and according to the length of time its several constituents are exposed to the action of heat during the progress of destructive distillation of the materials from which the tar is derived.

Tars which contain products of the paraffin series are not suitable for the manufacture of coal tar crudes from which coal tar colours can be made. The tars that are most valuable for making the intermediate products from which dyes are made are those containing hydrocarbons of the aromatic series. All tars contain phenols, some tars contain both products related to the paraffin series and products of the aromatic series. Such tars are suitable only for the manufacture of burning oils, lubricating oils, and sometimes yield solid paraffin.

Raw Materials

The principal primary raw materials for the production of coal tars containing products of the aromatic series are bituminous coals. These are distilled in gas works, in gas retorts, giving rise to gas tars of various kinds. They are also distilled in byproduct ovens designed for the production of metallurgical coke.

Tar is also obtained as a byproduct from gas producers, from blast furnaces where coal is charged, in the manufacture of water gas, and in the oil gas process.

Coal tar from gas plants and from coke ovens is available for distillation in Canada in considerable quantities. Tar from water gas and oil gas plants is produced in small amount, but there is no production at iron blast furnaces.

Properties and Constituents of Coal Tar

Coal tar is black and viscous; it possesses a disagreeable odour; the specific gravity of different coal tars varies from about 1·08 to 1·28. It is a very complex mixture of organic compounds, most of which belong to the aromatic (benzene) series. The chemical composition and the physical properties vary widely as they depend upon the coal used, upon the process, upon the character of the apparatus, and upon the temperatures used. As a rule tars produced by low temperature carbonization have a lower specific gravity than those produced when. the corbonization temperatures are higher. Heavy tars contain larger amounts of free carbon.

The constituents of coal tar may be grouped into four general classes:

Hydrocarbons which contain hydrogen and carbon in different ratios, the most important of which are benzene, toluene, xylene, naphthalene, and anthracene.

Phenols which contain hydrogen, carbon, and oxygen, the most important of which are carbolic acid and cresol. These products are weakly acid and are known as "tar acid."

Nitrogenous compounds which contain hydrogen and nitrogen. These products are basic and will therefore dissolve in acids. A large number of individual substances have been determined, but none of them are present in large enough quantities to be profitably extracted, except under very exceptional circumstances.

Miscellaneous substances which contain sulphur, nitrogen, or oxygen, ammonia, water, carbon bisulphide, and products derived from the decomposition of hydrocarbons. Ammonia and carbon bisulphide may be in part recovered during treatment of the tars, the other substances are for the most part impurities which must be removed.

The total number of separate compounds which are present in coal tar is stated to be about 218.

Uses of Coal Tar

Crude coal tar is used for a number of industrial purposes. It may be burned directly under boilers, or it may be used to make illuminating gas. It is used for road making and for manufacturing roofing felts and papers, being subjected to short preparatory treatment. It serves as a cementing material both for road making and in the manufacture of briquettes; usually a preliminary treatment to remove the lighter constituents has been applied to tars used for cementing. Pitch has been prepared directly from tar without distillation, but this is not usual commercial practice. Tar has been used for medicinal purposes, as an antiseptic, for denaturing alcohol for certain purposes, and lampblack and coke are made from it at times.

The principal use of coal tar is probably for the production of the coal tar crudes from which the intermediates that form the basis of the dye industry are made.

Processes and Products

Many of the constituents of coal tar can be recovered by fractional distillation. This process depends upon the fact that when two or more substances having different boiling points are mixed it is possible to separate the material having the lower boiling point from the other by heating the mixture to a temperature at which that substance will volatilize. It will then vaporize first, will escape from the containing vessel, and can be condensed in suitable apparatus. Near the end of the operation the escaping vapour will probably be contaminated with products whose boiling temperature is slightly higher. At this point the boiling will usually decrease for a time until the temperature rises near the vaporization temperature of the constituent with the next lowest boiling point. The constituents of coal tar have vaporization points which vary greatly; benzene boils at 80° C., while anthracene boils at 370° C. By keeping the fractions separate it is feasible to effectively separate many of the constituents.

Tar is subjected to fractional distillation in special retorts, usually vertical, with concave bottoms, bricked in, and provided with flues so that hot gases pass around the stills. There is also supplied much auxiliary apparatus to condense and collect the different fractions, to clean the stills and pipes, and to keep the operations moving forward satisfactorily. Tar retorts vary in capacity from 10 tons to about 35 tons per charge.

Heat is supplied by the combustion of coal, oil, tar, or gas, depending upon conditions of fuel supply at the different plants.

The process of distillation is carried on until a temperature of about 400° C. has been reached. Approximately 55 per cent of the original charge will then remain as a thick black mass which becomes solid pitch on cooling. Where this pitch is required for road work or for making roofing pitches or felts it is softened by running in some waste creosote oils from a previous batch of materials.

Once the operation is started the flow of condensed distillates is maintained as nearly constant as possible. As the operation continues the temperature gradually rises, and the specific gravity of the distillates increases. The apparatus is so arranged that the distillates can be diverted into different receivers. In current practice three separate portions are obtained, light oil up to 170° C., heavy oil up to 270° C., and anthracene oil or "green grease" up to 400° C. In some plants five fractions are obtained, named respectively, first light oil to 105° C., light oil to 210° C., carbolic oil to 230° C., creosote oil to 270° C., anthracene oil to 400° C. Other fractionating points may also be used.

The first distillate contains chiefly hydrocarbons of the benzene series. It is agitated alternately with dilute sulphuric or hydrochloric acid to remove basic substances, and with alkalies to remove tar acids; it is then subjected to several washings with water to complete as far as possible the removal of impurities. After removal of impurities the fraction is subjected to repeated fractional distillation in special stills to separate the principal constituents. The principal products recovered are benzene, toluene, and xylene. Both crude and rectified products are marketed.

The carbolic oils yield naphthalene on standing. This is removed by use of a filter press or a centrifuge. The oil is then treated with hot sodium hydroxide which forms compounds with the phenols and makes it possible to remove them. A second crop of crude naphthalene is obtained from the oil after the removal of phenol. The crude naphthalene thus obtained is washed with hot sodium hydroxide, agitated with dilute sulphuric acid, followed by a little dilute alkali to remove the acid, and then distilled. The sublimate is caught in a special condensing chamber lined with cotton or other fabric.

Phenols and cresols are separated from the carbolic oils by treatment with dilute sodium hydroxide. The resulting solution is purified by blowing steam through it. The sodium compounds formed are then decomposed by adding sulphuric or hydrochloric acid. The salts and the phenols are then separated by fractional distillation in special apparatus. Commercially pure white carbolic acid is obtained in this way. The residues are not usually subjected to further treatment to remove other phenols and cresols present, but the mixture is used directly for preserving timber.

Anthracene is separated from the anthracene oils by a special process, the yield being approximately 10 per cent.

There are numerous other products present in the different fractions, but these are rarely separated. The greater portion are mixed in various proportions and are used for industrial purposes.

It is to be noted that different kinds of creosotes are produced for commercial purposes from different kinds of tars, and these creosotes are applied industrially for different purposes. Creosotes are used for timber preservation, for sheep dips and insecticides, for the manufacture of certain greases, for lighting, and in one process for the recovery of benzol. Crude carbolic and cresylic acids are recovered together and used for timber preservation.

Refined tar for road treatment is prepared by distilling of the light oil and middle oil. When the liquid reaches a predetermined specific gravity, usually 1·05 at 15° C., the heat is turned off the still and the contents are allowed to cool to about 120° C. At this point crude creosote oil having a specific gravity of about 1·063, from which all anthracene has been removed, is added to the still, in the proportion of 115 gallons of heavy creosote to 2,000 pounds of tar in the original charge. The mixture is agitated with air to insure thorough mixing and is then run off into a receiver to cool. The specific gravity of the finished product ranges between 1·12 and 1·16.

Tar for roofing felts and papers is prepared much in the same way, the specific gravity being about 1·05 at 15° C. at the end of the distillation operation. When the still has cooled to 105° C. crude creosote oil is run in and the mixture agitated. This oil has a specific gravity of 1·045 at 15° C., and the proportion commonly used is 85 gallons to every 2,000 pounds of tar in the original charge.

The diagram which accompanies this section shows many of the principal products obtained by the treatment of coal tar distillation products and also indicates some of their applications.

The principal primary products that are obtained from coal tar are anthracene, benzene, creosote oil, cresol, cresylic acid, cumol, naphthalene, phenol, pyridine, toluene, and xylene. These are termed coal tar crudes. These products are the basis from which are derived about 300 compounds, known as coal tar intermediates through the application of suitable treatments with acids and alkalies. These intermediates are the basis of the coal tar dyes. A discussion of the dye industry is beyond the limits of this report.

A number of coal car crudes are used for the manufacture of explosives. The principal products used for this purpose are benzene, toluene, xylene, napthalene, phenol, cresol, and anthracene.

Statistical Data

The production of coke oven tar has been recorded annually for some years in the reports on mineral production issued by the Department of Mines. This record is being continued in the reports of the Dominion Bureau of Statistics. The coke made by these ovens is used in the iron and steel industry, and in copper smelting. The annual output of coke, and consequently of the tar also, fluctuates with the market demand for these metals. The production reached a maximum of over 14,000,000 gallons in 1920. Since that date the recovery has declined, but during the last year it is again rising.

The production of gas tar from the various plants which manufacture illuminating gas for domestic use in different municipalities throughout Canada has not been determined. The author has estimated that these plants require about 425,000 tons of gas coals annually. This amount of coal would yield approximately 4,250,000 gallons of tar.

Benzene, toluene, xylene, and naphthalene are the principal coal tar crudes made in Canada. Statistical data with respect to the production of these products and with reference to other products of the tar distillation industry are issued by the Dominion Bureau of Statistics.

Coal tar intermediaries for the production of dyes are not made in Canada. Aniline was made for a short time from imported aniline oil. Some attempts have been made to produce other colours, but, so far as known none of the enterprises have been commercially successful.

The size of the Canadian market for dye products is not known, and no systematic attempt has ever been made to ascertain our requirements. In this connection attention is drawn to the report on "Artificial Dyestuffs used in the United States" by Thomas H. Norton.[1] A similar investigation of the Canadian situation would be of benefit to Canada. It is

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[1] Bureau of Foreign and Domestic Commerce, Washington, Special Agents Series, No. 121, 1916.

reasonably certain that the manufacture of coal tar dyes would not be commercially practicable in Canada, but such an investigation would be the first step in ascertaining the size of the dyestuff market within the Empire. Present information on this subject is very vague. Attempts to ascertain the British market, made during the war, were not successful.

Canadian Situation

Coke oven tars are produced at four plants in Canada, one being located in Nova Scotia, two in Ontario, and one in British Columbia. The plants in Ontario use imported coals. The other two plants use local coals.

Gas tar is produced at 24 plants in Canada and in St. Johns, Newfoundland. One of these plants in Nova Scotia and one in New Brunswick use local coals. Two in Quebec use either Nova Scotia coal or imported coal. Fifteen plants in Ontario use imported coals and five in British Columbia use local coal.

Carburetted water gas, oil gas, or water gas are produced in 16 plants and it is presumed that these plants have a small output of tars. The output of producer plants is not known and the number of plants is not on record.

Tar distillation plants are located at Sydney, Halifax, St. John, Montreal, Toronto, Hamilton, Sault Ste. Marie, and Vancouver, nine in all, there being two plants in Montreal.

The principal products made at these plants in Canada are roofing tars, road tars, crude creosote, crude carbolic acid, and light oils, products for timber preservation, sheep dips, sprays, fungicides, and insecticides. The light oils, occasionally some middle oils, and crude products are exported to foreign refineries.

PETROLEUM DISTILLATION

Petroleum is a thick heavy inflammable oily liquid found in certain localities at or near the surface of the earth. It is also variously known as crude oil, rock oil, or mineral oil. The colour varies from light amber to yellow, dark reddish brown, greenish black, or black. It nearly always shows a greenish fluorescence and possesses a very characteristic odour. Petroleum is generally lighter than water, the specific gravity varying from 0·771 to 1·060.

Raw Materials

Petroleum as it occurs in nature is a very complex mixture of a number of liquid and volatile hydrocarbon compounds. It may also contain free carbon and compounds of nitrogen, oxygen, and sulphur. The proportions in which these different compounds are present differ with different oils. There are also differences in the number of compounds that can be recovered from any given oil. These compounds belong chiefly to the paraffin series. Some oils contain both paraffin and asphalt, while others contain asphalt only. Refiners generally recognize two leading classes, those with a paraffin base yielding solid hydrocarbons of the paraffin series on distillation and those with an asphaltic base, which are rich in asphalt and yield little or no paraffin on distillation.

The geological conditions under which deposits of petroleum occur are well known. These deposits are not confined to any one formation, and are found widely distributed in different parts of the world. Crude petroleum is obtained by drilling wells through overlying strata to tap accumulations of oil in natural reservoirs below. These natural reservoirs are rarely open spaces, but more frequently are they beds of porous strata, the interstices of which are filled with natural accumulations of oil. The escape of the oil under natural conditions has been prevented by the occurrence of impervious overlying strata, by the presence of water in strata in surrounding areas, or by both. The depths to which these wells have to be sunk vary from less than 100 feet in rare instances to more than 4,000 feet.

Treatment Processes

Petroleum oils are separated into various constituent products by fractional distillation. The method used varies with the character of the oil and with the products desired. Under suitable conditions it is possible to recover a number of different products by fractional distillation only, without decomposition. Most oils, however, are subjected to a process of dry distillation which results in the partial decomposition of some of the products, and the formation of others. This method—termed "cracking"— leads to the production of a number of oils which are of a lower specific gravity than would normally have been obtained from the oil treated.

Primary distillation is usually performed in horizontal steel cylinders mounted in brick work. The stills are heated by direct firing from the end or side. The fuel used may be oil, coal, or petroleum coke, this latter being a residual end product of the operations. Condensers and other accessory apparatus are so arranged that the condensed distillates obtained are split into a number of predetermined fractions, as the temperature of the still rises. Where desirable, these several products are subjected to re-distillation for division into smaller fractions and for purification. In some plants the crude oil is heated in the first, or crude oil stills until only tar remains. This latter is accumulated and distilled separately. In some of the more modern plants the distillation process is carried through in the crude stills to the production of coke.

Products of Petroleum Distillation

The principal products primarily obtained from an oil with a paraffin base are naphtha (including gasoline), burning oils, lubricating oils, wax, and coke. These products are subjected to further refining, subdivision, and purification by treatment in special stills or other apparatus. Where oils with an asphaltic base are distilled the products obtained are similar to those already mentioned. The burning oils are not usually as good, the lubricating oils are heavier and have a lower flash point, and the residues consist of asphalt instead of tar and cylinder stock.

Natural Products Associated with Petroleum

Natural gas is very frequently found in association with crude petroleum deposits. It also occurs independently. Inflammable natural gas consists of gaseous hydrocarbons of the paraffin series and also usually contains small percentages of nitrogen, carbon dioxide, olefins, and occasionally oxygen. Some natural gases contain very light hydrocarbons (gasoline) which can be extracted by the use of suitable solvent oils or by compression and cooling. Such gases are said to be " wet " and the gasoline recovered from it is termed casing head gasoline. Natural gas is used as a fuel, for lighting, and for the manufacture of carbon black. (See also Natural Gas in section on Industrial Gases.)

Shale Oil. Certain shales contain large percentages of bituminous material. Such shales yield paraffin oils when subjected to dry distillation. The formation of these oils during the distillation processes is apparently due to the decomposition of the organic matter present. The products obtainable from the distillation of suitable shales are ammonia (recovered in aqueous solution and converted into the sulphate), phenols, naphtha, burning oils, paraffin oils, and wax.

Ozokerite. A number of deposits of a natural paraffin have been found at several points in America, Europe, and elsewhere. The material is yellowish brown to green or black in colour, translucent to opaque, and has a greasy feel. Ozokerite is sometimes distilled principally for the recovery of the paraffin wax. It may also be refined without distillation. The refined product is marketed as ceresin.

Asphalt. Natural deposits of pitch are found in many localities throughout the world. These are generally called asphalt. A similar material is obtained as a residue from petroleum refining when the distillation process has been stopped before coking takes place. The material may be semi-fluid or solid. The colour of natural asphalts varies from brown to black. Asphalts consist of mixtures of hydrocarbons, complex carbon compounds derived from them, and some free carbon. Some of the principal varieties of asphalt having special properties, are severally known as albertite, elaterite, gilsonite, grahamite, impsonite, nigrite, or wurtzilite. Natural asphalts are refined by fusing. The heavier mineral impurities will then settle out. Natural asphalts are used chiefly for road construction. Asphaltic residues obtained in the distillation of crude petroleum are used chiefly for making weatherproof papers and felts, and for roofing.

Canadian Situation

Crude petroleum has been produced commercially for many years in the province of Ontario in the district between lakes Erie and Huron. Small quantities have also been produced in New Brunswick near Moncton, and in Alberta. Exploratory drilling is in progress in many places in western Canada, and recent reports are to the effect that oil has been discovered in one locality. The Fort Norman oil field in the Mackenzie River basin has also been under investigation; its area and capacity have yet to be determined.

CHAPTER IV

PHARMACEUTICALS

General

All chemical substances whether natural or artificial products affect living protoplasm in some way. The study of the action of chemical substances, except food products, on all kinds of living organisms from unicellular bacteria and amoebae to man constitutes the science of pharmacology. Closely allied to this science is *therapeutics.* The latter is concerned with the remedial properties and conditions of application of products, while the former is concerned with the remedies themselves, their derivation, and properties.

Substances which are used as drugs or which exert effects upon animal tissues or organs are termed pharmacological products. Pharmaceutical chemistry is therefore the branch of chemistry relating to pharmacy. It includes the study of the occurrence and properties of drugs, methods of analyzing them, the preparation of medicines, particularly with reference to the ingredients used and their arrangement, and includes the study of toxicology and antidotes for poisons.

Pharmaceuticals may then be defined as the products which are used in pharmacology and therapeutics, and the manufacturer who is engaged in the making of these products is a pharmaceutical manufacturer.

Raw Materials

The substances that are used in the preparation of pharmaceuticals come from three main sources, minerals, plants, and animals.

(1) Chemical elements may be used alone or in combination. Iron, mercury, bismuth, carbon, iodine, and many other inorganic products derived from natural minerals, or compounds of these, have therapeutic value and are used by the pharmacist. Chemical compounds such as alcohol, ether, chloroform, and numerous other artificial products are also employed.

(2) Plants supply many chemical substances which cannot be made artificially, such as the exudations from which resins, gums, and oils are extracted. Plants also produce and store within their tissues alkaloids, glucosides, and vegetable acids that are utilized for medicinal purposes. A very few of these have also been made synthetically from coal tar chemicals.

(3) Animals supply special gland secretions from which products of therapeutic value are made, such as thyroid extract, pancreatin, pepsin, and other ferments. Musk, cod liver oil, and the various serums and antitoxins that are obtained from animals by special treatments may also be classed as pharmaceutical preparations.

The general enumeration that has been given in the three preceding paragraphs is sufficient to indicate that the source of raw materials used for the production of pharmaceutical preparations is very wide.

The preparation of chemical salts of the elements for pharmaceutical purposes consists largely in preparing these salts by the usual methods, and afterwards purifying them completely for therapeutic application.

The various products obtained from plants are secured by different methods. Experience and investigation have shown that desirable constituents of plants are sometimes concentrated at certain points. The parts of plants used to secure vegetable drugs may therefore consist of buds, flowers, twigs, bark, roots, exudations, galls, or woods of certain specific kinds. The desirable products are removed from the raw materials by processes of solution and extraction. Various solvents, such as water, alcohol, ether, or others, acids or alkalies, or salts of metals, are used for this purpose. The extracts are then subjected to such treatment as may be necessary to obtain the product finally desired.

The products obtained from animals are also obtained by various methods which have been determined by experiment.

The number of substances used for the preparation of pharmaceuticals is very great. One manufacturer informed the author that he had between seven and eight thousand products in his stock room. A list of raw materials used in this industry is therefore beyond the scope of this report. It is sufficient to add that many fine chemicals derived from natural mineral products are required by the industry.

Products

A classification of pharmaceutical products was proposed by Buchheim and is given in the Encyclopaedia Britannica, eleventh edition. In this classification those substances having similar actions are grouped together, each group being named from the best known member. The following brief statements are abstracted from this article. No attempt has been made to indicate whether the products mentioned are made in Canada.

1. *Acids.* This includes sulphuric, hydrochloric, nitric, phosphoric, tartaric, citric, acetic, lactic, carbolic, salicylic, tannic, and many others.

2. *Alkalies.* This includes potassium and sodium hydroxides, aqua ammonia, carbonates and bicarbonates of sodium, potassium or lithium, lithium citrate, calcium carbonate or hydroxide, magnesia and magnesium carbonate, soaps, and other products of a similar nature.

3. *Easily absorbed Salts.* Sodium chloride is the best known of these. The group also includes sodium nitrate, potassium chloride or nitrate, and the alkaline bromides or iodides.

4. *Salts absorbed with difficulty.* This group includes the sulphates of sodium, potassium, and magnesium, acetates and tartrates of potassium or sodium, magnesium citrate, sodium phosphate, and similar salts.

5. *Heavy Metals.* These include aluminium, antimony, arsenic, bismuth, chromium, copper, gold, manganese, mercury, lead, platinum, and silver. Both soluble and insoluble compounds are used to obtain various physiological effects.

6. *Halogens.* This group includes iodine, bromine, and chlorine, both in the free state and in combination with other elements.

7. *Sulphur.* Sulphur in itself has no action but it forms sulphides, sulphites, or sulphuretted hydrogen with secretions, and these products have pronounced physiological effects.

8. *Phosphorus.* This includes compounds of this element such as phosphides and probably hypophosphites.

9. *Oxygen.* In addition to pure oxygen the group includes hydrogen peroxide, potassium permanganate, powdered charcoal, and some other oxidizing agents.

10. *Carbonic Acid.* Carbon dioxide, carbon monoxide, and nitrous oxide are included in this group.

11. *Water.* This substance acts as a dilutent and as a solvent and has other effects. Mineral waters which contain salts in solution also belong to the group, although their effects are due largely to the salts in solution (see groups 3, 4, and 5).

12. *Tannic Acid.* This substance is present in many vegetable pharmaceuticals, such as gall nuts, oak bark, bearberry leaves, catechu, kino, red gum, logwood, witch hazel, and others, all of which are used in making astringents.

13. *Local Irritants.* This group is further subdivided into: (*a*) Those which act upon the alimentary canal, such as quassia wood, calumba root, taraxacum, gentian, chiretta, and many others, and (*b*) those which act on the skin, the best known of which is cantharides (Spanish fly). The active chemical in this case is a colourless crystalline substance, cantharidin. Similar substances belonging to the group are chrysarobin, mustard, pepper, and others.

14. *Male Fern.* This group includes male fern, santonin, cusso, pomegranate bark, pumpkin seeds, and many other substances which contain active principles that have a specific poisonous action on intestinal parasitic worms.

15. *Ethereal Oils.* This includes numerous substances which owe their action to the ethereal or essential oils which they contain. Some of these substances are cloves, pimento, myrtle, eucalyptus, caraway, fennel, dill, coriander, rosemary, lavender, peppermint, spearmint, nutmeg, cinnamon, sandalwood, turpentine, juniper berries, valerian, sumbul, and others; oleoresins, such as copaiba, cubebs, and Canada balsam; gum-resins, such as asafœtida, myrrh, ammoniacum, and galbanum; and true balsams, such as benzoin, storax, tolu, and Peru. The various camphors, such as laurel and Borneo camphor, menthol, and cumarin, which are oxidized derivatives of essential oils, also belong to this group.

16. *Phenol.* This group includes carbolic acid, sulpho-carbolates, creosote, wood tar, coal tar, oil of cade, thymol, salicylic acid, benzoic acid, naphthol, hydroquinone, cresol, guaiacol, ichthyol, saccharin, and many others.

17. *Alcohol.* This group includes a very large number of chemical products. Ethyl alcohol may be taken as the type. Other products are methanol, amyl alcohol, propyl alcohol, butyl alcohol, ether, acetic ether, paraldehyde, sulphonal, chloroform, methyl chloride, ethyl chloride, chloral hydrate, butylchloral hydrate, and numerous derivatives from these.

18. *Nitrates.* This group includes amyl nitrite, ethyl nitrite, methyl nitrite, nitroglycerine, sodium and potassium nitrites, erythrol-tetranitrate, and many other compounds made with nitrous or nitric acid.

19. *Alkaloids.* The principal substances in this group are morphine and related products derived from opium, such as codeine, narcotine, and laudanine. Other alkaloids are strychnine, brucine, caffeine, cocaine, atropine, hyoscyamine, homatropine, duboisine, daturine, nicotine, piturine, lobeline, pysostigmine, conine, gelsemine, sparteine, aconitine, delphinine apomorphine, emetine, quinine, phenacetin, acetanilide, phenazone, and many similar substances come within this group.

20. *Digitalis.* This group includes a large number of substances which have an action similar to that of foxglove leaves, including the active principles of stropanthus, squill, *Urechites suberecta, Convallaria majalis, Nerium Oleander, Helleboris niger, Antiaris toxicana* (Upas tree), and many others.

21. *Picrotoxin.*

22. *Saponin.* This includes many allied bodies which form an abundant soapy-looking froth when shaken up with water. They occur in plants such as *Quillaia saponaria, Polyala senega,* sarsaparilla, and others known collectively as the soapworts.

23. *Cyanogen.* This group includes compounds of cyanogen, such as hydrocyanic acid, potassium and sodium cyanide, cherry-laurel water, amygdalin, bitter almonds, and other products which contain this substance.

24. *Ferments.* This group includes such products as pepsin, diastase, pancreatic ferments, papain, pineapple ferment, taka-diastase, and others.

25. *Animal Glands and Secretions.* This includes products obtained from thyroid glands, suprarenal bodies, pancreas, spleen, bile, bone marrow, ovaries, and some others.

26. *Antitoxins.* These are substances which antagonize the toxins formed in the body by pathenogenic organisms, the toxins of snake venom and other animal poisons, and vegetable toxins, such as abrin, ricin, and related products.

27. *Neutral Fats.* This group includes cod liver oil, almond oil, olive oil, lard, lanolin, linseed oil, wax, spermaceti, and other fat oils. Paraffins, glycerine, and vaseline are not fats but they may be included although they do not act as foods; they have much the same effect otherwise as the fats and oils of vegetable or animal origin.

28. *Sugars, Starches, Gums, Gelatine.* These materials are used chiefly for their dietetic values.

Statistical Data

The pharmaceutical industries in Canada have been partially investigated by the Dominion Bureau of Statistics. The report issued by this bureau in 1922[1] shows the quantities and prices of some of the principal chemicals and other materials used by the industry in the years indicated. Annual reports are being issued.

The total value of the materials listed was $5,854,106 in 1919, this amount including $1,255,520 for containers, and $2,677,936 for unclassified materials, drugs, and chemicals. In the year 1920 these amounts were $7,029,594 for materials, which included $1,669,026 for containers, and $2,677,936 for miscellaneous products. In 1921 the total value of the materials used was reduced to $4,466,000.

The products of individual pharmacists throughout the country are not included in these enumerations.

Canadian Situation

According to the Dominion Bureau of Statistics[2] there were 97 firms in 1919, 100 in 1920, and 103 in 1921, engaged in the manufacture of patent and proprietary medicinal preparations, pharmaceuticals, toilet preparations, and the numerous other products made by these industrialists. In 1920 there were 61 plants in Ontario, 29 in Quebec, 7 in Manitoba, and one each in the provinces of Nova Scotia, New Brunswick, and British Columbia.

These enumerations appear to include wholesale establishments only. Many exactly similar preparations, but in less variety, are made by numerous individual pharmacists throughout the country, especially in the towns and larger villages. The total number of firms and individuals making these products is much larger than here given.

No attempt has been made to ascertain exactly what products are made in Canada by this industry and what raw materials are required. It is known that many crude products and refined chemicals are imported and that extracts, tinctures, tablets, and other products are made here from materials assembled from abroad. It is also known that numerous refined chemicals derived from products of mineral origin are required by the Canadian industries. There has, however, been no opportunity to properly investigate this market for these products, and its requirements are largely unknown.

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[1] Chemicals and Allied Products, 1919 and 1920, Dominion Bureau of Statistics, 1922, pp. 82-83.

[2] *Loc. cit.*, p. 81.

CHAPTER V

FINE CHEMICALS (ORGANIC)

General

Many chemical products are classified as fine chemicals, in contradistinction to those which have been described in the preceding chapters of this report as heavy chemicals. It is not possible to formulate a precise definition of the term "fine chemical" which will be of universal application. There are a number of chemical products, such as those used as developers in photography, or the synthetic drugs, which are universally regarded as fine chemicals. There are other products upon whose classification it is much more difficult to decide.

There seems to be a general consensus of opinion that chemical products which are made on a comparatively small scale under special conditions of manufacture by highly skilled labour working under competent technical supervision shall be called fine chemicals. Usually the products are of a high grade of purity and are correspondingly free from impurities; often they are rare products made only by a few manufacturers and the unit costs are comparatively high owing to the conditions of manufacture, complexity and cost of the processes, and rarity and relative costliness of the raw materials.

The Association of British Chemical Manufacturers classify fine chemicals in five groups, as follows: Analytical, Pharmaceutical, Photographic, Rare Earths, and Synthetic Essences and Perfumes.

The first four groups of fine chemicals can be further subdivided into inorganic and organic products. In this chapter reference is made to organic fine chemicals; the inorganic fine chemicals have been briefly discussed in chapter VI, part II.

Organic Fine Chemicals

A discussion of organic fine chemicals, their raw materials, and uses would necessitate a review of nearly the whole of organic chemistry. In other chapters references are made to ethyl alcohol and some of its derivatives, to methanol and associated products, to photographic chemicals, to pharmaceuticals, and to essences and essential oils. The numerous chemical products made from coal tar crudes, including some of the intermediates as well as the final products, are also classed as fine chemicals.

In the chapters above mentioned some reference has been made to chemicals which are made in Canada for use in the industry under discussion. A supplementary list showing a few organic fine chemicals that are known to have been made here is given below.

Table 13.—Fine Chemicals made in Canada (organic)[1]

Acid acetylsalicylic (aspirin); ammonium compounds (benzoate, oxalate, salicylate, tartrate); amyl acetate, butyrate, and nitrite; bismuth com-

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[1] The products listed were all manufactured in Canada at one time. They are not all now being produced, but manufacture could be resumed if warranted by commercial conditions.

pounds (ammonium citrate, oxalate, salicylate, subgallate); caffeine citrate; cellulose nitrate; camphor monobromide; chloroform (pure); collodion; diarsenol; ethers [acetic, butyric, nitric, sulphuric (including anaesthetical)]; iron compounds (ammonium tartrate, citrate, quinine citrate, quinine strychnine citrate, strychnine citrate, potassium tartrate, oxalate); lithium compounds (benzoate, salicylate); mercury compounds (oleate, salicylate); methyl salicylate; neo-diarsenol; neo-phenarsenyl; phenarsenyl; potassium compounds (antimony tartrate, citrate, tartrate); quinine and compounds (bisulphate, hydrochloride, phosphate, valerianate); sodium compounds (acetate, benzoate, citrate, oxalate, salicylate, sulphocarbolate); strychnine compounds (citrate, nitrate, sulphate); zinc compounds (acetate, oleate, sulphocarbolate).

Canadian Situation

No systematic studies of the fine chemical manufacturing industries in Canada have been made. The preceding list names a few products that were being made here prior to the war. During the war production of most of these compounds ceased, and it has not been possible to ascertain how far it has since been resumed. In other chapters references have been made to some fine chemicals which are utilized in the industries discussed. Analytical chemicals are not known to be made in Canada. Pharmaceutical chemicals are made by a number of firms, but the exact products made and those imported have not been ascertained. Photographic chemicals of organic origin are not made in Canada. Essential oils are for the most part imported and synthetic perfumes are not known to be made here, with the exception of methyl salicylate.

Statistical studies have not been made by any official bureau, and available import records give no important information with respect to the Canadian consumption or requirements of these classes of chemical products. A few groups of products of this class are mentioned in published trade returns, indicative of the fact that a considerable market for these products exists in Canada.

PART IV

CHEMICAL INDUSTRIES

MANUFACTURING GROUP

INTRODUCTORY

There are a number of industries whose finished products are obtained by the application of complex chemical processes to various kinds of raw materials. In some cases primary chemical products are made from natural mineral or organic products within the industry merely for the purpose of making secondary or higher and more complex compounds for fabrication into finished products. The finished products are usually complex chemical compounds, mixtures of more or less complex compounds with natural materials, or more or less complex mixtures of natural materials. The products used may be either inorganic or organic; the processes are always chemical and often physical as well.

The principal feature common to the group of industries considered in this part of this report is that both processes and products depend upon chemical means. The sources of raw materials, the processes used, and the finished products are very diverse.

The industries considered in this part of this report are the manufacture of explosives and fertilizers, the ceramic group including glass production, the latter being discussed in a separate chapter, and a number of miscellaneous minor industries making more or less complex chemical products for industrial uses. The minor industries discussed are the manufacture of insecticides, fungicides, blueing, boiler compounds, and inks. A few other products might have been included here, but it was not considered desirable to extend the list further.

CHAPTER I

EXPLOSIVE MANUFACTURE

An explosive may be defined as a product in which the constituent elements are capable of re-combination or dissociation in a very short space of time, through chemical reactions, whereby large quantities of gas at high temperatures are suddenly released. The release of these gases results in sudden and violent increases in pressure and is usually accompanied by shock. Each explosive is a chemical product or a mixture of chemical products which must be prepared with accuracy and precision. The manufacturing of these products is therefore a highly specialized industry. Usually an explosive factory is given over to the manufacture of a single product only, though this product may be prepared for the market in a variety of forms. In such a factory the ingredients of the explosive may be merely assembled and blended, or they may be first produced from raw materials assembled for that purpose.

Raw Materials

The subjoined list includes the names of the principal chemicals that are used in the preparation of the various kinds of explosives made in this country. It may be noted that the basis of manufacture of most explosives is sulphuric acid. While this acid is made in Canada from native pyrites, much of that used in the manufacture of explosives is made from imported sulphur. During the whole period of the late war Canada was largely dependent upon imported sulphur for the manufacture of the principal explosives produced for military purposes, a dependence which still continues. Canada is also dependent upon foreign supplies of nitrates from which to make nitric acid for the manufacture of these products.

A large number of explosive mixtures or compounds are put upon the market for specific purposes, and under trade names which are not necessarily indicative of their chemical composition. In the subjoined list of chemicals used in the manufacture of explosives account has been taken of the composition of the principal explosives sold under trade names, but no attempt has been made to make the list sufficiently comprehensive as to include all of these. The list includes not only the names of the raw materials used in the industry, but also the names of a number of compounds made from these chemicals to be used as constituents of explosive mixtures.

Table 14.—Principal Materials used in the Manufacture of Explosive Compounds or Mixtures, and in Fireworks

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

Minerals: Asphaltum; bauxite; *graphite; kieselguhr; pyrites; sand; slate (pulverized)*; sulphur.

Metals: *Aluminium (powder)*; magnesium (powder); mercury; *silver; zinc.*

ACIDS: *Hydrochloric, nitric,* oxalic, picric, *sulphuric.*

INORGANIC CHEMICALS: *Aluminium sulphate* (*crystals*); ammonium compounds (chloride, *hydroxide,* nitrate, oxalate, perchlorate, sulphate); antimony sulphide; barium nitrate; calcium compounds (*carbonate,* chlorate, *silicide, sulphate*); *ferric oxide;* magnesium compounds (*carbonate, oxide,* sulphate); *manganese dioxide;* potassium compounds (*alum,* bichromate, *chlorate,* chloride, nitrate, *perchlorate,* sulphate); sodium compounds (biborate, *bicarbonate, carbonate, chlorate, chloride, hydroxide,* nitrate, *perchlorate,* sulphate, sulphide); zinc oxide.

ORGANIC CHEMICALS: *Acetone;* alcohol (*ethyl*); ammonium picrate; *benzene; nitro derivatives of benzene; cellulose* (cotton, wood); cresols; diphenylamine; ethers; fulminates (*mercury, silver*); *glycerine; mineral jelly; naphthalene; nitrated starch; nitrated wood; nitro-cellulose; nitro-glycerine;* nitro-naphthalene; *nitro-toluene;* oils (*mineral,* vegetable); *paraffin; phenol;* resinates (potassium, sodium); *toluene; vaseline.*

MISCELLANEOUS PRODUCTS: Charcoal (*poplar, willow*); *clays; coal; corn meal; corncob meal;* cotton; *glass* (*powdered*); gums; *parchment paper;* peanut shell meal; resins; rice hulls; *sawdust; starch; sugar;* turmeric; vegetable ivory meal; *wheat flour;* wood meal.

Products

The explosive industries of Canada are engaged largely in making products suitable for use in the mining of coal and metallic ores, in quarrying, in road and railroad excavating, for petroleum and natural gas production, and for clearing land of stumps and occasionally of boulders. There are several firms producing sporting powders and small arms ammunition is made by others. Fireworks and signals are manufactured at several points. In addition a number of military explosives are produced. The useful applications of explosives are numerous and no one product is suitable for all purposes. The principal products of this industry in Canada are gunpowders for sporting, military, and industrial purposes; blasting powders; dynamites and nitroglycerine; several nitro-compounds; fulminates; fuses; squibs; detonators; caps; fireworks; railway and marine signals.

Statistical Data

Statistical data showing the quantities of the several products made, and the quantities of chemicals required by this industry, annually, are not available.

The returns compiled from the records of the Department of Customs show that quantities of these products are imported annually. Some of these data are included in the tables presented on pages 8-27. Certain of the products imported are required for the manufacture of explosives and are not produced in Canada. The importations include large quantities of sporting ammunition, blasting explosives, percussion caps, detonators, fireworks, and other products which could easily be produced in this country. The available returns do not classify these products in specific detail, and it is not possible to determine the exact quantities of each product imported. In some instances the local demand for a specific product may be too limited to warrant the manufacture of that product here.

Canadian Situation

There are eighteen firms engaged in the manufacture of explosive products in Canada. Eleven firms are primarily engaged in the production of chemical explosives, three of these making fulminate of mercury only. Seven other firms and two firms of the first group, nine in all, are making such products as fireworks, fuses, detonators, or signals. These products contain chemical products which possess certain of the characteristics of explosives, and which demand the same care and technical skill in the production.[1] One firm is engaged in the manufacture of small arms ammunition.

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[1] Consult annual reports of the Chief Inspector of Explosives, Department of Mines, for detailed information.

CHAPTER II

FERTILIZER INDUSTRY

General

Artificial manures form a group of chemical products that are of inestimable importance to the future of the agricultural industry of Canada. Such products are essential to intensive farming and to increased food production. The percentage of available agricultural land in Canada in a virgin condition has been gradually diminishing, and during the last decade the area of unoccupied lands has been steadily shrinking. There are still large areas, particularly in the western provinces, which are capable of producing heavy grain yields for many years to come without the aid of artificial manures. But, on the other hand, all the older occupied areas show diminished production wherever the use of fertilizer materials has been neglected. The continued increases in the total annual values of agricultural products have undoubtedly been attained largely through the utilization of additional areas of virgin soil, and through increase of agricultural population. The time will come, and in fact has come to large areas in the older provinces and in the older parts of the newer provinces, when the continuous removal of essential plant food constituents from the soil by cropping without replacement will deplete these soils. It is possible to temporarily restore the soil fertility by special treatment, without the direct use of fertilizers, by promoting natural processes of mineral decomposition and soil formation, but such procedure is slow, means idle land yielding no income, and therefore heavier overhead charges against the productive areas, and at best is only temporarily successful.

Present conditions demand maximum production per acre as well as per individual worker. Maximum yields can only be obtained by maximum cultivation, which in turn indicates the use of the best available crop foods. The crop yield per acre and the crop yield per individual worker can both be greatly increased by the application of the proper fertilizer constituents, if these applications are made scientifically and with due regard to the needs of the particular soil area under treatment.

The fertilizer industry in Canada is only in its infancy. The present market for artificial fertilizers is restricted to a few areas, chiefly in the immediate vicinity of the larger cities. The great majority of agriculturists, with the exception of those technically trained and a comparatively few others, are not at present in the market to secure products of this kind. Owing to this condition it is probable that the development of a large fertilizer industry in this country will also involve the development of a market by the maintenance of an intelligent and systematic campaign of educational advertising.

The development of large fertilizer industries appears to offer one of the best opportunities available in Canada for extensive industrial expansion in a direction where there is promise of a large home market, as well as a possible export market.

The principal constituents of artificial manures are of three types—nitrogen fertilizers, phosphates, and potashes. Some soils are improved by the addition of indirect fertilizers such as gypsum (or land plaster), ground limestone, or similar products. Very recent investigations have shown that on certain soils sulphur, sulphuric acid diluted, or a product supplying sulphur is beneficial when applied in limited amount. The following sections enumerate the principal raw materials of the fertilizer manufacturing industry and discuss briefly the Canadian situation with respect to each material.

Nitrogen Fertilizers

Nitrogen fertilizers are of two types—those derived from animal wastes, and natural or artificial chemical salts. The first group includes abattoir wastes (such as dried blood, tankage) and fish guano; the second, such products as nitrate of soda, sulphate of ammonia, and nitrogen products made from atmospheric nitrogen such as cyanamide, nitrite of soda, and nitrite or nitrate of lime.

Abattoir Wastes. There are abattoirs located in all the principal centres of population throughout Canada. These plants produce a number of waste animal products which are valuable fertilizer constituents. All the larger plants conserve their wastes and either utilize them in fertilizer manufacture themselves, or transfer them to fertilizer plants. In many of the smaller centres waste animal products are destroyed. The quantity available in any one locality is small, but an investigation would be necessary before it could be stated whether it would be commercially feasible to save this waste by preliminary treatment and then ship to larger works for final preparation.

Statistical data as to the quantity of abattoir wastes produced annually are not available. At the present time a considerable portion of this material is exported, chiefly to the United States.

The principal products available for use in fertilizer manufacture are dried blood (usually the clot only and not the entire blood) and tankage (the latter includes all waste and scrap not otherwise useful, all fats and oils having been extracted). Hoofs and horns are occasionally converted into fertilizer by fine grinding. Modern practice now tends to convert many of these products into nitrogenous foods for domestic animals, and the amount available for use in fertilizers is thus proportionally diminished. It should be commercially practicable to utilize the local animal wastes of abattoirs in small communities in this way when it is not feasible to make them into fertilizers or to ship them to larger centres.

The total number of large firms in Canada operating abattoirs is, according to available lists, sixty-seven, plants being listed in all the provinces except Prince Edward Island. There are known to be a large number of smaller organizations or individuals not included in the list. No records are available to show what waste products suitable for fertilizer manufacture are produced by these smaller firms, nor what disposal is made of the waste.

Fish Guano. The waste product from the fisheries is variously known as fish scrap, fish guano, or fish meal. With this material may be included whale guano made from the waste scrap of the whaling industry.

The operation of our fisheries on the Atlantic and Pacific coasts, and on the Great Lakes of the interior results in the production of much waste material containing oil and nitrogenous matter, the latter suitable for fertilizers. When the subject was investigated by the author there was found to be one firm operating in Nova Scotia and three in British Columbia utilizing fish waste, the products being glue, fish oil, and nitrogenous scrap. This latter was in part used for stock and poultry foods, and in part for fish guano which was sold in the United States. The whaling company was making similar products. These plants were operated during a portion of the year only, dependent upon the availability of supplies of raw material, which are for the most part seasonal. One plant is now in continuous operation throughout the year.

On lakes Erie and Superior there is a considerable quantity of similar waste available seasonally, all of which is discarded and destroyed. Similar conditions will probably prevail on Great Slave lake as the fisheries develop.

An experimental investigation on the utilization of the fish waste for the Great Lakes fisheries was made on behalf of the Commission of Conservation, by J. B. Fielding in 1916.[1] Mr. Fielding estimated the available fish waste in Canada at 250,000 tons.

A second investigation made on behalf of the Advisory Council for Industrial Research in 1917 showed over 300,000 tons of raw material produced, of which it was estimated that probably half would be available for conversion. This investigation does not appear to have included the fish waste available from the fresh water fisheries, which as noted above amounts to a considerable tonnage yearly. The waste yields oil, protein foods for stock and poultry, and fish guano for fertilizer manufacture. The subject is being investigated further on behalf of the Research Council, and presumably a report will be issued on the results.[2]

Natural Guano. This material is not found in Canada in commercial quantities. Supplies are occasionally imported for special purposes. Its high cost precludes its use in ordinary farming operations, though it may be occasionally used for special crops and in truck farming.

Nitrate of Soda. Chili saltpetre, or crude nitrate of soda, is not found in Canada. All supplies are imported either directly for delivery at Atlantic and Pacific coastal points, or indirectly through the United States for delivery at interior points.

Sulphate of Ammonia. This product is made from ammonia obtained as a byproduct in the distillation of coal and during the manufacture of coke. It is produced at one plant in Nova Scotia, two in Ontario, and one in British Columbia. It could also be produced in small quantities at the larger gas works, where soft coal is distilled in several of our larger communities. At present the waste ammonia liquors from these gas works

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[1] Utilizatiion of Fish Waste in Canada, J. B. Fielding, Commission of Conservation, Ottawa, 1918.

[2] Annual Report of the Administrative Chairman, Honorary Advisory Council for Scientific and Industrial Research, March, 1918.

are utilized for other purposes. At the smaller works they are discarded.

A large proportion of the sulphate of ammonia produced in Canada is exported.

Air Nitrates. Processes have been developed to a commercial scale for the fixation of atmospheric nitrogen. Atmospheric nitrogen is said to be "fixed" when a chemical compound has been produced that contains nitrogen derived from the air. Present processes produce two types of compounds—those in which both atmospheric nitrogen and oxygen have been combined with hydrogen to form nitric or nitrous acid, and the group in which atmospheric nitrogen has been combined with carbon and a base to form compounds known as cyanamides ($CN \cdot NH_2$). The most common compound of this type is calcium cyanamide ($CN \cdot NCa$ or $CaCN_2$).

These products are made by the use of electric power, and their profitable production demands very cheap power and large scale operation. The principal products are nitrates (of soda, lime, less frequently potash), nitrites, and calcium cyanamide. The subject is discussed more fully in the chapter on the production of nitrogen compounds.

Ammonia gas can be made from cyanamides. This gas can then be oxidized to form nitric acid. Acid thus formed can be neutralized with another portion of ammonia producing ammonium nitrate, a material that can be utilized as a fertilizer constituent.

At the present time there is only one plant in Canada engaged in the production of air nitrates. This plant is located at Niagara Falls, Ontario, and makes calcium cyanamide, the present capacity being about 75,000 tons per annum. Another plant was projected in British Columbia, and an experimental unit was erected; it has since been abandoned.

Canada possesses a number of large water powers suitable for development for the production of air nitrates. These occur chiefly in the provinces of Quebec, Ontario, and British Columbia. The greater number are located in sparsely populated regions, but many of them are accessible from existing railway lines. While these large units are unsuited for ordinary industrial development, where small blocks of power must be distributed to a number of users they are eminently suited for the development of an industry which requires large blocks of power for continuous service.

The development of the agricultural industry not only in Canada, but throughout the Empire will undoubtedly create an expanding demand for air nitrates for fertilizer manufacture. National foresight would appear to require that a number of Canadian water powers within the national domain, especially selected because of their suitability, should be set aside as a reserve to be devoted to this industry as the need arises.

Phosphates

The group of materials containing phosphorus that are used as fertilizers or in fertilizer manufacture comprises the following materials: apatite, a natural mineral [$(CaF)\ Ca_4P_3O_{12}$ or $3Ca_3P_2O_8\ CaF_2$]; tetra-calcium phosphate ($4CaO \cdot P_2O_5$); tri-calcium phosphate ($3CaO \cdot P_2O_5$); di-calcium phosphate ($2CaO \cdot P_2O_5 \cdot 4H_2O$); mono-calcium phosphate ($CaO \cdot P_2O_5 \cdot H_2O$). These materials, with the exception of the last mentioned, are not soluble in water. These substances are found in certain natural mineral deposits. Apatite and rock phosphate also occur in artificial products (basic slags) made from natural minerals.

Apatite. This mineral occurs in Canada, particularly in central Ontario and in the counties of Pontiac and Ottawa, Quebec. It is usually found associated with mica. The Canadian production reached its maximum in 1889, when 30,988 tons, valued at $10.21 per ton, were produced. There has been no large production since 1893, and during the last few years very little has been sold. The decline in production was coincident with the development of the high grade deposits of phosphates in Florida. Production since 1892 has been associated with the mica production, and the apatite shipped was in the nature of a byproduct. The mines are not developed in advance of mining and no estimate of the available tonnages of unmined apatite is possible. It does not appear probable that these mines can produce apatite profitably for fertilizer manufacture at present prices and there is no assurance that large supplies are in reserve.

Rock Phosphates. Deposits of mineral phosphates occur in many parts of the world. No sedimentary deposits of commercial grade have yet been reported in Canada. Thin bedded deposits of low grade (25–27 per cent P_2O_5) have been found in the Rocky Mountains in the vicinity of Banff, Alberta, but these are difficultly accessible and are not suitable for the manufacture of superphosphates by the present methods. Exploration of the region south of Banff, along the Spray river, Kananaskis lake and Elk River valley towards the Crowsnest Pass, has shown that these deposits become thinner and contain less phosphoric acid.

Certain shale beds in the carboniferous strata of southern New Brunswick also contain natural phosphates. Applications of these shales to marsh lands have proved efficaceous in a number of instances. Systematic searches for commercial phosphate deposits do not appear to have been made in eastern Canada.

At the present time supplies of this material for use in Canada are all imported. They are obtained chiefly from Florida, though similar material of lower grade is also produced in Tennessee and Kentucky. The development of a fertilizer industry in western Canada would at present necessitate the importation of rock phosphate from deposits in the states of Montana or Idaho.

Basic Slay. Basic slag is a byproduct of the steel industry. Phosphorus, occurring in apatite or other minerals in the ores, fuel, and fluxes used in the iron industry, gradually accumulates in the pig iron, and is finally removed in the later processes of steel manufacture. This basic converter slag may contain phosphorus equivalent to as much as 40 per cent of tri-calcium phosphate. Basic slag is usually ground to 100 mesh or finer and used in this form as a fertilizer constituent, without further treatment.

Bones, Bone Black, Bone Ash. Animal bones contain tri-calcium phosphate (about 44 per cent) as well as nitrogenous organic material (about 28 per cent). Untreated bones also contain fat which can be removed by suitable treatment. Ground bones containing the original fats are of little value as a fertilizer. If the fat has been extracted the finely ground bone material is a valuable fertilizer supplying both phosphorus and nitrogen.

Bones are calcined to form bone black, which is used for clarifying solutions, particularly in the manufacture of sugar. Exhausted bone black from the sugar refineries forms a valuable fertilizer material.

Bone ash, made by completely calcining bones, or bone black, consists largely of tri-calcic phosphate, and is used as a fertilizer material.

A limited supply of these materials is available in Canada, partly from the abattoirs, and partly from collections of junk dealers and sugar refinery residues. No statistical data as to the quantity produced annually have been compiled.

Superphosphates. Superphosphates (or acid phosphate) are made by the treatment of tri-calcic phosphate with the proper proportion of sulphuric acid. They form one of the principal constituents of most artificial manures and are also used alone for treating certain soils. The present Canadian consumption is approximately 50,000 tons per annum.

Formerly Canadian requirements were all imported. A small quantity was made in Canada from imported rock phosphate during the years 1918-19. More recently a plant having a capacity of 75,000 tons per annum was constructed in Ontario, the intention being to export any surplus production above Canadian requirements. This plant has only been operated intermittently owing to market conditions.

The raw materials required for the manufacture of this product are rock phosphate and sulphuric acid. As already stated deposits of sedimentary rock phosphate of commercial grade are not at present known to occur in Canada. The deposits of apatite known are undeveloped, the cost of mining is high, and it is very doubtful if any large tonnage of phosphatic material can be secured annually from these deposits. Certainly no large quantity is available to-day. It will therefore be necessary to secure phosphate rock by importation. The sulphuric acid situation has already been discussed under that caption.[1]

Potashes

Four potash salts produced from natural deposits in Germany were used principally in fertilizers prior to 1914. These are:—

Kainite—a double salt of potassium and magnesium ($KCl \cdot MgSO_4 \cdot 3H_2O$), containing when pure 18·9 per cent potash (K_2O). The commercial product contained a good deal of sodium chloride and was sold with a guarantee of a minimum potash content of 12·4 per cent.

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[1] A bulletin on the occurrence of Phosphate in Canada, by H. S. Spence, has been issued by the Mines Branch.

Manure salts were essentially mixtures of sodium chloride, magnesium sulphate, and potassium chloride. They were sold as a low grade fertilizer material, and the potash content varied from 20 to 30 per cent.

Muriate of potash—the commercial name for the chloride (KCl). This is a high grade refined product containing about 80 per cent potassium chloride, and the balance sodium chloride. This product was also used in the manufacture of a number of potash salts, such as the hydroxide, carbonate, nitrate, chlorate, and perchlorate.

Sulphate of potash. This salt was also a high grade, partly refined product containing about 90 per cent potassium sulphate. This product also found applications in chemical industry and was used in the production of certain other potash salts.

In addition to the above small quantities of potash salts were obtained from wood ashes and from the residues available after the manufacture of beet sugar.

Supplies of potash salts for use in Canada were almost wholly derived from Germany, some were imported directly, some through Great Britain, and the balance through the United States, the latter amounting to nearly half the total imports. Data with respect to the importations are given in the statistical tables.

An estimate made in 1918 shows that our annual requirements of potash salts are the equivalent of approximately 1,200 tons of potash (K_2O). Certain phases of the subject were investigated by the author in 1918. The results of the investigation were published in a bulletin issued by the Mines Branch in 1919, entitled "Potash Recovery at Cement Plants."[1]

Apart from importations from French Alsace and the United States the available sources of supply of potash salts in Canada are as follows:—

Cement Mills. It was estimated in 1918 that the annual losses of potash salts in cement mill flue dust in Canada amounted to 4,280 tons in 1917 and 2,700 tons in 1918. Naturally the annual losses are dependent on the annual production of cement and vary from year to year. It is possible to recover at least 60 per cent of the potash salts in the flue gases. The potash salts recovered from cement flue gases will normally be in the form of sulphate, owing to the presence of sulphur in the fuel used in the process of cement burning. It is possible to convert nearly all the sulphates into chlorides by using suitable reagents during the process of cement burning without affecting the value of the cement. The question of cost of recovery in comparison with the market value of the product will determine whether the introduction of any process of potash recovery will be profitable. One Canadian mill in Ontario has introduced a spray recovery system, but this has not been operated commercially and is now idle.

Kelp. Methods of recovering potash and other salts from sea weeds, and especially from the giant kelp of the Pacific coast, have been under investigation for a number of years. About 9 per cent of the total potash salts produced in the United States in 1918 were from this source. Kelp occurs in large areas on the Pacific coast of British Columbia. Experimental

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[1] Mines Branch Bulletin, No. 507. Out of print.

work on a small scale has been carried on, but no commercial development has yet followed. Crude estimates of the supplies available indicate that they probably greatly exceed our present annual needs. It has not been demonstrated that the material can be treated profitably on a commercial basis at the present market prices for the products obtained.

Wood Ashes. Hardwood ashes contain low percentages of potash salts, rarely in excess of 5 per cent. A small production of this material is still available in Quebec and Ontario at irregular intervals, but it cannot be regarded as an important or reliable source of commercial supply.

Potash Silicates. There occur in Canada a number of deposits of siliceous minerals containing potash, notably orthoclase feldspar, labradorite, and nepheline. Successful commercial methods for recovering the potash content and the aluminium content of these materials have not yet been developed, apart from the manufacture of cement, although many processes have been tried.

Natural Potash Salt Deposits. Deposits of natural salts containing potash and potash brines have been found in Canada only in one locality. A recent discovery of potassium chloride in association with a deposit of rock salt has been reported from the vicinity of Malagash, Nova Scotia. Development work has not reached a stage at which it is possible to predict whether the salt is present in quantities large enough to make the deposit of commercial importance. From time to time rumours and reports of the discovery of potash salts in brines from the Rocky Mountain region of Canada have appeared. Investigation has failed to substantiate these reports in any case.

Other Fertilizer Materials

Deposits of gypsum are known in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, Alberta, and British Columbia. A certain amount of ground gypsum or land plaster is already produced from Canadian deposits and there are sufficient resources available to take care of all the probable needs of the agricultural industry.

Deposits of limestone occur in every province of Canada. Ground limestone for use as a fertilizer material is also produced at a number of localities, and the quantity can easily be increased to meet all needs.

The use of sulphur materials has not become standard practice in the fertilizer industry and they do not need to be considered here.

Imports and Exports

The principal products imported and exported by this industry are presented in tabular form on another page under the caption Fertilizers. Reference should also be made to the item calcium phosphate, monobasic, in the import list of chemicals. Statistical data covering the annual imports, exports, and home production will be found in the annual reports of the Dominion Bureau of Statistics.

Fertilizer Manufacture in Canada

There are about seventy-nine firms in Canada operating eighty-two plants engaged in the manufacture of fertilizers. Only two firms have complete plants including acid chambers. One of these, in British Columbia, is in active operation, the other, in Ontario, was in operation for a few months, and has closed temporarily. Six plants, one each in Nova Scotia, New Brunswick, and Quebec, and three in Ontario are provided with rock grinding and acidulating machinery, but are not provided with acid plants. Thirty-three plants make ammoniacal fertilizers from organic waste materials, and market a number of grades of mixed fertilizers, but do not prepare phosphates. Two of these plants are located in Nova Scotia, five in Quebec, twelve in Ontario, three in Manitoba, one in Saskatchewan, two in Alberta, and eight in British Columbia. Twelve of these plants handle fish guano from fish scrap, and the rest utilize abattoir waste. There are forty-one plants which purchase all their raw materials and confine their operations to dry mixing only. These plants are distributed throughout the Dominion, there being six in Nova Scotia, five in New Brunswick, eight in Quebec, thirteen in Ontario, and nine in British Columbia.

Summarizing the foregoing statements there are nine fertilizer plants in Nova Scotia, six in New Brunswick, fourteen in Quebec, twenty-nine in Ontario, three in Manitoba, one in Saskatchewan, two in Alberta, and eighteen in British Columbia. In addition to the foregoing there are several abattoirs who prepare their tankage for fertilizer production, but who dispose of it in bulk to grinding and mixing plants, or export it to the United States.

It should also be noted that for business reasons several organizations find it desirable to operate under more than one firm name, mixed fertilizers of identical composition being marketed under special brand designations. These have been included in the foregoing summary as if they were separate and independent organizations.

CHAPTER III

CERAMIC INDUSTRIES

The ceramic industries produce many kinds of useful and ornamental objects from numerous varieties of clays, sands, and related natural products. The art of decorating these objects by modelling, painting, glazing, enameling, or similar means naturally constitutes a phase of the industry. Ceramic materials and art methods are also employed for preserving, finishing, or decorating objects not primarily products of the ceramic art, particularly articles formed from metals.

Raw Materials

The principal raw materials of the industry are clays and shales, of which there are many varieties, feldspars and quartz. The natural minerals utilized in the industry number about one hundred and thirty. Most of these are only rarely required and are used for the production of certain special objects or effects. In addition there are at least one hundred and sixty-five chemical elements and compounds which find applications in this industry.

The subjoined lists are limited to those materials used by the several branches of the industry as developed in Canada, and relate chiefly to the production of glazes and enamels. Some Canadian works import prepared glazes and enamels in powdered form and do not make their own. No attempt has been made to investigate the nature and extent of the importations. The names of the metallic oxides more commonly used for preparing coloured enamels have been included in the lists, although manufacturers may be purchasers of products made from the oxides, and not of the oxides themselves.

Table 15.—Principal Products used in Ceramics

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

Minerals: *Barytes; calcspar; clays* (ball clay, *fire clay, kaolin, some shales*); cryolite; feldspars (*albite, orthoclase*); *fluorspar; gypsum; pyrolusite;* quartz (flint, *silica sand, ground silica, quartzite*).

Chemical Compounds: Acids (boric, *hydrochloric,* hydrofluoric, *sulphuric,* titanic); ammonium compounds (carbonate, chloride); barium compounds (carbonate, chloride, chromate); cadmium sulphate; calcium borate; *cobaltous chloride;* lead compounds (antimonate, borate, *carbonate, chromate*); *magnesium carbonate;* oxides (aluminium, antimony, chromium, *cobalt,* copper, *iron, lead,* magnesium, manganese, *nickel,* tin, zinc); *plaster of Paris;* potassium compounds (acid antimonate, aluminate, bichromate, carbonate, nitrate); sodium compounds [aluminate, biborate, *carbonate* (*calcined*), *chloride,* meta-antimonate, nitrate, silico-fluoride, sulphate]; whiting.

Products of the Ceramic Industry

The best known branch of the industry is probably the making of bricks from plastic clays and shales. Numerous varieties of bricks, adaptable to many industrial uses are also made from non-plastic materials. The principal kinds of structural materials made from non-plastic materials are sand-lime brick, clinker brick, slag brick, and other varieties of closely related products, such as concrete brick, blocks, and roofing tiles. The refractory products made in Canada are silica brick, three kinds of fire brick, and special fire clay shapes for locomotives and other boilers.

Other products of the ceramic industry are vitrified brick; drain pipe and sewer pipe of many kinds; tiles in great variety, used principally on walls, floors, and roofs of buildings; delf and porcelain wares; enameled and sanitary wares; enameled metal products of many kinds; ornamental and art objects.

Statistical Data

The statistical data available place the total value of the importations of clays and clay products at $7,520,000 in the fiscal year ending March 31st, 1918, $6,965,251 in 1919, and $6,371,567 in 1920. In the calendar year 1919 the total value placed upon the products of this industry manufactured in Canada was $7,906,366; building brick and fireproofing contributed 71·2 per cent to this total and sewer pipe and tile 21·3 per cent. The pottery products were valued at $890,320, but only $185,475 of this amount is credited to Canadian clays, the balance representing the value of products made from imported clays.[1]

The trade statistics based on the customs returns furnish a partial classification of the various products imported. Much more detailed information is desirable in order to ascertain the nature and extent of the home market for such products as could be manufactured profitably in this country. Much detailed statistical information with respect to the industry is given in the annual reports of the Division of Mineral Resources and Statistics of the Mines Branch, and the records are being continued by the Dominion Bureau of Statistics.

No statistical data are available showing in detail the various raw materials, other than clays, imported for the manufacture of ceramic products in Canada. The extent of the home market for chemical compounds used in this industry cannot be ascertained from existing records.

Canadian Situation

The Canadian market for the higher art products of this industry is very limited, and home manufacture is therefore largely confined to the commoner varieties of products. These products are chiefly those used in building and construction. A limited range of products for household use and house decoration are also produced.

The principal domestic products are clay bricks, floor tiles, building blocks, drain tile, and sewer pipe, all made in many varieties. Fire clay

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[1] Mines Branch, Division of Mineral Resources and Statistics, Report for 1919.

products, refractory linings, crucibles, porcelain products for electrical insulation, calcined and dead burned magnesite, silica brick, sanitary ware, jugs, crocks, churns, water coolers, and related products are also made in a few plants. The available lists of manufacturers of these products show eight firms engaged in the manufacture of clay sewer pipe, twenty-two firms producing a number of varieties of refractory and other special products, and about four hundred and seventy-five firms engaged in the manufacture of building blocks and other clay products. Complete lists of manufacturers are maintained in the Mineral Resources Division of the Mines Branch.

Glazes and enamels are applied to clay products, particularly certain grades of brick, tiles, sewer pipe, porcelain products, sanitary ware, and household utensils at nine potteries in Canada. Ceramic enamels are applied to numerous metal objects, such as household utensils, sinks, bath tubs, and hospital equipment in at least eight plants.

The clays, feldspars, and silica deposits of Canada, and the suitability of these different products for industrial purposes have been very fully investigated and a series of special reports on these materials has been prepared.[1] It is therefore unnecessary to refer to the Canadian resources in these materials.

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[1] See Mines Branch list of publications.

CHAPTER IV

GLASS INDUSTRIES

Glass is an amorphous product made by the fusion of silica, usually in the form of natural or artificial sand, with one or more salts of the alkali metals, and one or more salts of certain basic metals. The commoner forms of glass, such as window glass, bottle glass, or plate glass are well known. There is also a great variety of special glasses used in the manufacturing arts and for decorative purposes, which are less well known.

Raw Materials

The principal raw material in almost all glasses is silica. This is usually supplied in the form of sand. Silica may be obtained from natural deposits of loose sand, or by the crushing of sandstones or quartzites. The highest grades of transparent glass require a nearly pure sand. Common glasses can be made from less pure material. The presence of small amounts of clay products does not necessarily affect the final product, but the presence of iron oxide is undesirable, except for use in the cheapest grades.

Natural silicates, such as feldspars, which contain alumina and potash salts in combination with silica, can be used in the manufacture of some grades of glass. Certain salts of boron or phosphorus can be used for making a silica-free glass.

The alkali salt usually employed in glass making is sodium carbonate (soda ash). The sulphate (salt cake) is also used, particularly in the manufacture of window and plate glass. It is more difficult to use than the carbonate and it has not hitherto been employed in Canadian plants. Small amounts of sodium nitrate are required, chiefly as a reducing agent. The corresponding salts of potassium, particularly the carbonate and nitrate, are sometimes used.

The principal basic material used is calcium, supplied as the carbonate (limestone) or as the oxide (burnt lime), or as the hydroxide (hydrated lime). Lead oxide, usually in the form of red oxide, or as litharge, is used to increase the refractive power of the glass and to improve the brilliance of the product. A number of other basic chemicals, such as salts of antimony, arsenic, barium, magnesium, or zinc, are employed to produce certain desired effects in the manufacture of special glasses.

The principal raw materials used in the Canadian glass industry are silica and soda ash—both materials being produced locally and also imported. Local limestones are used. Relatively smaller quantities of pyrolusite, sodium nitrate, arsenious oxide, nickel and cobalt oxides, potassium chlorate, and a few other chemicals are also required.

Table 16.—Principal Materials used in the Glass Industry

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

MINERAL PRODUCTS: *Apatite;* clays (*china, fire*); cryolite; *feldspar; fluorspar; hematite; limestone; pyrolusite; silica.*

CHEMICAL OR METALLURGICAL PRODUCTS: Acid, boric; aluminium oxide; antimony; antimony compounds (oxide, sulphide); *arsenious oxide;* auric chloride; barium compounds (carbonate, sulphate); cadmium sulphide; calcium compounds [carbonate, *hydroxide* (*hydrated lime*), *oxide* (*lime*), phosphate (bone ash)] carbon (*coke*, or *organic materials* such as *oats, bark, sawdust*); *chromium oxide; cobalt oxide;* copper oxide; ferric compounds (*oxide, sulphate*); lead oxides [*red, yellow* (*litharge*)]; magnesium oxide; manganese dioxide; *nickel oxide;* potassium compounds (carbonate, dichromate, nitrate); selenium; silver nitrate; smalt; sodium compounds [biborate, *carbonate* (*soda ash*), nitrate, *sulphate* (*salt cake*), uranate]; sulphur; uranium oxide; zinc oxide; zirconium oxide.

Products of the Glass Industry

Glasses are sometimes named on the basis of their principal basic constituent as lime glass, lead glass, or potash glass. White glass, or opal glass, and coloured glasses are made by the addition of certain special materials, added to produce the desired texture and colour effects. The name flint glass is generally applied to any clear transparent glass, though it was formerly applied only to potash glass. Optical glass, as the name implies, is a special glass used for making lenses for optical instruments.

Glass production in Canada is confined almost wholly to the making of lime glass, used in the production of window glass, wire glass, and bottles of various kinds. Special varieties of certain glasses for the manufacture of electric lamp bulbs, lamp shades, and similar products are also made.

Statistical Data

Segregated statistical data showing the requirements of this industry in Canada are not available. Customs statistics show imports and exports of finished products but the items are not given separately in such a way that unsatisfied home markets for specific products can be ascertained. Import returns are tabulated elsewhere in this report pages 18-20). In the three fiscal years prior to the war the average valuation assigned to imported glass products was $4,832,498. During the three fiscal years after the war the total valuations of imports were $5,265,149, $5,254,203, and $6,839,656 respectively, certain mixed items in the tariff records being omitted.

The average importations in the three years before the war included common and colourless window sheet, 49,848,522 square feet; unbeveled plate in sheets or panes not exceeding 7 square feet each, 1,756,053 square feet; unbeveled plate in sheets or panes exceeding 7 square feet each, but not exceeding 25 square feet each, 1,410,826 square feet; unbevelled plate n.o.p., 1,919,480 square feet; and beveled plate, 12,426 square feet. The total average valuation of these two grades of glass alone amounted to $2,356,760 annually, exclusive of bent plate, which was valued at $114,861.

Canadian Situation

There are six firms in Canada engaged in the production of glass. One of these makes only certain grades of window glass, including wire glass. One firm specializes in globes, shades, and bulbs for electric lamps. The other four produce bottles, fruit containers of several types, lamp chimneys, and related products. A new firm has recently been organized to produce plate and window glass, large quantities of which are now imported.

The Canadian Trade Index contains the names and addresses of thirty-seven other Canadian firms engaged in the production and sale of glass products, fabricated from various grades and kinds of glasses, nearly all of which are imported,but none of these firms actually make the glass which they utilize.

The Canadian market for coloured glasses and for other special glasses is limited, and these are almost wholly imported.

The trade statistics, compiled from the import returns issued by the Department of Customs, and tabulated in another part of this report, would appear to indicate that the home market for certain glass products, especially window and plate glass, is broad enough to warrant the establishment of additional plants. In this connection a special investigation of the sources of silica for the manufacture of glasses has been carried out by the Mines Branch, and a report on silica in eastern Canada is now available. On the other hand the plants making these products have recently shut down, the alleged reason being their inability to compete with foreign importations under present conditions.

CHAPTER V

MISCELLANEOUS MINOR INDUSTRIES

INSECTICIDES AND FUNGICIDES

The modern agriculturist finds it necessary to protect his orchards and many crops by the use of suitable poisons, which enable him to control the ravages of insect pests or to prevent damage by fungi. Many merchants find it necessary to protect their stocks of perishable goods both from the ravages of insects and from rodents, and nearly every householder must also protect his possessions from similar pests. These needs have caused the development of an important group of subordinate chemical industries engaged in the production of poisonous mixtures and solutions suitable for these purposes.

The poisons used, with few exceptions, are chemical products derived from minerals. In many cases non-poisonous chemicals or minerals are used in association with the active poison to serve as carrying media to facilitate application and to retain the poison in a suitable position long enough for the pest which it is desired to destroy to come in contact with it. The several different poisons employed are necessarily adapted to meet varied conditions and to combat different kinds of pests.

Uses of Insecticides and Fungicides

Nearly all insects can be destroyed by subjecting them to treatment with poisonous gases or vapours, but it is not always feasible to use fumigants for this purpose. Chemicals used in this way are carbon bisulphide, sulphur dioxide, hydrocyanic acid, and formaldehyde.

Many insects, such as the locust, grasshopper, cucumber beetle, larvæ of many moths, and others, chew their food. These are best destroyed by spreading a suitable poison upon their food in such a way that it is masticated and taken into the stomach. It is there rendered soluble by the intestinal secretions and causes the death of its host. Compounds of arsenic with some one of several metals are most frequently used for this purpose—arsenate or arsenite of lead, aceto-arsenite of copper (Paris green), arsenate of lime, arsenate or arsenite of soda, arsenious oxide. The dry powdered roots of white hellebore, which contains a poisonous alkaloid, are also used for this purpose.

Insects which feed by sucking plant juices, such as aphids and plant lice, are combated by the use of chemicals which have a corrosive effect upon their body tissues, or by the use of fine powders which clog their breathing apparatus and cause death by asphyxiation. Such mixtures are lime-sulphur solutions, fish-oil soaps, kerosene or crude petroleum emulsions, caustic soda or potash solutions, carbolic acid, crude cresol emulsions, nicotine solutions, and other products are used to combat this type of insect.

A special group of insecticides are employed under such names as cattle dips, mange cures, or other designations to combat insect pests that are injurious to farm animals, such as horses, cattle, hogs, sheep, or dogs. Insoluble arsenical salts in suspension, lime-sulphur dips, kerosene emulsions, fish-oil soap emulsions, carbolic acid, pyrethrum powder, and other products are used for this purpose. Sulphur and mercurial ointments are also employed occasionally.

Fungi are low forms of plant life which are parasitic upon other living plants from which they draw nourishment as hosts. They develop from a unicellular fruit known as a spore, which in a way corresponds to the complex multicellular seeds of the higher plants. The plant itself consists of a more or less complex mass of thread-like interlocking fibres termed a mycelium. The mycelia of fungi may grow upon the surface of the host or within its tissues. Fungicides are designed either to destroy the spores of fungi and thus prevent their growth and the development of the mycelia, or they are intended to destroy the mycelia themselves and prevent the development of the plant to maturity and the production of spores. Compounds of copper, particularly copper sulphate in combination with lime, are widely used for this purpose. A preparation of lime and sulphur, potassium sulphide solution, mercurious chloride, and formaldehyde are also used under certain circumstances.

Insecticides and fungicides are usually applied as sprays, aqueous suspensions of the chemicals being specially prepared for this purpose. They may also be compounded as dry powders and dusted on. The use of these products has resulted in the development of a large variety of accessory appliances for spraying or dusting, ranging from the small hand blower used in applying pyrethrum powder to large power sprays and dusting machines operated by hand power or gasoline engines. These appliances are usually made from metal products. This industry therefore offers a large market not only for certain kinds of chemical products which are required annually, but also for a fair quantity of metal products which are needed in the manufacture of accessory apparatus, whose life extends over several seasons.

Raw Materials

The principal chemicals used in the manufacture of the products required by this industry are named in the following lists without regard either to the particular class of pest against which they are used, or to the method of preparation for use, or to the method of application. Many consumers purchase the necessary raw materials and make their own mixtures in accordance with well known formulae.

Table 17.—Materials used in Insecticides or Fungicides

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

ARSENIC COMPOUNDS: Arsenates (*calcium, lead,* sodium); arsenites (barium, calcium, *copper,* lead, zinc); calcium arsenite and arsenate mixed as London purple; *copper aceto-arsenite* (*Paris green*); *oxides* (*arsenic, arsenious).*

OTHER CHEMICALS: *Acid, sulphuric; ammonia;* calcium compounds (*hypochlorite, oxide* as fresh burned lime); carbon bisulphide; copper compounds (*sulphate*, carbonate); *formaldehyde;* lead compounds (acetate, nitrate; mercuric chloride; nicotine, crude; *nicotine sulphate; paraformaldehyde;* potassium compounds (hydroxide, sulphide); sodium compounds (*carbonate, cyanide, hydroxide*); sulphur (flour, flowers).

PETROLEUM PRODUCTS: *Kerosene; paraffin oil; petroleum, crude.*

TAR PRODUCTS: Asphaltum; *coal tar; coal tar oil* (*neutral, high boiling*); *cresylic acid, crude; gas tar; phenol, crude;* pine tar.

ADULTERANTS: Barium compounds (carbonate, sulphate); *calcium sulphate* (*gypsum or land plaster*); *cement; dust* (from roads); *flour; lime.*

MISCELLANEOUS MATERIALS: *Grease* (*low grades*); oils (castor, *fish*, rosin); pyrethrum powder; quassia chips (extract of); rosin; soaps (*fish-oil, potash, soda*); *tobacco extract;* Veratrum album (ground roots of, sold as white hellebore).

Statistical Data

The production and sale of insecticides and fungicides in Canada have not been studied statistically, and there are no reliable data available covering the home market for these products. It has been stated authoritatively that over $300,000 per annum is spent for sprays in the orchard districts of Nova Scotia alone.

The report on Chemicals and Allied Products, 1919 and 1920, issued by the Dominion Bureau of Statistics, gives the values of the materials used in making insecticides as $11,541 in 1919 and $80,420 in 1920. The selling value of the products for the respective years are placed at $32,924 and $140,701 respectively. In addition the import figures of the Department of Customs show 45,678 pounds of Paris green valued at $16,255 imported in 1919, and 2,811 pounds valued at $1,192 in 1920. Importations of other arsenical compounds do not appear to have been listed separately.

There are reasons for believing that the Canadian agricultural industry consumes much larger quantities of insecticides than are indicated by the above figures, but accurate statistical data are not segregated in such a way that the extent of this market for the different products can be ascertained.

Canadian Situation

The list of manufacturers of insecticides given in the report of the Dominion Bureau of Statistics for 1919 and 1920 names two firms in Quebec, and four in Ontario. The names of a number of firms manufacturing arsenical compounds, coal tar products, and wood distillation products that are marketed as insecticides, fungicides, and cattle dips are not included in the above list. There are eight additional plants known to be making these products, and one in British Columbia mixing orchard sprays, so that at least fifteen Canadian firms are engaged in making the products of this industry. In addition, some persons purchase the requisite materials in the open market and mix their own sprays, dusting powders, or dips for individual use, or for use by local groups or coöperative organizations.

At the present time a large quantity of arsenious oxide produced in Canada is exported, and certain arsenical salts are imported in relatively smaller quantities.

BLUEING

The laundry industry of this country (both public and domestic) consumes annually a large quantity of blueing, which is used to increase or intensify the white appearance of undyed bleached cotton and linen fabrics. Quantities are also used in textile mills and in the manufacture of granulated sugar and other white powders.

Commercial blueing is made in a variety of ways. The blue colour is due to the presence of a blue dye or a blue coloured inorganic salt. Sulphate of indigo, aniline blue, *soluble Prussian blues,* and ultramarine are used for this purpose. Potassium ferrocyanide and ferric chloride in proper proportions may be used to make Prussian blue directly. Other chemicals used in the compounding of laundry blueing are *sodium sulphate,* sodium biborate, and oxalic acid. Liquid blueing consists of solutions of some one of the colours indicated. Solid blueing in the well known balls and cakes is produced by the use of *starch, glucose,* or gum arabic as a body.

There are no statistical data available with respect to this industry. The annual consumption in public and domestic laundries, in textile mills, and in the manufacture of sugar and other products whose whiteness is intensified by the use of blueing must be very large. While our records only contain the names of three firms making these products, it is probable the number of manufacturers is greater.

The trade statistics of the Department of Trade and Commerce show importations of laundry blueing valued at $55,448 in 1914, which had risen to an average value of $108,380 in the three years following the armistice.

BOILER COMPOUNDS

The natural waters obtained from streams, lakes, or wells for use in steam boilers contain salts of lime and magnesia, and sometimes other compounds in solution. As the water is evaporated and used as steam these salts tend to concentrate in the boiler and to form a scale on the tubes and shells. Boiler compounds are designed either for treating the feed water to remove as much as possible of the undesirable constituents, for the purpose of preventing the formation of a coherent scale within the boiler, or to facilitate the removal of scale already formed.

The usual impurities in boiler water can be retained in soluble form or can be precipitated before the water is charged to the boiler by the use of sodium hydroxide or calcium hydroxide. Soda ash is also used with sodium hydroxide, or it may be applied alone. Other chemicals that are occasionally used in boiler compounds are alum, ammonium chloride, sodium bicarbonate, sodium sulphate, stannic chloride. A compound containing sodium tannate is suitable for use with some waters. This is usually compounded by using sodium carbonate with a solution containing tannic acid, obtained from spent tan bark, catechu, or other source of tannin. Potash salts may be used in place of sodium salts with satisfactory results.

Some classes of scale can be loosened or the adherence can be prevented by the use of kerosene. Paraffin oil and other petroleum oils heavier than kerosene are sometimes used, but natural petroleum is unsuitable because of the presence of tars and volatile constituents. Colloidal substances, such as sugar, molasses, gum arabic, or dextrine, are present in some boiler compounds.

It is customary for some manufacturers to add colouring substances to boiler compounds to disguise the ingredients. Turmeric, gamboge, potassium permanganate, and aniline colours, either blues or reds, may be used with this object in view. They serve no useful purpose other than to make it possible to obtain a high price for a cheap compound from ignorant purchasers.

The Dominion Bureau of Statistics reports six Ontario firms engaged in the production of boiler compounds in 1920. The selling value of the products is given as $188,144 in 1919 and $253,683 in 1920. The value of the raw materials used in the industry is stated to have been $70,305 in 1919 and $90,868 in 1920. No information is available with respect to manufacturers of these compounds in the other provinces, and data relating to the consumption of soda ash and other chemicals by this industry have not been segregated.

The Canadian Trade Index lists seventeen firms dealing in boiler compounds. Two of these are located in Quebec, fourteen in Ontario, including four firms listed by the Dominion Bureau of Statistics, and one in Alberta. Available lists do not show any manufacturers preparing these compounds in Nova Scotia, New Brunswick, Manitoba, Saskatchewan, or British Columbia.

INKS

Inks are defined as coloured fluids used for writing, drawing, or printing. Writing fluids usually have only a slight viscosity, while printing inks are more viscous and resemble paints or varnishes; drawing inks are only slightly more viscous than writing inks and will be included with the latter.

Writing fluids consist either of clear solutions of any colouring matter suitable for the purpose, or suspensions of an insoluble coloured compound in an extremely fine state of division. The main bulk of the fluid portion of writing inks is water, to which, in some cases, a small amount of a water soluble colloid such as gum arabic (gum senegal) has been added. The earliest kind of ink used was made from charcoal and glutinous vegetable exudations, or gum, or gelatine. The same type of ink survives to-day for some uses, and is more familiarly known as India ink or Chinese ink. The cheaper varieties consist of charcoal and glue; higher grades are composed of lampblack made from sesamum oil, resin or resinous woods mixed with gelatine, to which a small amount of gum camphor and substances containing essential oils has been added. Another ancient ink is made from sepia, a natural colouring matter derived from squids or cuttlefish. Sepia ink may be made in the same way as India ink, or it may be suspended in a suitable fluid for writing.

The principal requirements of a modern writing fluid are good colour, permanency, stability, and non-corrosive properties. The colour of an ink depends upon the chemicals used in its preparation. Carbon inks and inks containing ferric gallate or ferric tannate are black and practically permanent. Inks made from aniline colours fade rapidly in sunlight and less rapidly in the dark. The stability depends upon the chemicals used; an ink which does not decompose on standing and in which solids do not collect is the most desirable. Inks which contain free acids tend to corrode pens, or the paper, or other material upon which the writing is placed; it is obvious that non-corrosiveness is an essential characteristic of good inks. Writing inks should not be too viscous, otherwise they will not flow easily and will tend to clog pens. They should be capable of penetrating the fibre of the paper on which they are used but should not pass through; they should dry rapidly after application; in the bottles or ink stands they should neither ferment nor support the growth of moulds.

Varieties of Inks

Black ink, as ordinarily prepared, is made from nut galls and ferrous sulphate. Nut galls contain tannic acid which can be removed by crushing the galls and steeping in water. The aqueous solution is then exposed to the air to partially oxidize the tannic acid to gallic acid. The same result can be obtained by fermentation. The addition of ferrous sulphate results in the formation of a ferric gallate which is a blue-black insoluble compound that remains in suspension in the solution, which also contains ferrous gallate and ferrous tannate. The suspension of the colouring matter is facilitated by the use of a little gum arabic. Pure gallic acid and pure tannic acid can be used with ferrous sulphate to produce a black ink. Ink made in this way when first used has little colour. The black colour develops in the fibre of the paper upon which the writing is placed after it has been exposed to oxidation by the air. It is therefore customary to add preliminary colouring matter, such as a blue-black dye (alizarin) to the ink. Such an ink gives a blue-black line which turns black on exposure to the light for a few hours. The standard ink adopted by the United States government, and by several other governments, is made with tannic acid, gallic acid, ferrous sulphate, dilute hydrochloric acid, phenol, soluble blue dye, and water. Formerly a little gum arabic was used also, but this has been discontinued as unnecessary. Many commercial inks are made from similar ingredients, although the relative proportions of each are not the same. Another black ink sometimes made is prepared by using a solution of logwood (haematoxylin) and potassium bichromate, to which small quantities of chrome alum and oxalic acid are added. If kept acid this ink is stable, but if made alkaline it does not maintain its stability.

Carbon inks, when fluid, consist of finely divided carbon (lampblacks, carbon black) suspended in water by the use of a colloid. They are slightly brownish in tone except when made with some carbon black. Solid carbon ink (India or Chinese ink) has been mentioned above.

Coloured inks are usually aqueous solutions of corresponding aniline dyes, and lack permanency. Soluble Prussian blue can be used to make a blue writing fluid.

Inks for copying or for use on typewriter ribbons contain glycerine, syrup, or similar substances, to keep them moist, and they are usually thicker or more concentrated than writing inks. Mimeograph inks may contain shellac and borax in addition to the ordinary colouring matters. Marking inks may contain carbon, they may contain chemicals that act upon the cellulose of the fabric upon which they are used producing permanent coloured compounds, they may contain permanent dyes and a mordant, or they may consist of a natural plant juice or extract which acts as a dye when suitably prepared.

Stamp inks may contain glycerine, oleic acid, or castor oil, as well as the colouring compound. A white ink usually contains zinc oxide in suspension.

Sympathetic inks contain a chemical salt in solution which is invisible under ordinary conditions when used for writing on ordinary fabrics. Such writing is made visible by suitable means, according to the particular salt used in the writing fluid. Some salts become visible if dried thoroughly by warming the paper, disappearing again when exposed to ordinary moist air; others show colour when exposed to the action of light; others require the application of another chemical, either ammonia fumes or dilute solutions of salts.

Evanescent inks contain a coloured compound which is not permanent in character, the colour soon disappearing after use. Iodide of starch in suspension can be used as a writing fluid, and the colour will disappear in a few days. Certain aniline colours are also very fugitive.

Printing inks are much more viscous and usually slower drying than writing inks. In addition to suitable pigments they contain an oil or varnish body which may be made from various ingredients, oils, fats, greases, or waxes and resins, as well as a solvent and a drying medium. Petroleum, petroleum residues, and solvents, such as benzine, toluene, fractional distillates of petroleum, chloroform, carbon bisulphide, carbon tetrachloride, or acetone, are used in various mixtures. Products sometimes added to impart drying properties are linseed oil, chinawood oil, or turpentine. Other ingredients are rosin, gum dammar, and soap. The blacks are made from lampblack, vine blacks, and carbon black; the coloured inks by the use of aniline dyes or mineral pigments, such as ochres, cinnabar, venetian red, and similar products.

Table 17a.—Chemicals Used for Making Inks

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

CHEMICALS: Acids (*acetic*, *carbolic*, gallic, gallotannic, *hydrochloric*, oxalic, pyrogallic, *sulphuric*, tannic, tartaric); ammonium compounds (chloride, vanadate); aniline hydrochloride; *calcium hydroxide;* cupric chloride; ferrous compounds (*sulphate*, lactate); *glycerine; silver nitrate;* sodium compounds (biborate, *chlorate*).

COLOURS AND PIGMENTS: Aniline colours (various blacks, browns, blues, greens, reds, and yellows, eosine, erythrosine, indigo-carmine, nigrosines, tartrazine); blacks (carbon, *lampblacks*, vine); inorganic chemical pigments [Antwerp blue, carmine, Chinese blue, chrome green, *chrome yellow*, cobalt blue, crimson lake, emerald green, lithopone, orange lead, Prussian blue (soluble), titanium oxide, *white lead*, zinc oxide], mineral pigments (burnt sienna, burnt umber, cinnabar, *Indian red*, *red lead*, orange mineral, *venetian red*, vermilion, *yellow ochre*); vegetable colours (gamboge, madder, logwood).

GUM AND RESINS: Arabic; *beeswax;* dammar; mastic; shellac; white wax.

OILS AND FATS: Castor; chinawood; *linseed*; rosin; *mutton suet; oleic acid; petroleum; petroleum residues.*

SOLVENTS: *Acetone; benzene;* carbon compounds (bisulphide, tetrachloride); chloroform; *petroleum distillates; toluol; turpentine.*

MISCELLANEOUS: Gall nuts; *glue; gelatine; soaps;* tannin containing barks or extracts (selected); *molasses; sugar; syrup.*

Statistical Data

The five components of inks which are used in largest quantity are probably gall nuts or other materials containing tannin, ferrous sulphate. carbon black or lampblack, glycerine, and linseed oil. The other materials used are in special products and are required in relatively smaller quantities. There are no statistical data available showing any details of the requirements of this industry in raw materials, and the total annual production of inks in Canada is not known. The annual consumption of writing fluids in a country like Canada should be about 100,000 gallons. Available Customs statistics show an average importation of writing inks valued at $52,692 and $42,964 in the three (fiscal) year period prior to the war, and subsequent to the armistice respectively. The reason for the decrease in importations since the war is not apparent, but it may be due to increased production at home. The importations of printing inks for the same two periods averaged $103,489 and $194,545 respectively. Most of the importations come from the United States and Great Britain.

Canadian Situation

A report issued by the Dominion Bureau of Statistics lists ten firms manufacturing printing and lithographing inks, eight firms making writing fluids, and one firm making ink powders. The Canadian Trade Index lists eleven firms making printing and lithographing inks, twelve making writing fluids, and ten making stamp and stencil compounds. There are also nine firms producing carbon papers, and seven making typewriter ribbons.

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 mispickel) 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.

IRON INDUSTRY

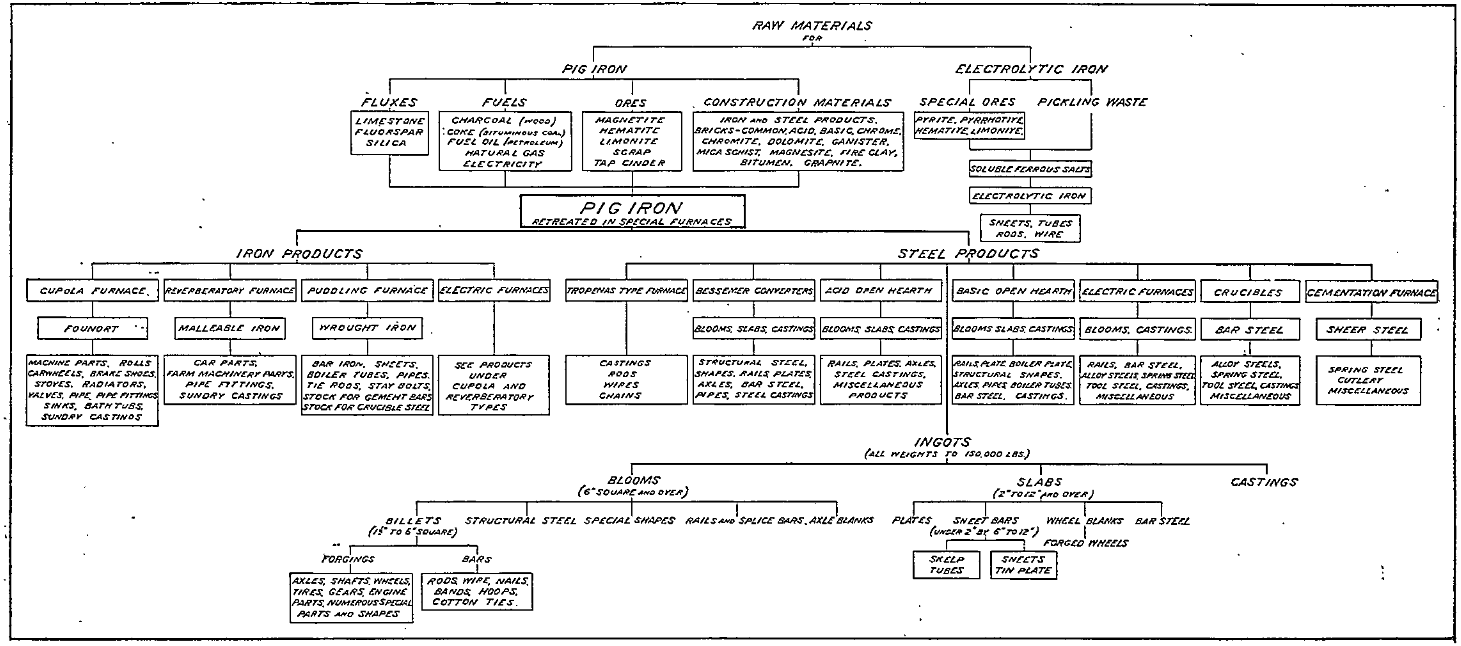


Diagram 11

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.

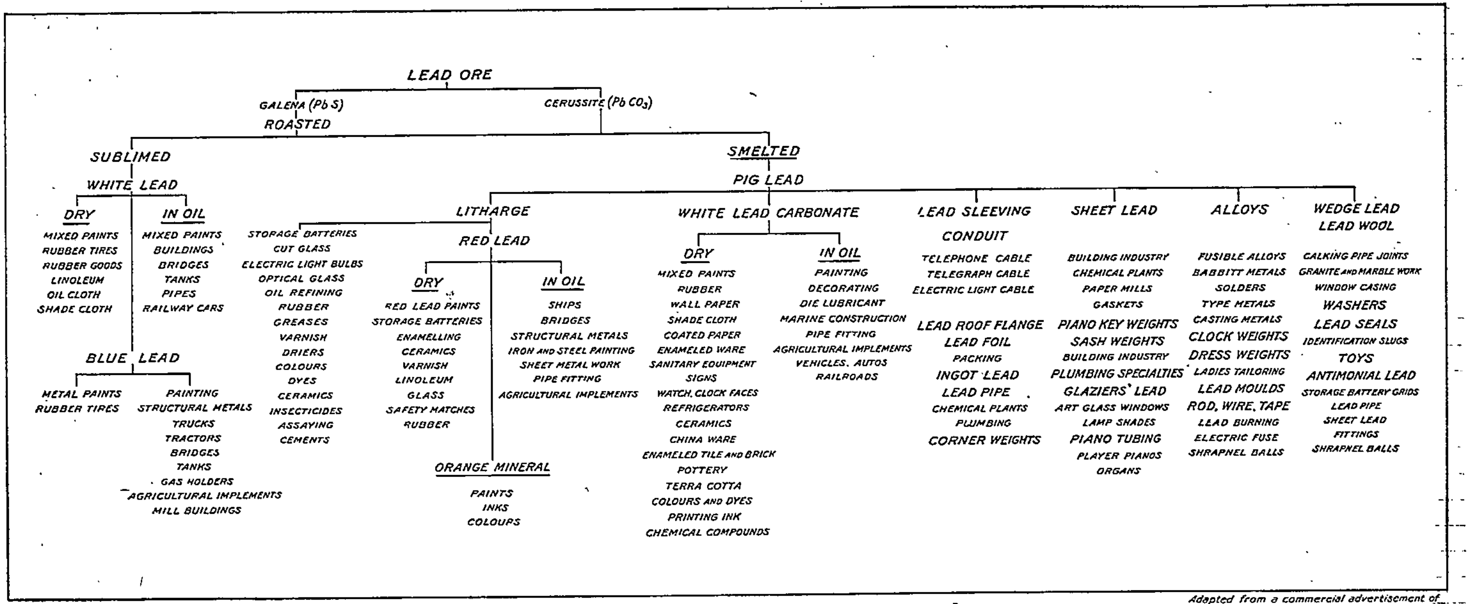
Process. One Scotch hearth, 18-ton capacity, is in operation in Ontario. Another plant, comprising a 30-ton water-jacketed blast furnace and two 10-ton open hearth furnaces, also located in Ontario, is at present idle. In British Columbia a large blast furnace plant and an electrolytic lead refinery 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	1,380,646	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

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[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	....	*s*1,808,323	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	*y*91,235	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.

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[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, 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-

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[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 Ganada 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

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[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.

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[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

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[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*,

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[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

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[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

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[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 predetermined 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, $1\frac{1}{8}''$ 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 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 wa	....	....	99,109	....	91,700
All other products and by-products	....	....	537,662	....	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 value	Quantity	Average value
	Average 1912-13-14	1912-13-14	Average 1920-21-22	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	58,538	980,419	65,415
Mucilage and adhesive paste	(Not given)	33,949	(Not given)	70,024
Gelatine and isinglass	608,383	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

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, carborundum, 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.

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