CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. G. McCONNELL, DEPUTY MINISTER.

MINES BRANCH
EUGENE HAANEL, PH.D., DIRECTOR.

Products and By-Products of Coal

BY

Edgar Stansfield, M.Sc.

AND

F. E. Carter, B.Sc., Dr. Ing.

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Letter of Transmittal.

Dr. Eugene Haanel,
Director Mines Branch,
Department of Mines,
Ottawa.

Sir,—

I beg to submit, herewith, a bulletin on the products and by-products of coal. This bulletin was written—in collaboration with Dr. F. E. Carter—under instructions received from Mr. B. F. Haanel, Chief of Division of Fuels and Fuel Testing.

I have the honour to be,
Sir,
Your obedient servant,
(*Signed*) **Edgar Stansfield.**

OTTAWA, November 6, 1914.

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PRODUCTS AND BY-PRODUCTS

OF

COAL

PRODUCTS AND BY-PRODUCTS OF COAL.

INTRODUCTORY.

A number of reports and bulletins bearing on certain phases of the utilization of fuels have already been published by the Mines Branch of the Department of Mines. These reports have treated of anthracite, bituminous coal, lignite, and peat; have dealt with the mining and winning of the raw materials, methods of purification, and preparation for the market; and in addition, with the question of the advantageous use of different fuels for steam raising, and for the generation of gas for industrial purposes by means of the gas producer. Moreover, the subject of coking coals has been investigated, as also has the recovery of by-products in connexion with the manufacture of coke, and producer gas. But, so far, no report published by the Mines Branch has treated, as a whole, of the products and by-products obtained from the economic utilization of fuels; nor of the interdependence of the various industries manufacturing these commodities, or using them as raw materials.

The object of this report is to satisfy, as far as possible, the increasing need for a monograph on fuel products and by-products. The subject, however, is so comprehensive, that it is impossible—within the limits of a bulletin—to treat it other than in outline. But notwithstanding this limitation, it is hoped that the data furnished may prove to be a practical contribution to the progress and development of the industries concerned.

The subject matter of the present report is divided into two parts: (I) the production of coke, gas, ammonia, and tar from bituminous coal; and (II) the properties and uses of these products and by-products. Other fuels than bituminous coal are dealt with, but only in a tentative way, since bituminous coal is of overwhelmingly greater importance than any other fuel as a medium from which to obtain the commercial products particularized in Part I. In setting forth the results of these investigations, the aim has been to give prominence to the commercial rather than to the scientific aspect of the subjects treated, especially as regards their bearing on existing conditions in Canada.

The present time is particularly opportune for discussing the question of establishing new lines of trade and commerce; for, on account of the deplorable war conditions in Europe, all industries are more or less dislocated as regards supply and demand; and manufacturers, everywhere, are taking stock of current conditions, and considering future possibilities. The trade possibility that would naturally occur to most people interested in the commercial development of Canada, is the establishment of a coal-tar dye industry; since here, as in other countries, factories using dyes are being seriously inconvenienced, owing to the fact that Germany—by a combination of scientific research, technical ability, and commercial energy—has for years had practically a monopoly in the manufacture and supply of coal-tar dyes; and consequently, since the opening of the war, importation of this commodity from Europe has almost ceased. A reference to page 46, however, will show that the importation of dyes into Canada is not large, and that the prospect of developing a flourishing coal-tar dye industry is not encouraging. But offsetting this negative view, is a demonstration of the encouraging fact that there are other important by-products from coal which, although not figuring so prominently in the public eye, are nevertheless of much greater importance commercially. It is shown that a number of these are peculiarly suitable for production in Canada; and the Dominion could thus be rendered less dependent on foreign sources of supply.

PART I.

METHODS OF PRODUCING COKE, GAS, AMMONIA, AND TAR, FROM BITUMINOUS COAL.

The employment of coal for commercial purposes may be roughly classified under three main divisions as follows:—(1), the combustible matter in the coal is completely burned with an excess of air; (2), the combustible matter in the coal is completely gasified by partial combustion with a limited amount of air, or of air and steam; and (3), the volatile matter of the coal is vapourized by the application of external heat, in the absence of air.

Coal Burned under Boilers and in Furnaces.

In Class 1, the coal is burned under steam boilers and in furnaces, etc. The coal is fed in and burned, heat is generated, and ashes are left. In this class, heat is the main product; the only by-products being the valueless ashes and furnace gases.

Coal Gasified in Gas Producers.

In Class 2, the coal is gasified in the producer by blowing air and steam through it; but, by limiting the quantity of air supplied and having a deep layer of fuel, the coal is not completely oxidized, hence the gas produced is combustible. In this class the combustible gas is the main product, although ashes and heat are necessarily produced. The heat, which is generally kept as low as practicable by means of the steam, can be partially utilized, but is often a total loss. The gas is sometimes burned simply as a source of heat, while in other cases it is utilized as a source of power in internal combustion engines. As the gas leaves the producer it almost invariably contains more or less ammonia and coal tar, the quantities varying with the type of producer, with the amount of steam employed, and with the character of the coal gasified. By means of a suitable purifying plant, the ammonia and tar may be recovered from the gas before it is used. These residuals are, therefore, by-products from the utilization of coal in gas producers.

The Carbonization of Coal in Gas Retorts.

In Class 3, the coal is carbonized in gas retorts for the production of coal gas, and in coke ovens for the production of coke. In both cases the coal is heated, gas and other volatile products pass off, and coke remains in the retort or oven; but in the coal gas plant the gas is the main product, the coke being only a by-product; whereas in the coke-oven plant the conditions are reversed, the gas being the by-product. In both cases, however, the gas, as it leaves the coal, contains ammonia and coal tar vapours, and these are recoverable by-products.

The recovery of tar and ammonia from producer gas has been described, and the value of the latter as a fertilizer discussed in a recent report of the Mines Branch (Report No. 299, "Peat, Lignite, and Coal; their Value as Fuels for the Production of Power when utilized in By-Product Recovery Producers"). The tar obtained from gas producers need not be further considered here, as it is comparatively insignificant in amount. This latter condition is due partly to the relatively small number of gas-producer plants yet established, and partly to the fact that, with producers making gas for heating purposes, the tar is generally burned with the gas, while with few exceptions, power-gas producers are designed and operated to produce a minimum of tar.

The by-products obtained from gas works and from coke-oven plants are of very great importance. Before discussing these in detail, a brief description of the plants themselves will be given.

CITY GAS PLANTS.

In gas works the coal is coked in large fireclay retorts. These retorts are set in furnaces heated with gas from a producer using coke as fuel. The details of construction and methods of operation vary greatly, although the general principles of the process remain the same. The retorts are sometimes circular in cross section, and sometimes "D" shaped, or oval. The retorts may be set horizontally, vertically, or in an inclined position in the furnace. A bed of retorts having been prepared, and the furnace heated to the desired temperature—which is commonly about 1100°C.—the retorts are charged with coal through a door at the end, which is then at once closed. As the temperature of the coal gradually rises to that of the inside of the retort, the volatile constituents are driven off, and leave the retort through pipes provided for the purpose—coke being ultimately left in the retort. The coke is then removed, and a fresh charge of coal inserted. In some modern plants using vertical retorts, the above process is made continuous, the coal being fed in at the top, and the coke removed from the bottom. The volatile products, consisting of gas and vapours, are led under the surface of the liquid in a large horizontal pipe known as the hydraulic main, where some of the condensable constituents are condensed. The impure gas leaving this main is passed through a series of condensers, scrubbers, and purifiers, and thus cleaned ready for use for domestic heating, lighting, etc. From the hydraulic main, condensers, and scrubbers are obtained water containing ammonia, known as ammoniacal liquor, and a thick, black liquid known as coal tar. The ammoniacal liquor is the chief source of ammonia, the greatest part of which, after conversion into ammonium sulphate, is used on a very large scale as a fertilizer. Coal tar is the principal source of the innumerable coal-tar dyes, etc., which are described later.

As outlined above it is manifest that gas is the main product from the coal; while coke, ammonia, and coal tar are obtained as by-products. Not only the relative quantity, but the composition of the gas, etc., produced, are profoundly changed by varying the coal employed, the size of the charge, the shape and position of the retorts, the temperature and duration of the coking, or the gas pressure maintained in the retort. By increasing the quantity of gas obtained, its quality is usually decreased; as are also the quantity and quality of the tar. Every gas manufacturer has to decide for himself the best working conditions for his plant; bearing in mind the economic factors of his particular district.

The coal gas supply for city use is, to-day, largely supplemented by what is known as carburetted water gas. In the manufacture of water gas, coke or anthracite is burned in a suitable generator, by air being blown through it, and is thus heated to a temperature of at least 1100°C. At this point the air blast is cut off, and steam passed through the incandescent mass, whereby the combustible gases, carbon monoxide and hydrogen, are produced. The reaction between the steam and the hot carbon lowers the temperature in the generator; when, however, the temperature falls too low (as is shown by the high percentage of carbon dioxide in the issuing gases), the steam is cut off, and the generator again re-heated by means of the air blast. The water gas, obtained during the period when the steam is passed through the coke, is not rich enough to replace coal gas for ordinary use; it can be used, however, alone, or mixed with coal gas, after it has been enriched or carburetted by means of oil gas. This oil gas can be made from mineral oils, or from some of the higher boiling oils obtained by the distillation of coal tar. In either case the gas and oil are heated to a high temperature, whereby the oil is largely converted into permanent gases of high heating and illuminating value.

It can be seen that, by the use of carburetted water gas, some of the coke and the coal tar, obtained as by-products in the coal-gas plant, can be converted into gas, and the quantity of by-products left for disposal, thus reduced. Any coke in excess of the amount required for heating the retort furnaces, or for operating the water-gas plant, is sold as fuel.

COKE-OVEN PLANTS.

The coking of coal for the manufacture of coke is carried out in what are known as coke ovens. There are two types of these in common use, known respectively as beehive and retort ovens.

As already stated, coal during coking loses gas and volatile matter. In some cases these are immediately burned in or adjacent to the ovens, and produce the heat required; in other cases the volatile matter is collected, its more valuable constituents saved, and only the residual gases burned. Coke ovens, therefore, whether beehive or retort, can be classified as non-recovery ovens and by-product recovery ovens.

Three types of ovens will be considered as illustrating three of the above classes. The fourth class—the by-product beehive oven—is not very important, and is not employed in Canada.

Non-recovery Beehive Oven.

This is the simplest type of oven in common use. It has a circular floor and domed roof, and is usually built of brick or stone lined with firebrick. The ovens are built back to back, in long rows, with the object of economizing heat and space. In operation, a suitable charge of coal is fed into the oven through a hole in the roof, the brickwork of the oven having been left hot enough by the preceding charge to start the coking of the coal and ultimately to ignite the volatile matter driven off. Air is cautiously admitted through loose brickwork in the door in front, and in such a way that the volatile matter escaping from the coal is burned in the oven over the charge, and the coal and the coke preserved, as far as possible, from oxidation. The heat generated by the combustion of the volatile matter is radiated down from the roof, and completes the coking commenced by the heat from the brickwork, and the whole oven is raised to a red heat. When the coking is completed—usually after about 72 hours—the coke is drawn out and quenched with water, and a fresh charge of coal is introduced into the oven. In most beehive-oven plants the coke is drawn out by manual labour, as the shape of the oven is not suitable for the utilization of mechanical extractors. Occasionally, the hot waste gases leaving the oven are carried under boilers, and used to generate steam, but otherwise, coke is the one and only product of this type of oven.

Some beehive ovens have been so constructed as to allow of the recovery of by-products; but in these, the simplicity of the ordinary beehive oven is lost, without gaining the advantages obtained from the retort oven.

Non-recovery Retort Ovens.

In non-recovery retort ovens, the coal is coked in long, narrow retorts built of firebrick. The retorts may be arranged either horizontally or vertically, in batteries. They are made slightly wider at one end than the other, to allow of the ready discharge of the coke from the oven by means of a ram or by gravity. Coal is charged into a hot oven, as in the case of the beehive oven, but in marked contradistinction to the latter, no air is admitted into the oven itself. The volatile products from the coal leave the oven through special ports, are then mixed with air, and burned in flues surrounding the oven. The heat of their combustion is conducted back into the oven through the walls, and the coking of the coal is thus completed. The hot gases from the flues are often used to generate steam, but otherwise coke is again the one and only product of this type of oven.

By-product Retort Ovens.

The construction and operation of these ovens is in many ways similar to that of the non-recovery retort ovens, indeed so much so that some retort ovens can be operated either with or without by-product recovery. The difference consists in the fact that, with the recovery ovens, the gases and other volatile products from the coal are led away through pipes to a hydraulic main, and thence to a recovery plant where they are passed through condensers, scrubbers, etc.; and in this way ammoniacal liquor and coal tar are obtained—as in a coal-gas plant. Enough of the purified gas is then piped back to the battery and burned in flues surrounding the retorts to keep the ovens at the temperature requisite for good coking. In this type of oven, regenerators are commonly used to preheat the air and gas before they are burned in the flues. The resulting economy is such that, unless the coal is low in volatile matter, only half the purified gas is required to heat the ovens, while the remainder —a valuable by-product—can be used for other purposes. In this connexion it might be pointed out that the superior economies in the working of a by-product recovery coke-oven plant, as compared with a coal-gas plant, together with the superior quality of the coke produced, make the former a rival to the coal-gas plant, even as a means of supplying city gas; but the substitution is possible only where there is a large demand for coke of high quality.

Types of Coke Ovens Compared.

Until recent years there has been a decided prejudice against retort oven coke; the product of beehive ovens has been more in demand, especially for use in blast furnaces. This preference, however, is fortunately disappearing. As a matter of fact, retort ovens can make as good coke as beehive ovens, and can make more of it from ordinary coking coals. They have, moreover, a wider range of adaptability as they can produce a commercial coke from certain classes of coal which cannot be coked in a beehive oven. Hence the retort oven is gradually displacing the beehive oven, and in some countries the change is almost completed.

Beehive ovens, as a rule, are a nuisance in the neighbourhood where they are located, they burn or waste all the gases and volatile matter generated from the coal, and they give no return except that of the coke produced. Moreover, they also burn about 10 per cent of the coke itself. In other words, if, with a certain coal, a 75 per cent yield of coke is obtained in a retort oven, probably only 65 per cent would be obtained in a beehive oven. In the former case 134 tons of coal would be required to produce 100 tons of coke; whereas, in the latter case, 154 tons would be required. That is to say, for every 100 tons of coke produced in a beehive oven, 20 tons of coal, approximately, are needlessly wasted through the burning of the coke. From the ethical point of view, therefore, there can be no hesitation in condemning the beehive oven; while from the practical point of view it should be remembered that, in addition to the smaller yield, the greater waste of carbon in the beehive oven results in a higher percentage of ash in the coke produced. The beehive oven has the further disadvantage that the coking period is at least one and one-half times as long as in a retort oven, so that, if the charges are the same, it takes three beehive ovens to do the work of two retort ovens. The cost of working a beehive oven is also high, as the method of drawing the coke by manual labour is slow and expensive. The beehive oven is, however, very low in first cost, and being simple in construction, is also easy to keep in repair. These facts, together with the widespread prejudice in its favour, and the great number of managers and men familiar with its use—but unfamiliar with retort-oven practice—explain the reluctance of so many coke manufacturers to adopt retort ovens.

It is probable that in nearly all cases the non-recovery retort oven is, in the long run, more profitable than the beehive oven, and that it would certainly prove to be so in all large plants. The capital outlay is greater, but the working expenses are less; while the output of coke is at least 10 per cent more for the same amount of coal used.

In Canada, at the present time, the profits to be gained by the recovery of by-products are more doubtful. On account of the high capital cost of a by-product plant, it is essential that there should be a reasonably certainty of working full time; hence it is usual to erect large central plants, where they are capable of drawing supplies from several collieries, and where a good market for the products is of easy access. Evidence given before a Royal Commission on Coal Supplies in England would appear to show that, there, the value of the by-products will not only pay for the working of such a coke plant, and provide a profit, but will also pay for the capital outlay within ten years. Various uses for coal tar are given later; but it seems certain that by-product recovery coke-oven plants which produce tar, and the coal-tar industry which uses coal tar as a raw product, must grow up together.

At the present time, there are only two by-product recovery coke-oven plants operating in Canada; yet in 1913 these two plants were responsible for two-thirds of the total coke production of the Dominion. As coke is imported, their production, however, only amounted to half the total consumption of coke in the Dominion. We may confidently expect that the tendency of the future will be towards the recovery of coal tar and ammonia at all coke and gas plants.

CARBONIZATION OF PEAT, LIGNITE, ETC.

Not only bituminous coals, but wood, peat, lignite, bituminous shales, and other carbonaceous substances are also carbonized or coked on a commercial scale, and in such a manner as to yield gas, tar, etc. Bituminous coals, as already stated, yield coke, gas, ammoniacal liquor, and tar—the tar consisting mainly of aromatic hydrocarbons. Wood yields charcoal, tar, an aqueous distillate, and gas; the tar in this case contains chiefly phenolic derivatives; the aqueous distillate contains acetic acid, and is acid to litmus; while the gas is of low value. Tar from peat, lignite, or bituminous shales, is principally composed of aliphatic hydrocarbons; the aqueous distillate yielding ammonia. The coke residues from peat and lignite have, as yet, found little commercial use, but there are great possibilities in the Canadian West for a practicable method of carbonizing lignite, and then briquetting the carbonized residue, or in some other way converting it into a fuel suitable for domestic and general purposes.

The by-products from bituminous coals, however, are at present of such overwhelmingly greater commercial importance than the others mentioned above, that only the former are considered in this bulletin.

PRODUCTION OF COKE, GAS, AMMONIA, AND TAR, IN CANADA.

No official statistics are available to show the weight of coal coked annually in Canadian gas works, and the corresponding yield of gas, coke, etc.; but Mr. A. Hewitt, General Manager of the Consumers Gas Co., of Toronto, states that approximately five million gallons of tar are produced annually.[1]

Some idea of the relation between the coal coked and the products obtained at modern gas works can be obtained from some figures published in the Journal of Gas Lighting.[2] These show that the average "residuals" obtained during 1913 by the three London (Eng.) gas companies, per long ton (2,240 lbs.) of coal coked were: coke 12·47 cwt., coke breeze 5·20 bushels, tar 10 gallons, ammonia liquor 36·11 "gallons of 8 ozs.", and gas 12,420 cubic feet. The ammoniacal liquor referred to is of such a strength that 8 ounces of pure sulphuric acid are required to neutralize the "volatile"[3] ammonia in one gallon of the liquid. This corresponds to 0·674 pounds of ammonium sulphate per gallon; but the actual yield obtained is not stated. Although the above are called residuals, it is obvious that the weight of coke stated is the gross yield, rather than the net weight left after heating the retorts. The three companies in question used approximately 20·3 per cent, 21·1 per cent, and 12·3 per cent, respectively (mean 18 per cent) of the coke produced, to heat the retorts. Subtracting 18 per cent from the above coke yield, and assuming that a bushel of coke breeze weighs 50 pounds, then the net yields per 100 pounds of coal coked are approximately: coke 60 pounds, tar 0·45 gallons, gas 550 cubic feet, ammonium sulphate one pound.

Data collected by the Division of Mineral Resources and Statistics of the Mines Branch, show that, in 1913, 2,147,913 short tons (2,000 pounds) of coal were carbonized in Canadian coke ovens, and 1,517,133 tons of coke produced therefrom. Of the above, 1,456,361 tons of coal were coked in by-product

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[1] The publishers of the Gas Journal of Canada are now collecting gas works statistics for 1914, and hope to make the first publication of them by January 1, 1915.

[2] February 24, 1914, page 492.

[3] See page 26.

recovery coke ovens, with the production of 1,018,632 tons of coke; 8,371,600 gallons of tar; 10,663 tons of ammonium sulphate; and 3,353,831,100 cubic feet of surplus gas. The corresponding yields per 100 pounds of coal are: coke 70 pounds, tar 0·29 gallons, gas 115 cubic feet, ammonium sulphate 0·73 pounds. These figures are not comparable with those from the London gas companies, as no analyses of the coal coked are given in either case.

No statistics of the production of producer gas in Canada are available.

Coke, gas, ammonia, and coal tar are—as already shown—the main products or by-products obtained from the distillation of coal in gas retorts, or in coke ovens. These, and their derivatives, will now be considered separately, and in greater detail. Benzene, one of the most valuable by-products of coal, will be considered under the heading of coal tar, but a much richer source of this product is the "crude benzol" directly recovered from coke-oven and coal gas by washing with heavy oil or by other means. Formerly, when the standard of coal gas was its "candle power," it was not possible to remove the benzol from this gas, but now, where, as in Canada, calorific value has been introduced as the standard, the gas may be scrubbed and the gas works should be able to supply a largely increased quantity of benzene.[1]

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[1] On page 11 it was pointed out that by-product plants producing tar and the coal-tar industry using tar must grow up together. In Technical Paper 89 of the Bureau of Mines Washington, on Coal-Tar Products, published since this was written, H. C. Porter points out the fact that, if the gas at present produced in coke-oven and coal-gas plants were thoroughly stripped of benzol, the increased demand for benzene and its homologues caused by the war could be met at once to a considerable extent. This would remove the necessity of waiting several years for the establishment of new by-product recovery plants, or for the conversion of existing plants into by-product recovery plants.

PART II.

PROPERTIES AND USES OF COAL PRODUCTS AND BY-PRODUCTS.

COKE.

Coke is the name given to the solid residue left by the destructive distillation of coal, or of some other carbonaceous substances. It consists mainly of carbon, together with the original ash of the coal, but always contains small amounts of volatile matter which the temperature attained in the coking process has failed to drive out during the time the heat was maintained.

When coal is strongly heated in absence of air, it is decomposed, and loses water, gases, and volatile compounds. Many coals so heated first fuse or soften, and then harden as decomposition progresses, ultimately leaving a strong coke. This coke, although quite hard, is light and cellular, owing to the bubbles produced by the escaping gases while the mass is soft. Neither anthracite nor lignite coalesces when heated, hence neither is capable of making commercial coke. The fragments left after the heating might strictly be described as coke, but they are approximately the same size and shape as the original pieces of coal, and bear little or no resemblance to the hard porous substance commercially known as coke. Some bituminous coals also fail to coke, or else make so weak or impure a material as to be worthless.

Coke bears the same relation to coal that charcoal does to wood. For many purposes, such as blast furnace smelting, coke is so far superior to coal as a fuel, that it is necessary to go to the trouble and expense of coking the coal before use. The chief advantages of coke as a fuel are:—

(1) It is strong and hard, and does not crumble or soften when burning; thus it can support a heavy charge of ore, etc., in a furnace, without crushing or melting down and obstructing the blast.

(2) It burns without producing tar or smoke.

(3) It has a high calorific intensity; that is to say, a higher temperature can be obtained by burning coke than by burning coal, although a given weight of coal will naturally evolve a larger quantity of heat than will the coke produced from it.

Coke is the main product of coke-oven plants, and is a by-product of gas plants. A coke manufacturer selects coal that is capable of giving good coke, and treats it in such a way—with regard to the mass coked, temperature of oven, and duration of coking—as will produce a good quality of coke. The gas manufacturer naturally regards the quantity and quality of gas produced as his chief consideration, the quality of coke being only of secondary importance; his choices of coal, etc., are, therefore, all made from the view point of gas production. Consequently gas or retort coke is practically always inferior to oven coke, as regards hardness, strength, lustre, etc.; but the former has advantages over oven coke for certain purposes, since it contains more volatile matter, and consequently burns more readily.

Table I gives analyses of a coal, and of a coke produced from it. The coal sample came from the Foord seam, Allan Shaft Colliery, Pictou County, N.S. and the coke was made in an Otto Hoffman, by-product recovery, retort oven at Sydney, N.S. This coke was a high grade metallurgical coke, and one of the best produced in the long series of coking tests carried out in connexion with the "Investigation of the Coals of Canada," Mines Branch Report No. 83, Vol. I.

TABLE I.

Analysis of Coal, and Coke Produced therefrom.

	Coal.	Coke.
Proximate analysis of dry coal or coke		
Fixed carbon %	57·1	87·3
Volatile matter %	33·7	0·6
Ash %	9·2	12·1
Ultimate analysis of dry coal or coke		
Carbon %	77·8	
Hydrogen %	5·0	
Sulphur %	0·6	
Nitrogen %	2·2	
Oxygen %	5·2	
Ash %	9·2	
Duration of coking Hours		48
Yield of dry coke from dry coal %		71·9
Apparent specific gravity		0·92
Real specific gravity		1·86
Percentage cell space or porosity		50·7

Uses of Coke.

The most important uses of coke are in metallurgical operations, such as the smelting of iron in blast furnaces; the remelting of iron in the iron foundry; and the smelting of copper, lead, nickel, silver, etc. Oven coke is always used for these purposes, as a strong, hard coke is required. For blast furnaces, great compressive strength is essential; but for copper smelters, porosity is important. During 1913, 1,417,148 tons of coke were used in the blast furnaces of Canada; this amounted to about 65 per cent of the total consumption of metallurgical coke in the Dominion.

Gas coke is chiefly used for steam raising, domestic heating, etc. It has the great advantage over soft coal that it can be burned in an ordinary grate without producing smoke and soot; this is a matter of great importance for the cleanliness of our cities even now, and will become more so as the cities increase in size. Where hard coal is burned, nothing is gained as regards smoke reduction by a change to coke; there is, however, a great deal to be said in favour of coking all bituminous coal that will form a commercial coke, thus obtaining the two clean fuels coke and gas, and recovering the valuable by-products tar and ammonia.

Gas coke can prove satisfactory for steam raising only where it is burned under suitable conditions. It has a comparatively high temperature of ignition—although not so high as that of oven coke—and requires a good draught. It gives a more localized heat than coal, on account of the absence of flame, and when burning freely gives a more intense heat; it is therefore liable to cause troubles such as the burning of the firebars and the formation of clinker. The latter trouble is accentuated by the fact that coke naturally contains a higher percentage of ash than the coal from which it is made. The difficulties attending its use are, however, not unsurmountable, as is shown by its successful use in many plants. A suitable furnace should be employed, and the method of stoking adapted to the fuel. Crushing the coke to a small uniform size is generally advantageous. Troubles due to ash and clinker would be reduced if the coal for use in gas plants were first washed, as is frequently done with coal for coke-oven plants. Washing the coal would also reduce the sulphur in the resulting coke.

Coke is also used in gas producers. Many of the small suction gas plants are designed to operate either on anthracite or on coke.

Gas coke is a good fuel for domestic heating when burned in a suitable furnace; but before the prejudice against it can be removed it will have to be realized that a proper design of furnace must be employed.

In England, houses are generally heated with open grate fires, in which soft coal is burned, and although the open fire has many advantages in a temperate climate over other methods of heating, such use of soft coal is wasteful of fuel and plays a large part in the pollution of the atmosphere. These conditions have recently led to the introduction of a low temperature coke; the coal is coked in gas retorts maintained at a much lower temperature than is usually employed, whereby only about two thirds of the volatile matter is removed. This type of coke, of which "Coalite" is the best known example, ignites at a much lower temperature than ordinary coke and burns more readily, thus giving a bright, cheerful, smokeless fire. The commercial development of such smokeless fuel in England has been slow, both on account of prejudice and of the difficulty of making a wholly satisfactory and uniform product. In Canada the need for such a fuel is far less, but even here conditions might easily arise where low temperature carbonization would prove advantageous. Low temperature carbonization produces a greater yield of solid fuel in proportion to the gas than is yielded in ordinary practice; it should therefore be advantageous in a place where, possibly on account of the scarcity of hard coal or the competition of natural gas, there is a comparatively larger market for a solid, furnace fuel than for city gas. Not only the proportionate yield, but also the actual yield of coke is increased by low temperate coking; the yields of gas and tar are correspondingly lower. The gas produced is, however, richer, and the tar more valuable than those obtained by the usual methods.

Recovery coke oven practice also yields a proportionately larger supply of solid as compared with gaseous fuel than is the case with ordinary gas works practice; because at the coke ovens, gas is used to supply the heat for coking, whilst at the gas works coke is used for this purpose. It has already been pointed out that modern by-product recovery coke plants have recently been installed in certain places as a means of supplying city gas; but such installations are only possible where there is a good demand for metallurgical coke. A study of the statistics of coke suggests that, in some Canadian cities, a coke-oven plant might possibly prove more profitable than a gas plant. During 1913 the coke imports exceeded the exports by 655,671 tons, an amount greater than the coke production of either of the two by-product coke-oven plants, during that year.

In 1913, 1,517,133 short tons of oven coke were produced in Canada; and 1,530,499 tons were sold or used by the producers.

Exports amounted to 68,235 tons, and imports to 723,906 tons.[1]

GAS.

The three principal gases which have been mentioned are city gas, coke-oven gas, and producer gas. It has been explained that city gas is frequently a mixture of ordinary coal gas with a carburetted water gas, oil being used for carburetting; some Canadian cities, however, are supplied with coal gas alone, and others with carburetted water gas alone.

Gases vary so widely in composition with the conditions under which they are made, that it is difficult to give strictly typical analyses; Table II, however, gives an indication of the types of gas which go to make up the ordinary mixed city gas.[2] Table III gives actual analyses of a city gas, a coke-oven gas, three types of producer gas, and, for comparison, a natural gas. The calorific values are in British Thermal Units per cubic foot of gas measured moist at 60°F., under a pressure of 30 inches of mercury. They have been calculated as in Report No. 83, of the Mines Branch, "An Investigation of the Coals of Canada," Vol. II, p. 168. The assumption is made that the saturated hydrocarbons are all methane, and the unsaturated hydrocarbons ethylene. This assumption probably causes no appreciable error in the calculated calorific value for a producer gas; but it is liable to cause a serious error in the case of a city gas, and an even greater error when applied to an oil gas. Determinations made with a Boys gas calorimeter showed that the actual gross calorific value of the city gas given in the table was 636 B. Th. U., and of the natural gas, 930 B. Th. U.

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[1] Preliminary Report on the Mineral Production of Canada during 1913, by John McLeish, Mines Branch Bulletin No. 283.

[2] The oil gas shown is of the Pintsch gas type as in the carburetting process the oil gas never exists alone and cannot be analysed.

TABLE II.

Typical Gas Analyses.

	Retort coal gas.	Water gas.	Oil gas.	Carburetted water gas.
Hydrogen........................%	50	50	30	36
Saturated hydrocarbons ....%	34	1	38	14
Unsaturated hydrocarbons ....%	4	—	25	9
Carbon monoxide.................%	8	40	—	30
Carbon dioxide...................%	2	5	—	5
Oxygen.........................%	—	—	—	—
Nitrogen........................%	2	4	7	6
Inflammable gases................%	96	91	93	89
Calculated calorific value, gross B.Th.U.	590	300	880	500
Calculated calorific value, net B.Th.U.	530	270	810	450

TABLE III.

Examples of Gas Analyses.

	City gas.	Coke-oven gas.	Producer gas.			Natural gas.
			Coal.	Lignite.	Peat.	
	1	2	3	4	5	6
Hydrogen.......%	39·5	48·5	12·5	19·0	10·3	—
Saturated hydrocarbons.......%	31·8	32·8	3·3	1·5	2·4	91·6
Unsaturated hydrocarbons... ..	5·1	3·6	0·2	0·1	0·4	—
Carbon monoxide.........%	14·6	5·5	10·7	16·1	20·2	—
Carbon dioxide.%	1·7	2·4	10·1	11·7	9·9	—
Oxygen.........%	0·6	0·3	0·8	0·7	0·3	0·2
Nitrogen (by difference)......%	6·7	6·9	62·4	50·9	56·5	8·2
Inflammable gases ....%	91·0	90·4	26·7	36·7	33·3	91·6
Calorific value by calculation, gross B.Th.U.	574	560	111	129	128	916
by calculation, net B.Th.U..	516	500	101	118	120	822

No. 1. Montreal city gas, which is coal gas mixed with carburetted water gas.
" 2. Coke-oven gas from Nova Scotia coal coked in Otto Hoffman oven.
" 3. Nova Scotia coal in McGill gas producer.
" 4. Alberta lignite in Westinghouse gas producer.
" 5. Ontario peat in Körting gas producer.
" 6. A natural gas from Alberta.

When coal is distilled at low temperatures, the primary products of decomposition are principally water vapour, oxides of carbon, and hydrocarbons. As the temperature increases, the hydrocarbons break down and hydrogen is produced, more volatile matter is also driven off from the coke, and the lighter constituents of the tar are converted into gas. The yield of gas is thus materially increased, but at the expense of the rich hydrocarbons in the gas and the more valuable constituents of the tar. The tendency of gas works managers is to increase the yield of gas by increasing the temperature of the retorts; but from the standpoint of conservation it would be better to distil the coal at lower temperatures, and then dilute the resulting gases with a cheaper product, such as water gas.

The production of city gas in Canada is largely reduced by the competition of natural gas. There are at present some thirty nine companies supplying city gas, the net prices charged per thousand cubic feet for illuminating purposes ranging from $0.70 to $2.40. Twenty-three companies are employed in the distribution of natural gas, the corresponding prices ranging from $0.15 to $0.70. The production of natural gas in Canada in 1913 was, approximately, 20,345 million cubic feet.

In many countries gas companies are compelled to supply gas of a certain minimum quality. In the days when gas was chiefly burned in open flat-flame burners for illuminating purposes, a gas of a certain candle power was insisted on; with the introduction of incandescent mantles for gas lighting, the heating power of the gas became more important, and a dual standard was created in certain places. Now that city gas is used almost entirely for cooking, domestic heating, lighting with incandescent mantles, and power production, the candle power of the gas when burned in the open flame is of no importance, and the calorific value, or heating power of the gas is of vital importance. This change is to the advantage of both producer and consumer, as it allows the gas manufacturer to supply a satisfactory gas at a lower cost than was possible when the gas had to be rich in illuminants.

The output of surplus coke-oven gas in Canada in 1913 amounted to 3,354 million cubic feet. This gas is at present used in the steel works, to which the coke-oven plants are an adjunct, for heating furnaces, roasting limestone, etc. As already stated in connexion with coke production, one possible development in this country is a by-product recovery coke-oven plant to supply oven gas for city use, and also to produce metallurgical coke, tar, and ammonia.

No figures are available for the annual output of producer gas in Canada. As can be seen from the analyses given in Table III, producer gas is a low grade fuel, but it is correspondingly low in cost of production, and is used to a great extent for heating steel furnaces, and in other metallurgical processes; also for power production in internal combustion engines. In many works where producer gas is used for heating large furnaces, the gas is taken hot from the producers and led to the furnaces without cooling. A gas containing tar is actually better than a clean gas in such cases, as the tar vapour notably increases the calorific value of the gas; producers of the updraft type are, therefore, employed at such works, because they generate from bituminous coal, a gas rich in tar, and are moreover simple in construction and operation. Where the gas has to be cooled and led through pipes, and where it is to be used for internal combustion engines, a tar-free gas must be obtained. This is accomplished by the use of anthracite or coke in a simple producer, or, where a fuel richer in volatile matter is employed, by means of specially designed producers, usually of the down-draft, or the double-zone type, and by means of tar extractors.

Uses of Gas.

Gas is used for illumination, in which case it is usually burned inside incandescent mantles; for heating and cooking; for power generation in internal combustion engines; for heating small technical appliances; and for heating all kinds of large furnaces, as for example in the iron and steel industries, and in the manufacture of cement, glass, china, etc.

A great economy was effected in gas illumination when the incandescent mantle replaced the flat-flame burner; a still further economy can be attained by the use of high-pressure gas. High-pressure gas is particularly suited to street and factory lighting; and for this purpose it is displacing electricity in several of the largest European cities.

High pressure gas is also used for generating high temperatures in furnaces. The greatest advance made in the use of gas for furnace work, however, was due to the introduction of recuperators and regenerators. In these, the waste heat from the gases leaving the furnace is used to pre-heat the air, or the gas and air entering the furnace, thus enabling a high temperature to be readily obtained. The high efficiency obtainable by gas heating with the regenerative system, together with the greater ease of control with gaseous than with solid fuel, and the greater cleanliness of the former, has led to the almost entire disuse of solid fuel in many large industries.

The last few years have seen the commercial introduction of a flameless method of burning gases, known as surface combustion. In many cases this has been shown to result in greatly increased efficiency; hence in the next few years, considerable developments may be expected along these lines.

AMMONIA.

Ammonia is obtained as a by-product in the distillation of coal in gas works, in coke-oven plants, and in producer-gas plants. The quantity depends on the percentage of nitrogen present in the coal; but other factors, e.g. the temperature and shape of the retorts, ovens, or producers, have also an influence on the fraction of the nitrogen which is evolved as ammonia. Generally, nitrogen is present in coals to the extent of one or two per cent, but in gas works only about 14 per cent of this is recovered as ammonia in the gas; this latter percentage may be sensibly increased by adding lime to the coal, or by passing steam through the retort during distillation. Increasing the steam used also increases the ammonia yield from gas producers. The Mond producers are run so that a very high yield of ammonia, amounting to about 60 per cent of the nitrogen of the coal, is obtained by means of the large excess of steam which is passed through the fuel bed; the steam favours the increased percentage of ammonia by lowering the temperature of the producer below the point at which ammonia decomposes, and also by acting as a diluent to the gases evolved.

In gas and coke-oven plants some of the ammonia is washed out from the gas in the hydraulic main, purifiers, etc., but the bulk of it is recovered from washers and scrubbers installed for the purpose. As small a volume of wash liquor as possible is used in these washers, to prevent undue dilution of the ammonia in the resulting ammoniacal liquor.

Coal gas and coke-oven gas contain ammonia, carbon dioxide, sulphuretted hydrogen, cyanides, etc. As these gases combine chemically and dissolve in water, the ammoniacal liquor obtained is a complicated solution containing the following ammonium salts: acid and neutral carbonates, acid and neutral sulphides, thiocarbonate, cyanide, thiocyanate, ferrocyanide, sulphate, thiosulphate, sulphite, chloride, and acetate. Because solutions of the carbonates, sulphides, cyanide, and acetate readily give up their ammonia when boiled the ammonia in these salts is called "volatile." The other compounds require the addition of lime to liberate the ammonia, which in these salts is said to be "fixed." The ratio between the "volatile" and "fixed" ammonia in gas liquors varies widely, but that liquor with the largest proportion of "volatile", is naturally the most valuable. In producer-gas plants the gas is washed in towers by dilute sulphuric acid, and ammonium sulphate is directly produced.

The ammoniacal liquor obtained as above is distilled before and after the addition of lime, and the ammonia liberated is passed into sulphuric acid yielding ammonium sulphate, or into water yielding the ammonia solution generally known as ammonia, ammonium hydroxide, ammonia water, etc. This treatment of the gas liquor is not profitable in smaller plants, and from such places the liquor is generally shipped to central plants for distillation.

Uses of Ammonia.

A strong solution containing about 10 per cent ammonia, as obtained by simple distillation, is largely used for the manufacture of ammonia soda, and for cleaning purposes; while the more concentrated solution "liquor ammoniæ", and anhydrous liquid ammonia, are used in refrigerating machinery. Ammonium nitrate, which is usually made from ammonium sulphate and sodium nitrate, is being increasingly used in explosives. Ammonium chloride, which is produced directly from the gas liquor, or from ammonium sulphate by boiling with common salt, or obtained from waste liquors of ammonia-soda works, is used for soldering, for galvanizing iron, for calico printing, and for Leclanché cells and dry batteries. A process by which ammonia is converted into nitric acid has recently been patented by Ostwald, and will probably prove to be a very important application of ammonia. Ammonium sulphate is the most important salt of ammonia; its possible useful application as a fertilizer is practically unlimited. As yet the need of fertilizers has not been felt so keenly in Canada as in older established countries, but its use here is bound to extend rapidly. During the last year there has been a tendency for the price of ammonium sulphate to drop, partly owing to the competition of other fertilizers now produced on a large scale by the fixation of atmospheric nitrogen by electrothermic processes, and partly owing to the progress which is being made with Haber's synthetic process for ammonia production. The war has caused a brisk demand for nitrates in the manufacture of explosives, and the removal of these nitrates from the fertilizer market, should bring about an increase in the price of ammonium sulphate.

CYANIDES.

In the dry distillation of coal, up to 2 per cent of the nitrogen of the coal is evolved in the form of cyanide, and is recovered both in the washers and scrubbers along with the ammonia, and in the purifiers where ferrocyanide is formed with the ferric oxide. The potassium cyanide, ferrocyanide, and ferricyanide, which are worked up from cyanogen compounds of the gas, are very important by-products of the gas industry. In the twelve months ending March, 1914, Canada imported 1,615,490 pounds of potassium and sodium cyanides, and 166,901 pounds of yellow and red prussiate of potash (potassium ferro- and ferricyanide). The simple cyanides have a wide application in mining operations; the yellow prussiate is used for making potassium cyanide, for dyeing, and for case hardening steel; and the red prussiate is much used in photography.

COAL TAR.

The composition of tars varies enormously with the apparatus employed, the coal used, the method of working, etc. Lunge quotes the two following sets of values for gas-works tar, which may be taken as typical. These tars were made from the same coal in the same works; but in the one case the coal was coked in a horizontal retort, and in the other in a vertical retort.

Analysis of Gas-Works Tar.

	Vertical.	Horizontal.
Specific gravity, about	1·1	1·2
Free carbon	2–4%	20·0%
Distillation yields:—		
Water	2·2%	3·5%
Light oil	5·9%	3·1%
Middle oil	12·3%	7·7%
Heavy oil	12·0%	10·2%
Anthracene oil	16·0%	11·6%
Pitch	49·7%	62·0%

Coke-oven tar usually contains less free carbon than ordinary tar and is therefore more mobile. Its specific gravity is from 1·14 to 1·19, and when distilled it yields on an average the following products:—

Analysis of Coke-Oven Tar.

Water	2·7%
Light oil	1·4%
Middle oil	3·5%
Heavy oil	9·9%
Anthracene oil	24·8%
Pitch	56·4%

Tar from gas producers differs from the above in that it contains considerable quantities of water. A sample of gas producer tar gave the following distillates:—

Analysis of Gas-Producer Tar.

Below 230°C	5·4%	by volume.
230°C—300°C	10·1%	"
From 300° until oil solidified	14·5%	"
Oils solidifying on cooling	10·4%	"
Coke	30·5%	by weight.
Water and loss	32·6%	"

Water-Gas Tar.

A tar commonly found in gas works is water-gas tar. This is not actually a product of coal, but is produced by the cracking of the oil used for carburetting the water gas. It is thinner than ordinary tar, is usually brown in colour, and contains much water. The amounts of free carbon and of phenols in this tar are minute, and the higher boiling oils produced from it contain only small quantities of naphthalene and anthracene.

Uses of Tar.

Probably the greater part of the world's production of tar is distilled in order to obtain the more valuable products described later; but there are many uses for entirely raw tar, or for tar in its dehydrated state (i.e. after it has been heated in closed vessels to remove the water, and, incidentally, to recover the benzol). Dehydrated tar finds wide application in the preparation of roofing felt, and for preserving timber, stone, iron, etc. Tar has, weight for weight, a slightly higher heating value than coke, and is now being used as a fuel. Formerly it was simply poured on to solid fuel, but under these conditions combustion was by no means complete; now the tar is usually injected in the form of a fine spray by means of steam or air and so comes in intimate contact with the air, this resulting in complete combustion. Tar is sometimes simply mixed with coke for heating retorts in a gas plant or used in conjunction with coke-oven gas for heating coke ovens. It is also converted into a gas by being passed through red-hot tubes.

There are so many valuable products which may be obtained from tar that its use as a fuel is, from the standpoint of conservation, to be condemned; but it must be admitted that in very many cases the tar has to be used in this way. Large gas and coke-oven plants can profitably have a tar-distilling plant in addition; but the distillation of tar in small works is not remunerative. In the latter case, the tar may be shipped to central distilling plants, but even this procedure is not commercially possible where the gas or coke-oven plant is isolated, and consequently the cost of transportation high. In such cases the use of tar for fuel is the only possible one.

Distillation of Tar.

Coal tar is distilled in wrought iron stills. These stills are usually upright cylinders of 10 to 20 tons capacity, sometimes heated by steam, but more often by a direct fire. As water in tar sometimes causes bumping in the stills, it is removed as completely as possible beforehand. With thinner tars the water settles out on the surface at ordinary temperatures sufficiently well to be run off, but thicker tars require to be moderately heated to cause a satisfactory separation. The still-head is connected with a condensing worm, from which the various products of distillation are conducted into different receivers. At the end of the distillation process, the fire is drawn out and the temperature allowed to fall to a point at which the pitch left behind in the still—though remaining liquid—will not ignite when it comes in contact with the air. This pitch is then run out into barrels, or other suitable receivers. Sometimes, in the last stages of the distillation, superheated steam or a vacuum is utilized, since either of these causes the high-boiling-point products to pass over at a lower temperature than would otherwise have to be employed. Recently, tar has been successfully treated in continuous distillation apparatus.

As is shown below, the various first products of coal tar give, on refinement, numerous compounds of supreme importance in technical chemistry. The amounts of these compounds obtained from tar vary considerably with the nature of the tar itself; and the following figures merely give an approximate idea of the quantities which may be expected from an average coal tar:—

Derivatives of Coal Tar—

Benzene and homologues	2·5%
Phenol and homologues	2·0%
Pyridine and other bases	0·25%
Naphthalene	6·0%
Heavy oil	22 %
Crude anthracene (30% pure)	1·5%
Pitch	60 %
Water and loss	6 %

The *Light Oil* (see Table IV), which is 3—6 per cent of the original tar, contains:—

Phenols	5 –	15 %
Pyridines	1 –	3 %
Sulphur compounds		0·1%
Nitriles	0·2 –	0·3%
Neutral substances	1·0 –	1·5%
Hydrocarbons	80 –	100 %

The hydrocarbons are almost completely aromatic, four-fifths being benzene and its homologues, and one-fifth naphthalene.

The *Middle Oil*, which constitutes 8—12 per cent of the tar contains:—

Phenol	10%
Cresols	20%
Naphthalene	30%
Residue—heavy oil	40%

In addition, the oil contains considerable quantities of pyridine and other bases.

The *Heavy Oil*, 10—12 per cent of the tar, is a semi-liquid product containing:—

Naphthalene	30%
Cresols and homologues	10%
Pyridine bases	6%
Unknown hydrocarbons	40%

Anthracene Oil, which is 11—16 per cent of the tar, contains about 3 per cent pure anthracene, 6 per cent phenols, and numerous other liquid and solid compounds.

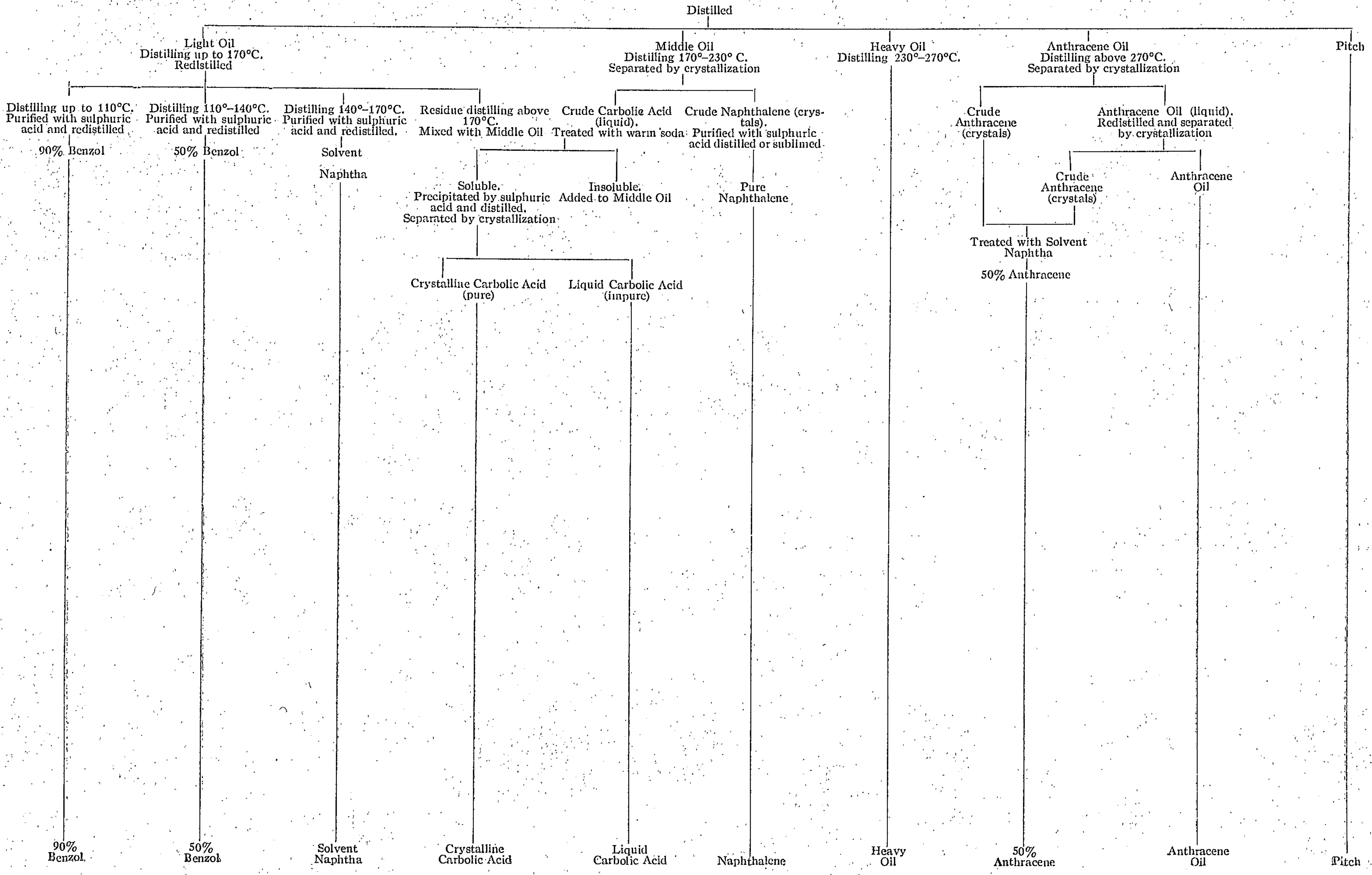
Pitch, amounting to as high as 60 per cent of the weight of tar, contains varying quantities of free carbon: thus, coke-oven pitch and vertical retort pitch may contain as low as 2 per cent free carbon; while in horizontal retort pitch there may be as much as 40 per cent.

The following table shows, diagrammatically, the first products of a tar distillation, and a typical method by which these are worked up in many tar distilleries to obtain the further products shown. These products are themselves the parent substances of innumerable compounds, many of which are of the greatest technical importance, as will be seen later.

The ranges of temperature mentioned are given merely to indicate the approximate limits between which the different oils are collected, and not to put down any definite rule of distillation. Tar distillers vary their method of working considerably, according to the demand for different products; for example, with a strong market for creosote oil (heavy oil), the distiller will desire to make as much of that product as possible, hence may collect the oil between wider limits than is indicated in the table, and sell the product without further purification.

TABLE IV.

COAL TAR.



COMMERCIAL PRODUCTS OF COAL TAR; THEIR USES AND DERIVATIVES.

90% Benzol.

Uses.—

As a solvent for the manufacture of colours, for extracting fat from bones and seeds, and for making iron varnishes; also, as a detergent; as a fuel for internal combustion engines; and for carburetting gas.

Derivatives.—

By distillation, pure benzene, toluene, xylene, etc., are obtained. Benzene is widely used in the preparation of numerous technical organic products. From it nitro-benzene, aniline, etc., are readily obtained, and therefore it is the parent substance of the numerous aniline dyes; of many artificial perfumes; and of photographic developers, etc. Toluene and xylene are used in the preparation of certain dyes. The former gives on nitration trinitrotoluene, a substance used in the manufacture of explosives.

50% Benzol.

Use.—

As a substitute for the 90 per cent benzol, in the manufacture of certain dyes.

Solvent Naphtha.

Uses.—

As a solvent for rubber in the preparation of waterproof fabrics; as a detergent; and as a solvent in the purification of anthracene.

Crystalline Carbolic Acid.

Use.—

As an antiseptic.

Derivatives.—

By nitration, carbolic acid gives picric acid, which is used in the manufacture of many important explosives, and of some dyes. It is the source of many substances used in the colour industry (e.g. salicylic acid), and of certain photographic developers (e.g. metol).

Liquid Carbolic Acid.

Uses.—

As a liquid antiseptic, and as the active principle of disinfectant soaps, powders, etc.

Naphthalene.

Uses.—

For carburetting gas; for disinfecting purposes; for driving explosive motors; for preserving raw hides; and sometimes also for fuel. Crude naphthalene is usually employed for the above purposes.

Derivatives.—

Pure naphthalene is the starting point in the manufacture of a large number of important artificial colours (phthalein colours, azo-colours, indigo, etc.).

Heavy Oil. Also called Creosote Oil.

Uses.—

As an illuminant where smoke is no objection; as an antiseptic; as a timber preservative; as a lubricant; as a binder, when mixed with pitch, in the manufacture of patent fuels; as a fuel; and as a solvent.

50% Anthracene.

Uses.—

Not important.

Derivatives.—

Anthracene is the raw material from which alizarin and other important colouring matters are manufactured.

Anthracene Oil.

Uses.—

For lubricating purposes; for timber preservation; for making soft from hard pitch; for removing naphthalene from coal gas.

Pitch.

Uses.—

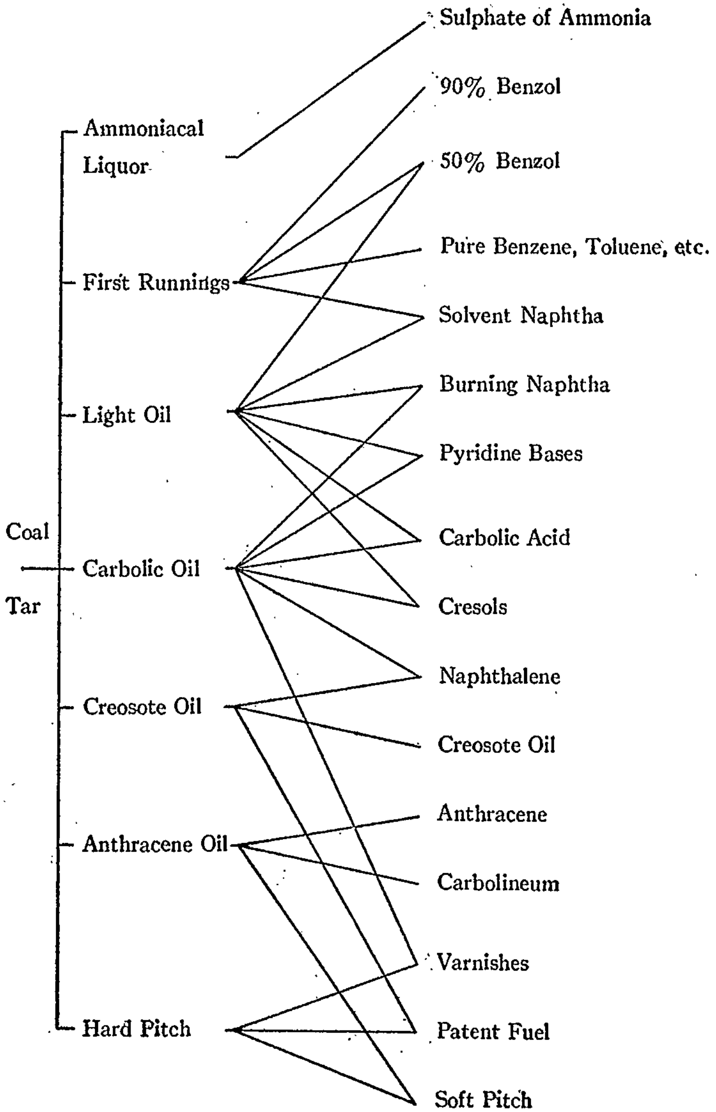
For road making; for preparing artificial asphalt by admixture with heavy oil; for manufacturing varnishes by admixture with middle oil; for making patent fuels, after softening by admixture with heavy or anthracene oil; for insulating cables, etc.; for roofing; and for making coke for electric carbons.

Lunge gives the following diagram, which shows clearly the various first products obtained from coal tar.

TABLE V

First Products from Coal Tar

(*Lunge*)



COAL TAR IN THE INDUSTRIES.

The many uses mentioned for the substances enumerated above clearly indicate their vast technical importance. The commercial aspect of the relations of these coal-tar products to certain large industries is discussed in the following sections:—

Timber Preservation.

Wood, when exposed to moisture, or set in water, may decay through the action of different organisms or fungi; or it may be destroyed by insects. To prevent this, the timber is soaked in some chemical which will act as a poison to such enemies. Mercuric chloride, copper sulphate, and zinc chloride, are examples of suitable poisons, and of these the last named is widely used. They are, however, all soluble in water, and may be rather quickly washed out by rain, etc. Creosote oil, on the other hand, is an efficient preservative which is insoluble in water and consequently is more permanent in its action. It gradually evaporates, but, if a heavy oil be chosen, the rate of evaporation is very slow. Coal tar—also insoluble in water—is often used; but its penetrating power is small. Creosote oil is, therefore, the most suitable material for timber preservation, and is most used in Canada.

The wood to be preserved is put into iron tanks, which are then closed and evacuated; the heated oil is now run in and the wood allowed to remain immersed under pressure for some time to ensure the complete filling of the pores. The preservative, to be effective, should contain high-boiling oils; for general purposes not more than 50 per cent of it should distil below 315°C., but for wood paving blocks not more than 55 per cent should distil below that temperature. Economy of creosote oil can be obtained by the use of an inferior oil, which should be mixed hot, in the proportion of 80 parts oil to 20 parts of coke-oven tar, the latter containing not more than 5 to 6 per cent of free carbon. The penetration of such a mixture is not less than that of creosote oil, if the time for which the timber is kept under pressure be slightly increased.

On the American continent the demand for creosote oil is much greater than the supply. In 1913 the United States consumed, for timber preservation, over 90 million gallons (Imp.) of the oil, and of this 62 per cent was imported from Europe. Between 60 per cent and 70 per cent of the total quantity of oil consumed was used for the treatment of railway ties, some 25 million being thus treated. In Canada, 19 million cross-ties are used annually, and only about 10 per cent of these are creosoted; but even for this comparatively small number, Canada does not produce sufficient creosote oil. If all the tar produced in gas and coke-oven works in the country were distilled, the home supply of creosote oil would still be quite unequal to the demand, and tar distillers would therefore be certain of a sale for one of their most important products.

Road Making.

Raw tar is sometimes used in the making of roads; but it is better to employ the prepared or dehydrated tar. This is generally poured or sprayed on existing roads. In dry weather it serves to keep the surface free from dust, and in wet weather it protects the road material from the disintegrating effects of water. In the actual construction of roads coal-tar pitch and asphalt are much used instead of tar. Coal-tar asphalt is made by mixing pitch with suitable quantities of creosote and anthracene oils; and, although it cannot entirely replace the natural asphalt in street paving, it is a very good substitute. For making sidewalks a mixture of coal-tar pitch and natural asphalt is often employed, sandy material being ground up with the mixture, which is then melted and mixed with gravel.

The use of pitch, etc., in the making of roads is increasing rapidly; and even at the present time there is a good demand for this residual material from the distillation of coal tar.

Disinfectants.

Carbolic acid in its pure crystallized state is used for medicinal purposes, as an antiseptic, etc.; but it has a much wider application in the crude state for disinfectant purposes generally. The impure carbolic acid has a strong unpleasant smell. It becomes partially liquid on standing, and in this state is much used for disinfecting sewers, stables, etc. Various preparations of carbolic acid or the other phenols are made to render the application of the disinfectant more convenient. The most important preparations are those in which the phenols are combined with soap; but carbolic-acid powders, which are mixtures of carbolic acid and lime, etc., are extensively used. Naphthalene sometimes replaces carbolic acid as a disinfectant, being used in sick rooms, etc., and is often preferable to carbolic acid for the dressing of wounds. It also acts as a preventive against moths, etc.

Explosives.

Phenol is the parent substance of several important explosives, and most of the carbolic acid produced is used in their manufacture. By the nitration of phenol, picric acid is formed, and this acid and its still more explosive salts are utilized in the preparation of such explosives as lyddite, melinite, etc. Trinitrotoluene and trinitrobenzene are also used in various preparations for the manufacture of explosives; the corresponding dinitro compounds explode only when admixed with saltpetre, etc.

Power Production.

The use of tar as a fuel has already been mentioned, but in addition to this, some of the products of distillation are useful for power production. The most important is benzol, which is being increasingly used in internal combustion engines, since it has a higher heating value than petroleum spirit, and does not appear to deposit much more carbon in the cylinder. The technical benzol, consisting of 95 per cent benzene and 5 per cent toluene, is generally used for this purpose. Until the value of naphthalene in the preparation of colours was discovered, that substance was considerably used as a fuel; it is still sometimes used for heating purposes, being injected in the liquid state into furnaces as was described for tar; and is also used for driving explosion motors. Heavy coal-tar oil also finds some application as a fuel.

The introduction of the Diesel engine has opened up a new and important use for heavy oils. The great success with which the Diesel engine has already met is due partly to its simplicity and economy, and partly to its adaptability for using many kinds of liquid fuel. Although most kinds of crude oil are applicable, it is preferable partially to refine the fuel before use. It has been shown that mineral oils freed from benzene, lignite tar oils, and animal or vegetable fat oils, can always be used as fuel; but that coal-tar oil, and also vertical retort, water gas, oil gas, and coke-oven tars may be used only with the aid of special apparatus. Tars from horizontal or inclined retorts cannot be used. The following specifications for coal tar or tar oil for Diesel engines are given by Rath and Rossenbeck (Zeit. Ver. deutsch. Ingen. 1913, page 1490):—

1. Tar oils must not contain more than 0·2 per cent of solids insoluble in xylol, nor more than 0·05 per cent of incombustible matter.
2. Water must not exceed 1 per cent.
3. The residue on coking must not be greater than 3 per cent.
4. At least 60 per cent by volume of the oil must distil over below 300°C.
5. The lower calorific value must not be less than 8,800 Cals. per kilogram.
6. The flash point must not be below 65°C.
7. The oil must be quite fluid at 15°C., and must not deposit solids on standing for half an hour at 8°C.

In Canada petroleum products for power production (gasoline and heavy oil) are much cheaper than in most European countries; so that benzol and other coal-tar distillates cannot readily compete with petroleum products as fuels in this country.

Detergents and Solvents.

The more volatile distillates from coal tar are important solvents. Benzol is used as a solvent in the colour industry; and, owing to its solvent action on fatty matters, it is used either alone or mixed with alcohol for cleaning fabrics. Petroleum "benzin" is also largely used for the latter purpose. Solvent naphtha, which is composed of the slightly higher boiling distillates, finds application in the manufacture of waterproof fabrics, where it is used to dissolve the india-rubber. Naphtha is the best solvent for anthracene, and is widely used in the manufacture of that substance.

Colour Industry.

The most important application of the various distillation products of coal tar is in the colour industry. Many of the purified first products are the parent substances of numerous important dyes. Benzene, on nitration, forms nitrobenzene, from which aniline is readily obtained by reduction, and this, in turn, is the most important material used in making the long list of aniline dyes. Naphthalene on oxidation gives phthalic acid, which is used in the preparation of fluorescein, of the eosin dyes, as well as of anthranilic acid, which is necessary for the production of artificial indigo. Anthracene on oxidation forms anthraquinone, which is the parent substance of the widely used alizarin dyes.

It would be a difficult matter, and probably an unprofitable one, to attempt at present to form a coal-tar dye industry in Canada. The manufacture of colours is so closely connected with the manufacture of all kinds of other chemicals—inorganic as well as organic—that it would be practically impossible to found the industry; furthermore, there is no one dye which is sold in very large quantities, so that any firm which began to manufacture colours would have to be in a position to make, in comparatively small quantities, several hundred different dyes. It is the popular idea that the coal-tar dye industry is a huge one, and that it constitutes a high percentage of the trade with Germany. The trade of the United States is divided in the census into various branches, one of which is "Chemical and Allied Products;" this division includes nine separate subdivisions, one of which is called "Dyestuffs and Extracts."

The imports under the latter subdivision constitute only 3·8 per cent of the imports of the whole division; of this amount only 27·8 per cent comes under the heading "Artificial Dyestuffs" and "Extracts for Dyeing." It will be seen, therefore, that, in the United States at any rate, the total trade in coal-tar dyes is, in reality, a comparatively small one. Canada imported during the year 1913-14, aniline and coal-tar dyes to the value of $469,050, of which $223,871 was paid to Germany, and $174,531 to the United States.

In confirmation of the above statement that it is at present impracticable to found a coal-tar dye industry in Canada, the following paragraphs are quoted from an interview with Dr. Bernhard C. Hesse, of New York, published in the September 1914 issue of the "Metallurgical and Chemical Engineering." Although his statements refer to conditions in the United States, yet his remarks are well worth consideration, as it is quite evident that, to an even greater extent, the difficulties he mentions would arise, should an attempt be made to found such an industry in Canada.

> In the coal-tar industry the following three divisions may be made for convenience and clarity:—
>
> 1. Products from coal tar by distillation, expression, and like operations.
> 2. Products obtained from 1 by chemical transformation, but not themselves dyes.
> 3. Dyes made from 2.
>
> The key to the situation lies in division 2, and in this Germany controls the world's market. This control is due to the facts, that, while the growth of this division was relatively slow, yet the field has become very much interwoven, each of its hundred or more products being dependent upon or made up of one or more other products, so that no one of them is of use without still others; and that the industrial and commercial conditions or relations have grown with the technical development so that the coal-tar dye industry is really a conglomerate of many separate parts acting and reacting upon each other, commercially and industrially. Not a single one of the 22 factories in Germany is wholly independent of other factories in Germany, whereas together they are independent of sources outside of Germany, or can very readily be so should occasion arise. It would not do merely to transplant even the largest German works to this country; a part of probably each German works would be necessary to produce here or anywhere a complete

and self-contained industry. Such a transplanting of the coal-tar dye industry would be comparable to an attempt to transplant to this country *every single branch* of, say, the textile industry or any other highly ramified and diversified art.

Germany's supremacy in this field has been for more than 30 years a standing challenge not only to the chemists and capitalists of the United States, but to the chemists and capitalists of all the rest of the world as well. Except Switzerland, no country has succeeded in selling to Germany more coal-tar dyes than it buys from Germany, but all of them *without exception* buy more of intermediate products, i.e., division 2, from Germany than they sell to Germany.

There is another side to this, namely, the investor's side. A self-contained and complete coal-tar dye industry in this country would to-day call for preparedness to make about 700 different dyes. In the fiscal year 1913-1914 this country imported indigo to the extent of $1,093,226, alizarin to the extent of $845,459, both of which are without tariff protection, $7,464,134 worth of aniline dyes with a duty of 30 per cent, and aniline oil with a duty of 10 per cent. This means 700 different aniline dyes would average a gross annual income each of about $10,000. To introduce 700 different sets of operations, and perhaps half that many different sets of apparatus, *at one time*, to produce on the average for each set of operations a gross of $35 per day, can hardly be regarded as an attractive proposition when the initial lump gross outlay would be not less than $5,000,000 actual cash. Each of these 700 products requires good manufacture from the start, because good qualities of each are already on the market. It is one thing to grow and develop such an industry or art and to maintain it against newcomers, but it is quite a different thing to build it up afresh in its entirety in the face of competition, and to hold it against those who developed the business, know all its ins and outs, have their experience and plant bought, paid for, and written off, long ago. It could hardly be expected that, if successful, this industry would employ as many as 7,000 people all told, and the gross makes out less than 0·4 per cent of our total import business.

With unlimited and immediately available capital the American chemist can build up such a complete industry, but the dividends would be a long way off. Capitalists, American or otherwise, do not take kindly to such handicaps or obstacles, and justly so.

The truth seems to be that the whole of this industry cannot be successfully transplanted, and attempts to transplant part only have not resulted in any self-contained and independent industry anywhere, but in an industry the real roots of which are still in German soil; even if it could be transplanted as a whole, the net result would not be commensurate with the expense, effort, and risk connected with it. What portion or part, if any, or what equivalent of a complete and self-contained industry for all the domestic needs of this country could ultimately be transplanted here, is a problem that has had the serious attention of competent chemists and capitalists in this country for many years, without a definite or satisfactory answer thereto having been arrived at. Whether the present conditions will contribute to a solution of the problem cannot be decided out of hand; the first impression certainly is that they will *not* so contribute.

CANADIAN TRADE STATISTICS.

Some statistics have already been given in the text; but, in order to group together figures in a more convenient form, the following tables (compiled from Mineral Production of Canada, 1913, by J. McLeish, Mines Branch, Ottawa; from Trade and Navigation Unrevised Monthly Statements of Imports Entered for Consumption, March, 1914; and from Weekly Report, No. 554, Department of Trade and Commerce, Canada) have been arranged for products mentioned in this report, and also for products which compete with, or have any bearing upon them:—

TABLE VI.

Canadian Production, Exports, and Imports For Calendar Years 1912 and 1913.

Article.	Production.		Exports.		Imports.	
	Quantity. Short tons.	Value. $	Quantity. Short tons.	Value. $	Quantity. Short tons.	Value. $
Coal:—						
1912	14,512,829	36,019,044	2,127,133	5,821,593	14,595,810	39,478,037
1913	15,115,089	36,250,311	1,562,020	3,961,351	18,201,953	47,949,119
Coke:—						
Output 1912	1,406,028	....	57,744	252,763	628,174	1,702,856
Output 1913	1,517,133	....	68,235	308,410	723,906	2,180,830
Sold, or used by producers 1912	1,411,229	5,164,331				
Sold, or used by producers 1913	1,530,499	5,547,694				
By-products from coke ovens, 1913:—						
Gas (thousand cubic feet)	3,353,731	866,150				
Tar (galls.)	8,371,600					
Ammonium sulphate (tons)	10,608					
By-products from gas works, 1913:—						
Tar (estimated galls.)	5,000,000[1]					
Petroleum:—						
1912 (galls.)	8,516,762	345,050	....	....	....	11,978,053
1913 (galls.)	7,982,798	406,439	45,798	7,851	....	13,339,326

[1] Figure supplied by A. Hewitt, Consumers' Gas Company, Toronto.

TABLE VII.

Canadian Imports.

Articles and countries whence imported.	Twelve months ending March, 1914.		
	Quantity.	Value in dollars.	Tariff.
Coal, anthracite, and anthracite dust:—	Tons		
From G. Britain	33,909	149,529	Free
U. States	4,351,833	20,584,198	"
Other countries	57	399	"
Coal, bituminous slack such as will pass through a ¾″ screen:—			
From G. Britain	1,711	3,935	General
U. States	2,934,286	4,296,010	"
Coal, bituminous, round, and run of the mine—and coal N.O.P:—			
From G. Britain	964	3,478	General
"	711	2,412	Preferential
U. States	10,798,271	21,768,147	General
Other countries	18,301	66,694	"
Coke:—			
From G. Britain	337	2,199	Free
U. States	708,440	2,058,715	"
Coal and pine tar, crude, in packages of not less than 15 gallons:—	Galls.		
From G. Britain	18,684	881	Free
U. States	2,625,731	112,309	"
Other countries	2,375	622	"
Coal and pine pitch:—			
From G. Britain	127,670	6,509	Free
U. States	1,329,889	74,733	"
Other countries	20	7	"
Asphaltum or asphalt, solid:—	Cwts.		
From G. Britain	15,598	15,412	Free
U. States	715,716	601,960	"
Mexico	246,676	159,073	"
Germany	17,521	9,259	"
Other countries	74,843	47,918	"

TABLE VII.—*Continued.*

Articles and countries whence imported.	Twelve months ending March, 1914.		Tariff.
	Quantity.	Value in dollars.	
Asphalt, not solid:—			
From G. Britain............		39	Preferential
U. States.............		33,318	General
Asphaltum oil:—			
From U. States.............		28,087	Free
Carbolic or heavy oil:—	Galls.		
From G. Britain............	329,639	57,414	Free
U. States.............	683,117	53,599	"
Other countries	9,441	3,307	"
Dyeing or tanning articles in a crude state used in dyeing or tanning, N.O.P.:—	Lbs.		
From G.Britain.............	309,590	13,705	Free
U. States.............	7,852,591	143,299	"
Germany.............	147,356	5,559	"
Other countries	38,482	1,712	"
Aniline oil, crude:—			
From G. Britain............	54,410	5,677	Free
U. States.............	27,240	2,961	"
Other countries	15,000	2,664	"
Aniline salts:—			
From G. Britain............	131,444	10,035	Free
U. States.............	4,360	625	"
Aniline and coal-tar dyes, soluble in water, in bulk or packages of not less than 1 lb. weight, including alizarin and artificial alizarin:—			
From G. Britain............	191,516	37,840	Free
U. States.............	563,375	174,531	"
Germany.............	1,354,928	223,871	"
Switzerland...........	128,785	32,553	"
Other countries	1,691	255	"

TABLE VII.—*Continued.*

Articles and countries whence imported.	Twelve months ending March, 1914.		Tariff.
	Quantity.	Value in dollars.	
Aniline dyes in packages of less than 1 lb. weight:—	Lbs.		
From G. Britain	1,300	206	General
"	480	52	Preferential
U. States	875	334	General
Other countries	50	15	"
Coal-tar base or salt (paranitraniline):—			
From U. States	16,166	2,316	Free
Other countries	21,645	3,081	"
Indigo:—			
From U. States	3,608	1,414	Free
Indigo, paste and extract of:—			
From G. Britain	1,265	90	Free
U. States	20,479	3,170	"
Germany	125,990	20,388	"
Ammonia, sulphate of:—			
From G. Britain	273,206	7,757	Free
U. States	77,131	2,944	"
Other countries	1,094	148	"
Fertilizers unmanufactured, N.O.P.:—			
From G. Britain		5	Free
U. States		996	"
Other countries		2,072	"
Saltpetre or nitrate of potash:—			
From G.Britain	146,611	7,610	Free
U. States	1,002,317	51,556	"
Germany	560,700	25,708	"
Soda, nitrate of, or cubic nitre:—			
From G.Britain	480,966	12,719	Free
U. States	35,898,258	826,277	"
Chili	43,578,050	767,265	"
Germany	229,774	8,568	"
Other countries	75,133	3,547	"

TABLE VII.—*Continued.*

Articles and countries whence imported.	Twelve months ending March, 1914.		Tariff.
	Quantity.	Value in dollars.	
Acid nitric:—	Lbs.		
From G. Britain	8,480	497	Preferential
U. States	254,196	13,610	General.
Ammonia, nitrate of:—			
From G. Britain	114,545	6,502	Free
U. States	268,186	17,982	"
Norway	340,886	19,973	"
Germany	180,576	9,645	"
Other countries	1,667,851	93,888	"
Nitrate compound, adapted for use in the manufacture of explosives:—			
From U. States	4,800	300	Free
Blasting and mining powder:—			
From G. Britain	280,200	28,294	Preferential
U. States	54,330	3,732	General
Giant powder, nitro, nitroglycerine, and other explosives, N.O.P.:—			
From G. Britain	56,696	37,151	Preferential
U. States	273,882	52,856	General
Salammoniac:—			
From G. Britain	378,767	20,670	Free
U. States	68,573	4,147	"
Germany	297,069	14,834	"
Other countries	40,363	1,891	"
Cyanide of potassium, cyanide of sodium, cyanogen bromide for reducing metals in mining operations:—			
From G. Britain	685,068	100,706	Free
U. States	928,707	142,997	"
Germany	1,715	204	"

TABLE VII.—*Continued.*

Articles and countries whence imported.	Twelve months ending March, 1914.		Tariff.
	Quantity.	Value in dollars.	
Potash, red and yellow prussiate of:—	Lbs.		
From G. Britain............	52,098	5,969	Free
U. States............	5,997	908	"
Germany............	59,109	7,259	"
Other countries	49,697	5,886	"
Soda, prussiate and sulphite of:—			
From G. Britain............	42,415	3,711	Free
U. States............	79,942	4,246	"
Other countries	33,495	2,907	"
Gasoline under 0·725 specific gravity at 60 degrees temperature:—	Galls.		
From U. States............	27,451,397	4,466,986	Free
Petroleum, crude, fuel and gas oils (0·8235 specific gravity or heavier at 60 degrees temperature):—			
From U. States............	177,879,835	5,994,318	Free
Petroleum, crude, gas oils other than naphtha, benzene and gasoline, lighter than 0·8235 but not less than 0·775 specific gravity at 60 degrees:—			
From U. States............	45,853	4,903	General
Coal oil and kerosene, distilled purified or refined:—			
From G. Britain............	175	33	General
U. States............	19,278,099	1,350,502	"
Other countries	2,205	563	"
Illuminating oils composed wholly or in part of the products of petroleum, coal shale or lignite, costing more than 30 cents per gallon:—			
From G. Britain............	1,611	787	Preferential
U. States............	165,766	65,427	General
Other countries	913	510	"

TABLE VII—*Continued.*

Articles and countries whence imported.	Twelve months ending March, 1914.		Tariff.
	Quantity.	Value in dollars.	
Lubricating oils composed wholly or in part of petroleum and costing less than 25 cents per gallon:—	Galls.		
From G. Britain............	2,853	643	General
"	10,388	2,369	Preferential
U. States.............	5,134,973	707,811	General
Other countries	8,520	1,985	"
Lubricating oils, N.O.P.:—			
From G. Britain............	8,967	3,062	General
"	105,496	36,444	Preferential
U. States.............	991,316	333,584	General
Other countries	6,804	3,580	"
Petroleum, products of, N.O.P.:—			
From G. Britain............	26,819	6,740	Preferential
U. States.............	5,138,909	618,506	General
Other countries	546	121	"

NOTE.—N.O.P. signifies "not otherwise provided for."

CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS.

1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.d., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

5. On the location and examination magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba: manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11. Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. *Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

* A few copies of the Preliminary Report, 1906, are still available.
† Publications marked thus † are out of print.

†18. Graphite: its properties, occurrence, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposit of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

21. Summary report of Mines Branch, 1907–8.

22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side)and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907–8.

25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D. (Out of print.)

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a. The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908. Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep, Peat Expert.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by W. R. Ells, LL.D.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907-8.*

†31. Production of cement in Canada, 1908.

42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories at the Department of Mines, 1906-7-8. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analysis of oil-shales—by H. A. Leverin, Ch. E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron ore deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs, and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled 'A solution of the peat problem,' 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second edition, enlarged.)

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

† Publications marked thus † are out of print.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
    Vol. I—Coal washing and cooking tests.
    Vol. II—Boiler and gas producer tests.
    Vol. III—(Out of print.)
        Appendix I
            Coal washing tests and diagrams.
    Vol. IV—
        Appendix II
            Boiler tests and diagrams.
    Vol. V—(Out of print.)
        Appendix III
            Producer tests and diagrams.
    Vol. VI—
        Appendix IV
            Coking tests.
        Appendix V
            Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

†79. Production of iron and steel in Canada during the calendar year 1909.
†80. Production of coal and coke in Canada during the calendar year 1909.
85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

90. Proceedings of conference on explosives.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Second edition.)

93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911; containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Fréchette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

NOTE. *The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of cement, lime, clay products, stone, and other materials in Canada, 1910.
†115. Production of iron and steel in Canada during the calendar year 1910.
†116. Production of coal and coke in Canada during the calendar year 1910.
†117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

154. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa. 1910-11. Report on—by B. F. Haanel, B.Sc.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201. The mineral production of Canada during the calendar year 1911. —Annual report on—by John McLeish, B.A.

† Publications marked thus † are out of print.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.
†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.
183. General summary of the mineral production in Canada during, the calendar year 1911. Bulletin on—by John McLeish, B.A.
†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.
†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, PhD.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224.)

230. Ecomomic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.

257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.

†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. v. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
Vol. I.—Technology and Exploitation.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

320. The mineral production of Canada during the calendar year 1913. Annual report on—by John McLeish, B.A.

Note.—*The following parts were separately printed and issued in advance of the Annual Report for 1913.*

315. The production of iron and steel during the calendar year 1913. Bulletin on—by John McLeish, B.A.

316. The production of coal and coke during the calendar year 1913. Bulletin on—by John McLeish, B.A.

317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.

† Publications marked thus † are out of print.

318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. Bulletin on—by John McLeish, B.A.

319. General summary of the mineral production of Canada during the calendar year 1913. Bulletin on—by John McLeish, B.A.

322. Economic minerals and mining industries of Canada. (Revised Edition).

323. The Products and by-products of coal. Report on—by Edgar Stansfield, M.Sc., and F. E. Carter, B.Sc., Dr. Ing.

336. Notes on clay deposits near McMurray, Alberta. Bulletin No. 10—by S. C. Ells, B.A., B.Sc.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, Coal mines, Stone quarry operators, Manufacturers of clay products, and Manufacturers of lime; copies of the lists may be obtained on application.

IN THE PRESS.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
    Vol. II.—Occurrence of petroleum and natural gas in Canada.
    Also separates of Vol. II, as follows:—
        Part I, Eastern Canada.
        Part II, Western Canada.

325. The salt industry of Canada. Report on—by L. H. Cole, B.Sc.

331. The investigation of six samples of Alberta lignites. Report on—by B. F. Haanel, B.Sc., and John Blizard, B.Sc.

334. Electro-plating with cobalt and its alloys. Report on—by H. T. Kalmus, B.Sc., Ph.D.

338. Coals of Canada: Vol. VII. Weathering of Coal. Report on—by J. B. Porter, E.M., D.Sc., Ph.D.

344. Electrothermic Smelting of Iron Ores in Sweden. Report on—by Alfred Stansfield, D.Sc., A.R.S.M., F.R.S.C.

FRENCH TRANSLATIONS.

†4. Rapport de la Commission nommée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrence, exploitation, dressing, and uses. Report on—by A. W. C. Wilson, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910-11. Bulletin No. 8—by A. v. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

196. Investigation of the peat bogs and peat industry of Canada, 1909-10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. v. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. v. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

† Publications marked thus † are out of print.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

231. Ecomomic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma. E., and others—
 Vol. I—Coal washing and coking tests.

IN THE PRESS.

179. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others—
  Vol. II—Boiler and gas producer tests.
  Vol. III—
    Appendix I
      Coal washing tests and diagrams.
  Vol. IV—
    Appendix II
      Boiler tests and diagrams.

314. Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

MAPS.

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905. (See Map No. 186.)

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1905.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howellts Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12, concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. v. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

†41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nystrom and A. v. Anrep. (Accompanying report No. 30.)

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

*49. Magnetometric survey of Western Steel Iron claim, at Sechart, Vancouver island, B.C.—By E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47).

*53. Iron ore occurrences, Ottawa and Pontiac counties, Quebec, 1908—by J. White and Fritz Cirkel. (Accompanying report No. 23.)

*54. Iron ore occrurences, Argenteuil county, Quebec, 1908—by Fritz Cirkel. (Accompanying report No. 23.) (Out of print.)

*57. The productive chrome iron ore district of Quebec—by Fritz Cirkel. (Accompanying report No. 29.)

†60. Magnetometric survey of the Bristol mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†61. Topographical map of Bristal mine, Pontiac county, Quebec—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 67.)

†64. Index map of Nova Scotia: Gypsum—by W. F. Jennison.
†65. Index map of New Brunswick: Gypsum—by W. F. Jennison.
†66. Map of Magdalen islands: Gypsum—by W. F. Jennison.
(Accompanying report No. 84.)

†70. Magnetometric survey of Northeast Arm iron range, Lake Timagami, Nipissing district, Ontario—by E. Lindeman. Scale 200 feet to 1 inch. (Accompanying report No. 63.)

†72. Brunner peat bog, Ontario—by A. v. Anrep.
†73. Komako peat bog, Ontario—by A. v. Anrep.
†74. Brockville peat bog, Ontario—by A. v. Anrep
†75. Rondeau peat bog, Ontario—by A. v. Anrep.
†76. Alfred peat bog, Ontario—by A. v. Anrep.
†77. Alfred peat bog, Ontario: main ditch profile—by A. v. Anrep.
(Accompanying report No. 71.)
(Out of print.)

†78. Map of asbestos region, Province of Quebec, 1910—by Fritz Cirkel. Scale 1 mile to 1 inch. (Accompanying report No. 69.)

†94. Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts—by L. H. Cole. (Accompanying Summary report, 1910.)

†95. General map of Canada, showing coal fields. (Accompanying report No. 83—by Dr. J. B. Porter.)

†96. General map of coal fields of Nova Scotia and New Brunswick. (Accompanying report No. 83—By Dr. J. B. Porter.)

†97. General map showing coal fields in Alberta, Saskatchewan, and Manitoba. (Accompanying report No. 83—by Dr. J. B. Porter).

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†98. General map of coal fields in British Columbia. Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological map of Austin Brook iron bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Brook iron bearing district—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog Ontario—by A. v. Anrep. (Accompanying report No. 151.)

*119–137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron bearing district, Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110).

†146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†152. Map showing the location of peat bogs investigated in Ontario—by A. v. Anrep.

†153. Map showing the location of peat bog as investigated in Manitoba—by A. v. Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. v. Anrep.

†158. Transmission peat bog, Manitoba—by A. v. Anrep.

†159. Corduroy peat bog, Manitoba—by A. v. Anrep.

†160. Boggy Creek peat bog, Manitoba—by A. v. Anrep.

†161. Rice Lake peat bog, Manitoba—by A. v. Anrep.

†162. Mud Lake peat bog, Manitoba—by A. v. Anrep.

†163. Litter peat bog, Manitoba—by A. v. Anrep.

†164. Julius peat litter bog, Manitoba—by A. v. Anrep.

*165. Fort Francis peat bog, Ontario—by A. v. Anrep.

(Accompanying report No. 151.)

†166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mine to 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman.

†173. “ Crean Hill mine—by Prof. A. P. Coleman

†174. “ Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.)

†175. “ showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. “ Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. “ No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. “ showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits' Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 194.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean (Accompanying report No. 222.)

†221. Dawson mining district, Yukon, Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 345.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

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†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bots investigated in Quebec—by A.v. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec “ “

†270. Small Tea Field peat bog, Quebec “ “

†271. Lanoraie peat bog, Quebec “ “

†272. St. Hyacinthe peat bog, Quebec “ “

†273. Rivère du Loup peat bog “

†274. Cacouna peat bog “ “

†275. Le Parc peat bog, Qebec “ “

†276. St. Denis peat bog, Quebec “ “

†277. Rivière Ouelle peat bog, Quebec “ “

†278. Moose Mountain peat bog, Quebec “ “

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch. (Accompanying report No. 291.)

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

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†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by E. Lindeman, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

Address all communications to—

DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA.

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