CHAPTER IX

MARKETS

The purpose of this chapter is to review the market for coal in Canada, indicating how much coal is used, what kind of coal it is, and by whom and for what purpose it is used. An attempt has been made to examine any trends in the market that are considered to be of importance.

As is so often the case with Canadian affairs, the analysis of the coal market in Canada can best be handled if it is approached on a regional basis. For this reason we have attempted not one review but four—one for the Maritime Provinces, one for Ontario and Quebec, one for the Prairie Provinces and one for British Columbia. In each case the movement of coal from one region into another has been dealt with in the region in which it was consumed. Coal exported to other countries has been dealt with in the region in which it was produced.

The general method has been to examine, one region at a time, the use of coal for domestic purposes, by industry, by coke and gas plants, by railroads and for ships' bunkering. In order to achieve this treatment, a considerable amount of preliminary work of a statistical nature was required. Fortunately, in recent years the Dominion Bureau of Statistics has collected for the use of the Office of the Coal Controller a great deal of information on the coal consumption in Canada. This material has been made available to the Commission and from it tables of coal consumption by region, by source and kind of coal, and by type of consumer, have been prepared. Those tables, with explanatory notes, are presented in Appendix D. This Chapter has been planned to be read without reference to those tables, but attention is called to them because they are the immediate source of most of the figures used in the chapter and because they may be of assistance as reference material to anyone who wishes to pursue market analysis in a different way or to carry it further.

The statistics available on coal consumption do not show separately the use of coal for domestic purposes, that is, its use in dwellings for cooking, water heating and space heating. They do, however, show separately retail sales of coal, that is, all sales of coal at retail prices. The great bulk of coal sold at retail prices is used for domestic heating purposes, and in this chapter figures on retail sales are used as though they were figures on domestic consumption. This procedure involves some error, for retail sales include sales to small commercial and industrial establishments for uses not properly referred to as domestic.

Throughout the following sections no overall forecasts of coal consumption are made. There are a few attempts to forecast the coal requirements for some specific purposes, but such attempts are the exception rather than the rule. The reason for the absence of general forecasts is, of course, that prophesying about coal consumption is a very hazardous thing to do. Over the past twenty years coal consumption has fluctuated within wide limits and it is by no means certain that it will not continue to do so. In the preceding chapter the relationship between coal consumption and the level of industrial activity over the past two decades was examined. The closeness of that relationship makes it clear that a forecast of coal consumption is, in effect, a forecast of the level of industrial activity, a forecast we are not equipped to undertake.

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THE MARITIME MARKET

In this section the market for coal in the provinces of New Brunswick, Nova Scotia and Prince Edward Island will be examined. Because of special problems peculiar to the marketing of coal mined in New Brunswick, there follows at the end of the general discussion a special examination of the market for New Brunswick coal.

The Maritime area relies more heavily on coal for its energy than does any other of the areas into which Canada has been divided for purposes of market analysis. It is estimated that in recent years coal supplied nearly three-quarters of the energy obtained from all sources, with the other quarter coming in more or less equal amounts from water power, petroleum and wood fuel. This general statement should be qualified by noting that the relative importance of petroleum increased considerably during the war years, mainly at the expense of coal. There is some natural gas used in Moncton and vicinity but the amounts are so small that they are almost insignificant in the over-all energy picture.

Production

The Maritime region is one of the principal coal-producing areas in Canada, with an annual output in the neighbourhood of 7,000,000 tons. The coal produced is almost all high volatile bituminous. The bulk of the production is on Cape Breton Island but there are important producing areas on the mainland of Nova Scotia in Cumberland County and Pictou County and in New Brunswick in the area around Minto.

COAL CONSUMPTION IN THE MARITIMES

(In net tons)

—	1937	1939	1940	1943
Retail Sales	1,148,000	1,179,000	1,324,000	1,403,000
Industry, including coke and gas plants	2,142,000	1,878,000	2,326,000	2,498,000
Railways	729,000	679,000	917,000	1,339,000
Bunkers	387,000	426,000	530,000	600,000
Total	4,406,000	4,162,000	5,097,000	5,840,000

The Retail Market

According to the 1941 Housing Census, the principal fuel for domestic heating in each province of the Maritimes was wood, which was used in 61 per cent of all Maritime dwellings. Coal and coke were the heating fuels used in only 37 per cent of Maritime dwellings. The use of wood was concentrated in the rural areas, with coal predominant in the urban areas. Relatively small amounts of fuel oil, and in New Brunswick some gas, were also used.

The following table gives a summary of retail sales of coal and coke in the Maritimes. The figures include sales of coal and coke by collieries to their employees and others for domestic use.

RETAIL SALES OF COAL AND COKE IN THE MARITIMES

(In net tons)

—	1937	1939	1940	1943
Anthracite	142,000	136,000	137,000	141,000
Other Coal	1,006,000	1,043,000	1,187,000	1,262,000
of which Imported	*51,000*	*40,000*	*37,000*	*12,000*
Coke	60,000	54,000	63,000	95,000
Total	1,208,000	1,233,000	1,387,000	1,498,000

Speaking generally, the coals produced in the Maritimes are not entirely suitable for use in hand-fired natural-draft domestic heating equipment. Although there is some medium volatile coal produced locally, most of the production is high volatile which, in the process of combustion, produces a considerable volume of volatile gases. Unless particular care is taken in the firing of hand-fired natural-draft equipment, the volatile gases produced will not be completely burned in the combustion chamber and a good deal of smoke and soot will result. It is this disadvantage of the local coals that accounts for the use of anthracite and imported bituminous by householders in the Maritimes. In total, the consumption of these imported domestic fuels was about 175,000 tons annually in the pre-war years, of which more than one-half was United Kingdom anthracite. The imported fuels were more expensive than local coals and the use of them was therefore restricted to those willing and able to pay a premium in order to enjoy the benefits of their superior burning characteristics.

Before the war the retail sales of Canadian bituminous coal were about 900,000 to 1,000,000 tons per year, of which approximately three-quarters were sold in Nova Scotia. About three-quarters of the Canadian bituminous sales were of sizes suitable for natural-draft equipment. Nearly all of the mines operating in the Maritimes delivered some coal to the retail market, but the variation in suitability of the output of the various mines for domestic use has resulted in some producers capturing much more than a proportionate share of that market. This appears to have been particularly true of the Springhill operation in Cumberland County and Old Sydney Collieries in Cape Breton, the output of the former being preferred because of its lower volatility and somewhat higher ash fusion temperature and that of the latter because of a lower ash content and a firmer structure than other Nova Scotia coals.

The disadvantages of a high volatile coal for domestic use are overcome by the use of underfeed stokers. There is in the Maritimes a considerable market for stoker coal and several operators have been specially sizing and at least one has been oil treating fuel for domestic stoker use.

Coke is a relatively unimportant domestic fuel in the Maritimes; in pre-war years only about 60,000 tons were consumed annually, most of it in Nova Scotia. Practically all the coke used was made from Canadian coal. The main source of the coke sold retail is the Dominion Steel & Coal Corporation plant at Sydney, although small tonnages come from the Nova Scotia Light and Power Company plant at Halifax and the New Brunswick Power Company plant at Saint John. Although the Dominion Fuel Act of 1927 was intended to encourage the construction of coke and gas plants in Ontario and Quebec rather than the Maritimes, the Halifax plant qualified under it and to the end of 1944 had received federal assistance to the extent of $117,000.

THE INDUSTRIAL AND COKE AND GAS MARKETS

The following table gives the consumption of coal by industry in the Maritimes:

COAL CONSUMPTION BY INDUSTRY IN THE MARITIMES INCLUDING USE IN COKE AND GAS PLANTS

(In net tons)

—	1937	1939	1940	1943
United Kingdom anthracite	1,000	1,000	1,000	Nil
United States bituminous	2,000	2,000	2,000	22,000
Canadian bituminous	2,139,000	1,875,000	2,323,000	2,476,000
of which used in coke and gas plants	*700,000*	*644,000*	*927,000*	*856,000*
Total	2,142,000	1,878,000	2,326,000	2,498,000

From the above figures it is clear that there is no significant use of imported coal by Maritime industry.

In order to indicate the relative importance of various industrial consumers, the following approximate breakdown of the industrial totals for 1937 and 1943 is presented:

—	1937	1943
	Net Tons	Net Tons
Use of coal in iron and steel industry by Dominion Steel and Coal Corp. and affiliates	875,000	1,220,000
Colliery use, excluding deliveries to colliery employees	400,000	315,000
Central electric station industry	215,000	300,000
Wood and paper industry	345,000	405,000
Other industrial use	307,000	258,000
Total industrial use of coal	2,142,000	2,498,000

The iron and steel industry is by far the largest industrial consumer of coal in the Maritimes. The major operations in that industry are those of Dominion Steel and Coal Corporation Limited, and over a number of years the steel operations of that corporation have used about 20 per cent of the coal produced by mines affiliated with it. The steel industry generally is very vulnerable to the cycle of economic prosperity and depression, and the Nova Scotia industry is no exception. The coal requirements of the Dominion Steel and Coal Corporation's steel operations have varied from about 160,000 net tons in 1932 to 1,325,000 tons in 1942. The pronounced instability of so important a market constitutes one of the most serious marketing problems of the Nova Scotia coal industry.

About four-fifths of the coal used by the Sydney Steel Plant is slack, the remainder being screened lump and run-of-mine. The slack is used chiefly for making metallurgical coke, the screened coal for gas production for open-hearth furnaces, and the run-of-mine coal for general steam raising purposes. It was the availability of large quantities of slack at low prices that led to the establishment of the steel plant at Sydney in 1899. The outlet provided by the steel plant since that time for enormous quantities of slack has been of tremendous importance to the coal operation, for the slack would otherwise have been extremely difficult to market. In addition, the steel plant provided an all-year-round market for coal, which is important in view of the suspension of water-borne shipments during winter months.

The second largest outlet for coal is the operation of the collieries themselves. Normally, the Maritime collieries use between 300,000 tons and 400,000 tons annually, most of it under boilers. In Nova Scotia, and particularly in Cape Breton, a substantial portion of the steam raised in collieries is used for the generation of electricity. The Dominion Steel and Coal Corporation owns and operates over 70,000 kilowatts of generating capacity in the Cape Breton and New Glasgow areas, of which about 85 per cent of the net output is used in the coal and steel operations of the Corporation. Most of the electricity generating plants owned by the Corporation have been designed to use slack, which would otherwise be without a ready market, and the outlet thus provided for upwards of 150,000 tons per year makes an important contribution to the over-all efficiency of the mining operations.

In addition to coal used by companies for the generation of electricity for their own purposes, the central electric station industry in the Maritimes uses 200,000 tons or more annually for the generation of electricity for public sale. The main source of central electric station electricity in the Maritimes is water power; in fact, in 1943 only 35 per cent of the total central station output in Nova Scotia, and 22 per cent in New Brunswick was thermally generated. The water power resources of the Maritime Provinces are, however, limited. The recent report by H. G. Acres and Company to the Federal Department of Mines and Resources on the possibility of using tidal power in the Petitcodiac and Memramcook estuaries, indicates that that source of energy is not likely to be of practical importance. Prince Edward Island is, of course, too small to have any rivers suitable for hydro developments. The rivers of Nova Scotia do not provide either sufficient head or a sufficient volume of controllable flow to make any further hydro developments in that province very attractive. In New Brunswick the water power possibilities of the St. John River and its tributaries are by no means exhausted, but further use of them will depend primarily on successful action being taken to control the flow in that drainage system. It so happens that the areas in which control measures must be taken are mainly in the State of Maine and in the Province of Quebec, making interprovincial and international agreements necessary before adequate action to that end can be undertaken. The New Brunswick Natural Resources Development Board is pressing for such action in the belief that only by developing her water power resources can New Brunswick obtain the large sources of cheap electricity which she needs so badly. However, it is by no means certain that all the required expansion of electricity output will be obtained from water power developments, and it appears probable that the central electric station demand for coal in that province will continue to expand.

The only other important industrial user of coal in the Maritimes is the wood and paper industry, which uses upwards of 350,000 tons annually, mainly in pulp and paper plants. This industry provides an inportant outlet for both New Brunswick and Nova Scotia coal.

The Railway Market

In pre-war years bituminous coal requirements of all railways in the Maritimes ran at about 700,000 tons per annum. The Maritime requirements amounted to about 10 per cent of total railway requirements in Canada. Normally, no significant amounts of imported coal were used by railways in the area.

The following table gives details of railway uses of bituminous coal for the various years:

BITUMINOUS COAL CONSUMPTION OF ALL RAILWAYS IN THE MARITIMES

(In net tons)

—	1930	1933	1937	1940	1943
Canadian coal	808,000	574,000	728,000	916,000	1,282,000
Imported coal	32,000	Nil	1,000	1,000	57,000
Total	840,000	574,000	729,000	917,000	1,339,000

The Canadian National Railways is, of course, the principal coal consuming railway in the Maritimes; its requirements amounting to about 75 per cent of total railway requirements. Over the four-year period, 1936 to 1939 inclusive, the Canadian National Railways used on the average about 400,000 tons of Nova Scotia coal and about 125,000 tons of New Brunswick coal per year. Since most Maritime mines are located on or near Canadian National Railway lines, the coal is normally moved by rail to the point at which it is required. The Canadian Pacific Railway Company operates only about 25 per cent of the Maritime railway mileage, and therefore its coal requirements are much smaller than those of the Canadian National Railways. In the years 1936 to 1939 inclusive, the Company purchased just under 90,000 tons per year, of which substantially less then one-half was New Brunswick coal. Coal mined at Springhill, Nova Scotia, is used on the Dominion Atlantic Railway, a Canadian

Pacific Railway Company subsidiary. Coal mined at Minto is used exclusively on the Company's branch lines in New Brunswick, but due to its relatively low B.t.u. value and high ash content it has been found impossible to use it in main line heavy traffic operations. Therefore, the general practice has been to use Sydney coal for Canadian Pacific Railway Company main line operations in New Brunswick between Saint John and McAdam.

The Bunker Market

At one time the bunker market was of considerable importance, but in recent years it has suffered severely from competition by oil. In 1939 coal deliveries to ships' bunkers totalled 426,000 tons, while in the same year oil deliveries amounted to the equivalent of about 450,000 tons. There is a limited amount of United States and United Kingdom coal imported for bunkerage but for all practical purposes bunkerage needs are met by Cape Breton production.

The Maritime bunker market is a very uncertain one, subject to very severe contractions when ocean-borne trade declines. Not only are there then fewer ships at sea, but those at sea tend to have less than a full cargo of revenue freight and take on bunker coal to maximum capacity at ports where the lowest price prevails. Because of the high cost of production of Maritime coal, Maritime ports are not low price ports.

Despite some recent successes in improving the efficiency of coal-burning marine power equipment, it is anticipated that coal will have, in the next few years, no relief from the pressure of oil in the bunker market.

The Export Market

Over the past two decades the export market for Canadian coal from the Maritimes has been quite unstable. In 1930 exports ran at about 375,000 tons; in 1932 they fell to about 160,000 tons; in 1935 they reached nearly 300,000; and in the three pre-war years they were about 200,000. Under the impact of war they rose to over 500,000 tons per year.

The two principal destinations of exported coal have been Newfoundland and the United States. Since the end of World War I, Newfoundland has normally imported approximately 300,000 tons of coal per year from all sources, although the year to year figures have fluctuated from about 220,000 tons to about 400,000 tons. The three major suppliers of this tonnage have been Canada, the United Kingdom and the United States, with the share of the market that each enjoyed changing very substantially from year to year. In the period around 1920, Canadian bituminous exporters enjoyed almost the whole of the Newfoundland market; throughout the 1920's they held about two-thirds of that market; and from 1930 on their share fell steadily until in the pre-war years they supplied just over one-third of the coal imported by Newfoundland. The situation was greatly disturbed during World War II for Newfoundland became an important base for United Nations operations of various kinds; thus, although exports of coal from Canada to Newfoundland expanded considerably during war years, little significance can be attached to the fact.

The instability of this market for Canadian coal is due mainly to the keen competition experienced from United Kingdom coal. The United Kingdom imports a large proportion of the pulp and paper production of Newfoundland and the returning ships carry coal to Newfoundland at very favourable ocean rates. Although the steel industry in Nova Scotia secures its ore from Newfoundland, technical shipping considerations preclude the use of ships built for the ore-carrying trade from taking coal to Newfoundland.

The United States market for Maritime coal has, over the last twenty years, been in the neighbourhood of 100,000 tons annually. Since 1938 this amount has been divided between New Brunswick and Nova Scotia producers, the former exporting in the neighbourhood of 30,000 tons a year. Practically all of this coal is absorbed by paper companies of the Maine-New Brunswick border.

At one time the Nova Scotia producer enjoyed a considerable market in New England. For example, in 1902 the Dominion Coal Company had a five-year contract for the delivery of 540,000 tons annually to Everett, Massachusetts. By 1913 exports to the United States had fallen to 258,000, and during World War I the United States market for Nova Scotia coal disappeared. For more than twenty-five years the New England States have been supplied from United States sources, despite the fact that since 1934 Canadian coal has been permitted to enter United States duty free. In the light of the recent history of production costs in Nova Scotia, there is no reason to believe that the Nova Scotia producer can recapture any part of the New England market.

THE MARKET FOR NEW BRUNSWICK COAL

Production in New Brunswick

From the middle '20's to the end of 1933 output of New Brunswick mines was fairly steady at about, and usually just over, 200,000 tons. In 1933, it rose sharply to 312,000 tons, and it fluctuated between 315,000 tons and 370,000 tons up to the end of 1938. In 1939 it again rose sharply to 468,000 tons and reached the maximum ever achieved in 1940 with 547,000 tons. Production fell off slowly in 1941 and then rapidly until in 1944 only 345,000 tons were mined.

Most New Brunswick coal is classified as high volatile "A" bituminous and as such is comparable in rank with most Nova Scotia coal. In grade, however, it is much inferior, containing more ash, more sulphur and, as received, more moisture than almost all Nova Scotia coal.

The Market in New Brunswick

New Brunswick is the natural market for the output of New Brunswick mines, and over the past ten years it has always absorbed at least 85 per cent, and usually more, of New Brunswick production. Even so, since 1935 New Brunswick mines have never supplied more than 40 per cent of the province's coal requirements. Nova Scotia is the principal external source of coal used in New Brunswick, and amounts received from that source have always exceeded local production, usually by a wide margin. In addition, coal is imported from the United Kingdom and the United States. In the immediate pre-war years about 75,000 tons per year were received from Britain, and some 30,000 tons per year from the United States. Most of the coal received from both the latter sources was anthracite.

It is impossible to find any one pre-war year which is truly typical, insofar as the disposition of New Brunswick coal is concerned, for the demand for the product was changing rapidly in that period. As a basis for discussion, however, the following approximate breakdown of the use of New Brunswick coal in New Brunswick for 1939 is presented:

—	Net Tons	Percentage of all N.B. Coal used in N.B.
Purchased by railways	179,000	46
Purchased by pulp and paper industry	130,000*	33
Consumed in Grand Lake Plant of N.B. Electric Power Commission	27,000	7
Domestic and Commercial use	25,000*	6
Residual—mainly miscellaneous industrial use	31,000	8
Total	392,000	100

*Estimate.

The railways have normally been the largest consumers of New Brunswick coal. In the years before the war they took almost one-half of the New Brunswick production, which met just under one-half of their total coal requirements in the province. However, despite their increasing coal needs, since 1940 the railways have used less New Brunswick coal, until by 1943, of all coal used by the railways in New Brunswick only 14 per cent was New Brunswick coal, constituting only 28 per cent of total New Brunswick production. The chief reason for the declining railway use of New Brunswick coal has been that lump coal, which the railways normally consume, has not been available. It is significant, however, that the price differential in favour of New Brunswick coal as against Nova Scotia coal, which has previously induced the railways to use the former coal, has largely disappeared. It is, therefore, by no means certain that the railway market can be regained as and when lump coal becomes again available.

By far the largest industrial coal consumer in New Brunswick is the pulp and paper industry. Since 1940 the coal requirements of that industry have exceeded 300,000 tons per year, of which upwards of 120,000 tons has been New Brunswick coal. Much of the New Brunswick pulp and paper industry is centred around the Bay of Chaleur, an area in which the local coal received very little freight protection from Nova Scotia coal and in which, therefore, competition with Nova Scotia coal has always been very keen. The decreasing price differential between New Brunswick coal and Nova Scotia coal, previously referred to, will tend, therefore, to make this outlet very difficult to hold.

The third largest customer of the New Brunswick mines has been the New Brunswick Electric Power Commission. The chief generating plant of that Commission, and the largest fuel plant in the province, is the Grand Lake Plant of 20,000 k.w. capacity. This plant has been specially designed to burn Minto slack coal. Since 1939 its consumption has increased rapidly to about 80,000 tons in 1944. In 1944 the Grand Lake Plant provided more than 80 per cent of the electricity requirements of the Commission's system. The New Brunswick Electric Power Commission is at present constructing a thermal generating station at Chatham, New Brunswick, which is also designed to burn Minto slack coal. This unit will have a capacity of 12,500 k.w., and provision is being made to duplicate the unit in the future, should the demand for electricity warrant it. If this plant does in fact use Minto coal, it will increase very substantially the Commission's coal requirements. However, the plant is so located that it has fairly good access to Nova Scotia coal, and it will presumably use that product if the economics of the situation are definitely in its favour.

The New Brunswick producers have never been able to develop any very substantial domestic and/or commercial market. In part, this is due to the fact that about 75 per cent of the dwellings in the province are heated principally by wood fuel; in part because Minto coal is not a particularly satisfactory domestic fuel, and even those who burn coal prefer either anthracite or Nova Scotia bituminous. The Minto coal that has been sold in this market has been used mainly in hospitals and public buildings for steam raising. It can be used with good results in furnaces having proper stoking facilities, but due to the limited use of coal for domestic heating purposes, there does not appear to be much prospect of any substantial domestic market for stoker coal being developed. The introduction on a large scale of newly developed bituminous coal-burning heaters would increase somewhat the domestic use of Minto coal, providing, of course, that the price was competitive.

In addition to the markets discussed above, there exists a miscellaneous industrial market for Minto coal, located largely in the area around Saint John. This market is at best not large and, even should it be supplied completely by the New Brunswick product, it could not absorb a very large percentage of the output maintained in recent years.

The Market Outside of New Brunswick

Although the shipments of New Brunswick coal out of New Brunswick have never exceeded 15 per cent of her total production, and have usually been substantially less, there has been on occasion a fairly important market for it both in Quebec and in the State of Maine.

Shipments to Quebec have been possible only with the aid of Federal subvention payments. Such shipments rose from 14,000 tons in 1935 to 54,000 tons in 1940. Since that time, however, the Quebec market has been lost to New Brunswick coal, and by 1943 only 6,000 tons of Minto coal were moved into Quebec.

Since 1938 there has existed a fairly suitable market for about 30,000 tons per year of New Brunswick coal in Maine. This coal has been used chiefly by pulp and paper plants, and has been mostly slack coal. Despite the limited size of the outlet, it constitutes a very substantial percentage of the total market for Minto slack coal.

Summary

The principal competition to New Brunswick coal in the Maritime market comes from Nova Scotia coal, and the indications are that since 1939 the competitive position of New Brunswick coal producers in that market has deteriorated appreciably. Because New Brunswick coal, while approximately equal in rank, is inferior in grade and therefore in heating value to most Nova Scotia coal, coal users can be induced to use it only if its cost per ton to them is sufficiently less to compensate for its disadvantages. In pre-war years the cost differential in favour of New Brunswick producers was in most cases significantly larger than it was at the war's end. Until the New Brunswick industry improves substantially its position relative to its competitors in Nova Scotia, the market in the Maritimes for New Brunswick coal will be seriously restricted.

CENTRAL CANADIAN MARKET

In this section will be discussed the market for coal in Quebec and Ontario. The two provinces will be referred to together as Central Canada.

According to estimates made for 1937 and 1943, about one-half of the energy obtained from all sources in Central Canada was obtained from coal. The relative importance of coal in this area is much less than in the Maritimes, about the same as on the Prairies and much greater than in British Columbia. The most important alternative source of energy in Central Canada is water power, from which about one-third of all the energy used was obtained. Only in British Columbia is the reliance of this area on water power equalled. The remainder of the energy has been obtained from petroleum and wood fuel, with the former having been rather more important than the latter. Although the relative position of petroleum has declined during the war years, due principally to difficulties in supply, its importance is expected to increase considerably during the next decade. The use of wood fuel and its probable future importance are discussed below in the section on the retail market. Some natural gas is consumed in southwestern Ontario. Although the importance of this fuel is great in that area, it is very small in the over-all picture.

Production

There is normally no production of coal in either Quebec or Ontario. Seventy miles south of James Bay there are peat-like deposits classified under the A.S.T.M. classification as lignite, but the coal is of such inferior quality that the only production there has been experimental and insignificant in amount.

Consumption Estimates

The following table presents estimates of coal consumption in Central Canada by type of consumer for some recent years.

CONSUMPTION OF COAL IN CENTRAL CANADA

(In net tons)

—	1937	1939	1940	1943
Retail	5,838,000	6,303,000	6,113,000	8,350,000
Industrial	5,311,000	5,031,000	5,573,000	8,255,000
Coke and Gas Plants	2,595,000	2,394,000	2,962,000	3,610,000
Railways	4,162,000	4,189,000	4,830,000	7,463,000
Bunkers	521,000	528,000	520,000	535,000
Total	18,427,000	18,445,000	19,998,000	28,213,000

Quebec and Ontario consume more coal than all the rest of Canada. To illustrate the individual and also the combined importance of these two provinces, the following table is presented. In order to allow a wider selection of years and to show the provincial totals separate'y, the figures below are estimates of coal available for consumption rather than actual consumption.

COAL AVAILABLE FOR CONSUMPTION

(In net tons)

Year	Ontario	Quebec	Ontario and Quebec	Canada
1929	15,400,000	5,200,000*	20,600,000	35,300,000
1933	8,800,000	4,400,000*	13,200,000	23,100,000
1937	14,200,000	5,000,000	19,200,000	31,500,000
1939	12,200,000	5,000,000	17,200,000	29,200,000
1943	19,500,000	8,700,000	28,200,000	45,600,000

*Includes an unknown but considerable tonnage shipped to Ontario.

These figures indicate that Ontario uses from two-thirds to three-quarters of the coal used in Central Canada and about two-fifths of that used in all of Canada.

Apart from its size the outstanding feature of the Central Canadian market is the extent to which it is supplied by foreign sources, particularly the United States. The relative importance of the various sources for 1937 and 1943 is shown below.

—	1937	1943
	Per cent	Per cent
United States	71	93
United Kingdom	6	2
Other foreign	3	Nil
Total imported	80	95
Canada	20	5

The Retail Market

The Housing Census of 1941 revealed that of all the occupied dwellings in Ontario and Quebec in that year, 53 per cent were heated principally by coal and coke, 41 per cent by wood fuel and 3 per cent by each of fuel oil and gas.

The importance of wood fuel in the domestic heating market in Central Canada is much greater than is generally realized. In both provinces, particularly in Quebec, the use of wood fuel is concentrated in rural areas where it is used to a very much greater extent than all other fuels combined. Unfortunately, statistics of wood fuel consumption are not very satisfactory. However, the Dominion Bureau of Statistics figures indicate that in 1940 5,300,000 cords of firewood were cut on farms in Ontario and Quebec. To this must be added mill-waste used as fuel, the volume of which in 1943 was at least 400,000 cords. On the basis that 1.75 cords of wood fuel are approximately equal to one ton of anthracite coal in heating value, the coal equivalent of wood fuel used in Central Canada in 1940 was probably about 3,250,000 tons. Since 1940 the use of wood fuel appears to have declined somewhat. Its future importance is difficult to predict for the cutting of wood for fuel is, to a considerable extent, a depression industry, the output falling when other work is available. However, the depletion of wood lots in the region will probably cause a long-term downward trend in the use of this fuel.

The relative importance of fuel oil for domestic heating has not hitherto been very great, although estimates for consumption suggest that the Housing Census returns underestimate the extent of its use. During the war years the consumption of fuel oil for domestic heating declined, but now that both oil and the equipment required to use it are again available, its importance is increasing rapidly. It is expected that the use of fuel oil for domestic heating will continue to expand for the next few years.

The Housing Census figures for gas include both natural and manufactured gas. The importance of each of these appears to be roughly equal. The reserves of natural gas in southwestern Ontario have been steadily declining and the use of the fuel has fallen somewhat as a result. However, arrangements recently made whereby natural gas may be imported during off-peak months from the United States pipeline network give promise that the importance of this fuel in the area will be maintained. Manufactured gas is supplied to a number of urban areas throughout the region. Details of the plants supplying it may be found in the section on the coke and gas industry.

A table presenting detailed statistics of retail sales of coal and coke in Central Canada for the years 1928 to 1932 inclusive, 1937, and 1939 to 1945 inclusive, is included in the Appendix. A summary of this table is given below. The percentages shown are of total retail sales of coal and coke in Central Canada.

RETAIL SALES OF COAL AND COKE IN CENTRAL CANADA

(In net tons)

—	1928	1932	1937	1940	1943	1945
Anthracite	3,504,000	2,967,000	3,122,000	3,263,000	4,167,000	3,173,000
Per cent	55	49	46	45	45	36
Other coal	1,756,000	1,697,000	2,716,000	2,850,000	4,183,000	3,786,000
Per cent	28	28	40	39	45	42
of which Canadian	475,000	386,000	587,000	614,000	165,000	243,000
Per cent	7	6	9	8	2	3
Coke	1,073,000	1,356,000	1,000,000	1,134,000	957,000	1,988,000
Per cent	17	23	14	16	10	22
Total coal and coke	6,333,000	6,020,000	6,838,000	7,247,000	9,307,000	8,947,000

The figures indicate that anthracite has been the main domestic fuel in Ontario and Quebec. Next in order have come bituminous and lower-rank coal and then coke. Most of the domestic coke used in the area was made in Canada, but only one of the larger suppliers, namely, Montreal Coke and Manufacturing Company, uses any appreciable quantity of Canadian coal. Even allowing for the Canadian coal content in domestic coke sales, Canadian coal over the past twenty years has not provided more than about 10 per cent of the coal and coke requirements of the retail market in Central Canada.

More than 90 per cent of the anthracite imported into Canada enters the retail trade in Ontario and Quebec. Of the remainder, approximately half enters the retail trade in the Maritimes, and the other half is used by industries in Ontario and Quebec. The use of anthracite in Western Canada is so limited that it can be ignored. Retail sales in Central Canada constitute, therefore, the great bulk of the anthracite coal trade.

The special advantages of anthracite for domestic heating are well known—it provides relatively clean, smokeless, continuous heat with a minimum of attention. In hand-fired equipment with natural draft, larger sizes of anthracite known as domestic sizes, and ranging from about $\frac{9}{16}$ inch diameter upwards, are used; in forced draft equipment, smaller sizes, known as buckwheat sizes, and ranging from about $\frac{9}{16}$ inch in diameter downwards, are used. In the early 1930's there was a strong trend towards blower-type equipment, most of it designed to burn United Kingdom buckwheat and smaller sizes. In addition to its use for domestic heating, anthracite is also used for several purposes where clean heat is particularly important, for example, in bakeries, in malting plants, and in poultry brooders.

Anthracite imports by country of origin from 1922 to 1945 inclusive are given in the following table:

TOTAL IMPORTS OF ANTHRACITE INTO CANADA BY COUNTRY OF SOURCE

(In thousands of net tons)

Calendar Year	Total Anthracite Imports	United States	United Kingdom	Russia	Germany	French Indo-China	All* Others
1922	2,694	2,514	180	...	...	...	...
1923	5,168	4,906	262	...	...	...	...
1924	4,183	3,908	275	...	...	...	...
1925	3,799	3,250	549	...	...	...	...
1926	4,243	3,883	272	...	50	...	38
1927	4,064	3,265	788	...	5	...	5
1928	3,737	3,203	526	6	...	...	1
1929	4,020	3,173	729	117	...	...	...
1930	4,256	2,956	996	291	11	...	1
1931	3,178	2,236	876	...	61	...	5
1932	3,138	1,686	1,399	...	52	...	1
1933	3,036	1,430	1,606	...	...	...	...
1934	3,537	1,804	1,644	...	72	...	18
1935	3,451	1,670	1,455	...	205	54	67
1936	3,536	1,686	1,331	...	360	97	62
1937	3,558	2,003	1,134	154	258	...	8
1938	3,724	1,977	1,199	15	411	30	91
1939	3,978	2,606	1,035	...	294	44	...
1940	3,973	2,644	1,329	...	...	...	...
1941	3,941	3,311	630	...	...	...	...
1942	4,802	4,422	380	...	...	...	...
1943	4,459	4,074	385	...	...	...	...
1944	4,413	4,195	218	...	...	...	...
1945	3,411	3,383	28	...	...	...	...

*Includes Alaska, Belgium, China, Morocco, Netherlands and Newfoundland.

Before 1922 Canada was entirely dependent on the United States for anthracite. The strike in the U.S. field in 1922 resulted in the importation in the following years of some anthracite from the United Kingdom. However, a more significant thing to be noted is the large importation from the United Kingdom commencing in 1932. This is in part explained by the imposition in that year of a duty of 50 cents per ton on United States anthracite, with anthracite from the United Kingdom remaining free under the preferential tariff policy. Large importations of anthracite from overseas continued until interfered with by war conditions. One difference between United Kingdom and United States anthracite is that the former has a lower ash fusion temperature and is therefore more suitable than the latter for use in forced-draft equipment where the removal of ash depends upon the fuel used having clinkering properties. A second difference, which explains the preference given to domestic sizes of Welsh anthracite, is that the Welsh coal has a lower ash content than the United States anthracite. German anthracite was brought into the country by the importers of United Kindom anthracite to supplement supplies from the United Kingdom. In that German anthracite, like United Kingdom anthracite, has a low fusion temperature of ash, as compared with Pennsylvania anthracite, it is a satisfactory substitute for the United Kingdom product in forced-draft equipment. Russian anthracite is reported by the trade to be unexcelled, and, considering that in 1929 it was a new source of supply, relatively large amounts were imported in that and the following year. From 1931 until 1937 there was an embargo on the importation of this coal. It is difficult to estimate how much anthracite will be available in the future from either the United Kingdom or Russian sources. The depressed nature of the industry in the United Kingdom, and the high cost of production, may militate against its effective competition with anthracite from United States sources, and supplies available from Russia will, to a considerable measure, be dependent on the trade policies which that country adopts.

In the early 1920's there was considerable concern expressed in this country by various committees charged with investigating Canadian fuel supply over the meeting of Canada's anthracite requirements. At that time the United States was practically the sole source of anthracite imported into Canada. There had been an acute anthracite shortage in the winter of 1918–19, due largely to the great increase in demand, generated by the war, both here and in the United States, and a second crisis in the winter of 1922–23, precipitated by a five months' strike in the United States anthracite fields in 1922. Furthermore, it was believed that United States anthracite reserves were inadequate to prevent a long-term contraction of imports. The United States Bureau of Mines had unofficially warned the Canadian Department of Mines that within a very short time Canada would have to work out her own solution for replacing the anthracite previously imported from the United States, and three bills were placed before the United States Congress to place an embargo on the export of anthracite to Canada. The bills were not passed, but it is not surprising that Order in Council P.C. 2381 of November 25, 1922, which set up the Dominion Fuel Board, referred to "the certain ultimate necessity of substituting other fuels for anthracite coal for domestic heating purposes in Central Canada". The task of advising on the best means to effect that substitution was one of the principal tasks with which the Dominion Fuel Board was charged.

Notwithstanding the concern as to United States anthracite reserves that prevailed in the 1920's, the enquiries of this Commission have demonstrated that there is now no reasonable ground for anxiety. Production in the Pennsylvania anthracite fields is presently in the neighbourhood of 60 million tons annually, at which level the field is estimated to have a life of over 100 years. Furthermore, Central Canada is regarded by anthracite producers as a natural and favourable market for their product, and, barring an unexpected demand in the eastern States for anthracite, or prolonged interruption of production, Central Canada should be able, with confidence, to look for anthracite supplies of 4,000,000 tons, or even a greater amount, annually, from this source. Assurances as to anthracite reserves have been furnished to the Commission by the producers, by the Commonwealth of Pennsylvania, and also by the United States Department of Mines, and it is on information furnished from these sources that the prediction of reasonably adequate reserves is made.

Many informed and disinterested observers in the United States are of the opinion that the Pennsylvania anthracite industry is much more likely to be limited by a restricted market than it is by inadequate reserves. Both before and during the war, anthracite has been under heavy pressure from bituminous coal, oil and natural gas. Increasing difficulties in the field due to the fact that the more readily available reserves are steadily being exhausted and the remaining ones are more costly to mine and tend to produce a less favourable balance of sizes, have contributed to the deterioration of anthracite's competitive position. While these considerations suggest that anthracite may continue to be more expensive than it was in pre-war years, they confirm the conclusion that there is no cause for alarm as to the adequacy of supply.

Most of the anthracite used in Canada is burned in equipment specially designed for it. Anthracite is a very low volatile fuel and therefore equipment designed for it has a smaller combustion space above the fire bed and a smaller flue diameter than it would have were it intended for more volatile fuel. This means that the success with which other fuels can be used satisfactorily in such equipment depends to a considerable extent on their volatile content. Coke, like anthracite, is a low volatile fuel and is in this respect a suitable substitute fuel. Bituminous and lower-rank coals increase in volatile content as the rank falls. While even the so-called low volatile bituminous coals are more volatile than anthracite, they are not sufficiently so to be unsatisfactory substitutes in this respect. However, the volume of gas given off during combustion by high volatile bituminous is so great that it is difficult to obtain complete combustion of it in the combustion chamber and soot, smoke and lower efficiency result. The volatility of a fuel is not the only consideration which determines its suitability as a substitute for anthracite in equipment designed for anthracite. In forced-draft equipment, for example, the clinkering properties of the fuel used are often the determining factor. But volatility is probably the most important single factor, particularly in natural-draft equipment. Over a period of a few years the type of combustion equipment installed must be considered as more or less fixed, and the nature of the rigidity which this circumstance introduces into the retail market must be borne in mind when considering the part played by alternatives to anthracite in the retail market in Central Canada.

The importance of coals other than anthracite in the retail trade appears to have grown substantially over the last three decades. From the Final Report of the Fuel Controller of World War I it would appear that bituminous and lower rank coals were then much less used by small consumers than is the case today. In the years 1928 to 1932, about 27 per cent of the coal and coke sold retail was coal of bituminous or lower rank. In 1937 the comparable percentage was 40 per cent and it has remained at about that level during World War II. The wartime experience may, however, be misleading, for both anthracite and coke were relatively scarcer than bituminous and other coals during the period.

Retail sales of coals other than anthracite in Central Canada in the twelve months beginning April, 1940, are given below. The period is believed to be typical of the pre-war years except that United Kingdom bituminous coal did not normally enter the retail trade.

—	Thousands of Net Tons	Percentage of Total Retail Sales of Coal and Coke
United States low volatile bituminous	670	9.2
United States high volatile bituminous	1,495	20.5
United Kingdom bituminous	33	0.5
Nova Scotia bituminous	438	6·0
Western bituminous and sub-bituminous	176	2.4

In 1940 about 70 per cent of retail sales of United States high volatile in Central Canada were stoker and slack sizes, indicating that this coal was used predominantly in automatic combustion equipment. In contrast, nearly 85 per cent of retail sales of low volatile coal were of domestic sizes, used chiefly in hand-fired natural-draft equipment. The reason for this difference as suggested earlier, is that, whereas low volatile coal tends to be a more or less satisfactory substitute for anthracite in hand-fired, natural-draft equipment, high volatile coals are a less satisfactory substitute unless automatic or specially designed equipment is used.

Because Nova Scotia coal is a high volatile coal, it is not a very satisfactory substitute for anthracite in the type of small hand-fired equipment common in Central Canada. By 1940, Nova Scotia coal had won most of the retail market for high volatile coal in the Quebec and Montreal areas, and rather less than half of that market in the Ottawa area. No Nova Scotia coal has been sold retail in the Toronto area, which normally absorbs nearly two-thirds of the United States high volatile coal sold retail in Central Canada.

Recent developments in the design of small combustion equipment may increase the retail outlet for Nova Scotia coal in Central Canada. Efforts currently being made to develop stoves and furnaces which will burn satisfactorily a wide variety of bituminous coals are discussed in the chapter Combustion. The fact that in 1940 the retail trade of the Montreal area absorbed more than 1,400,000 tons of coal of all kinds, of which only about 300,000 tons was from Nova Scotia, indicates the size of the market that suitable combustion equipment might open to Nova Scotia coal.

During the 1920's there were numerous experiments made in the shipment of Western sub-bituminous coal to the Ontario market. The high transportation cost is, of course, the main factor prejudicing such movement. With the introduction of what is commonly known as the "flat rate" subvention of $2.50 per ton in 1933, movement of this coal to Ontario stabilized itself at around 60,000 tons annually. This coal has a B.t.u. value of from 10,000 to 11,000, and some of it (notably that from Drumheller) stores favourably only under cover. It is particularly satisfactory as a substitute for wood fuel for domestic use. During World War II, with coal in short supply, the movement of this coal into Ontario increased substantially, reaching about 270,000 tons in 1942 and then supply problems in the West resulted in the Coal Controller prohibiting further shipments to Central Canada. In 1943 the Emergency Coal Production Board sponsored a number of stripping operations in Alberta producing sub-bituminous coal, and for the coal year ending March 31, 1946, close to 250,000 tons of strip and deep seam sub-bituminous coal moved eastwards to meet emergency conditions in Ontario. Small amounts of this tonnage found their way into Quebec.

During the summer of 1946, with a coal shortage in prospect for the coming winter, further movement of Alberta sub-bituminous coal into Central Canada is being facilitated by the Coal Controller.

If any satisfactory arrangement could have been worked out in the pre-war years for spring and summer movement of this coal to Central Canada and adequate storage facilities had been available there, the flow into that market might have been considerably larger. As it was, however, delivery was normally postponed until the fall months, at which time the western sub-bituminous mines were usually taxed to meet the requirements of the market to which they ordinarily had access without assistance, and many deliveries contracted for were not made. As long as movements of western coal to Central Canada have the effect of accentuating the seasonal characteristics of the industry, they are not likely to become very great.

Some mention must be made of the prospects for the development of a movement of Alberta low volatile bituminous coal into Central Canada for domestic use. There are in Alberta various deposits of low volatile bituminous coal which, from the point of view of combustion, would be a suitable substitute for anthracite in the equipment common in the region. So far this coal has never been adequately prepared in larger sizes for the domestic market in Central Canada and there has been no significant movement of such sizes. There has, however, been a small movement of briquettes, principally from Canmore Mines. Plans for doubling the size of the briquetting plant at that mine are now under way and the movement of briquettes is likely to increase, provided that subvention assistance is not reduced. It is also probable that there will be steps taken by one or more low volatile operators to improve the preparation of domestic sizes, with the purpose in part of developing a market for such sizes in Central Canada. One of the principal difficulties involved in such an attempt is that the low volatile coal of Alberta is very friable and a heavy percentage of fines would result from the long rail shipment and the handling involved in movement to Central Canada.

Since early in the 1920's a good deal of attention has been paid to the possibilities of increasing the use of domestic coke as a substitute for anthracite in Central Canada and various kinds of Federal aid have been offered to stimulate its use. Details of the development of the coke and gas industry in Canada and of the effect which government aid had on that development are provided in the chapter Products and By-Products. Comment here will be restricted to observing that while domestic coke is a reasonably satisfactory substitute for anthracite, the latter fuel is normally preferred and coke can be sold to domestic users only when it is offered at a somewhat lower price. Although domestic coke consumption in Central Canada has been 1,000,000 tons or more annually since 1928, except for the years of World War II, it has not expanded to the degree that many had hoped. The increase in its use in 1945 was due largely to efforts of the Coal Controller to meet an over-all shortage of solid domestic fuels and is not likely to be representative of the next few years.

The Industrial Market

Industry requires energy for three principal purposes—for power, for process heating, and for space heating. In Central Canada coal has had to face strong competition from alternative energy sources in all these fields. Power needs are met mainly by water power; at least four-fifths of the power machinery installed in Central Canadian industry is fed by hydraulically generated electricity. Of the remainder, smaller power units generally use fuel oil and there are only a few plants, mainly in southwestern Ontario, that obtain their power requirements from coal. In the field of process heating coal has faced strong competition from both water power and petroleum. Vast quantities of secondary hydro power are used for this purpose, mainly by the pulp and paper industry. Since the secondary power supplies are concentrated in the St. Lawrence Valley, the incidence of this competition falls particularly heavily on that section of the market to which Nova Scotia coal has easiest access. Throughout both the process heating and space heating fields there is a substantial and expanding use of petroleum products. In 1939 fuel oil deliveries in the two provinces for industrial use amounted to the coal equivalent of about 800,000 tons; by 1944 they had risen to the coal equivalent of nearly 1,500,000 tons. The wartime consumption may not be maintained, but industrial use of petroleum is expected to be considerably above the pre-war level in the years to come. After allowing for an expanding use of both water power and petroleum, however, coal will probably remain the main source of energy for industrial process and space heating.

It is estimated that the consumption of coal in Ontario and Quebec by all industrial users, other than the coke and gas industry, was about 5,000,000 tons per year in the more prosperous pre-war years. The annual consumption has fluctuated considerably with changes in the level of activity from about 3,600,000 tons in 1933 to 8,300,000 tons at the peak of wartime consumption. Details of the volume and source of industrial coal used in Central Canada for some recent years are given in the following table:

INDUSTRIAL USE OF COAL IN ONTARIO AND QUEBEC

(In net tons)

—	1937	1939	1940	1943
Anthracite	125,000	126,000	139,000	203,000
United States bituminous	3,468,000	3,250,000	3,635,000	7,089,000
Canadian bituminous and lower rank	1,713,000	1,650,000	1,793,000	962,000
United Kingdom bituminous	5,000	5,000	6,000	1,000
Total	5,311,000	5,031,000	5,573,000	8,255,000

The consumption by industry of anthracite in the pre-war years was normally less than 150,000 tons per year, and therefore not important. All but a small percentage of the anthracite so used was of small sizes, the availability of which was a sort of by-product through degredation of the supplying of domestic sizes to the retail market. Except for this small amount of anthracite, the coal used by industry in Central Canada has been bituminous coal.

Some ideas of the relative importance of various industries as users of bituminous coal may be obtained from the Census of Industry Reports prepared by the Dominion Bureau of Statistics. In the calendar year 1940, the bituminous coal consumption in Ontario and Quebec of the larger coal-consuming groups was as follows:

	Tons
Wood and paper products	1,600,000
Non-ferrous metal products	780,000
Iron and steel products	640,000
Non-metallic mineral products	610,000
Vegetable products	530,000
Textiles and textile products	480,000
	4,640,000

In the immediate pre-war years about 70 per cent of the bituminous coal required was supplied by United States mines. During the war years the dependence of industry on United States sources increased substantially until by

1945 about 95 per cent of the bituminous coal used was United States coal. The reliance of Central Canadian industrialists on United States coal has been, both in peace and in war, one of the outstanding features of this market. Throughout the 1930's it was the policy of the Canadian Government to increase the use of both eastern and western coal by industry in this area by means of subvention payments designed to make Canadian coal competitive with United States imports in areas where, without aid, they would not be. Although much of the discussion following is concerned with the factors affecting the use of Canadian coal in Central Canada, it must be borne in mind that the principal source of supply has always been the United States.

In the pre-war years Nova Scotia mines provided about one-third of the coal required for industrial purposes in Central Canada. The industrial use of Nova Scotia coal amounted to from 1,500,000 to 2,000,000 tons annually and accounted for more than one-half of all the Nova Scotia coal moved into Central Canada. The first year for which figures are available to show the use of Nova Scotia coal and imported coal by smaller areas is that beginning April 1, 1940. These figures are given below. The smaller areas are those used by the Dominion Bureau of Statistics and shown on a map reproduced annually in "Coal Statistics for Canada".

USE OF BITUMINOUS COAL BY INDUSTRY IN CENTRAL CANADA FOR TWELVE MONTHS APRIL, 1940, TO MARCH, 1941, INCLUSIVE[1]

(In thousands of net tons)

—	Nova Scotia Coal		Imported Bituminous Coal	Total Bituminous Coal	Nova Scotia Coal as Per Cent of Total Bituminous Coal
	Tonnage Used	Per Cent of Total Nova Scotia Coal Used			
Quebec Area	160	9.8	355	515	31
Montreal Area	722	44.5	242	964	75
Ottawa Area	202	12.4	293	495	41
Northern Area	392	24.2	413	846[2]	46
Kingston Area	5	0.3	100	105	5
Toronto Area	101	6.2	1,302	1,403	7
Windsor Area	42	2.6	531	573	7
Western Area	Nil	Nil	195	222[3]	Nil
Total	1,624	100.0	3,431	5,123[1]	32

[1] Table covers 94 per cent of industrial tonnage of bituminous coal used in Ontario and Quebec.
[2] Includes 41,000 tons of Western Canadian coal.
[3] Includes 27,000 tons of Western Canadian coal.

A considerable part of this market for Nova Scotia coal was won only with the aid of Federal subventions. From one-half to two-thirds of all the Nova Scotia coal moved into Central Canada in the middle and late 1930's was aided by subvention payments.

The price factor (price net of subvention where applicable) was, of course, the major factor determining the extent to which Central Canadian industrialists used Nova Scotia coal, but there were a number of other factors. In the first place, approximately 10 per cent of the United States bituminous used by industry was low volatile coal. Generally speaking, low volatile coal commands a premium over high volatile coal and the use of it is largely explained by its particular suitability for the equipment in which it is used. For such equipment Nova Scotia coal would be unsuitable. Secondly, Nova Scotia coal has a lower ash fusion temperature than many, though not all, of United States coals and in some combustion equipments Nova Scotia coal will not perform satisfactorily for that reason. Furthermore, Nova Scotia coal has a higher sulphur content than some United States coals and in furnaces where the material to be heated is in direct contact with the products of combustion, for example, in the baking of bricks and porcelain, the reheating of steel billets, etc., the presence of sulphur in the combustion gases can have very harmful effects. The Dominion Steel and Coal Corporation has estimated that the market affected in Quebec and Eastern Ontario by equipment unsuitable for the use of Nova Scotia coal because of ash fusion temperature and sulphur content is approximately 500,000 tons per year. Since a part of the tonnage included in that figure has already been displaced by secondary power, the market restriction in that area due to unsuitable equipment is unlikely to be more than 300,000 tons annually.

There are undoubtedly a number of plants in Central Canada which have never used Nova Scotia coal but which could use it satisfactorily if it were available at a competitive price and in adequate volume. There are, however, for the reasons listed above, a number of others which could not. There has been and still is available from the United States a much wider range of coals than from Nova Scotia and industrialists have chosen their combustion equipment accordingly. This circumstance must not be left out of account when considering the market that would exist for Nova Scotia coal in Central Canada if the price could be made competitive.

After 1940 the movement of Nova Scotia coal into the central industrial market fell off until in 1945 it almost ceased. It is just now beginning to move again. Notes on the present competitive position of Nova Scotia coal will be included at the end of this discussion of the Central Canadian market.

Very little western Canadian coal entered the industrial market in northwestern Ontario during the 1930's. That market consists principally of pulp and paper mills at Kenora, Fort Frances and Dryden and was supplied mainly by United States coal from docks at Fort William and Duluth. From 1937 on some sales were made by western bituminous mines in this area with subvention aid, and the market expanded until 1942 when, by order of the Coal Controller, shipments were discontinued. The accessability to stock piles of United States coal at lake-head ports is a considerable inducement to industrialists in the area to use United States coal rather than to stockpile Canadian coal themselves. For this reason the western bituminous operators claim that they will not be able to compete with United States coals under a subvention provision such as that of P.C. 4740 in effect since June 5, 1942, which does no more than equalize laid-down costs.

THE COKE AND GAS MARKET

Little will be said here about the coke and gas industry for that industry is dealt with at length in another section of this report. The industry is a large consumer of coal, about 90 per cent of which in pre-war years was United States bituminous. The only plant which has used a large tonnage of Canadian coal is that of the Montreal Coke and Manufacturing Company at Ville LaSalle.

Coke consumption in Central Canada for a few recent years is given below.

COKE CONSUMPTION IN CENTRAL CANADA
(In net tons)

—	1937	1940	1943	1945
Retail Sales	1,000,000	1,134,000	957,000	1,988,000
Industrial Use	1,268,000	1,698,000	2,539,000	2,480,000

The main use of industrial coke is by the Steel Company of Canada at Hamilton and Algoma Steel Corporation at Sault Ste. Marie for metallurgical purposes.

The Railway Market

In the pre-war years the coal consumption of the railways in Central Canada was about 4,200,000 tons annually. Railway requirements have, however, varied over the last 15 years from 3,315,000 tons in 1933 to 7,463,000 tons in the peak war year, 1943. The use of petroleum in the region is very limited and is restricted to a few diesel locomotives employed for switching purposes. Further details of railway coal consumption for various years are given below.

COAL CONSUMPTION OF THE RAILWAYS IN CENTRAL CANADA

(In net tons)

—	1930	1933	1937	1940	1943	1945
Canadian coal	746,000	879,000	1,157,000	1,593,000	258,000	122,000
Imported coal	4,295,000	2,436,000	3,005,000	2,713,000	7,205,000	7,296,000
Total	5,041,000	3,315,000	4,162,000	4,306,000	7,463,000	7,418,000

In all the years covered in the table above, railway consumption in Central Canada amounted to about 55 per cent of total railway consumption in all of Canada.

Most of the bituminous coal used by the railways in Central Canada has been United States coal. In this respect the region was unique; in fact, more than 98 per cent of the bituminous coal imported into Canada for locomotive use in 1939 was used in Ontario and Quebec. During the war years the demand for coal was too heavy to allow this situation to continue and substantial quantities of United States coals were used on the Prairies.

The consumption of United States bituminous coal by railways in Central Canada was nearly 3,000,000 tons per year in pre-war years. Of the two larger railways, the Canadian Pacific Railway Company bought United States coal through a number of Canadian importers in Montreal and Toronto, whereas the Canadian National Railways obtained the major part, and in some years practically all, of its United States requirements from mines which it owns and operates in Ohio, known as the Rail and River Coal Company. The Canadian National Railways expect that in the post-war years about 500,000 tons per annum will be available from the output of the Rail and River Coal Company for use in Canada.

The use of Canadian bituminous coal by the railways in Ontario and Quebec first exceeded 1,000,000 tons in 1934, and reached a maximum of nearly 1,600,000 tons in 1940, after which, due to war conditions, it fell off steeply until by 1944 it was only 100,000 tons. The use of Nova Scotia coal was fairly steady at about 1,100,000 tons annually from 1936 to 1940 inclusive, and declined very rapidly after 1941. Purchase of western Canadian coal for use in Ontario rose from 80,000 tons in 1938 to nearly 700,000 tons in 1941 and then dropped off to 55,000 tons in 1943.

The principal railway user of Nova Scotia coal in Quebec in pre-war years was the Canadian National Railways. This is illustrated by the following table:

COAL CONSUMPTION BY RAILWAYS IN QUEBEC
Averages for Years 1936–1940, Inclusive
(In net tons)

—	Nova Scotia Coal	Imported Coal	Total Coal	Nova Scotia Coal as Per Cent of Total Coal
Canadian National Railways	669,000	34,000	703,000	95
Canadian Pacific Railway Company	124,000	280,000	404,000	31
All other railways	8,000	17,000	25,000	32
Total	801,000	331,000	1,132,000	71

Of an average annual consumption of about 270,000 tons of Nova Scotia coal in Ontario by railways during the years 1936 to 1940 inclusive, at least 80 per cent was used by the Canadian National Railways. In 1939 this railway extended the use of Nova Scotia coal to points as far west as Toronto and Cochrane. A substantial part of the coal purchased by the Canadian National Railways in Nova Scotia moved under subvention. In the years from 1936 to 1939 the average annual tonnage of this company's purchases under subvention in Nova Scotia was 612,000 net tons, amounting to 47 per cent of total purchases in that province. In the fifteen years from 1930 to 1945, subventions were paid on 5,072,000 net tons of Nova Scotia coal purchased by the Canadian National Railways.

The coal requirements of the Canadian Pacific Railway Company in Central Canada are substantially smaller than those of the Canadian National Railways. In the pre-war years the Canadian Pacific Railway Company limited its use of Nova Scotia coal to divisions between Montreal and Quebec City in the Province of Quebec. On all other lines in Quebec and in Eastern Ontario, and on the main line from McAdam Junction, N.B., to Montreal, little, if any, Nova Scotia coal was used.

In the pre-war years the Nova Scotia coal available for railway use in Central Canada was normally run-of-mine coal. The burning of fines in locomotives is inefficient due to stack loss, and therefore run-of-mine coal, because it contains a higher percentage of fines, is a less suitable fuel than screened coal. The difference in the extent to which the two major railways use Nova Scotia coal appears to arise from the greater preference of the Canadian Pacific Railway Company for prepared sizes. In this connection it might be noted that Dominion Steel and Coal Corporation Limited erected a mobile screening plant at its Windmill dock for the purpose, among others, of furnishing prepared sizes for the Ontario Northland Railway, whose operating experience has dictated the use of sized coal. An increase in the supply of screened coal to the railroads by the Nova Scotia producers results in slack sizes, which must also be marketed; screened coal can, therefore, only be provided for the railways insofar as there is a market for the resulting slack.

A very considerable amount of Nova Scotia coal for locomotive purposes is marketed in Central Canada by the aid of subventions which are based on the difference between the laid-down cost of Nova Scotia coal and the United States coal that would otherwise be used. Therefore, the closer railway consumption can be to Montreal, to which point Nova Scotia coal is water-borne, the less will be the amount of aid per ton necessary to make the Nova Scotia coal competitive. Consequently, if Nova Scotia coal, as made available to railway purchasers at Montreal, had been acceptable to the Canadian Pacific Railway, and more of it had been used by that company and less by the Canadian National Railways, the same amount of Nova Scotia coal could have been marketed in Central Canada at a lower cost to the Federal Treasury.

The bituminous coal producers in western Canada are particularly dependent on the railways for an outlet, and with the introduction in the early 1930's of the subvention policy, specific provision was made to encourage the furtherance of western coal for use by the railways into Ontario. The aid commenced at points near the boundary of Manitoba and Ontario. The tonnage moved gradually increased until the disturbances caused by war resulted in United States coal meeting locomotive needs in most of Manitoba. The following table shows purchases by each of the major railways on which subventions were paid. Small amounts of the tonnages shown were consumed in Manitoba, but most of the coal was used in western Ontario.

ALBERTA AND BRITISH COLUMBIA CROW'S NEST COAL MOVED UNDER SUBVENTION FOR RAILWAY USE

(In net tons)

Year	Canadian National Railways	Canadian Pacific Railway Company
1933	8,272	16,732
1937	8,572	77,928
1939	68,133	176,095
1941	207,105	518,492
1944	2,979	9,725

The above figures reveal that, in contrast to the situation in eastern Canada, the Canadian Pacific Railway Company made greater use than did the Canadian National Railways of the subvention provisions to expand the market for western Canadian coal.

There is at present little prospect that western Canadian coal will be moved into Ontario for railway use in the future without subvention or comparable assistance.

The Bunker Market

Bunker deliveries from Central Canadian ports are restricted largely to lake and river vessels. For the pre-war years very little is known about this trade and the figures shown, ranging just over 500,000 tons per year, are no more than indications of the order of its magnitude. Most of the bunker coal supplied was United States bituminous.

NOTES ON NOVA SCOTIA AND UNITED STATES BITUMINOUS COAL IN THE CENTRAL CANADIAN MARKET

For more than twenty years the most interesting and decidedly the most controversial feature of the Central Canadian bituminous coal market has been the role played in it by Nova Scotia coal. There are two main reasons for this. The first is that for almost the whole of the period it has been the policy of the Federal Government to encourage by financial assistance the movement of coal from eastern and western Canadian mines into Central Canada. The second is that, due largely to the capacity of the Nova Scotia mines and to the fact that they are more favourably located for the Central Canadian market than are those of the other coal-producing provinces in Canada, the great bulk of the bituminous coal that has moved into Ontario and Quebec with the aid of Federal subvention payments has been Nova Scotia coal.

Tonnages of Nova Scotia and United States bituminous coal retained for consumption in Ontario and Quebec from 1929 to 1943 are set out in the following table:

NOVA SCOTIA AND UNITED STATES BITUMINOUS COAL RETAINED FOR CONSUMPTION IN QUEBEC AND ONTARIO

(In net tons)

With Nova Scotia coal shown as a percentage of total Nova Scotia and United States bituminous coal retained for consumption.

—	Quebec		Ontario		Quebec and Ontario	
	Nova Scotia Bituminous	United States Bituminous	Nova Scotia Bituminous	United States Bituminous	Nova Scotia Bituminous	United States Bituminous
1929	2,671,000	....	85,000	....	2,756,000	14,310,000
Per cent	....	....	....	....	16	....
1931	1,811,000	....	99,000	....	1,910,000	10,173,000
Per cent	....	....	....	....	16	....
1933	1,710,000	....	469,000	....	2,179,000	8,058,000
Per cent	....	....	....	....	21	....
1935	1,722,000	736,000	926,000	8,326,000	2,648,000	9,062,000
Per cent	70	....	10	....	23	....
1937	2,232,000	1,360,000	1,211,000	10,789,000	3,443,000	12,149,000
Per cent	62	....	10	....	22	....
1939	2,256,000	1,297,000	1,293,000	8,350,000	3,549,000	9,647,000
Per cent	63	....	13	....	27	....
1941	1,922,000	4,104,000	177,000	13,496,000	2,099,000	17,600,000
Per cent	32	....	1	....	11	....
1943	678,000	6,334,000	....	16,945,000	678,000	23,279,000
Per cent	10	....	....	....	3	....

It is readily apparent from the figures that United States bituminous mines have been a far more important source of supply for the Central Canadian market than have the Nova Scotia mines. Even in 1939, when movements from Nova Scotia reached their peak, both absolutely and relatively, nearly three tons of United States bituminous moved into Central Canada for each ton of Nova Scotia bituminous. During the years of World War II, the decline in Nova Scotia production and the rapid rise in Maritime coal requirements very nearly eliminated the tonnage of Nova Scotia coal that could be allotted to the Central market and the bituminous coal requirements of the Central provinces in the latter war years were met almost entirely from United States sources. Now that the war is over there will once again be a considerable tonnage of Nova Scotia coal available for the Central Canadian market. The question of what aid, if any, should be extended by the Federal Government to facilitate the movement of that tonnage is perhaps the basic question of Federal coal policy. The purpose of this note is to survey briefly the more important factors affecting the competitive strength of Nova Scotia bituminous coal in the Central market and then to attempt some indication of what may be expected to happen in that market in the near future if no direct aid is granted to Nova Scotia coal.

The United States mines from which bituminous coal normally moves into Canada are located in the Eastern Appalachian area. This area is rectangular in shape, running from the New York-Pennsylvania border south into Tennessee. It comprises the following coal-producing districts:

District No. 1 .... Central Pennsylvania
District No. 2 .... Western Pennsylvania
District No. 3 .... Northern West Virginia
District No. 4 .... Ohio
District No. 6 .... West Virginia Panhandle
District No. 7 .... Southern Low Volatile
District No. 8 .... Southern High Volatile

With the addition of District No. 5—Michigan, from which no coal is exported to Canada, these Districts constitute what is known as Price Area No. 1. During World War II, Canada imported a considerable amount of coal from District No. 9—Western Kentucky, District No. 10—Illinois, and to a lesser extent District No. 11—Indiana, all in Price Area No. 2. This coal moved to the head of the lakes for use principally on the western lines of the railways. Normally, however, there is very little bituminous coal shipped into Central Canada other than from Price Area No. 1.

Generally speaking, the highest quality coal produced in the United States is produced in Price Area No. 1. From it has come all of the coal used to fuel the highly industrialized middle Atlantic and New England States, as well as almost all of the United States bituminous moved into Ontario and Quebec. Price Area No. 1 produces more than two-thirds of the bituminous coal produced in the United States. In the years 1936 to 1940 its output averaged nearly 300,000,000 tons annually and by 1944 it had risen to almost 425,000,000 tons. In the pre-war years approximately four per cent of the coal mined was shipped into Central Canada; during the war years the figure rose to nearly six per cent. Although the Central Canadian market absorbs a relatively small part of the total production of the area, there are a number of operators in it to whom the Canadian market is of first-rate importance.

The bituminous producers in Price Area No. 1 enjoy a considerable advantage over those in Nova Scotia in respect of cost of coal at the mine. This advantage is due mainly to the higher productivity of labour in the United States mines, which in turn is due in part to the fact that the United States coal seams are easier to mine. The average output per man per day in the deep-seam bituminous mines in the three States which are the principal sources of imported coal, namely Pennsylvania, West Virginia and Kentucky, was 5.3 tons in 1944, having risen from just under 5 tons in 1939. In contrast, the output per man per day in the largest Nova Scotia operation, that of the Dominion Coal Company, was approximately 2.7 tons in 1939, fell to about 1.7 tons in 1944, and still lower in 1945. The above comparison understates the actual position in that the United States mines supplying Canada generally achieve a higher productivity than the average for their States. The increase in overall output per man per day of the United States mines has been achieved despite the fact that very much more attention has been paid in recent years to the cleaning and sizing of the coal raised. The effect of better preparation has been to improve the grade of the coal and to strengthen thereby its competitive position in the market.

There are a great many independent bituminous operators in the United States and the bituminous coal market there has, therefore, normally been a highly competitive one. During World War I the capacity of the industry was greatly expanded and, since post-war bituminous requirements were considerably below the wartime peak, the industry was troubled continuously by surplus capacity. This circumstance intensified the competition between producers, particularly during the early 1930's. Under the combined effects of general industrial depression and fierce competition from alternative energy sources, bituminous coal requirements shrank rapidly. For the five years 1931 to 1935 inclusive, production fell to an average of about 350,000,000 tons annually, compared with nearly 500,000,000 tons throughout the 1920's. Competition between coal producers became extremely bitter, price warfare raged continuously and bankruptcy was widespread. All but the strongest operators were in difficulty and even they were not secure.

Under such circumstances, it is not surprising that there grew rapidly within the industry an interest in some sort of regulation which might alleviate the evils of excessive competition. In 1925 the report of the United States Coal Commission had recommended a measure of regulation by the Interstate Commerce Commission by means of a licensing system and, in both 1928 and

1932, bills based on this proposal and sponsored by the United Mine Workers of America were introduced in Congress. Neither bill got beyond the Senate Committee. In 1932 the high volatile operators in the southern fields launched Appalachian Coals Incorporated, the primary function of which was to establish and control minimum prices. In 1933, under the National Industrial Recovery Act, the Federal Government required coal operators to abide by a "Code of Fair Competition for the Bituminous Coal Industry", calling for the maintenance of minimum prices and elimination of unfair competitive practices. This code remained in effect until a Supreme Court decision of May, 1935, invalidated the Recovery Act, although segments of the coal industry had been conspicuous in evading it before that date. In August, 1935, the abandoned code was replaced by the Bituminous Coal Conservation Act, which created a National Bituminous Coal Commission, to supervise the determination of minimum prices for coal according to a prescribed formula, and the enforcement of those prices. This Act, in turn, was declared unconstitutional by a Supreme Court decision of May, 1936. It was followed by the Bituminous Coal Act of 1937 (commonly known as the Guffey-Vinson Coal Act), which provided for the establishment of minimum prices for coal sold in the United States or forwarded to Canada. It called for minimum prices to be established for each District in each Price Area such that the return to the Price Area as a whole would equal the weighted average costs of the Area and such that existing fair competitive opportunities would be preserved. Administration of the Act was put in the hands of a National Bituminous Coal Commission, appointed by the President by and with the advice and consent of the Senate. Expenses were to be met by appropriations made from the Federal Treasury and all bituminous coal producers were required to pay the Treasury an excise tax of 1 cent per ton on all output except that sold to governmental bodies and for export.

Effective minimum prices under the Bituminous Coal Act of 1937 were not established until September 3, 1940. All the mines in each District were given a letter classification for grade and a number classification for size for each variety of coal they produced and schedules were set up fixing the minimum price per net ton f.o.b. mines, for each combination of letter and number. In order to preserve existing fair competitive opportunities, the coal was further classified according to the market area into which it moved, with a different District minimum schedule for each market area. Normally, coal shipped to Canada moved under the minimum price schedules for Buffalo. As costs changed in the years that followed, the minimum price schedules were revised. However, the demand for coal increased so rapidly after Pearl Harbor that there was need for the enforcement of a maximum rather than a minimum price for coal. Accordingly, in May, 1942, the Office of Price Administration established maximum prices f.o.b. mines for all mines producing coal in the United States. Since that time there have been amendments made to the maximum price schedules to reflect increased costs of production brought about by wage increases and changes in working conditions approved by the Government. Maximum price schedules are still in effect in the United States and the demand for coal has remained so great that coal is at present selling at or near the maximum prices f.o.b. mines allowed under these schedules.

In the meantime the Bituminous Coal Act of 1937 has expired and it has to date (September, 1946) not been re-enacted. It is not our intention to forecast whether or not this Act will be re-enacted. On the one hand, the legislation is favoured by the producers of the major part of United States bituminous coal and is supported solidly by the United Mine Workers. Supporters of the legislation point out that the problem of surplus capacity in the industry, which contributed so largely to the price cutting in the 1930's, has been exaggerated during World War II. On the other hand, the competition offered by petroleum and natural gas is growing steadily and the low cost producers are bound to feel that minimum price regulation will reduce unnecessarily their ability to compete with these alternative energy sources. Their attitude will find support in the general disinclination which there appears to be in the United States to continue Government regulation of industry any longer than is absolutely necessary.

The decision that the United States Government makes on the question of whether or not to re-establish minimum price regulation of the bituminous industry will have important repercussions on the coal market in Central Canada. If there is no regulation it is to be expected that in no more than a year or two there will be fairly vigorous price cutting by individual United States bituminous producers. Once price warfare starts, it will probably grow increasingly fierce and the price of bituminous coal in Central Canada may drop sharply. If, on the other hand, minimum price regulation is re-introduced, prices will probably decline much less. It seems only reasonable to expect some reductions in United States bituminous prices in any event, but the relative competitive strength of Nova Scotia coal in the Central market will undoubtedly be substantially greater if there is minimum price regulation in the United States than if prices are left completely uncontrolled.

In the years before World War II, Nova Scotia coal was competitive with United States bituminous coal without subvention aid on dock at Montreal, and at all ports lower on the St. Lawrence River. Consequently, a considerable tonnage of Nova Scotia coal moved into Quebec without direct financial aid. The figures for both unassisted and assisted movements from Nova Scotia into Central Canada for years from 1929 to 1943 are set out below. All Nova Scotia movements into Central Canada benefited from tariff protection of 50 cents per ton before June, 1931, and 75 cents per ton after that time. The term "unassisted" as used here means, therefore, unassisted by subvention.

SHIPMENTS OF NOVA SCOTIA COAL INTO CENTRAL CANADA

(In net tons)

—	Unassisted by Subvention	Assisted by Subvention	Unassisted Nova Scotia Tonnage as Per cent of Total Nova Scotia and United States Bituminous Retained in Central Canada
			Per Cent
1929	2,451,000	305,000	14
1931	1,508,000	402,000	12
1933	795,000	1,384,000	8
1935	1,010,000	1,589,000	9
1937	1,406,000	1,909,000	9
1939	1,240,000	2,421,000	9
1941	107,000	2,015,000	.....
1943	225,000	453,000	.....

The percentages shown above are of unassisted Nova Scotia tonnage to total Nova Scotia and United States bituminous tonnage retained for consumption in Central Canada and provide a rough index of the competitive strength of the Nova Scotia coal in the market for the years covered.

The approximate competitive position of Nova Scotia and United States coals alongside dock, Montreal, in 1939 and as at September, 1946, may be illustrated by the following cost figures:

SUMMER—1939

—	Nova Scotia Slack		United States Slack	
	Dominion Coal Co.	Old Sydney	District No. 2	District No. 3
	$	$	$	$
F.o.b. mine, net ton	3.41	3.81	1.40	1.10
Rail freight and loading	0.35	0.35	1.65	1.85
Vessel freight and insurance	0.61	0.61	0.86	0.86
Duty	....	....	0.75	0.75
F.a.s. Montreal dock	4.37	4.77	4.66	4.56

SEPTEMBER—1946

—	Nova Scotia Slack		United States Slack	
	Dominion Coal Co.	Old Sydney	District No. 2	District No. 3
	$	$	$	$
F.o.b. mine, net ton	7.21	6.31	3.31	3.03
Rail freight and loading	0.45	0.45	1.85	2.08
Exchange	....	....	0.03	0.03
Vessel freight and insurance	1.40	1.40	1.01	1.01
Duty	....	....	0.75	0.75
F.a.s. dock Montreal	9.06	8.16	6.95	6.90

The figures for Nova Scotia slack are based on information provided by the Dominion Steel and Coal Corporation. The f.o.b. mine costs include allowances for depreciation and depletion; in 1939 these allowances totalled about eighteen cents per net ton. The figures for U.S. slack are averages of actual costs incurred by one large importer in the Montreal area. In 1939 prices f.o.b. U.S. mines and vessel freight rates were matters of negotiation, and costs f.a.s. dock Montreal varied considerably from shipment to shipment; for example, mine prices for $\frac{3}{4}$-inch slack varied from $1.00 to $1.25 in District No. 3. In September 1946, U.S. coal normally sold at the ceiling price, but the ceiling varied from mine to mine; for example, some mines in District No. 2 were selling $\frac{3}{4}$-inch slack at $3.51.

It will be observed that in 1939 Dominion coal was strongly competitive at Montreal. At that time Old Sydney coal was somewhat less competitive, although it was not much out of line with the more expensive District No. 2 coals. By September 1946 the situation had changed radically. All coals had become much more expensive at Montreal, but the increase in the cost of Nova Scotia coals was much greater than in that of United States coals. In September 1946, Dominion coal was more than $2.00 per net ton more expensive than either District No. 2 or No. 3 coals. Old Sydney coal was more strongly competitive, but it was about $1.25 more expensive than U.S. coals. In any event, the production of Old Sydney Collieries is only about one-fifth of that of the Dominion Coal Company, and it seems unquestionable that if Nova Scotia coal is to move into the St. Lawrence market in any volume a considerable portion of it must come from the Dominion Coal Company.

The effect of the deterioration in the position of Nova Scotia coal is that it is at present not competitive with United States bituminous coal anywhere on the St. Lawrence River except possibly below Riviere-du-Loup and on the Gaspé Peninsula. If the present relationship continues, there will be no Nova Scotia coal of any consequence moved into the Central Canadian market without subvention assistance. Moreover, a very considerable subvention per ton would be required to move the coal even as far west as Montreal.

It is not easy to forecast what changes will occur in the competitive position of Nova Scotia coal in the St. Lawrence market in the next few years. The cost of moving Nova Scotia coal from the mine to the dock at Montreal is about 90 cents per ton more at present than it was in 1939, due largely to the increase in shipping rates. It is thought likely that these rates will remain above the pre-war level, although it is possible that they may be reduced by 50 per cent of the increase. Even should this happen, it would only improve the position of Nova Scotia coal in Montreal by 45 cents. The major uncertainty for the future is the cost at mine of Nova Scotia coal. In 1939 the Dominion Coal Company had an output per man per day of about 2.7 tons, whereas in 1945 it had fallen almost to 1.5 tons. While there does not appear to be any obvious physical reason why production per man per day could not return to the pre-war level, it is not at all certain that it will. However, to illustrate the effect that an improvement in output per man per day would have on the cost of coal at mine, it is estimated that, were an output of 2.2 tons per man per day to be reached, the coal could be produced at a cost of about $5.70 per net ton. This would amount to a reduction of $1.50 per ton in the present cost.

Insofar as the position of United States bituminous coal is concerned, it has already been emphasized that very much will probably depend upon whether or not minimum price regulations are brought into effect. The greater the post-war decline in United States bituminous coal requirements the more important will this factor be. In any event, some reduction in price at mine is to be expected. In respect of freight, there have recently been hearings conducted by the Interstate Commerce Commission in connection with an application by the United States railways to raise their rates on coal and other commodities. In the case of coal moving to Great Lakes ports, the increase asked was 15 cents per ton, or 7 cents per ton over the 8-cent increase recently granted for the duration of the hearings. It is widely believed that the increases asked by the railways will be granted. These increases, should they be granted, may very well be offset, however, by reductions in the water rates on coal moving as far down the St. Lawrence River as Montreal.

Although changes in the future are very much matters of speculation, it does seem abundantly clear that the competitive position of Nova Scotia coal in the Central Canadian market has deteriorated seriously during the war years and that, unless there is considerable improvement in the output per man day of the Nova Scotia mines, very little Nova Scotia coal will move into the Central Canadian market without direct financial assistance.

THE PRAIRIE MARKET

The term "Prairie", as used here, covers all of the Provinces of Manitoba, Saskatchewan and Alberta.

Coal is the major source of energy on the Prairies; in both 1937 and 1943 it appears to have provided slightly more than one-half of the energy obtained from all sources. The order of importance of the other sources is petroleum, wood fuel, water power and natural gas. There is a very considerable regional variation in the incidence of alternative energy sources on the coal market. Water power is important only in Alberta and Manitoba, the heaviest use of wood fuel is in Manitoba and northern Saskatchewan, while the use of natural gas is largely confined to Alberta. The probable trend in the next few years in the importance of these alternative energy sources is discussed in the chapter Sources of Energy. The main uncertainties are connected with the reserve situation in respect of petroleum and natural gas. Unless further substantial petroleum reserves are found on the Prairies, coal may recapture a part of the market now using liquid fuel. If, on the other hand, natural gas reserves are proven to be as substantial as some now consider them to be, there is a possibility that the piping of the natural gas to additional communities on the Prairies may reduce the use of coal for domestic heating.

Production

Within the Provinces of Alberta and, to a lesser extent, Saskatchewan, lie several of the major coal-producing areas of Canada. Production in Alberta was about 5,500,000 tons per year in the late 1930's and rose to 7,750,000 tons per year during World War II. Of the Alberta output, more than one-half is bituminous coal and the remainder is sub-bituminous. It is common practice in Western Canada to classify all Alberta production as either "steam" coal or "domestic" coal. In a very general way this classification is based on use, the first group including those coals which are used primarily for steam raising, the second, those coals which are used primarily for domestic heating. Because it is a use classification, it does not accord exactly with the recently adopted A.S.T.M. classification, though, broadly speaking, coals of high volatile "A", or higher rank, are spoken of as "steam" coals, and those of lower rank as "domestic" coals. For convenience, the steam-domestic terminology will be used in this discussion of markets, although the reader is warned that the terms are somewhat misleading, some "steam" coal being very suitable for domestic heating, and "domestic" coal being used to a considerable extent for steam raising. The "steam" coals are produced on the eastern slopes of the Rocky Mountains, principally in the areas of the Crowsnest Pass, Mountain Park, Cascade and Nordegg. "Domestic" coal is produced on the same slopes in the Coalspur and Saunders areas and at many points on the Prairies, principally in the areas of Drumheller, Edmonton and Lethbridge.

Coal production in Saskatchewan was about 1,000,000 tons per year in the late 1930's and rose to more than 1,500,000 tons per year during the war years. All of the Saskatchewan production is lignite coal. It comes from the southern part of the province, mainly from the vicinity of Estevan.

There has been production of a very few thousand tons of lignite coal annually in the Deloraine district of Manitoba. The output is, however, much too small to be of any significance.

Consumption Estimates

The following table summarizes coal consumption on the Prairies by type of consumer:

COAL CONSUMPTION ON THE PRAIRIES

(In net tons)

—	1937	1939	1940	1943
Retail	2,661,000	2,488,000	2,583,000	3,546,000
Industrial	996,000	966,000	1,076,000	1,545,000
Coke and Gas Plants	155,000	164,000	168,000	177,000
Railways	2,342,000	2,276,000	2,568,000	3,492,000
Total	6,154,000	5,894,000	6,395,000	8,760,000

The principal market for the output of Prairie mines is in the Prairie region. Except for the latter years of World War II, almost all of the coal consumed in the Prairies was produced there. Such coal as was imported in pre-war years came almost entirely from the United States, and was special purpose coal.

The Retail Market

According to the Housing Census of 1941, nearly one-half of Prairie dwellings were heated principally by wood fuel. The importance of wood fuel was by no means uniform throughout the Prairies. In general, Manitoba relied more upon it than did Saskatchewan, and Saskatchewan more than Alberta. From the limited evidence available, it would appear that the importance of wood fuel has declined considerably throughout the Prairie region since 1941. The next most important fuel for house heating on the Prairies was coal, it being used in 1941 in some 45 per cent of Prairie dwellings. Of coal used for this purpose it is estimated that about 25 per cent was used in Manitoba, mainly in the Winnipeg area; about 40 per cent in Saskatchewan with consumption widely distributed; and about 35 per cent in Alberta. The importance of natural gas was not very great in 1941, at which time only about 7 per cent of Prairie dwellings used it as a principal fuel. In the areas in which natural gas is available, however, it is extremely important. The four main urban centres in Alberta, Edmonton, Calgary, Lethbridge and Medicine Hat, rely heavily on gas, and expanding pipelines supply a number of smaller communities. Proven reserves of natural gas in Alberta continue to grow and the use of the fuel for domestic heating is expected to increase slowly. Up to the present time there has been no appreciable use of natural gas in Saskatchewan. There is in prospect a pipeline from the Unity field to Wilkie and North Battleford, but it appears to be questionable whether sufficient reserves have been proven in Saskatchewan to justify a pipeline to Saskatoon. Development in Saskatchewan is, however, still in the primary stage and the piping of natural gas to Saskatoon may come fairly soon. Natural gas reserves in eastern Alberta are adequate to supply several Saskatchewan cities, but as yet the Alberta Government has shown no disposition to commit itself to allowing the export of gas over a long period of years.

The use of petroleum for domestic heating on the Prairies has not so far been very great, but there is evidence that its use is expanding at the expense of coal and wood. The future use of petroleum fuels for domestic heating on the Prairies depends very largely on the success that is achieved by current efforts to discover additional petroleum reserves in Alberta.

Retail sales of coal on the Prairies have in recent years been upwards of 2,500,000 tons per year. Further details of retail sales of coal and coke are given in the following table:

RETAIL SALES OF COAL AND COKE ON THE PRAIRIES

(In net tons)

—	1937	1939	1940	1943
Anthracite	4,000	3,000	5,000	2,000
Canadian coal	2,612,000	2,445,000	2,546,000	3,405,000
United States bituminous	45,000	40,000	32,000	139,000
Coke from coal	60,000	65,000	59,000	66,000
Total	2,721,000	2,553,000	2,642,000	3,612,000

The figures make it clear that there is only a very limited use of imported coal for domestic heating purposes. This has not always been true; in fact, at one time United States producers enjoyed a very substantial retail market in Manitoba. Before 1918 some 400,000 to 500,000 tons per year of anthracite were used from Lake Superior westward, much of it in Manitoba. As a result of the serious shortage of anthracite at the end of World War I, shipments to this market were seriously restricted. Alberta coal producers, aided by the Alberta Government, took advantage of this situation to develop a substantial market for the output of mines which are now classed as sub-bituminous mines. Anthracite never regained its importance in the Manitoba market; by 1927 imports of that fuel had fallen to 33,000 tons, and they have continued to decline since that time. Up until the end of the 1920's, United States bituminous producers enjoyed a retail market of from 150,000 to 200,000 tons per year in Manitoba. Since that time the sales have declined steadily, largely due to the aggressiveness exhibited by the Saskatchewan lignite producers. By the end of the 1930's, the only market for United States coal left on the Prairies was the small one indicated by the above table, almost all of which is in Winnipeg. Most of the United States bituminous that does come in is used in domestic stokers especially designed for it, and that use promises to be steadily reduced by the introduction of stokers designed to use Canadian coals.

It is extremely difficult to break down retail sales on the Prairies by the field of origin of the coal. As a rough approximation, however, it appears that at the end of the 1930's about one-quarter of the coal sold retail was the output of "steam" mines in Alberta, the second quarter was Saskatchewan lignite, and the remainder was "domestic" coal from various Alberta districts.

Very little is known about the retail market of the "steam" mines. A portion of their retail tonnage is probably used for industrial and commercial purposes. A further portion is undoubtedly used in domestic stokers. Some of it is used in hand-fired, natural-draft domestic equipment; at least two of the "steam" mines produce a low volatile bituminous coal, which is a very satisfactory smokeless fuel for such equipment. Since 1937 there has been an increase in production of briquettes from the fines of these two low volatile bituminous operations. A large part of the output of briquettes is taken by the railways; nevertheless in 1940 some 70,000 tons entered the retail trade.

The market for Saskatchewan lignite production is more or less restricted to the rectangle lying between a line from Moose Jaw east to Winnipeg and the United States border. Prior to 1930 the main product of the Estevan field was deep-seam lump for the retail market. Since that time the development of stripping in that field, and the installation by coal consumers of suitable combustion equipment have increased the importance of the industrial market for lignite until, during the war years, the industrial market probably eclipsed in importance the retail market. In 1943, for example, only about 25 per cent of the output of the Estevan field was lump, the remainder being industrial sizes. There is a growing retail market for stoker sizes of lignite, particularly in Winnipeg, either alone or mixed with United States bituminous stoker coal. By 1937 there was an estimated retail sale of some 320,000 tons of Saskatchewan lignite in Manitoba. The retail market for this coal in Saskatchewan was probably somewhat smaller. There is one briquetting plant in the Estevan area with a capacity of about 60,000 tons per year. In this plant is briquetted not raw coal but the char from a low-temperature carbonization process. In recent years this plant has been operating at near capacity, and has found ready market for its output in Saskatchewan and Manitoba. Practically all of the briquettes sold are used for domestic purposes.

The production of "domestic" coal in Alberta comes from a number of fields. Some of these fields supply no more than a local market as, for example, does the Edmonton field; others ship widely to almost all points on the Prairies and to some extent to Ontario, notably the Drumheller and, to a lesser extent, the Lethbridge fields. Speaking generally, Alberta "domestic" coal producers supply the entire retail market for coal in Alberta and northern Saskatchewan, and meet strong competition from Saskatchewan lignite along the line from Moose Jaw to Winnipeg. In the Winnipeg market they have felt increasingly keen competition from Saskatchewan lignite, particularly insofar as the higher rank "domestic" coals are concerned.

The Industrial Market

As at the outbreak of World War II the industrial market for coal on the Prairies was approximately 1,000,000 tons per year. Except for a few thousand tons of United States anthracite and United States bituminous, this market was supplied by western Canadian coal producers.

Western Canadian coal producers gained access to a substantial portion of the Manitoba industrial market only with the aid of Federal subvention payments. From 1930 on such payments were made on coal moving into that market from British Columbia Crowsnest, Alberta and Saskatchewan mines. During the 1930's the tonnage thus aided ran at about 100,000 tons annually from Alberta and from 50,000 to 100,000 tons annually from the British Columbia Crowsnest and it rose more or less regularly to 164,000 tons in 1937 from Saskatchewan. As at the outbreak of World War II over 300,000 tons per year of western Canadian coal were moving into the Manitoba industrial market with subvention assistance. These figures include movements to the coke and gas plant of the Winnipeg Electric Company Limited.

The costs of several western Canadian and United States coals on car at Winnipeg are presented in the table on the facing page. The figures for Canadian coals are after the price increases following the wage increases of October, 1946. This information indicates that Canadian coals are at present just competitive in the Winnipeg market. It is believed, therefore, that western Canadian coal will in the future be competitive without subvention aid throughout more of the Prairie market than it was in the pre-war years.

Because the Prairie provinces are not highly industrialized, the total industrial energy market is not large. The main competition that coal producers have met in the market has come from water power and petroleum. The use of petroleum for industrial purposes has not been very great but its competitive pressure was increasing fairly rapidly in the immediate pre-war years, particularly in the areas around the major western refineries. There has been some use of natural gas as an industrial fuel in Alberta and, as proven reserves of this fuel grow, its use may expand somewhat.

In order to indicate the relative importance of the larger industrial coal users on the Prairies, the following figures of coal consumption in 1941 are presented. They cover about 1,000,000 tons of an estimated industrial consumption of 1,300,000 tons for that year.

	Tons
Central electric stations	356,000
Dominion Briquettes and Chemicals Ltd	120,000
Colliery briquetting (Alberta)	118,000
Other colliery consumption	170,000
Meat packing	68,000
Non-ferrous metal smelting	54,000
District heating in Winnipeg	52,000
Cement manufacturing	40,000
Sugar manufacturing	38,000

The figures given above indicate the importance of the central electric station industry as a consumer of coal. Even so, well under one-half of the electricity generated in Alberta, and practically none of that generated in

COST OF COAL ON CARS AT WINNIPEG

District of Origin	United States Coals As at September, 1946				Canadian Coals As at November, 1946			
	Coal	Size	Cost on Car at Winnipeg	Approx. B.t.u. as received	Coal	Size	Cost on Car at Winnipeg	Approx. B.t.u. as received
			$				$	
1	Central Pennsylvania	Slack	10.56	13,600	Mountain Park	Slack	9.60	12,900
		Nut	11.21	13,800		Nut	10.05	....
		Lump and Egg	11.21	13,800		Lump	11.30	13,100
3	Fairmont	Slack	10.07	13,300	Crow's Nest	Slack	9.67	13,800
		Nut	10.57	13,600		Nut	10.17	....
		Lump and Egg	10.57	13,700		Lump	11.17	14,200
8	West Virginia High Volatile	Slack	10.75	13,900	West. Can. Bellevue	Slack	9.42	12,400
		Nut	11.05	14,000		Nut	9.82	....
		Lump and Egg	11.15	14,200		Lump	11.07	13,500
10	Southern Illinois	Slack	9.89	11,900	Drumheller	Nut	8.05	9,200
		Nut	10.54	12,070		Egg	10.35	....
		Lump and Egg	10.84	12,240		Lump	10.80	10,000
					Saskatchewan	Slack	2.80	7,300
						Stoker	3.90	7,300

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Manitoba, is generated thermally. Even in Saskatchewan, where almost all the generation is thermal, about 20 per cent of the energy required is obtained from petroleum. Nevertheless, the relative importance of this market justifies special attention being paid to it.

It appears that Saskatchewan must continue to rely on the thermal generation of electricity. There are in Saskatchewan two hydraulic stations, a large one on the Churchill River near the Manitoba border, and a much smaller one on the Charlot River, north of Lake Athabaska; both of these stations are, however, much too far north to supply any of the electricity requirements of the populated areas. The only water power sites of any importance lying within transmission distance of populated areas are on the Saskatchewan River, north of Melfort. For a number of years consideration has been given to hydraulic developments there, but the sites are not entirely satisfactory and so far nothing has been done. The general pattern of electricity generation in the province is that the larger plants burn coal while the smaller ones burn oil, the principal coal-burning stations being at Saskatoon, Moose Jaw and Estevan. In 1939 the central electric station industry in the province consumed about 140,000 tons of coal, in 1941 over 175,000 tons, obtained from Saskatchewan and Alberta mines. Rural electrification may increase somewhat the industry's coal requirements but the increase is not likely to be substantial.

Alberta is served by both coal and hydraulic generating stations. Somewhat more than one-half of the power used in the province is generated in hydraulic stations of the Calgary Power Company on the Bow River, and is transmitted to Calgary and widely throughout the province over that company's lines. The largest coal-burning station is the municipal plant at Edmonton. In the late 1930's this plant used about 65,000 tons of coal per year. Consumption rose to over 150,000 tons annually in 1944 and 1945, during which period the plant supplied some 70,000,000 kilowatt hours net to the Calgary Power Company pending the completion of the Lake Minnewanka plant of that company. The Edmonton plant is an important outlet for the mines of the Edmonton coal field, whose total production in pre-war years was about 475,000 tons per year. While the coal requirements of the Edmonton plant during the war years are considered to have been abnormally high, the fact that the plant is to be increased substantially by 1948 gives promise of an annual coal consumption considerably in excess of the pre-war tonnage.

There are in Alberta three other coal-burning plants large enough to be important in their local coal markets. They are located at Drumheller, Lethbridge and Sentinel. They consumed 30,000, 15,000 and 8,000 tons respectively in 1941.

The development in mining fields of large coal-burning generating stations designed to use slack coal is often offered as an attractive solution to the marketing problems of Alberta coal producers. Alberta coals are relatively friable and the limited outlets existing for fines unquestionably constitute one of the major problems of most of the fields. The "domestic" mines, whose chief saleable product is lump coal, and whose fines have not been found easy to briquette cheaply and satisfactorily, would benefit enormously from such a development. The prospects for such a development are not, however, bright. The great water power potential of the Bow River and the general suitability of the various sites on it for power installations give hydro-electricity a strong initial advantage over coal. Much of the power market in Alberta lies within such easy transmission distance of those sites that coal cannot compete for it effectively. Even where thermal generation is competitive with water power, coal will probably come under increasing pressure from natural gas. The possibility that coal may, in the near future, capture a much larger share of the electricity market than it presently holds is therefore considered to be remote.

The coal requirements of three briquetting operations on the Prairies have been included in the figures of industrial consumption. The operations are those of the Dominion Briquettes and Chemicals at Taylorton in the Estevan field, Canmore Mines at Canmore and Brazeau Collieries at Nordegg. The Saskatchewan operation has a capacity consumption of 120,000 tons of coal per year, producing about 60,000 tons of briquettes. By a combination of carbonization and briquetting the process achieves an up-ranking of the local lignite coal to produce a high-grade domestic fuel. Unfortunately, the process requires lump coal and therefore contributes nothing to the problem of the disposal of fines. The Alberta operations at Canmore and Nordegg have been designed to use the fines of the mines to which they are connected. Their coal consumption has grown from about 19,000 tons in 1936 to 240,000 tons in 1944. Most of the Nordegg production has gone to the Canadian National Railways to be used as locomotive fuel, while most of the Canmore production has gone into the retail trade.

The Coke and Gas Market

Prairie coke and gas production comes almost entirely from two operations, that of the Winnipeg Electric Company in Winnipeg, and of the International Coal and Coke Company Limited in Coleman, Alberta. The former consumed about 56,000 tons in 1940; the latter about 109,000 tons. After a good deal of experimentation, and some difficulty in obtaining the quality required, the Winnipeg Electric Company was, at the outbreak of war, using mainly Canadian coal; the International Coal and Coke operation was using coal from its own mines exclusively. Most of the coke produced in Winnipeg is used for domestic heating and the operation is the main source of domestic coke for the Prairies. The major part of the output of the International Coal and Coke operation goes to the Consolidated Mining and Smelting Company for industrial purposes.

The Railway Market

Consumption by the railways accounts for some 35 per cent to 40 per cent of all the coal used on the Prairies. About one-half of this consumption is by the Canadian Pacific Railway Company and the other half by the Canadian National Railways, the requirements of all other railways being relatively small. Further details of railway consumption in selected years are given in the following table:

RAILWAY COAL CONSUMPTION ON THE PRAIRIES

(In thousands of net tons)

—	1930	1933	1937	1940	1943
Canadian	2,504	2,093	2,299	2,552	2,607
Imported	147	75	42	13	886
Total	2,651	2,168	2,341	2,565	3,493

The railway market for Canadian coal on the Prairies has increased more or less steadily since the beginning of the century. In the early days of railroading United States coal was used almost exclusively on western lines, but as mines were opened up in Alberta the use of Canadian coal gradually expanded. By 1930 there was relatively little United States coal used by railways in the Prairie provinces and throughout the 1930's imports continued to decline until by the outbreak of war there was practically nothing else but Canadian coal used in the area. By this time, in fact, the Canadian National Railways were using western coal west of Port Arthur and Armstrong, and the Canadian Pacific Railway Company was using Canadian coal west of White River. A relatively small amount of Canadian coal was moved into eastern Manitoba with the aid of Federal subventions, but it is almost true to say that by the outbreak of war Canadian coal for railway use was competitive with United States coal as far east as the Manitoba-Ontario boundary.

As a result of the great increase in the requirements of almost all Prairie coal users during World War II and the necessity of diverting a substantial volume of Prairie coal production to the west coast of the United States to meet an emergency situation there, the railways found it necessary once again to import a considerable quantity of United States bituminous coal for use on the Prairies. Both major railway companies have stated their intention of returning to the use of Canadian coal when it again becomes available, providing that its competitive position has not seriously deteriorated.

The great bulk of the coal consumed by the railways on the Prairies is high volatile "A" bituminous, or higher rank, and is supplied to each of the major railways by operations on their own lines. The principal suppliers are as follows:

To the Canadian Pacific Railway Company

The Crow's Nest Pass Coal Company Limited.... Fernie, B.C.
West Canadian Collieries Limited.............. Blairmore, Alta.
International Coal & Coke Company Limited.... Coleman, Alta.
The Canmore Mines Limited................... Canmore, Alta.
McGillivray Creek Coal & Coke Co. Limited..... Coleman, Alta.
Hillcrest-Mohawk Collieries Limited............ Bellevue,Alta

To the Canadian National Railways

Brazeau Collieries Limited..................... Nordegg, Alta
Cadomin Coal Company Limited............... Cadomin, Alta.
Mountain Park Coals Limited.................. Mountain Park, Alta.
Luscar Coals Limited.......................... Luscar, Alta.

For each of these groups, sales to the railway account for a very substantial proportion of their total sales. During the 1930's purchases by the Canadian Pacific Railway Company accounted for upwards of 70 per cent of the total sales of coal and briquettes by the above-mentioned Canadian Pacific Railway Company suppliers. During the same period, sales to the Canadian National Railways accounted for upwards of 85 per cent of total sales by the above-mentioned Canadian National Railways suppliers. It is therefore clear that the fortunes of these mines are very closely tied to railway coal requirements.

Considerable amounts of lower rank bituminous coals were also used by the railways as locomotive fuel. The principal suppliers of this coal were Coal Valley Mining Company Limited and Sterling Collieries Company Limited, both in the Coalspur area.

It is generally recognized that the most desirable coal for locomotive use is that which has been washed and which does not contain an excessive percentage of fines. The limitation on the percentage of fines is particularly important with low volatile coals. The railways in western Canada normally accept run-of-mine coal, although they do urge that the amount of fines be kept within reasonable limits. Because of the high percentage of fines in his run-of-mine, one low volatile operator briquettes a proportion of his production for railway use. Over the past years there has been steady improvement in the quality of the coal delivered by western operators to the railways. The notable improvement over the last two decades in the operating efficiency of both major railways, as reflected in the pounds of coal used per gross ton mile, has been due in no small part to the efforts of the operators in this connection.

There is a relatively small amount of fuel oil burned in Alberta in locomotives by both major railways in the immediate vicinity of the Alberta-British Columbia border. This area is merely the fringe of the much larger area in British Columbia in which oil is used extensively as a locomotive fuel. The reasons for the extensive use of fuel oil by the railways in British Columbia are discussed in the section on British Columbia markets.

In addition to their use of bituminous coal in locomotives, the railways were using, at the outbreak of war, about 350,000 tons per year of sub-bituminous and lignite coal for stationary installations and station heating. The Canadian Pacific Railway Company has zoned its western lines territory and used Saskatchewan lignite from Kenora west to Regina, and Alberta sub-bituminous particularly from the Drumheller, Lethbridge and Medicine Hat fields, from Moose Jaw to Calgary. Plants on the northern lines were supplied from the Edmonton field. The policy of the Canadian National Railways in this respect seems to have been somewhat similar. The expansion of this market for sub-bituminous and lignite coal has been facilitated by the introduction of modern combustion equipment.

The Export Market

In times of normal supply, there has been an export to the United States from Prairie mines of about 40,000 tons per year. Some two-thirds of this tonnage was bituminous coal of the "steam" variety, most of it from the Alberta Crowsnest Pass; the other one-third has been "domestic" coal, mostly from the Lethbridge area.

There is a widespread belief that there exists a large potential market for Alberta coal in the adjoining States of Montana and North Dakota. A survey of the coal supply of these areas reveals that this belief involves a serious misunderstanding of the market situation in that area. The coal requirements of these States are not large, for the area is not highly industrialized; moreover, most urban areas in Montana are well served by natural gas, and central Montana is supplied by hydro-electricity generated on the Missouri River. The coal production in Montana in recent years has far exceeded 5,000,000 tons, varying in rank from lignite to high volatile bituminous "C". The output of the higher rank coals, which are at least the equivalent of Lethbridge coals, is from mines having a man-day production of some 7 tons compared with about 3.5 tons for the Lethbridge area. In addition, strip mining is relatively extensive. Montana producers ship coal to various points from Minnesota west to Washington. At many points in Montana, the local producers are subject to strong competition from Wyoming coals. Wyoming production in 1942 was about 8,000,000 tons, most of it being of bituminous rank suitable for locomotive use. Finally, there is in North Dakota a production of lignite coal which, in 1942, was 2,500,000 tons, which precludes any significant export to that State from the lower-rank Alberta and Saskatchewan fields. Such a survey makes it abundantly clear that any hope of a large market for Prairie-mined coal in the adjacent United States is without reasonable foundation.

THE BRITISH COLUMBIA MARKET

The importance of coal as a source of energy is less in British Columbia than in any of the other areas into which Canada has been divided for purposes of the discussion of coal markets. According to estimates made for 1937 and 1943, coal was approximately equalled in importance as a source of energy by each of water power and petroleum. The importance of water power in this province is as great relatively as it is in Ontario and Quebec, while the importance of petroleum products is nearly twice as great in British Columbia as in any other area in Canada. Furthermore, there is relatively more wood fuel used in this area than in any other in Canada; in fact, it appears that wood fuel provided somewhere from 15 per cent to 20 per cent of all the energy used in British Columbia.

This information indicates quite clearly that coal in British Columbia is under very strong pressure from almost all the alternative sources of energy and explains why the market for coal in that province is so limited. During the pre-war years the consumption of coal in British Columbia was just over 1,500,000 tons annually. During the war years it reached 2,000,000 tons annually but it is now declining and it is anticipated that consumption in the area will be well under 2,000,000 tons per year in the post-war years. There may be some slight lessening in the competitive strength of wood fuel in the area, but there is no reason to expect any decline in the use of water power or petroleum, and the combined pressure of all alternative sources of energy on coal is not likely to be reduced.

Production

Before the turn of the century production in British Columbia had attained a level in excess of 1,000,000 tons annually, and it reached a peak of 3,300,000 tons in 1910. In the past fifteen years, though always in excess of 1,000,000 tons, it was only during the years of World War II that it reached 2,000,000 tons. All the coal produced in the area is of bituminous rank. The principal producing areas are Vancouver Island, the Crowsnest Pass district in the southeastern part of the province, the area south of the main line of the Canadian Pacific Railway in the vicinity of Merritt and Princeton, and the Telkwa district, 200-odd miles east of Prince Rupert. The latter two of these areas are usually referred to as the Inland district.

Nearly 90 per cent of the province's coal output comes from the Island and Crowsnest Pass Districts. Since 1940 the Crowsnest Pass district has been a larger producer than the Island district and it promises to remain such. Future production on the Island is in considerable measure dependent on the mineable reserves remaining, concerning the size of which there is some doubt, whereas production from the Crowsnest Pass area, where reserves are adequate, will be wholly determined by the market available. The area around Merritt and Princeton at one time produced over 200,000 tons annually but its output has fallen in recent years, and even during World War II it produced less than 150,000 tons a year. The natural conditions in this district are unfavourable and it does not show promise of being an important factor in the future. The Telkwa area produces only about 8,000 tons annually. Although the selection of a year that is completely representative of any extended period is impossible, the comparative production of the various districts may be judged by figures for 1940, which are as follows:

	Tons
Crowsnest Pass	869,704
Island	821,051
Inland	177,091
Total	1,867,846

Consumption Estimates

Estimates of the consumption of coal in British Columbia by type of user for a few recent years are given below.

COAL CONSUMPTION IN BRITISH COLUMBIA

(In net tons)

—	1937	1939	1940	1943
Retail	504,000	485,000	559,000	718,000
Industrial	390,000	375,000	380,000	491,000
Coke and gas plants	166,000	171,000	192,000	263,000
Railways	285,000	257,000	245,000	475,000
Bunker	200,000	241,000	176,000	81,000
Total	1,545,000	1,529,000	1,552,000	2,028,000

The Retail Market

The outstanding feature of the market for domestic heating fuels in British Columbia is the widespread use of wood fuel. According to the 1941 Housing Census, 75 per cent of the occupied dwellings in the province were heated principally by wood fuel in one form or another, a percentage equalled only in New Brunswick. Since a further 6 per cent of the British Columbia households were heated principally by fuel oil, the domestic heating market for coal, coke and manufactured gas has been limited to about one-fifth of the dwellings in the province.

The following table shows the retail sales of coal and coke in British Columbia for various years.

RETAIL SALES OF COAL AND COKE IN BRITISH COLUMBIA

(In net tons)

—	1937	1939	1940	1943
Canadian bituminous and sub-bituminous	500,000	485,000	558,000	717,000
United States bituminous	4,000	Nil	1,000	1,000
Coke from coal	27,000	23,000	23,000	23,000
Total	531,000	508,000	582,000	741,000

The increase in the domestic use of coal during the war years can be explained in large part by the shortage that developed in the supply of sawdust and millwood. There are at present some developments in the wood industry in British Columbia that suggest that post-war supplies of sawdust and millwood may continue to be somewhat restricted. However, it is anticipated that this fuel will, to a substantial extent, recapture the position that it occupied prior to the war. It is also anticipated that the use of fuel oil for domestic heating will continue to expand. Therefore, the use of coal for domestic heating is expected to return to something not far above the pre-war level.

Of the retail sales in pre-war years about 200,000 tons were island production. The remainder of the coal came from inland mines and from Alberta. There has, for some years, been a substantial movement of coal from the Drumheller area into this province but a great part of the increased demand of war years was met by "domestic" mines in the Coalspur area of Alberta. The Macleod River mine is the largest shipper to British Columbia from that area, but various other mines there have shipped and are shipping into the coast market. Drumheller will no doubt continue to be a source of supply for the interior around such centres as Kamloops and Revelstoke and some of this coal will probably move to the lower mainland. The Coalspur coals, because they enjoy a rail rate of $4.10 as against a Drumheller rate of $5.00 and possess better weathering qualities and higher calorific values than the Drumheller coals and are also free-burning in character, should continue to enjoy a good part of the market which has been developed for them in the war years. It appears that the post-war retail market in British Columbia should provide an outlet for upwards of 300,000 tons of Alberta coal.

The only coke and gas plant supplying any appreciable quantity of coke for retail sale is that at Vancouver. Coke as a domestic fuel enjoys little preference in the equable coastal climate and there is very little reason to expect any substantial increase in retail sales of coke in the province.

The Industrial Market

The consumption of coal by industry in British Columbia in pre-war years was about 380,000 tons annually. The relative importance of various industrial consumers may be judged from the following estimates, which are based mainly on 1940 consumption.

	Tons
Mining and smelting	240,000
Cement	30,000
Pulp and paper	25,000
Sugar	20,000
Central electric stations	10,000
Colliery use	30,000
	355,000

The overall energy requirements of industry in British Columbia are somewhat limited, for the province is not highly industrialized. Within the industrial energy market coal has met very strong competition from water power, from petroleum and from wood fuel. By far the greater part of the electricity generated is generated hydraulically; even for that portion which is thermally generated fuel oil and wood fuel are probably each as important as coal. There are very many undeveloped water power sites of large potential on the west coast, particularly on the Fraser River and its tributaries. The B.C. Power Corporation Limited is at present engaged in an extensive water power project on one of these tributaries, the Bridge River. So far there has been very little use made of secondary power in the province. Whether or not further hydraulic developments will allow the use of substantial quantities of secondary power is very much open to question, but it does seem clear that the primary power requirements of the province will continue to be supplied mainly by water power. Fuel oil deliveries for industrial heat and power, exclusive of railway use of ships' bunkering, amounted to the equivalent of 275,000 tons of coal during the immediate pre-war years. Fuel oil was used in large quantities by pulp and paper mills located at tidewater and receiving the fuel water-borne from California. Fuel oil use for industrial purposes increased by more than 50 per cent in war years and would have increased more if sufficient oil had been available. Most of the wood fuel used in the province enters the retail trade; nevertheless, very substantial use is made of it for steam raising, either for power generation or process heating, particularly by pulp and paper mills and sawmills. An effort was made during the years of World War II to ease the oil situation by the diversion of wood fuel in the form of hogged fuel to industrial consumers. The use by industry of wood fuel in the post-war period may be expected to decline somewhat, but the market opened is more likely to be filled by oil than by coal.

The Coke and Gas Market

There are two large coke and gas operations in British Columbia, that of the Crow's Nest Pass Coal Company at Michel, which used 88,000 tons of coal in 1939, and that of the B.C. Electric Power and Gas Company Limited at Vancouver, which used 71,000 tons of coal in 1939. Most of the coke produced by the Vancouver plant is sold in the retail market, whereas the output of the Crow's Nest Pass plant is supplied for the most part either to Consolidated Mining and Smelting Company, or exported to Idaho. The Consolidated Mining and Smelting operation brings in substantial quantities of coke from the International Coal and Coke plant at Coleman, Alberta.

The Railway Market

The consumption of coal by railways in British Columbia was about 275,000 tons annually in pre-war years. Statistical information is inadequate to indicate the source of the above tonnage except in the case of Island coal, which annually appears to have amounted to 60,000 tons. The balance is, of course, supplied largely by British Columbia and the Alberta mines in the Crowsnest Pass and by the Mountain Park area in Alberta. Until production in the Princeton area suffered a marked decline, the Canadian Pacific Railway secured a portion of its supplies from that area. During the years of World War II railway consumption rose to 475,000 tons due to large increases in traffic, particularly in freight.

The relatively limited use of coal by the railways in British Columbia is due to the extensive use made of fuel oil by the railways in that area. It is only on mountain divisions that Canadian railways use oil for steam raising in locomotives, but it so happens that almost all of these divisions lie within British Columbia. The Canadian National Railways use oil almost exclusively for all services west of Jasper. The Canadian Pacific Railway uses it exclusively on its main line between Field and Kamloops and also on secondary lines such as the Lake Windermere subdivision and on the Company's subsidiary, the Esquimalt and Nanaimo Railway, on Vancouver Island. The Canadian Pacific Railway uses oil and coal between Calgary and Field and between Kamloops and Vancouver on the main line and likewise both oil and coal are burned on the Kettle Valley line between Vancouver and Penticton. The Pacific Great Eastern Railway, owned and operated by the Province of British Columbia, and operating from Squamish to Quesnel with 387 miles of track, uses oil exclusively.

The conversion from coal to oil was effected about 1912, when an amendment to the Railways Act imposed increased responsibility on the railways for fires occurring adjacent to railway right-of-ways in forested areas. The use of oil was not, and never has been, made mandatory, but it appears to be conceded that the exclusive use of coal would necessitate a much more expensive patrolling of right-of-ways by the railways. The Canadian National Railways, in its submission, said that its records revealed that the chance of a coal-burning locomotive starting a fire was at least 25 times that of an oil-burning locomotive.

As might be expected there are other factors influencing the railways in their decision to use oil rather than coal. Their case in favour of oil may be summarized as follows: It is available at Prairie refineries and at tidewater on a favourable price basis. The use of coal would increase transportation costs in mountain areas where short tangents and long grades are encountered. Operating under these conditions with coal-burning locomotives would present special problems which would be reflected in slower and inferior service in both freight and passenger movements. Under mountain conditions it is imperative that locomotives develop maximum tractive effort, which is not possible with coal since the coal available contains a substantial percentage of fines. The use of oil increases the comfort and convenience of passenger service. Finally, the conversion to coal at this time would involve substantial expense. The Canadian

National Railways estimates that conversion to coal at the present time would involve a capital expenditure in excess of $1,000,000, and that annual operating expenses would thereafter be increased by $586,000. The Canadian Pacific Railway Company estimates the capital cost of conversion at $1,500,000, and would anticipate an annual operating disadvantage in the neighbourhood of $200,000.

The Canadian railways direct attention to the fact that all transcontinental lines in western mountain divisions in the United States, with the exception of one, use oil-burning locomotives, diesel electrics, or staight electric locomotives, and that the one exception, the Northern Pacific Railway, is now engaged in the conversion to oil.

In 1945 the Canadian Pacific Railway Company and its subsidiaries consumed 1,374,054 barrels of oil. For the same year the Canadian National Railways consumed 690,871 barrels of oil. Both railways secure a portion of their supply from Prairie refineries, Turner Valley in Alberta being the principal source of Canadian fuel oil. In the statistics accompanying submissions to the Commission by the railways, the Canadian Pacific Railway Company estimated that a ton of coal was equivalent to 3.75 barrels of fuel oil, while the Canadian National Railways used a lower figure of 2.5 barrels of fuel oil to a ton of coal. Both these estimates are based on operating tests and the difference between them is apparently due to variations in operating conditions and in the factors taken into account. Converting the oil consumption of each railroad into coal at its own equivalent, it appears that oil burned in locomotives displaced about 775,000 tons of coal in 1945.

In conclusion we should add that at the Commission's request both the Canadian Pacific Railway and the Canadian National Railways furnished us with submissions supplementary to their briefs, dealing exhaustively with the use of oil on mountain divisions. Copies of these submissions were furnished to all western bituminous operators and no serious attempt was made by the operators to answer the case made by the railways for their use of fuel oil rather than coal. It is quite evident from the submissions made to this Commission that neither railway contemplates now, or in the near future, any limitation on its present use of oil as a locomotive fuel.

The Bunker Market

Since 1931 Federal aid, ranging from 25 cents to $1.00 per ton, has been extended to British Columbia coal producers to assist them in meeting the strong competition from oil in supplying ships' bunkers. Bunker sales rose from 63,000 tons in 1931 to 241,000 tons in 1939. Since 1939, bunker sales have fallen sharply but this decline has been due largely to the inability of the mines to provide the coal under the short supply conditions of the war years. As from March 1, 1943, federal subsidy payments have been restricted to deliveries to tugs and other coastal shipping. Practically all of the bunker coal supplied in British Columbia has been island production, for it has been impossible for inland mines to meet the competition in the bunker market after paying rail freight. Throughout the last twelve years fuel oil deliveries in the province for bunkering purposes have been more or less regular at about 60,000,000 gallons annually, or the equivalent of approximately 400,000 tons of coal. It should, perhaps, be mentioned here that a substantial volume of coal, which might normally have been used for bunkering in British Columbia, was, during the war years, delivered to Russian vessels at Seattle.

The Export Market

A number of years ago the British Columbia coal producers held a very substantial export market in California and throughout most of the Pacific northwest. However, the discovery of oil in California terminated the market there and reduced it very substantially in all of the Pacific States. Up until 1929 the Great Northern Railway took substantial amounts of coal, at times exceeding 500,000 tons annually, from the Crowsnest Pass area. About that time the Great Northern Railway completed the conversion to oil-burning equipment of its mountain sections, and this market for Crowsnest Pass coal completely disappeared. There remains at present only two markets of any importance in the United States for British Columbia coal, one in the Puget Sound area centering around the City of Seattle, and the other in the vicinity of Spokane and the northern part of Idaho.

Before examining these two markets in any detail, there are a few general considerations which should be kept in mind. In the first place the State of Washington produced from 1,500,000 to 2,000,000 tons of coal annually in the pre-war years. A considerable part of this production was from mines owned by the Northern Pacific Railroad. This railroad is presently changing to oil in its mountain divisions and there is every prospect that its own coal production will be offered commercially, thereby intensifying competition in the Puget Sound area and more particularly in the Spokane area. The State of Washington imports large amounts of coal from Utah, Wyoming, Montana and Colorado. In general, these sources are at a disadvantage with the British Columbia mines in the matter of freight rates, but they are at an advantage in respect of mine prices. Moreover, the coal market in Washington is considerably reduced by the extensive use of fuel oil, hydro-electricity, and wood fuel throughout the area. Finally, although during World War II the export of Canadian coal to the Washington market increased very considerably, the circumstances which gave rise to the movements are not likely to be permanent. The Canadian Coal Controller and the United States Solid Fuels Administration for War collaborated continuously during the war period so as to satisfy demands for coal in the most convenient manner, and in order to meet the growing demand of the United States Pacific northwest considerable Canadian coal for steam raising and domestic purposes, and for bunkerage, was diverted to the State of Washington.

It has been said that the export of Canadian coal to the State of Washington is seriously restricted by State or Federal statutes or regulations preventing its use by public institutions or on public projects. The restrictions appear to be inconsequential. There is in force in the State one statute governing the purchase of commodities by public institutions which provides that goods produced in the State may be purchased when the prices for them are not more than five per cent in excess of the prices for such goods produced elsewhere, quality and service considered. Manifestly such a provision is not an effective restriction on the movement of Canadian coal into the State.

In the pre-war years the Island producers had a market for about 35,000 tons annually in the Seattle area. The market was mainly a domestic market and the chief competition came from Utah and Wyoming coal. During the war years the producers were unable to meet the full requirements of this market but it is anticipated that in the next few years they may be able to find an outlet for about 50,000 tons annually of their own production and a further 10,000 tons annually of Macleod River production. As at March, 1946, the retail prices for lump, nut and pea sizes were about the same for Island coals as for Utah and Wyoming coals.

Almost all of the British Columbia coal exported to the area of Spokane and northern Idaho comes from the Crow's Nest Pass Coal Company. The exports of this company have grown more or less steadily from 11,000 tons in 1934 to 172,000 tons in 1944. A portion of the wartime growth is thought to be only temporary, but the company anticipates a coal market of at least 115,000 tons per year in the post-war years. Small amounts of this coal have found their way into the retail trade but most of it is used by industrial consumers. A further 25,000 tons, or thereabouts, is exported annually to this area from the Alberta Crowsnest Pass area. It is believed that the British Columbia producer will continue to enjoy the major part of this Canadian export market because of the advantage which he possesses over his competitors in respect of ash content. The United States coals available for this area are higher in moisture, lower in fixed carbon and, in most cases, higher in ash than the Canadian coals and, therefore, their competition in the industrial market is not particularly feared. Nevertheless, it is considered unlikely that this market can be expanded beyond some 150,000 tons of Canadian coal in the near future.

There is also a considerable export of coke to this area by the Crow's Nest Pass Coal Company. Coke exports of this Company have grown from 7,400 tons in 1934 to 39,500 tons in 1944. It is believed that coke exports may continue to grow until a level of some 55,000 tons is reached.

CHAPTER X

COMBUSTION

This chapter deals with the use of coal and coke as fuels and the industrial, domestic, and locomotive equipment within which they are so used. District or central heating offers an alternative to the use of individual combustion units for space heating, and the experience of district heating systems on this continent is therefore reviewed in the last part of the chapter.

The most useful characteristic of coal is that under favourable conditions it will react chemically with oxygen in a process known as combustion, during which a considerable amount of heat is liberated. All coals contain some non-combustible moisture and ash, but they also contain fixed carbon and volatile matter which are combustible. The problem of coal combustion is to obtain from coal useful heat at the lowest possible cost per unit of such heat.

When coal is added to a fire in a stove or furnace, the fixed carbon and some of the volatile matter distilled off are burned in the air, called primary air, drawn through the firebed by the chimney draft. Normally the supply of primary air is inadequate to allow complete combustion of the volatiles, and additional air, called secondary air, is admitted above the firebed. If the supply of secondary air is inadequate, or if the air-gas mixture is cooled below its ignition point, or if the air-gas mixture is not ignited (which may happen if no glowing coals have been left exposed) combustible gases will be lost as smoke up the chimney leaving soot on the furnace walls and the flues. When all of the combustible matter is distilled off or burned, an ash residue remains which must be removed from time to time to leave room for fresh coal and to allow freer passage of primary air through the fire. If the ash residue has a low fusion temperature and if the fire is very hot, the residue may fuse to form a clinker which may seriously restrict the passage of primary air.

The heat losses during combustion may be classified as losses of actual heat or as losses of unburned combustible matter, that is, as losses of potential heat. Actual heat is lost by hot gases passing up the chimney and by heat radiated from the combustion equipment. Potential heat is lost by unburned combustible gases passing up the chimney and by unburned carbon passing through the grates into the ash-pit. It is a requirement of good combustion equipment that loss of actual and of potential heat be a minimum.

The gross heat value of a fuel (expressed in B.t.u./lb.) is a measure of the heat that would be generated by perfect combustion of a unit of the fuel. The useful heat actually obtained in any equipment per unit of the fuel burned can be measured, and the thermal efficiency of the equipment is usually expressed by giving the useful heat obtained as a percentage of the gross heat value of the fuel. Any hydrogen in the fuel is converted to steam during the process of combustion and the steam formed in this way, together with that resulting from the moisture content of the fuel, passes up the chimney uncondensed. The latent heat of the steam is therefore lost, with a consequent reduction in the thermal efficiency of the equipment. In determining the gross heat value of a fuel the products of combustion are cooled to room temperature and the latent heat in them is therefore recovered. If allowance is made for the loss of latent heat in determining the heat value of a fuel, the heat value arrived at is called the net heat value. The net heat value may be as much as 10 per cent lower than the gross heat value for a fuel with a high hydrogen content, such as, for example, natural gas. It may be only 2 per cent or less for a fuel with low hydrogen content such as, for example, anthracite or coke. It is an established practice in this country to express thermal efficiency as a percentage of gross heat value, despite the fact that the recovery of latent heat is not usually practicable.

The design of combustion equipment is complicated by the fact that coals vary over a wide range in their characteristics. A few of the respects in which coals vary, and the effect which the variations have on the burning properties of the coals, are described in very general terms in the following paragraphs.

(a) Volatile Content.—Combustion equipment and firing technique must ensure that the volatile matter distilled from coal is mixed with sufficient air under conditions of temperature and space to give prompt ignition and full combustion if a high thermal efficiency is to be secured. The reason that anthracite, coke and low volatile coals are said to be smokeless is that the volatile content of them is small, and even if the combustible gases driven off go up the chimney unburned little smoke is produced. As the rank of coal decreases from anthracite to about high volatile "C" the volume of combustible gases per unit of coal fired increases, and if secondary air is not supplied in the proper volume under suitable conditions the gases will pass off unburned, potential heat will be lost, and smoke will result. As the rank of coal drops below about high volatile "C", the proportion of total air that is required to burn the volatile matter declines. This drop is due to an increasing oxygen content in the volatile matter, and is associated with a decrease in smoke forming tendency. Thus both low and high ranking coals are more or less smokeless, while high volatile "C" rank coals have about the maximum tendency to produce smoke. Even these coals need not be smoky, for any coal can be burned smokelessly if it is properly fired in suitable equipment. It is seldom possible however to burn a high volatile fuel satisfactorily in equipment designed for a low volatile fuel.

(b) Caking Properties.—The tendency for coal particles to adhere together when heated varies considerably with different coals. In a forced draft furnace, as for example in a locomotive, coal which cakes is advantageous because it permits a higher draft without excessive loss of small particles up the stack. If, however, the coal cakes very strongly it may form a solid layer of coke over the firebed which will interfere with draft unless there is some provision for breaking it periodically. Some automatic equipment is designed so that it will break up any coke masses and strongly caking coals are therefore often suitable. In hand-fired domestic furnaces, however, coals that cake very strongly may be unsatisfactory.

(c) Ash Fusion Temperature.—If the temperature in the firebed rises above the ash fusion temperature of the coal used, the ash will fuse and may solidify on the grates or be projected onto the furnace walls with consequent loss of efficiency and furnace damage. For equipment in which high firebed temperature is attained a high fusion ash is therefore generally desirable, although some equipment is now designed for the collection of ash in fluid form, and for such equipment the fusion temperature of the ash must be below the temperature of the fire. Clinkers are more or less large fused agglomerates of ash and coke, and while in many kinds of equipment a non-clinkering ash is easier to remove, there are equipments which require that the ash clinker sufficiently to form a mass that can be removed from the firebed with tongs, while at the same time not clinkering so much as to form a slab that will interfere with air flow.

(d) Size of Coal.—If combustion is by natural draft a sized coal is advantageous, for fine coal may cut off the supply of primary air. Many stokers are designed to handle coal within a comparatively narrow range of sizes while other stokers will handle a wide variation in sizes although a narrow range of sizes in the coal used leads to more uniform combustion with almost any stoker. With pulverized coal burning equipment only very small particles can be used.

There are a number of other ways in which variations in the character of coals limit the range of equipments in which they can be used efficiently. The fact important to recognize is that the coal used and the equipment within which it is used must be suited to each other. For this reason the combustion equipment installed in Canada imposes restrictions on the range of coals which will meet the country's needs. We require not simply coal, but different kinds of coal, each kind in amount sufficient for the combustion equipments which can use it satisfactorily. This rigidity can be overemphasized; in the short run there is some flexibility in all equipment and there is considerable flexibility in some equipment, while in the long run, as equipment is replaced, types more suitable for the coals most readily available may be installed. Moreover, there is at present in both Canada and the United States a trend towards the installation of more flexible equipment and research being currently undertaken will probably reinforce the trend. Nevertheless, the rigidity cannot be ignored, and it can be misleading to think of coal requirements except in terms of the equipment within which the coal is to be used.

I INDUSTRIAL EQUIPMENT

Canadian industry, exclusive of coke and gas plants and the railways, uses about one-quarter of the coal consumed in the country. The coal is used in a great many types of combustion equipment. The operating principles of the more common type are reviewed below, with some reference to their use in this country.

(a) Hand-fired Grates.—Hand-firing is commonly used only for small industrial units though there are still some hand-fired units as large as 500 to 600 horse-power[1]. In general, this method of burning coal is cheap to install but inefficient, and is rapidly being supplanted by mechanical appliances such as underfeed, chain or travelling grate, overfeed and spreader stokers, or by pulverized coal burning equipment.

(b) Underfeed Stokers.—In the underfeed stoker raw coal is forced under the burning fuel bed by a mechanically operated ram or pusher. Volatile matter distills from the coal as it rises under the burning fuel bed, and both the volatile matter and resulting coke are ignited in the fuel bed, thus facilitating smokeless combustion. Primary air is generally supplied by forced draft fans. All types of underfeed stokers are similar in principle, but may vary in size from the small single to large multiple retort units. Single retort underfeed stokers are widely used on small industrial boilers of 200 horse-power or less. In some underfeed stokers a movement of the grates helps to move the fuel away from the retort; these are adaptable to rather wide furnaces and to boilers up to 500 to 600 horse-power. The multiple retort underfeed stoker was, for many years prior to the more recent development of the pulverized coal furnace, the standard in North America for large industrial installations, especially those using a coking coal. These stokers employ a number of rams or plungers to feed coal to the retorts. The fuel usually moves from the front towards the rear of the furnace where the ash is removed. When a large grate area is provided or when the grate surface is water-cooled, low rank coals may be burned successfully. Multiple retort stokers have been installed in single units capable of producing up to 500,000 pounds of steam per hour.

(c) Chain and Travelling Grate Stokers.—The chain grate is composed of a chain with short grate bars linked together to form a continuous loop which revolves around sprockets in the front and rear of the furnace. The travelling grate is made up of keys fitted into cross bars which are linked together at each end to travel over the sprockets; the front of each key rides on the tail of the preceding one to form a moving grate with small air spaces on each side of the key for air distribution. Coal is fed on to the front end of the grate from a hopper

[1] The horsepower rating used is the conventional boiler horsepower, equivalent to the conversion per hour of 34.5 pounds of water at 212° F. to steam at the same temperature.

before it enters the furnace. An adjustable gate at the furnace entrance regulates the depth of fuel on the grate, which may vary from one and one-half inches to a maximum of twelve inches. Forced air is admitted under the active grate area through two or more wind-boxes with regulating dampers on either side of each wind-box. This permits positive regulation of the quantity of air to burn efficiently the fuel on the different portions of the grate. This type of equipment is adaptable to the use of coals having high ash content and low ash fusion temperature, and is extensively used for handling the small sizes of low rank coals which cake only slightly or not at all. In Ontario and Quebec it is used to burn small sizes of anthracite coal or coke breeze.

(d) Overfeed Stokers.—In most types of overfeed stokers the coal is fed on to the top of a sloping grate from a hopper outside the furnace. The coal is coked by the aid of a fire-brick arch which reflects furnace heat down on to the fuel bed. The coal is moved slowly either to the rear or to the middle of the furnace, the burning progressing as the coal moves down the grate. The movement of fuel is effected by reciprocating or rocking motions of the grate bars, aided by gravity. Clinker and ash collect at the bottom and are dumped or crushed, according to the design of the stoker. Overfeed stokers are adaptable to a wide range of coals and to the use of refuse fuels such as sawdust and tanbark. However, they are restricted to low burning rates if excessive loss of unburned fuel in the ash-pit is to be avoided, and for this reason few have been installed in recent years.

(e) Spreader Stokers.—Spreader stokers were first designed to copy mechanically the method of hand-firing of coal on to a grate. Modern spreader stokers have a variable feeding device so that the coal is sprinkled uniformly over the entire surface of a horizontal forced draft grate, either by revolving paddles or by air jets, to give a fuel bed of from two inches to four inches in thickness. Air is forced at high velocity through small grate openings which insures uniformity of air flow and produces turbulence above the firebed permitting the fines to be burned in suspension. With this burning method, very high combustion rates per square foot of grate have been attained. Three types of grates are available, stationary, dumping and travelling, the latter being somewhat similar to chain grates. Spreader stokers are usually restricted to smaller units but have been installed under boilers of as much as 300,000 pounds of steam per hour capacity. They can use to good advantage caking and non-caking coals with either low or high ash content. Low fusion temperature of ash is not a disadvantage as such coal can be burned with practically no clinkering due to the thin fuel beds with which they operate. Recent installations almost invariably use slack coal of three-quarter inch or less, but coal with a top size up to two and a half inches can be handled in some installations.

(f) Pulverized Coal-burning Equipment.—Pulverized coal firing, in which the coal to be burned is first reduced to dust-sized particles in pulverizers of the ball, roller or impact type, was first adopted by the cement industry and later by metallurgical industries for furnace heating, but its main use at present is in large scale boiler units. There are two general classes of pulverized coal preparation systems: one, the storage or bin system and the other the unit or direct system. The bin system was used exclusively in earlier pulverized coal installations, but it is being rapidly replaced by the direct system in which the coal is pulverized only as required and fed directly to the burners. Slack or crushed coal flows by gravity from an overhead bunker to feeders which measure the supply to the pulverizers where it is ground to the required fineness. A controlled amount of primary air, which in many installations is pre-heated to take care of moist coal, is forced or drawn through the pulverizer to carry away the finely ground coal in suspension. This pulverized coal and primary air mixture is fired directly from the mill into a burner located at the entrance to the furnace. The volatile matter is almost instantaneously distilled from the dust, and is burned

rapidly due to the turbulence created by the burner design. A secondary air supply is introduced, usually around the burner, to complete combustion. As there is no fuel bed, the coal must be consumed in suspension in the combustion space. This method of burning coal has been vastly improved, particularly in the past ten years. A pulverized coal-fired installation may be limited to the kind of coal for which it was designed; however, the intensive study given to operating difficulties has resulted in the development of modern installations capable of highly efficient utilization of fuels ranging from anthracite to lignite. Pulverized coal equipment is becoming increasingly popular for boiler installations of 50,000 pounds or more of steam per hour capacity.

In the winter of 1945-46 a survey was made of industrial combustion equipment installed in Canada. The survey was not complete but it is estimated that in the equipment covered by the following table about 85 per cent of the coal used for steam raising in a normal pre-war year was consumed.

	No. of Units	Total Horse-power	Average H.P. per Unit	Coal burned as per cent of Total
Hand-fired Grates	4,065	328,000	80	13
Underfeed Stokers	3,343	456,000	140	34
Chain and Travelling Grate Stokers	506	202,000	400	12
Spreader Stokers	196	68,000	330	5
Pulverized Coal Burners	170	155,000	910	35
Overfeed Stokers	83	17,000	200	1
Totals	8,363	1,228,000	150	100

A review of these data on a geographical basis shows a relationship between the type of equipment, the coal available, and the industrial needs in any area. In Nova Scotia and New Brunswick for example, more than half of the coal used by industries, excluding coke and gas plants and railways, was burned in pulverized coal-burning equipment, due largely to the fact that such equipment is particularly suitable for large thermal-electric generating stations, and to the fact that Maritime coal is suitable for such equipment. In Central Canada many plants have been designed to use coal of low volatile content and high ash fusion temperature. Coal of this kind has been and continues to be available from the United States. These plants will not operate efficiently at high loads with high volatile coal of low ash fusion temperature, and are, therefore, not suitable for Nova Scotia coal. In western Canada, spreader stokers and chain grate stokers are more common than elsewhere, largely because of their suitability for the weakly caking or non-caking character of much of the coal mined on the Prairies.

There has been increasing recognition in recent years of the fact that efficient combustion equipment, particularly equipment able to use efficiently a wide range of coals, can make a material contribution to lower fuel costs. There is, for example, a trend toward the increased use of coal with an ash fusion temperature below 2300° F. Most Nova Scotia and New Brunswick coals, as well as many United States coals, are in this category and new plant installations in the areas where these coals are available are generally designed for their use. Consideration has also been given to the design of plants to use coal high in moisture; this development is of particular importance in Canada where coals as delivered tend to be somewhat high in moisture content due to long exposure to the weather during storage and handling. The relatively high cost of coal in Canada has resulted in increased attention being given to heat recovery apparatus, such as economizers and air pre-heaters. There is also a trend toward the more careful matching of steam-generating and fuel-burning equipment.

A good deal of both fundamental and engineering research to improve the efficiency of coal utilization is being carried on both in Great Britain and in the United States, with the activities of the British Coal Utilization Research Association outstanding in the United Kingdom, and those of Bituminous Coal Research Incorporated in the United States. Both these organizations frequently issue bulletins reporting on the success achieved in their laboratories and experimental stations on a wide variety of combustion problems.

Coal research in Canada has been largely fundamental in character, and has been carried on mainly by the Fuel Research Laboratories of the Dominion Government. Some coal operators have displayed considerable enterprise in providing engineering assistance in the installation of equipment suitable for their products. Both Saskatchewan and Alberta operators, the latter being assisted by the Alberta Government, have had considerable success in enlarging their markets by this means.

II DOMESTIC EQUIPMENT

Somewhat more than one-quarter of the coal used in Canada is sold at retail prices. For the most part this coal is used in domestic heating or other small combustion equipment. There are many kinds of small combustion equipment, but they are mainly modifications of three types;

(a) Stoves.—Stoves burning either coal or coke are normally used for space heating or cooking purposes. The fire pots are fitted with shaking grates and the delivery of heat is regulated manually by undergrate and chimney dampers. Stoves are usually hand-fired, but a small number of magazine self-feeding types are used with sized anthracite or coke.

(b) Hand-fired Domestic Furnaces.—Most of the domestic furnaces used to supply warm air, hot water, or low pressure steam for space heating are hand-fired and have shaking grates. Some hand-fired furnaces operate with forced draft supplied by thermostatically controlled blowers. In such cases the shaking grates are usually replaced by stationary grates with smaller air openings, and ash removal depends on the clinkering of the ash so that it may be extracted by clinker tongs.

(c) Domestic Stokers.—Stokers of the underfeed type for domestic use are made for both bituminous and anthracite coals. The present bituminous stoker is generally of the clinker type, where the ash in the form of clinker is removed from the grate by tongs. Such a stoker is most suited for fuel with an ash fusion temperature of from 2000° to 2400° F. Coal for these stokers should not be too strongly caking for coke that forms in the firebed burns less readily than uncoked coal and is, therefore, liable to accumulate unburned as a coke tree. The coke tree may rise up through the firebed to a considerable height before it topples over, thus interrupting the regular and complete combustion of the coal. Popular sizes of coal for the clinker-type bituminous stoker are seven-eighths to three-eighths inch for the larger, and three-eighths to one-eighth inch for the smaller domestic sizes. Anthracite-burning underfeed stokers include the ash removal type where the ash collected in the furnace is removed and carried to ash cans by screw conveyers, and the non-ash removal type where ash wiped off the outer edge of the retort by revolving "fingers" falls into an ash-pit to be removed manually. Anthracite for these stokers is usually closely sized in the buckwheat range of sizes. The ash should be of high fusion temperature (2600° F. or higher) to give a light ash and little clinker. Most types of underfeed stoker have been designed and constructed in the United States for specific fuels and their use is most general in those areas, principally Ontario and Quebec,

where such fuels are obtainable. Nevertheless, underfeed stokers are used satisfactorily in other areas and with other coals. An overfeed type of domestic stoker is also in use but it is only suitable for the more free-burning sub-bituminous and lignite coals found in western Canada. Here the coal is fed on to, and travels across, a small grate through which air is forced, the ash residue falling off the back of the grate into a container in or below the furnace. The ash fusion temperature is less important with this stoker, but the coal should not form so strong a clinker that it bridges the furnace and obstructs the flow of coal. As in underfeed stokers, sized coal is burned.

According to the records of The Stoker Institute of Canada about 37,000 stokers of domestic size are installed in Canada. It is estimated that less than 10 per cent of the bituminous coal, and only 1 per cent of the anthracite consumed in domestic equipment, is stoker fired. It appears, therefore, that most of the retail trade in coal is in coal to be used in hand-fired equipment.

Perhaps the most serious objection to hand-fired domestic equipment is that unless it is provided with suitable coal, a good deal of smoke and soot may be produced. Although good firing technique can reduce substantially the smoke produced, it is extremely difficult to burn smokelessly high volatile coal in normal hand-fired domestic equipment. This is the main reason why it is that in Central Canada anthracite, coke and low volatile coals make up the bulk of retail sales, while in western Canada sub-bituminous and lignite are the coals generally used for domestic purposes.

Research in domestic coal-burning equipment is directed toward the development of smokeless stoves and furnaces, and improved means of mechanical firing. Development work on furnaces, started by Professors Fellows and Myles of the University of Illinois about 1936, has progressed to the point where manufacturers are ready to place an improved furnace of their design on the market. This furnace utilizes the down-draft principle where the volatile matter driven off the coal by heat must pass through the incandescent fuel bed and mix with additional air before entering the combustion space. All tarry products distilled off are thus consumed with the result that there is no smoke or soot formed to coat the heating surface. Equipment built by a Cincinnati firm has been on field trials for several winters and shows promise. It holds 700 pounds of coal, or approximately two weeks' supply, and is thermostatically controlled by a new type of draft arrangement. At the Battelle Memorial Institute a principle of smokeless combustion has been developed which can be applied not only to space heaters but also to cooking ranges and to furnaces. This principle has been built into practical heaters not only in the laboratory, but also by several stove manufacturers, and it is anticipated that these will be available to the public at an early date. One Canadian stove manufacturer in eastern Canada has a space heater which has been tested by a leading coal company in field trials and found to be very satisfactory. Production is proceeding as fast as materials can be obtained, and further development work is in hand. Bituminous Coal Research Incorporated has two stokers under development at the Battelle Memorial Institute which are designed to burn all types of bituminous coals with mechanical ash removal. Research has also been carried on to overcome the trouble of coke tree formation. Two recent developments, one at the Pennsylvania State College and the other at Battelle Memorial Institute, appear to have solved the problem of coke tree formation. The first accomplishes the purpose by the principle of pre-oxidation of coal which decreases coking tendencies through the admission of air below the zone in which the coal becomes plastic. The second, an inverted underfeed type with coal and air flowing downward, prevents the formation of large masses of coke by the application of mechanical forces at the time that the coal is in the plastic stage. Tests indicate this stoker capable of handling coals with a wide range in coking properties. Both operate also with the removal of the ash in a dry fine state, which can be conveyed to a receiver automatically.

The anthracite industry, through the Anthracite Institute, is carrying on research in methods of burning domestic sizes. Intensive effort is being expended to complete development of an entirely new burning equipment known as the Anthratube. Field trials are now underway, and show some progress. The principle of operation is simply the feeding of sized anthracite by means of a screw in a water-jacketed tube; forced air is admitted, flowing counter to the movement of the coal, and produces very high burning rates. The ash residue is expelled from the opposite end of the tube into an ash pocket for removal. The very high rate of combustion permits the use of a small tube, which does not require the space presently used by the standard furnace and underfeed stoker.

The convenience and comfort of space heating through the use of oil or gas have presented the coal producer with severe competition. Nearly all of the research being conducted is aimed to provide equipment which is both cheaper and easier to operate in order that coal may compete more successfully with alternative fuels in the domestic heating market

III LOCOMOTIVE EQUIPMENT

About one-quarter of the coal consumed in Canada is used in railway locomotives. In the years prior to World War II close to 60 per cent of the bituminous coal mined in Alberta and British Columbia and approximately 25 per cent of the coal mined in Nova Scotia and New Brunswick was purchased by the Canadian railways, largely for locomotive use. The coal consumption of the two largest Canadian railways for selected years is given below. The figures include coal consumed in stationary plants, but nearly 90 per cent of the Canadian coal and nearly all of the United States coal was used in locomotives.

Year	Canadian National Railways	
	Canadian Coal	U.S. Coal
	Tons	Tons
1930	2,466,000	1,990,000
1933	2,223,000	1,020,000
1937	2,605,000	1,304,000
1945	2,169,000	4,504,000

Year	Canadian Pacific Railway	
	Canadian Coal	U.S. Coal
	Tons	Tons
1930	1,856,000	1,760,000
1933	1,503,000	1,026,000
1937	1,768,000	1,131,000
1945	2,177,000	3,038,000

The steam locomotive of today is a refinement of the "Rocket" designed and built by George Stephenson in 1829. The main features of the "Rocket" were a horizontal fire tube boiler, an exhaust blast, a reciprocating non-condensing steam engine, and a direct coupling of the moving parts to the driving wheels; these are the main features of most locomotives in use today. The thermal efficiency obtainable from such equipment is limited, but major improvements have been effected in the modern reciprocating steam locomotive. The modern coal-fired locomotive is much more powerful and operates more efficiently than the locomotive built prior to World War I, due in part, to the following improvements:

Fire Tube Super-Heaters—have allowed the use of super-heated steam, thereby increasing the power obtained from each pound of coal consumed;

Brick Arches—have been responsible for substantial savings in fuel through permitting better combustion conditions in the fire-box, thus increasing the evaporation per pound of coal consumed;

Feed Water Heaters—have decreased fuel consumption through the use of part of the waste heat in the exhaust steam to heat the water when it is taken from the locomotive tender and before placing it in the boiler;

Thermic Syphons and Circulators—which are now being used by many railways have added to the steam-making capacity by providing more heat absorbing fire-box surface;

Stoker-firing—has made possible coal-firing at the higher rate required by the larger and more powerful locomotives;

Combustion Chambers—have increased the volume of the combustion space and provided additional heating surface;

Valve Gear—improved valve gears have been developed, utilizing the steam from the boiler more efficiently, thereby saving fuel;

Water Treatment—through the use of various techniques for water treatment, boilers have been furnished with purer water, which reduces the cost of locomotive maintenance and results generally in fuel economy.

Improvement in locomotive design has over the years effected a marked saving of locomotive fuel. In 1920 the Canadian Pacific Railway Company used 148 pounds of coal per thousand gross ton miles for freight trains and 262 pounds per thousand gross ton miles for passenger trains. The comparable figures for later years are:

Year	Freight Trains	Passenger Trains
1925	120	225
1930	113	179
1935	109	185
1940	97	181
1944	105	182

Figures of pounds of coal consumed per thousand gross ton miles for the Canadian National Railways freight service for a few years are:

Year	Freight Trains
1925	140
1930	130
1935	127
1940	118
1945	114

The improvement in locomotive efficiency since 1923 admits of a graphic illustration. The Canadian National Railways advised this Commission that, if locomotive efficiency had remained at the 1923 level, that railway would have required in 1944 two million more tons of coal than was actually consumed in that year.

Diligent efforts are currently being undertaken to make further improvements, and only recently the Pennsylvania Railroad has placed in operation a coal-burning locomotive powered by a steam turbine geared directly to the driving wheels. Actual operating tests of this locomotive, the first of its kind to be built on this continent, give promise of success. This railroad now has in the process of development a 9,000 horse-power geared steam turbine coal-burning locomotive for use in passenger and freight service. The Baldwin Locomotive Works is now building three 6,000 h.p. turbine-electric stoker-fired locomotives for the Chesapeake and Ohio Railway Company. No such locomotive is in operation on any railroad on this continent today. However, the builder claims that in uniform flow of power at all speeds it will match any self-contained motive power unit now operating on rails.

Under the auspices of some of the railroads and coal operators in the United States, extensive research is being carried on to determine the possibility of perfecting a gas turbine locomotive using the combustion gases produced by burning pulverized coal to drive turbines, which in turn deliver power to the driving wheels either directly or through a generator-motor combination. This research is being followed with interest, especially by producers of coal, since the perfection of any such design should do much to meet the competition from diesel power.

At this time new ash pan designs to permit directional undergrate air flow are being tested by some of the Canadian and American railroads. It is claimed that reduced consumption of coal is effected by improved combustion of the coal particles in the furnace and by decreased loss of unburned cinders through the stack, and that the decreased emission of stack cinders will reduce the contamination of the road ballast, reduce fire hazards, and increase the availability of locomotives.

There has been considerable increase in the use of diesel locomotives on American railroads. The Chicago, Burlington and Quincey and the Santa Fe and Rock Island railroads are, in the passenger field, largely powered by diesels. Atlantic Coast Line and Seaboard, as well as a number of other American railroads, also operate diesel passenger locomotives. Of locomotives on order by Class I railroads in the United States as of September 1, 1945, 63 per cent of freight and passenger locomotives and 100 per cent of switch locomotives were diesels.

It is clear that diesel locomotives are offering keen competition to steam locomotives for both road and switching service. The main advantages of the diesel appear to be lower maintenance costs and a higher availability factor. Also, the diesel consumes fuel only while in use and there is no problem of providing it with water. On the other hand, the initial cost of a diesel locomotive is about twice as great as of a steam locomotive, measured on a horsepower basis. Availability is of no advantage unless it can be utilized, and utilization is one of the chief factors taken into consideration by mechanical officers on the Canadian railways in selecting the type of motive power to be purchased. Train schedules cannot always be arranged to permit of maximum utilization and, if the utilization is low, the interest on the capital investment has a considerable bearing on the cost per mile of operation. At present steam locomotives are considered more desirable than diesel locomotives for use in road service under Canadian conditions. The use of diesel locomotives in Canada has been limited to the switching field where they have proved more efficient than steam locomotives, and it is likely that their use for that purpose will be extended.

It may be that the increase in the size and efficiency of coal-burning locomotives may not proceed at the same rate as in recent years; nevertheless, there is still an opportunity for fuel economy by the replacement of older locomotives with the modern units. The following table shows the age of locomotives in use by Canadian railways:

More than 20 years old	3,326
More than 10 years and less than 20 years old	326
Less than 10 years old	473

These figures indicate that replacement will be necessary which will effect further economies in the use of fuel.

The improvement over the years in the thermal efficiency of coal-burning locomotives has been due in part to the use of better prepared coal. It is widely recognized that coal for locomotive use should contain no more than a limited percentage of smaller sizes, the percentage depending upon the kind of coal, the operating conditions of the railway, the design of the locomotives, etc. The disadvantage of smaller sizes is that under forced draft many of them are blown out the stack unburned and the heat value in them is wasted. A low percentage of ash also contributes to efficiency, for it permits more rapid combustion and cuts down heat losses through ash removal. The sizing of coal and its washing to reduce ash are both parts of coal preparation, further details of which may be found in the chapter Mining Methods. The preparation of coal is normally done by the mine operator and is his contribution towards more efficient utilization of his product.

Increases in the thermal efficiency of locomotives are paradoxically both the friend and the foe of bituminous coal production. Greater efficiency in the use of coal assists it to compete more successfully with other fuels, even though at the same time it reduces the demand. In the long run, coal operators have a vital interest in providing the market with a well prepared product and in sponsoring technical improvements, for by so doing they increase the chances for the continued use on a large scale of coal as a locomotive fuel.

IV DISTRICT OR CENTRAL HEATING

The term "central heating" has two meanings. In Europe it generally connotes one heating plant providing heat throughout a building without reliance on grates or stoves located at the point where heat is required. On this continent central heating is generally understood as a system whereby heat is produced in a central plant and conveyed in the form of steam or hot water by pipes to a group of buildings. This group heating is quite commonly called "district heating"; in this report the terms "district heating" and "central heating" will be used interchangeably.

The business of producing and distributing steam for heating and power purposes was first successfully undertaken in Lockport, New York, during the late 'seventies, prior to the introduction in 1880 of warm air and hot water furnaces for domestic heating. Domestic heating equipment has been much improved since 1880, but even yet, wherever it is necessary to use a solid fuel for the heating of dwellings, coal storage space is required, the fire demands periodic attention, ash removal is an inconvenience, and dirt and smoke may be a considerable nuisance. For these reasons heat piped under thermostatic control from a central plant is very desirable in climates having seasons where continuous space heating is necessary.

In district heating, steam or hot water is generated or produced at a central plant and piped to consumers. Many of the earlier plants were combined with installations for the generation of electricity by steam, the steam exhausted from the turbo-generators being conveyed to the consumer. Many plants of this character are still found and are being extended, while other plants have been developed to generate steam for district heating purposes exclusively. Some systems are a combination of both, the supply of exhaust steam being supplemented by live steam. Rather large mains are required for low pressure exhaust steam and, depending on conditions, small high pressure pipe lines may prove more economical. In some of the earlier installations the buried pipe was encased in a segmental wood log conduit. The modern practice is to have the buried pipes insulated and enclosed in an outer protective tile or concrete conduit. Under any system, insulation and proper drainage are essential to reduce transmission loss from radiation or condensation. On this continent, the mains are often laid out in a grid or a loop pattern, with connections at cross points in the line; this helps to maintain the pressure over the system and provides some insurance against loss of service in the event of a breakdown on any part of the transmission system. The use of small mains of about 3 inches to 2 inches in diameter, with three-quarter inch service connections, is being advocated, the steam being delivered from the heating plant at a pressure of about 100 to 150 pounds per square inch so as to maintain a high velocity in the main, the resulting high pressure drop having the effect of super-heating the steam and reducing condensation loss to a minimum. The mains are usually laid in the streets or alleys, but sometimes through the basements of the buildings served. In residential areas they are generally buried under the grassways, so that repairs will not disturb paved streets.

Metering of heat delivered usually follows one of three patterns, depending on the individual heating system. For low pressure steam it is usually measured by metering the condensate, for high pressure it is usual to meter the steam flow, while for hot water it is usual either to meter the temperature drop or to contract on keeping the space at a fixed temperature, the calculated heat loss determining the cost. The steam or hot water can be used in conventional standing, concealed, or base-board radiators, radiant heating, or by the use of heat exchangers to supply forced warm air filtered and humidified.

The location of the district heating plant must be carefully considered to take into account the following factors:

Shortest possible distance from plant to centre of steam demand consistent with land values and cost of steam mains,

Cost of feeder lines and best use of cross connections to form grid or loop system,

Facilities for coal and ash transportation;

Often a railway siding is a desirable location; nevertheless, coal can usually be transported more cheaply than pipe lines can be installed.

Land values,

Possible combination with existing electric power.

There is much material on the subject of district heating, and this report will not attempt a too technical review thereof. In 1919 C. A. Magrath, the Fuel Controller, devoted some space in his final report to discussion of its advantages, but the optimism underlying some of his comments has hardly been realized in the intervening years. In 1923 F. A. Combe prepared for the Dominion Fuel Board an informative study on central heating in Canada and the United States. Technical data can be secured through the National District Heating Association, Pittsburgh; the Bituminous Coal Research Incorporated, also of Pittsburgh; and the Battelle Memorial Institute of Columbus, Ohio; the latter two being engaged in research on the subject.

In the United States there are many systems supplying steam to commercial and factory areas. For example, uptown and downtown New York are widely served by a large utility with four central heating plants. Similarly, sections of populous centres such as Philadelphia, Indianapolis, Rochester, N.Y., Pittsburgh, Detroit, St. Louis, Dayton and Portland, Oregon, having heating systems. This development in business areas has been possible because the buildings supplied are relatively close to the central heating plant, and the total capital outlay for the steam plant and transmission lines is kept to a minimum for the steam put through the system. A system serving a residential area does not enjoy the same density of load and, as a consequence, is confronted with an investment in distribution lines disproportionate to the amount of steam that can be sold. Advocates of residential district heating counter with the observation that to some extent similar factors of load density and transmission loss are met with in the distribution of gas, water, and electricity to residential areas, but the comparison may disregard physical and engineering factors rendering conduit construction considerably more expensive. Research has suggested that systems employing high pressure steam with small pipes will reduce the capital investment and prove economically sound in built up residential areas, and the soundness of this idea will no doubt ultimately be tested by some installations. People naturally desire to buy heat comfort, and the maximum is certainly provided by district steam heat, but any heating project must compete with other methods of heating and the charge for comfort alone must not be too much higher than the cost entailed in the firing of furnaces either manually or by automatic equipment. Up to date it would appear that the public has not fully evaluated the intangible and indirect benefits of residential group heating.

Some of the advantages of heat generated in a central plant are:

Saving in plant investment, labour inconvenience and heating plant space,

Avoidance of coal and ash handling,

Cleanliness and better control of building temperature,

Elimination of smoke, particularly in congested commercial areas,

Reduction of fire hazards.

There is considerable institutional heating in Canada by central plants. To mention a few of them, they are—University of Toronto; Parliament and other Government buildings in Ottawa; University of Alberta; McGill University in Montreal; Dalhousie University; Toronto Terminal Railway Company, serving the Union Station, Royal York Hotel, federal and other buildings. In most cases these buildings are under one management, and none of them may present economic problems entirely comparable to those where heat is metered to a large number of individual patrons. In a report of this character some particulars of systems in Canada and the United States selling steam to the public may be of value, and render more readable our concluding comments on technical and economic aspects. A few systems in the United States will be dealt with, followed by details of the principal Canadian systems. To the reader unfamiliar with this subject, attention should be directed to some cardinal factors. Boiler efficiency is important and may reach a level of 85 per cent, although efficiency to 75 per cent should be regarded as good. The transmission loss involved, being a recurring expense, is of particular significance because the financial success of the operation is dependent on the return from delivered and paid-for steam. The ratio of capital to revenue which, generally speaking, should be 4 to 1 (or less) should be noted. Other factors must be weighed, but it is thought desirable at the very outset to stress the specific relevance of these factors.

DISTRICT HEATING SYSTEMS IN THE UNITED STATES

Overbrook Steam Heating Company

Overbrook is a suburb of Philadelphia, and this company started in business in 1893 with ten customers and now serves 1,570 homes and buildings in a residential district. The operation is exclusively one supplying steam for space heating purposes. The steam plant is architecturally in keeping with the amenities of a residential district, with a total of 3,753 boiler horse-power, and with a maximum capacity of 229,000 pounds of steam per hour. This steam, at low pressure, is fed to mains varying from 12 inches to 2 inches, with a total length of approximately 14 miles. The fuel used is customarily either barley anthracite or bunker "C" oil. The fuel cost appears to be 3.03 cents per thousand pounds of steam generated, and the overall cost for the same quantity of steam, including all operating costs and depreciation, without a return on the investment, is 57.4 cents. The plant boiler efficiency is 69 per cent, and the transmission loss is 23 per cent. For their fiscal year 1944-45 the revenue was $267,000, giving a revenue per thousand pounds of steam of 97.7 cents. The ratio of present capital to revenue is 2.93 to 1. This utility is in a healthy financial position having paid dividends for the past fifteen years after taking full allowable depreciation and creating reserves for future capital expansion. In addition, the company is entirely free from debt, bonded or otherwise. Having regard to the vicissitudes of district heating, particularly in areas lacking a commercial density of load, the steady progress of this company over a period of fifty years is significant.

Detroit Edison Company

District heating started in Detroit in 1903, combining a system of steam electric generation with utilization of exhaust steam for heating purposes, with a view to improving overall plant thermal efficiency. From this beginning the utility has expanded to four boiler plants serving 1,755 customers over an area in the heart of the city, apout 3.25 miles long and varying in width from one block to nearly one mile. The total horsepower of the boiler plants is 39,235. The mains vary from 20 inches to 4 inches throughout the area described, the larger mains in the downtown area being carried in tunnels 25 to 60 feet below street level, for a total length of 2.5 miles. The steam is sold on a guaranteed low pressure basis to the consumer and is produced exclusively with bituminous coal. The average of the boiler efficiency of the various plants is 77 per cent to 80 per cent, and distribution loss averages about 15 per cent. The gross steam earnings, reaching the substantial amount of $2,500,000 annually, is stated by the management to be an inadequate return on capital. This utility has found the competition of the isolated boiler plant particularly severe in the case of apartment buildings and hotels. The service to small customers is popular but the cost of underground mains is out of proportion to the amount of steam which can be sold in an area of detached residence or other small buildings, thus making the fixed charges more than the business can ordinarily carry. Experience in Detroit has demonstrated that the economy of the large central boiler plant, in comparison with the wastefulness of the domestic furnace or hot water boiler, does not always counterbalance the greater investment cost.

Duluth Steam Corporation

This utility started in 1932 for the purpose of generating steam exclusively for industrial and space heating purposes, and the system now serves an industrial, commercial and residential area. Though started at the inception of the depression of the 1930's, and suffering thereby, it has now emerged with its generation equipment loaded to 75 per cent of operating capacity. There are 253 customers; 15 per cent of the steam generated is used industrially and the balance for space heating. The plant has an installed boiler horse-power of 3,400. High pressure steam at 150 pounds is delivered to mains varying between 18 inches and 2 inches in diameter, the main system having a length of 6 miles. Coal is used exclusively as fuel; the cost per thousand pounds of steam is 33.3 cents and the revenue 84.8 cents. The boiler efficiency is approximately 75 per cent, and operating statistics would indicate that transmission loss is between 16 per cent and 18 per cent. The total investment in this plant is in the neighbourhood of $1,500,000 and for the fiscal year 1944-45 operating revenue was $484,000, making the ratio of capital to revenue 3.1 to 1. The base rate, or first block charge, is 97 cents per thousand pounds in winter and 82 cents in summer. This operating, starting under unfavourable circumstances, has made considerable progress and has reduced fixed liabilities to something in the neighbourhood of $230,000. It has managed over the period of its life to earn depreciation and has met all bond interest. As yet, no dividends have been paid to stockholders.

The City of Virginia, Minnesota

Virginia, a city in Minnesota, with a population of 13,000, is of particular interest in that it is probably the only community on the continent wholly served by a district heating system. The service is combined with that of supplying electricity, water and gas. The system began back in 1913 when the city bought a privately-owned waterworks and electric plant. This was later expanded in 1929 by taking over a lumber mill which supplied cheap steam and electric power to the community. Improvements were made until today the system is a fairly modern one with adequate generating facilities for electric power and steam heat. The installed boiler horse-power totals 5,518, with the steam passing into the mains either directly or through turbo-generators. The gross income from the sale of district steam for the fiscal year ending September, 1944, was $353,000. This municipal utility has always operated at a net loss when depreciation is included, being content as a municipal enterprise to operate on a non-profit basis. As the municipality virtually combines in one operation all the services commonly present in a modern community, differences of opinion can arise as to charges properly assignable to the district heating division. It is commonly stated, however, that space heating costs throughout this community are lower than costs in adjacent communities not having a utility of this character.

As was stated earlier, there are numerous district heating utilities in the United States, and the Commission gratefully acknowledges operating data furnished by the following utilities: New York Steam Corporation; Rochester Gas and Electric Corporation; Union Electric Company of Missouri; Central Heating Company of Eugene, Oregon; Northwestern Electric Company of Portland, Oregon; Consolidated Gas, Electric Light and Power Company of Baltimore; Western Massachusetts Electric Company of Pittsfield, Massachusetts. Some of these operations are similar to those described in more detail above. In many instances electric generation is combined with the steam service. It would appear that most of the utilities serving commercial areas are operating profitably, which gives rise to the current interest in the possibility of district heating being given general application to residential areas.

DISTRICT HEATING IN CANADA

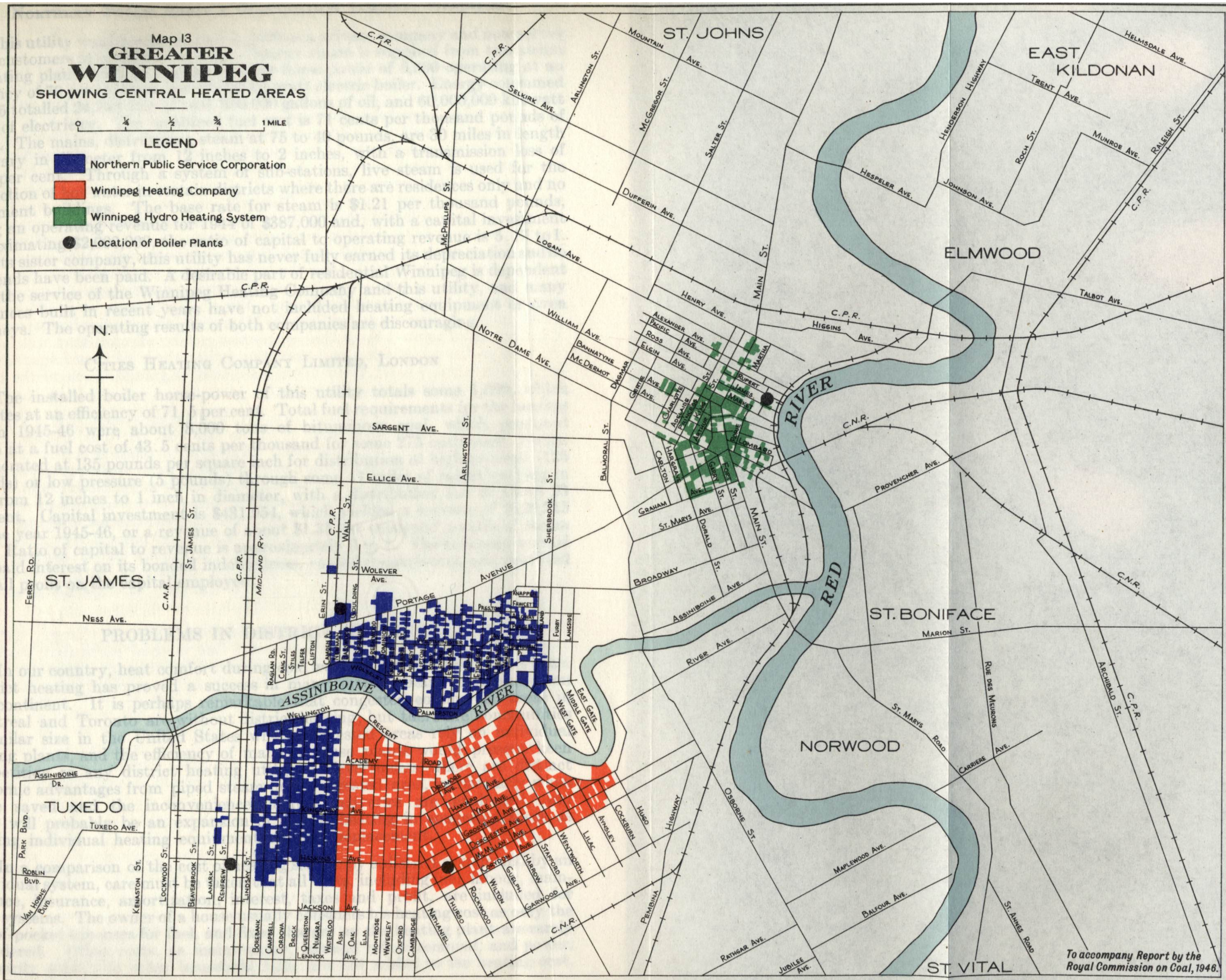
Mention has already been made of institutional heating in Canada. District heating proper was first attempted in the town of North Battleford, Saskatchewan, where exhaust steam from an electric steam generating plant was utilized to heat commercial buildings and a few residences. This utility is municipally owned, presently servicing 130 customers including 25 residences. Its relative success is probably explained by the fact that the cost of the entire distribution system was defrayed from current revenue. The city of Brandon, Manitoba, is another pioneer example of limited district heating development; this plant was established over twenty years ago, serving principally a commercial area with 190 customers. The utility is distinctly unprofitable; its operating costs are not being earned. The city of Winnipeg has three steam heating utilities—one, the Winnipeg Hydro Electric System (Steam Division) serving downtown Winnipeg, and two residential operations, the Winnipeg Heating Company and the Northern Public Service Corporation Limited, now under joint operating management. Appended, herewith, is a map showing the location of these three systems. London, Ontario, also has a steam heating system. Detailed information of the Winnipeg and London systems will follow.

Winnipeg Hydro Electric System—Steam Division

To overcome the interruptions caused by severe storms that affect transmission lines from hydro electric plants, a steam standby plant was completed in 1924. The plant was designed to provide district heating during the winter months when the likelihood of interference with transmission power lines is at a minimum. The system was expanded until today there are 284 customers being served in the downtown area of the city, which is exclusively commercial. The plant has a total installed coal-fired boiler horse-power of 6,650 and three electric boilers of 7,500 kw. each. The steam is fed at low pressure to the steam mains, which vary in size from 14 inches to 4 inches and have a total length of nearly 6 miles. Two-thirds of the required energy is furnished by off-peak and some peak hydro power and the balance by coal, about 13,000 tons annually, giving an average combined cost of fuel per thousand pounds of steam equal to 38.3 cents. The efficiency of the steam boiler is about 70 per cent, depending on load conditions, and the transmission loss in the mains is approximately 26 per cent. Revenue from the sale of steam heat for the last fiscal year totalled $431,000, or an income of $1.07 per thousand pounds of steam sold. The capital investment to date is $1,527,000, giving a ratio of capital to revenue of 3.55 to 1. Net bonded indebtedness as at the end of 1945 was $250,000, in which year a net profit of $50,000 odd was made. This utility, in addition to revenue from the sale of steam, receives $25,000 annually for its standby service to the hydro system and has the advantage of a high density of load, identification with a hydro electric system, and the availability of cheap off-peak hydro electric power.

Winnipeg Heating Company

This system (privately owned) was established in 1929 and now serves 1,600 customers. Its one steam plant contains an installed horse-power of 3,800, with an efficiency of 70 per cent and a 10,000-kilowatt electric boiler, the latter using off-peak power. The system consumed in 1945 a total of 7,500 tons of coal, 1,400,000 gallons of oil, and 42,000,000 kilowatt hours of energy, with a combined fuel cost of 50 cents per thousand pounds of steam. This steam is fed into distribution lines varying in diameter from 12 inches to 3 inches, with a total length of about 20 miles. Transmission loss of steam mains is 40 per cent. Capital cost of installed equipment totalled $1,000,000. The average rate received for steam is $1.44 per thousand pounds, giving a revenue in 1944 of $366,000 and a ratio of capital to revenue of 3.66 to 1. This system serves an exclusively residential area with many detached dwellings. The low load density, long transmission mains, and climatic conditions probably account for the high line loss.


Map 13
GREATER
WINNIPEG
SHOWING CENTRAL HEATED AREAS
¼ ½ ¾ 1 MILE
LEGEND
Northern Public Service Corporation
Winnipeg Heating Company
Winnipeg Hydro Heating System
Location of Boiler Plants
N.
ST. JOHNS
EAST KILDONAN
ELMWOOD
ST. JAMES
ST. BONIFACE
TUXEDO
NORWOOD
ST. VITAL
RED RIVER
ASSINIBOINE RIVER
C.P.R.
C.N.R.
MAIN ST.
PORTAGE AVENUE
NOTRE DAME AVE.
SARGENT AVE.
ELLICE AVE.
WOLSELEY
ACADEMY ROAD
CRESCENT
WELLINGTON
ASSINIBOINE AVE.
RIVER AVE.
BROADWAY
OSBORNE ST.
PEMBINA HIGHWAY
PROVENCHER AVE.
MARION ST.
ST. MARYS ROAD
HIGGINS AVE.
LOGAN AVE.
SELKIRK AVE.
HENDERSON HIGHWAY
To accompany Report by the Royal Commission on Coal, 1946.

Northern Public Service Corporation Limited, Winnipeg

This utility was likewise started in 1929 as a private company and now serves 1,740 customers in a residential area. District steam is supplied from two steam generating plants with an aggregate boiler horse-power of 5,300 operating at an efficiency of 70 per cent and one 10,000-kilowatt electric boiler. Energy consumed in 1945 totalled 24,750 tons of coal, 350,000 gallons of oil, and 60,000,000 kilowatt hours of electricity. The combined fuel cost is 71 cents per thousand pounds of steam. The mains, distributing steam at 75 to 40 pounds, are 30 miles in length and vary in diameter from 12 inches to 2 inches, with a transmission loss of 25.5 per cent. Through a system of sub-stations, live steam is used for the production of hot water in certain districts where there are residences only and no apartment buildings. The base rate for steam is $1.21 per thousand pounds, giving an operating revenue for 1944 of $387,000 and, with a capital investment approximating $2,000,000, the ratio of capital to operating revenue is 5.17 to 1. Like its sister company, this utility has never fully earned its depreciation and no dividends have been paid. A desirable part of residential Winnipeg is dependent upon the service of the Winnipeg Heating Company and this utility, and many residences built in recent years have not included heating equipment or even chimneys. The operating results of both companies are discouraging.

Cities Heating Company Limited, London

The installed boiler horse-power of this utility totals some 1,600, which operates at an efficiency of 71.5 per cent. Total fuel requirements for the heating season 1945-46 were about 8,000 tons of bituminous coal, which produced steam at a fuel cost of 43.5 cents per thousand for some 275 customers. Steam is generated at 135 pounds per square inch for distribution at high pressure (125 pounds) or low pressure (5 pounds) through some 11 miles of mains varying in size from 12 inches to 1 inch in diameter, with a distribution loss of about 23 per cent. Capital investment is $431,954, which yielded a revenue of $129,215 for the year 1945-46, or a revenue of about $1.35 per thousand pounds of steam sold. Ratio of capital to revenue is approximately 3 to 1. The company earned and paid interest on its bonded indebtedness, earned depreciation, and provided a small profit on the capital employed.

PROBLEMS IN DISTRICT HEATING

In our country, heat comfort during cold weather is of interest to everyone. District heating has proved a success in many metropolitan communities on this continent. It is perhaps remarkable that congested commercial areas in Montreal and Toronto are without district heating, but there are communities of similar size in the United States where congested areas rely on individual heating plants, and the efficiency of many of these plants would present keen competition to any district heating utility. Nevertheless, there are distinct economic advantages from piped steam in a congested area, particularly when space saved and the inconvenience of fuel deliveries are evaluated, and there will probably be an expansion in district heating in congested areas as existing individual heating equipment requires replacement.

In a comparison of the cost of heating service by a district system and by an individual system, care must be taken that all costs, including fuel, labour, maintenance, insurance, amortization, interest, taxes and profit, are included for both systems. The owner of a house usually considers his heating cost as only the out-of-pocket expenses for fuel, and fixed charges on the heating plant are rarely considered. Other costs, as maintenance, ash and refuse removal, and power, ordinarily paid with other household bills, are not added to the heating cost.

When all these costs, ordinarily neglected, are included, it may be found that the total costs for individual heating are not much lower than those of a district system.

The distribution system constitutes the largest single portion of the capital cost for a district heating plant. Even in a commercial and residential area this will be in the order of 50 per cent of the total cost. Research on new methods of construction may bring the cost down somewhat, but the cost of pipelines with adequate insulation will probably always militate against the extension of pipelines for long distances from a district steam plant to outlying residential areas where, if the houses are already built, only a fraction can be counted upon to take this service, as many will already have heating plants that are modern and in good condition. This will increase the cost of pipelines per customer. One solution for the long distribution lines from commercial to residential areas is to develop heating of groups of residential dwellings, from 25 to 200 or more in number, installations being best made when houses in the area are being constructed. For the larger groups, particularly for those made up of apartments or even of smaller multiple-family dwellings, the district heating system can be conventional in design. For smaller groups, as for 25 houses in a city block, studies made by Battelle Memorial Institute for Bituminous Coal Research Incorporated show that economies can be effected that will decrease the cost of the installation and operation below those of even larger systems, by installing the heating plant in the basement or garage of one of the homes, and by the simplification of equipment.

The main operating economy of a district heating system over a system of individual domestic heating units is in the fuel cost per unit of sensible heat obtained from the heating equipment. The central plant is able to burn coal of lower rank and lower grade than can individual units; such coal is, of course, much cheaper f.o.b. mine. Because deliveries to a central plant are on a much larger scale than to individual households, most of the expenses involved in retailing small tonnages can be avoided. Finally, the thermal efficiency of the combustion equipment that would be used in a central plant is very much higher than that of individual heating units. Whether or not a district heating system is a commercial success will depend largely on whether or not the lower cost of steam raising in a district heating system is sufficient to offset the larger overhead of, and the transmission losses inevitable in, the system.

The total cost of district heating, including the fixed charges, will vary according to the system of management. One method particularly suited to small or moderate-sized groups is the division of the capital cost of the system among the properties, and vesting the management in a co-operative committee elected by the owners.

CHAPTER XI

PRODUCTS AND BY-PRODUCTS

This chapter covers all uses of coal other than as raw fuel, and is divided into three parts, the coke and gas industry, the potential synthetic liquid fuel industry and the chemical industry based on products from coal. In Canada there is a coke and gas industry and a chemical industry based in part on coal and its products. There is no synthetic liquid fuel industry, but the section dealing with this subject is presented because of the wide interest in it.

THE COKE AND GAS INDUSTRY

The coke and gas industry is based largely upon a process known as the destructive distillation, or carbonization, of coal. In this process coal is subjected to a high temperature in the absence of air, whereby it yields solid, liquid and gaseous products. These include a solid residue called coke, which is mainly carbon, three liquid products known as tar, light oils, and ammoniacal liquor, and a considerable volume of combustible gases. The coke is used in metallurgical plants for the smelting and working of metals, as a domestic fuel, for the manufacture of gas, and as a raw material for the manufacture of chemicals. The liquid products are mainly sold as raw materials for chemical industries. Part of the gas may be burned to produce the heat necessary for the carbonization process, or it may all be distributed for industrial and domestic heating.

Generally speaking, only coals of bituminous rank are used for coking, and not all bituminous coals will coke. The general public is greatly impressed with the importance of anthracite because of its widespread use as a smokeless domestic fuel, but the presence on this continent of large reserves of bituminous coking coal is of far more importance to the industrial life of the continent.

The manufacture of coke from coal has been an established industry for a matter of 200 years. Three centuries ago the iron industry in Europe was wholly dependent upon charcoal as a fuel for iron smelting and other metal working operations, but as forests were depleted investigation led to the coking of coal to replace charcoal. At one time all coal was coked by a beehive process in which the volatile elements of the coal were burned. As the wastefulness of the beehive process was recognized, new processes were evolved, known as by-product processes, under which tars, light oils, and gas were recovered from the volatile ingredients. Even yet, however, the beehive process is used and during World War II many abandoned beehive ovens were reconstructed in order to increase the supply of coke for metallurgical purposes. A related industry, that of the manufacture of gas from coal, was established early in the nineteenth century. At first the two industries were quite distinct, but as the modern by-product plant can be used regardless of whether coke or gas is the main requirement, the two industries now merge into each other.

The processes used in the coke and gas industry are somewhat complicated, and vary from plant to plant. Some plants, referred to as coke plants, are designed to make coke, with the tar and gas merely by-products. Others, called gas plants, are designed primarily to make gas, with coke and tar as by-products. Still other plants use coke instead of coal as raw material, and make only gas.

On the next page are presented a few figures on a regional basis for the coke and gas industry in Canada. The figures in this table cover 28 plants, ranging in size from that at Sault Ste. Marie, with a rated capacity of over one and three-quarter million tons of coal annually, to small gas plants purchasing coke

COKE AND GAS INDUSTRY—SALIENT STATISTICS FOR 1937 AND 1944

—	—	Maritime Provinces		Ontario and Quebec		Western Provinces		All Canada	
		1937	1944	1937	1944	1937	1944	1937	1944
Employees	Number	390	470	3,090	3,650	550	630	4,030	4,750
Employees' wages and salaries	Thousands of $	470	870	4,500	6,950	740	1,120	5,710	8,940
Reported sales values of products	Thousands of $	4,200	7,800	33,700	56,200	3,800	5,600	41,700	69,600
Coal charged, Canadian	Thousands of tons	664	808	196	18	295	395	1,155	1,221
Coal charged, imported	Thousands of tons	...	...	2,399	4,061	26	34	2,525	4,095
Coal charged, total	Thousands of tons	664	808	2,595	4,079	321	429	3,580	5,316
Coke produced	Thousands of tons	450	590	1,910	3,130	210	300	2,570	4,020
Gas produced	Millions of cubic feet	6,540	10,300	34,950	64,800	4,520	4,100	46,010	79,100
Other products, sales values	Thousands of $	610	1,080	2,620	4,030	80	110	3,310	5,220
Coke imports	Thousands of tons	13	...	390	789	15	24	418	813
Coke exports	Thousands of tons	...	*	1	*	36	39	37	43
Estimated coke consumption;									
In three steel plants	Thousands of tons	320	430	530	1,230	...	...	850	1,660
Retail sales—domestic	Thousands of tons	60	120	1,000	1,290	90	80	1,150	1,490

* Figure not available.

and converting it into gas for a small local market. Five of these plants, located at Sydney, Sault Ste. Marie, Hamilton, Coleman and Michel, produce principally metallurgical coke. These five plants treat from one-half to two-thirds of all the coal coked in Canada. A number of other plants produce principally domestic coke and gas; examples of such plants are those at Montreal, Hamilton and Winnipeg. Most of the other plants in Canada produce principally gas, the largest of such plants being at Toronto, Ottawa, Quebec and Vancouver. In order to permit a comparison of the size of the coke and gas industry in Canada with that in the United States, we add that the total amount of all coal carbonized for all purposes in the United States was 74,500,000 tons in 1937 and 105,600,000 tons in 1944.

In the following pages we shall discuss in rather more detail the products of carbonization, the nature and availability of coal suitable for carbonization, the various processes used in the coke and gas industry, the larger plants presently operating in Canada, and the aid which has been given by the Dominion Government to the industry. The purpose of this survey is to increase understanding of the role played by the coke and gas industry in processing coal to provide suitable fuels for industrial and domestic purposes, and the potentialities of the industry as a consumer of Canadian coal.

THE PRODUCTS OF CARBONIZATION

Carbonization is a general term for the decomposition by heat, in the absence of air, of any carbonaceous substance such as coal, peat, wood or oil shale. The process is called coking only when the material treated is a coal that first softens when heated, so that the individual pieces agglomerate, and then hardens to form the cellular material called coke. Carbonization may be classified according to the temperature employed into high and low temperature carbonization as described later. The high temperature treatment of coking coal is by far the most important section of the carbonization industry in Canada.

A coking coal, like other coals, is comprised essentially of carbon, volatile matter and ash. When coal is coked the ash remains in the coke, and the volatile matter passes off more or less completely. The character of the coke varies widely with the rank of the coal, the temperature reached during coking, and the method of heating. The volatile matter as driven off is a decomposition product, and as such also varies widely in both quantity and quality with the conditions of decomposition. The yields are interrelated: if the coke yields are high, those of tar and gas must be low, and vice versa. Typical production from a ton of coal carbonized at a high temperature is 1,400 pounds of coke, 9 gallons of tar, 2.5 gallons of light oil, 12,000 cubic feet of gas and 6 pounds of ammonia.

Coke

When a coking coal is heated rapidly in the absence of air it passes through a semi-fluid state. The simultaneous decomposition of the coal, with consequent escape of gases and vapors, gives the plastic mass a cellular or porous character which it retains when further heating solidifies it into coke. The character of the coke is affected by the amount of volatile matter in the coal treated; a low-volatile coal giving a dense, hard coke, and a high-volatile coal a light, porous coke. The physical character of a coke is often all important, particularly with metallurgical coke for use in a blast furnace, where it should be strong enough to carry a heavy load. It is also desirable to be able to crush and size coke for the market without excessive production of the fine coke, called breeze. Cokes vary in reactivity, that is, in the ease with which they burn in air or are attacked by gases such as carbon dioxide and steam. A high temperature in the oven and the consequent deposition of a film of shiny, graphitic carbon on the coke by secondary decomposition of volatile matter tend to give the non-reactive character desired for metallurgical coke. A lower temperature in the oven and a shorter time of heating will leave some volatile matter in the coke, making it a desirable, reactive fuel for domestic heating.

The mineral impurities of the coal remain in the smaller weight of coke produced; the coke consequently has a higher percentage of ash content than had the coal. Thus, if a coal containing 9 per cent ash is coked to give a 75 per cent yield of coke, the coke has an approximate ash content of 12 per cent. A low ash content for coke is often essential; a small reduction in the ash content of coke may materially decrease the coke consumption in an iron blast furnace. The coke retains some of the sulphur of the coal; this is unimportant in domestic coke but may be particularly objectionable in metallurgical coke.

When non-coking coals are carbonized the individual pieces shrink but do not soften and change shape and the solid product, called char, disintegrates. Char may have a heat value in excess of that of the coal and after briquetting be a useful, reactive, smokeless fuel.

Coke for metallurgical purposes should be clean (that is, with low ash and sulphur), of low reactivity, strong, and of good physical structure. Different branches of the metallurgical industry, however, weigh these factors quite differently. Coke for domestic use should be clean, have a high fusion temperature ash, be carefully sized, be strong enough not to break when handled, and be reactive. Coke is a smokeless fuel and is, therefore, a substitute for anthracite. The heat value of coke, as of anthracite, varies with the ash content, but normally the heat values of domestic coke and anthracite are about equal, pound for pound. The need for a reactive coke is stressed, as otherwise it is hard to maintain a low fire in mild weather. Coke suffers in competition with anthracite on account of its bulk, since a furnace that will hold a charge of 30 pounds of anthracite will hold less than 20 pounds of coke.

Gas

The gases of commerce are mixtures, in widely differing proportions, of the non-combustible gases nitrogen, carbon dioxide, and oxygen with such combustible gases as carbon monoxide (322), hydrogen (325), methane (1,013), and some others. The figures in brackets are the heat values of the combustible gases in B.t.u. per cubic foot of gas. Natural gas, which is essentially methane, has a heat value of about 1,000 B.t.u. per cubic foot. Coal gas, made by the straight high temperature carbonization of coal, has a heat value of about 600 B.t.u. per cubic foot as it leaves the oven, while gases made by the complete gasification of coal may have heat values anywhere from the 430 B.t.u. down to as low as 120 B.t.u. per cubic foot. This wide range of heat values is of far greater significance in the distribution than in the utilization of gas. The actual composition of a gas is seldom of major importance, unless the gas is to be used in the synthetic chemical industry. Gas is a premium fuel because of its convenience and efficiency of use. The chief handicap for its widespread use for space heating is the seasonal demand. Its principal market is for cooking and water heating and certain industrial heating processes.

Tar, Light Oils and Ammonia

If the gases and vapours leaving a coke oven are cooled, a watery liquid condenses. This contains ammonia and ammonium compounds and is known as ammoniacal liquor. A heavy, dark-coloured, oily liquid known as coal tar also condenses. The gas left can be further treated to obtain from it a mixture of liquid hydrocarbons known as light oils. Tar and light oils are of great importance but only as raw materials for other industries; the use of them is described in Part III of this chapter.

SELECTION AND LOCATION OF COKING COALS

Coals used in the coke and gas industry are referred to as high volatile if with over 31 per cent volatile matter in the dry coal, medium volatile if with 22 to 31 per cent, and low volatile if not above 22 per cent. These limits may vary with the locality. A high volatile coal gives a high yield of tar and light oils, and a high yield of a gas of high heat value. It may, therefore, be preferred for a plant which specializes on gas production. The yield of coke, on the contrary, is low and it is light and porous. A low volatile coal gives a far smaller yield of tar and light oils, and also a lower yield of a gas. The coke yield is greater and it may have a hard, dense structure. In practice, low volatile coal is usually blended with other coals, and coal blends are preferred. A medium volatile coal is intermediate in yields of products and in their properties; in general, it gives the best coke. The following table gives typical by-product oven yields per ton of coal treated:

—	Low Volatile Coal	Medium Volatile Coal	High Volatile Coal
Coke—			
Yield by weight, lbs.	1,700	1,500	1,360
Gas—			
Yield by volume, c.f.	9,200	10,400	10,800
Tar and Light Oils—			
Yield by volume, gallons	3.8	10.5	12.9

Many plants, particularly those which make and sell different varieties of coke, find it advantageous to stock coals of two or three different volatilities. These can be blended in different proportions to give the desired products. Low ash fusion coal may also be blended with high ash fusion coal, and a coal giving a high expansion pressure when coked blended with one that expands less to avoid damage to the brickwork of the oven.

A coking coal should be low in ash. Excessive mineral impurities are a source of weakness in coke, cause trouble in domestic furnaces, and in a blast furnace necessitate the use of additional flux, and additional coke to heat the resulting slag. For this reason an increasing proportion of the coal charged to by-product ovens is first washed to reduce its ash. A low sulphur coal is always desirable. A coking coal should store well, for coke and gas makers commonly need to carry large stores of coal to ensure continuity of supply and to permit the summer purchase of coal for winter use.

Coking coals are mined in Canada only in Nova Scotia, Alberta and British Columbia; that is, in the extreme East and West. In Nova Scotia, low ash coals which coke well are mined in the Cape Breton area. These are high volatile, or gas coals, with a high sulphur content, but are made into metallurgical coke. The steel plant at Sydney is operated on coke made there from washed local coal. Nova Scotia coal is used in domestic coke and gas plants in Halifax, Saint John and Quebec, but it has proved difficult to extend the sale of this coal to the Montreal coke plant, with its highly competitive market. Exception was taken to the low fusion temperature of the ash because the householder, accustomed to burning non-clinkering anthracite, was unwilling to burn a coke which clinkered when the fire was forced in cold weather. Coal storage also caused some difficulty at the plant. It was found that some 35 per cent of washed coal from the Princess and Waterford No. 12 mines in Cape Breton could be satisfactorily blended with lower volatile United States coals. This, however, necessitated the expense of sending the coal through the washery of the Sydney steel plant; in addition, the segregation of any appreciable percentage of the best Cape Breton coal for a coke-manufacturing customer was prejudicial to the quality of the coal going to the coke ovens at the steel plant, and to the quality of mixed coal sold to other consumers. The Montreal company stated in their brief their willingness to use 40 per cent of the above washed coal, but added that they understood that the actual deliveries were all of such coal available. An average of 175,000 tons of coal was shipped annually to the Montreal plant in the seven years, 1935 to 1941 inclusive, but no coal in 1943 or 1944. Owing to emergency conditions created by coal and shipping strikes, the Coal Controller, during the 1946 season, diverted 75,000 tons of Nova Scotia coal to this plant for coking purposes.

Central Canada, west of Montreal, is entirely dependent for coking coal on importations from the United States. Importations include coals of high, medium and low volatile types to be blended in different proportions to meet the needs of particular plants. Thus, such a firm as the Consumers' Gas Company of Toronto will use a high volatile coal whereas the Algoma Steel Company, making metallurgical coke, will use a medium volatile blend. The difficulty experienced in supplying Nova Scotia coal for the Montreal coke plant makes it highly improbable that such coal for coking purposes could displace United States coal farther west. The large by-product coke plants at Sault Ste. Marie and Hamilton, in 1944, coked over three million tons of imported coal, and the gas plants at Toronto and elsewhere coked over three hundred thousand tons. 65 per cent of all the coal coked in Canada is treated in the part of central Canada west of Montreal.

Western Canada has low-sulphur coking coals in the mountain coal areas of Alberta and of British Columbia, and also on Vancouver Island. A high grade coking coal of medium volatile type is mined in the Crowsnest Pass area. The medium volatile coals of Alberta are also good coking coals, but have a higher ash content. They are normally washed for coking, but the ash content cannot be reduced economically below ten to twelve per cent. Low volatile coals are mined in Alberta, but these are non-coking in character, and so far have not proved suitable for blending. Vancouver Island produces high volatile coking coals, of which a large proportion of the fine sizes are carbonized in the gas plants at Victoria and Vancouver. Western coking coals are used for coking as far east as Winnipeg, and up to 50,000 tons of coke made from western Canadian coals are exported annually to the United States.

PROCESSES FOR COAL CARBONIZATION AND FOR GAS MAKING

High Temperature Carbonization Processes

Beehive Ovens

The beehive oven process is the oldest still in operation, but beehive ovens account today for less than four per cent of Canada's total carbonization capacity. The ovens are of simple fire brick construction, with a flat floor of twelve or more feet in diameter and a domed roof resembling a beehive. Coal is charged through a hole in the roof and air is admitted in restricted amounts through a door in one side. Volatile matter, driven off by heat, catches fire and burns over the charge, thus providing the heat required to complete carbonization. Carbonization proceeds from the top of the charge downwards. Volatile matter from the lower layers passing up through the already coked, and very hot, upper layers is decomposed, depositing a silvery, graphitic carbon on the coke. This gives the coke a silvery appearance, and a non-reactive character desirable for blast furnace use. The output per oven is small, since each charge may take three days to coke. The cost of operation is high, since the withdrawal of the coke from the oven is laborious, often being done manually. Before removal, the coke is quenched in the oven with water. The beehive oven is wasteful in that the volatile constituents, and some of the coke, are burned.

By-Product Coke Ovens

By-product coke ovens are operated to make coke, with the gas, tar, etc., recovered as by-products. The recovery of by-products contrasts with the Beehive process in which the volatile constituents and some of the coke are burned. No air is admitted to the charge, and the heat required reaches the coal through the walls, from flues in which gas is burned. The gas and other volatile matter from the heated coal are removed through offtakes and suitably treated for the recovery of by-products. The heating gas used may be the gas from the process, or a less valuable gas made for the purpose. Makes of ovens such as Koppers, Semet-Solvay and Wilputte may vary in size, shape and construction, but operate on the same basic principle. A full-sized modern by-product oven is a rectangular chamber over 40 feet in length, from 10 to 15 feet in height, and with an average width of about 18 inches. The oven has removable doors at each end and a slight taper from one end to the other, to facilitate pushing out the coke at the end of each run of eighteen hours, more or less. Batteries of 60 such ovens may carbonize as much as 1,500 tons of coal per day. The standard by-product oven plant has a very high capital cost. It can be operated with great efficiency, but only on a large scale. Attempts to use smaller sizes of ovens and plants have not always been successful.

One distinct variant of the by-product oven operated in Canada is the Curran-Knowles oven. This is a flat oven approximately 40 feet long by 8 feet wide, heated by flues below the floor. The capital cost is lower than that of other by-product plants, and it can be operated on a smaller scale. It also can treat highly swelling coals without difficulty. As the coal is coked from below, the volatile matter driven off does not pass through the hot coke, and the coke produced has, therefore, physical properties rather different from that of other by-product ovens.

Travelling-Grate Carbonization

The travelling-grate carbonization process of the Shawinigan Chemical Company is a high temperature process adapted to the special operating conditions of that Company. A coking bituminous coal is fed in a layer of three or four inches thickness, onto a travelling grate, 48 feet long by 10 feet wide, moving at a speed of 80 to 90 feet per hour. The coal is converted to coke by controlled combustion supported by air supplied from blower compartments below the grate. Coking proceeds from the top downwards. A coke suitable for the manufacture of calcium carbide is thus made at low capital and operating cost. The sensible and potential heat of the products of distillation are efficiently utilized by sending these products to the rotary lime kilns, where they are burned as fuel.

Gas Retorts

A gas retort is a container usually constructed of fire brick and externally heated in which coal is carbonized. In the larger modern plants in Canada continuous vertical retorts of English design are used. These retorts are continuously charged with coal which descends through the retort as the coke is withdrawn from the bottom. The Glover-West type of retort has a carbonization capacity of about five tons of coal per day; the Woodall-Duckham type up to twelve tons per day. An important feature of all vertical retorts, and some types of chamber ovens for making city gas, is their adaptability to the introduction of steam into the base of the retort. The steam reacts with some of the hot carbon (coke) to give "water gas". This reaction not only serves to cool the coke before it is discharged, but also increases the volume of gas produced in the retort. The advantage of modern gas retorts over by-product ovens is that with them a higher yield of gas may be obtained, and smaller plants successfully operated.

Total Gasification Processes

These processes, as their name implies, are used to convert coal, or coke produced by some high temperature process, into gas. There are substantially no by-products.

Gas Producer

A gas producer is a chamber, usually of brick or iron lined with brick, into which coal or coke is charged, and through which air and some steam are blown, completely gasifying the solid fuel. The air reacts with the carbon of the coke to form carbon-monoxide, which is diluted with nitrogen from the air. The process develops a high temperature in the fuel bed. The steam blown in reacts with some of the very hot coke to form two combustible gases, carbon-monoxide and hydrogen, thereby cooling the fuel bed and enriching the gas. The gases produced by blowing both air and steam through a deep coke fire have a heating value of about 130 B.t.u. per cubic foot. If coal is used, instead of coke, the gases will be enriched by the volatile matter from the coal.

Water Gas Generator

A water gas generator is somewhat similar to a gas producer except that it is equipped to blow air and steam alternately through the generator. Therefore, if a richer gas than producer gas is desired, the two stages of the process may be separated. Heated air can be blown through the coke to raise it to a high temperature, and the resulting gases burned to provide additional heat. Steam is then sent through the intensely hot coke, and the resulting water gas, with a heat value of about 300 B.t.u. per cubic foot, is collected. A complete cycle of blow and make takes about five minutes. Water gas is one source of synthesis gas, the uses of which are described elsewhere in this chapter. For use as city gas the water gas is enriched or carburetted by the addition of oil or other enricher. The oil and hot gas leaving the generator pass together through hot chequered brickwork where the oil is cracked to form permanent gases. A carburetted water gas commonly has a heat value of 500 to 600 B.t.u. per cubic foot, but this varies with the amount of oil used.

Oxygen Generated

Recent developments in connection with the use of a mixture of oxygen and steam have made possible the complete continuous conversion of coke, or coal, into a gas suitable for synthetic chemical manufacture, as described in the part of this chapter dealing with the production of synthetic liquid fuels.

Low Temperature Carbonization Processes

These processes have received very wide publicity during the past forty years and have often been proclaimed as about to revolutionize the coal industry, but up to date they have entirely failed to displace high temperature carbonization. Low temperature carbonization is carbonization at 1,100° F. or lower, in contrast with high temperature at 1,800° F. or higher. The essential characteristic of the low temperature process is that the tar is removed uncracked. The coke is weak, but is a free-burning, smokeless fuel. The tar is a good liquid fuel somewhat resembling crude petroleum, and, therefore, quite different from the coal tar used in the coal tar industry. The gas is of high heat value.

Low temperature carbonization was first advocated in England some forty years ago for a dual purpose, to reduce the serious smoke nuisance from domestic heating and to curtail the importation of petroleum. Some 800 low temperature processes were known by 1933, but up to that time only 220,000 long tons of coal per year were treated by low temperature processes in Great Britain. In 1944 in the United States the tonnages of coal carbonized by various processes were:

In by-product and beehive ovens..........	105,000,000
In gas plants..........................	1,400,000
In medium and low temperature processes...	400,000

No figures are readily available for low temperature separate from medium, but the tonnage of both was only one-third of one per cent of the total tonnage coked.

The Pittsburgh Carbonization Company uses a method known as the Disco process to produce low temperature coke in an externally heated rotary retort. The process results in small balls of dense smokeless fuel, which are particularly suitable for some types of domestic heating equipment. The low temperature tar produced, which is the only by-product, is fractionated at the plant. The residual pitch, high in carbon and ash, is charged back into the process.

The Lurgi low temperature process is in operation at Bienfait, Saskatchewan, where a non-coking lignite is treated in a low temperature carbonizer and the resulting char is briquetted and sold for domestic heating. The plant has a capacity of about 60,000 tons of briquettes a year. The raw coal is processed in massive vertical retorts by passing hot gases through the charge. The heating gases are obtained by the combustion of the distillation gases in combustion chambers connected to the retorts. The gas produced is used for processing while the tar produced is used to provide some of the binder required for briquetting. The early development work and construction of the original plant were financed by the Federal Government and the Governments of Manitoba and Saskatchewan through the Lignite Utilization Board of Canada. By 1924 this Board believed that it had demonstrated the commercial feasibility of carbonizing and briquetting Saskatchewan lignite and turned over the plant it had erected to a private company for a nominal amount. The operation was not successful, and the plant has changed hands several times. In the interval Lurgi carbonizers were installed. At present the operation is a commercial success, but at a capital cost to the present operator bearing no particular relationship to the cost of replacing the plant. Recent estimates of the cost of reproducing the plant vary from over $500,000 to over $1,000,000. Under the circumstances, it is not clear as to whether any substantial additions to the capacity of the present plant are commercially sound.

COKE AND GAS PLANTS

Twelve plants are described below as illustrating the types of plant and equipment operating in Canada at the present time. The first five of these produce mainly metallurgical coke while the others produce mainly domestic coke and/or gas. It should be understood, however, that operations in any plant may be varied to suit the current demand for products. Plants which primarily make metallurgical coke can and do make domestic coke, and similarly, plants normally making domestic coke can and do make metallurgical coke. Plants whose principal output is gas may also have coke for sale, the amount of which varies according to the current demand for gas.

Most of the coke consumed in Canada is made in Canadian plants. Over the past decade there has, however, been an annual import of from 400,000 to 900,000 tons of coke from the United States. Most of the coke imported is used in central Canada. Exports of coke during the same period have not exceeded 50,000 tons. Exported coke comes almost entirely from the plants in the Crowsnest Pass and is used mainly by metallurgical industries in Idaho.

The Dominion Steel and Coal Corporation of Sydney, N.S., operates a by-product coke oven plant, with 180 Koppers ovens. This operation is primarily for the production of blast furnace coke for its own steel plant, but some coke is sold for domestic use. Surplus gas is used in the steel plant and the tar is sold. The coal treated would not normally be used for metallurgical coke, as it is a high volatile, gas coal which, although low in ash, is rather high in sulphur; but it is used because more suitable coal is not available. However, the steel operations of the Company are distinctly handicapped by the poor physical properties and high sulphur content of the coke. It should be understood than an inferior coke adds to the cost of production of the steel without necessarily in any way impairing its quality. The Sydney plant in 1944 treated 786,000 tons of coal.

The Steel Company of Canada at Hamilton, Ontario, operates a by-product coke oven plant, with 80 Wilputte ovens. The coal treated is all imported from the United States, and the metallurgical coke produced is normally consumed in the steel plant. In slack times, however, a crushed and sized coke is sold for domestic heating. The gas produced is nearly all used by the Company. In 1944, 649,000 tons of coal were treated.

The Algoma Steel Corporation of Sault Ste. Marie, Ontario, operates the largest by-product coke oven plant in Canada, with 103 Wilputte ovens and 141 Koppers ovens. The capacity was materially expanded during the war, with Government assistance, by the addition of 86 of the latest type of Koppers-Becker underjet ovens. The coal used, imported by water from the United States, is of varying rank suitably blended for the production of high grade metallurgical coke. Whilst the coke and gas produced are mainly made for, and consumed in, the steel plant, some coke was marketed in the Toronto area during the war, and domestic gas is supplied to the local community, through the Great Northern Gas Company. International Nickel Company and Falconbridge Nickel purchase from 200,000 to 250,000 tons of coke annually from this plant. 1,764,000 tons of coal were treated in 1944, more than two and one-half times that treated in 1937.

The International Coal & Coke Company of Coleman, Alberta, operates 104 beehive ovens, and the Crow's Nest Pass Coal Company at Michel, B.C., operates Beehive ovens and 20 Curran-Knowles ovens. Each company uses its own coal. The coke is sold mainly for metallurgical use in Canada and in adjacent markets in the United States, the largest consumer being the Consolidated Mining and Smelting Company at Trail, B.C. The specifications for coke for the non-ferrous metallurgical industries of British Columbia are less stringent as to physical strength than are those for the iron and steel industries, so that a satisfactory metallurgical coke can here be made in the Curran-Knowles ovens. In 1944 the Coleman plant treated 102,000 tons of coal and the Michel plant 127,000 tons.

The Montreal Coke and Manufacturing Company operates the largest plant making primarily domestic coke and gas, a plant surpassed in coking capacity only by the three steel companies described above. The Company was formed in 1927 to operate a by-product coke plant with capital subscribed equally by the Montreal Light, Heat and Power Consolidated and the By-Product Coke Company of Canada, a wholly-owned subsidiary of Koppers Company of Pittsburgh. The Montreal company did not take advantage of the provisions of the Domestic Fuel Act when building their plant since they decided at the outset that it would be impossible to comply with the requirement to use 70 per cent Canadian coal and yet make a coke that could be sold in such a competitive fuel market as that of Montreal. Nevertheless, persistent efforts have been made, with technical assistance from the Dominion Fuel Board and the Bureau of Mines at Ottawa, to use the maximum percentage of Nova Scotia coal. As has been stated, up to 40 per cent could be blended with United States coals, but the Nova Scotia coal had to be of high grade, and the high price of such coal delivered in Montreal, compared with imported coals, made such blending possible only with Government aid to the coal producer. Smaller percentages have in fact been blended in recent years owing to inability to obtain larger supplies of the required grade from Nova Scotia. Equipment at the plant includes 59 Koppers ovens, and also 4 Koppers Kerpely ring-type gas producers, and a water gas plant. The coke made is largely sold for domestic heating in Montreal and the surrounding area of Quebec and Ontario, although some foundry coke is also made. The gas is distributed for domestic use by the Quebec Hydro Electric Commission. In 1944 the plant treated 565,000 tons of coal, all of it imported.

The Consumers Gas Company of Toronto, Ontario, is primarily engaged in the manufacture and distribution of coke and gas for the domestic market of Toronto. The coal used is all imported. Equipment includes 104 Glover-West vertical retorts, 220 Drakes horizontal retorts, and 8 water gas sets. In 1944 some 75 per cent of their coke was used for making gas. In 1944 some 283,000 tons of coal were treated.

The Hamilton By-Product Coke Ovens plant was built in 1924, after the Government had promised aid through tariff concessions. It replaced an earlier retort gas plant. Present equipment includes 25 Semet-Solvay ovens, 35 Wilputte ovens and water gas sets. All the coal is imported. In the year ending March 31, 1945, about 90 per cent of the coke was sold to war industries for metallurgical and similar uses, although in peacetime years about 90 per cent of the coke produced was sold for domestic use. The gas made is distributed through the United Gas and Fuel Company.

The serious wartime shortage of coke and gas in the Hamilton district was met by the erection of an additional plant comprising 54 Curran-Knowles ovens by the Department of Munitions and Supply. The plant has been operated by the Hamilton By-Products Coke Ovens. The plant cost over $4,000,000, has not operated economically, and it is anticipated that it will be scrapped when coal and coke are in long supply. In 1944 this plant carbonized 264,000 tons of imported coal.

The British Columbia Electric Power and Gas Company, Vancouver, B.C., was incorporated in 1926. In the present plant 40 continuous vertical retorts were first installed, but later 45 gas chamber coke ovens were built. These relatively small ovens, capable of producing domestic coke of good quality and large volumes of gas, were installed with a view to improving the coke structure, and, incidentally, to qualify under the Domestic Fuel Act. The equipment also includes gas producers and water gas sets. This plant used 114,000 tons of Canadian coal in 1944.

The Winnipeg Electric Company operates a by-product recovery coke oven plant primarily for the production of city gas. The gas and coke are sold locally, mainly for domestic use. The plant consists of a 17-oven battery of Koppers-Becker small gas ovens. It was constructed by Koppers, and used imported United States coals entirely until 1933. Experiments begun in 1930 led to the substitution of coal from British Columbia and Alberta. In 1944 this plant treated 37,300 tons of Canadian coal and 34,500 tons of imported coal.

The Ottawa Gas Company, Ottawa, Ont., operates a plant for the production and distribution of carburetted water gas for domestic and other use. The present plant, put into commission in 1939, replaced an earlier plant using horizontal gas retorts. In 1944, in round figures, this plant used 3,800 tons of coke and 1,110,000 gallons of oil.

GOVERNMENT ASSISTANCE TO THE COKE AND GAS INDUSTRY

In this section we shall consider Government assistance to the coke and gas industry under the following headings:

The Domestic Fuel Act
Assistance under various Orders in Council
Tariff Assistance and The Coke Bounties Act.

Detailed statistics have not been included because they are presented in the chapter Subventions and Other Aid.

The Domestic Fuel Act

The Domestic Fuel Act was the result of recommendations made by a number of bodies. Under the auspices of the Dominion Fuel Board a study was made in 1923 and 1924 of the possibilities of domestic coke as a substitute for anthracite in central Canada. In the opinion of the Dominion Fuel Board the study indicated that conditions were favourable and the time opportune for the erection of coking plants at a number of points in central Canada and that, if plants were built at those suitable points, it would be possible to produce enough coke to displace up to 35 per cent of our importations of American anthracite. The 1926 House of Commons Special Committee Investigating Coal Resources of Canada agreed with the Dominion Fuel Board and recommended that such legislation be enacted as would encourage the production of domestic coke. At about the same time two Royal Commissions recommended Federal Government action to encourage the production in Canada of domestic coke from Canadian coals. The first of these was a Nova Scotia Commission on the coal mines of that Province, the second was the Federal Royal Commission on Maritime Claims; both were under the chairmanship of Sir Andrew Rae Duncan. The second Commission declared that "there can be no doubt that the establishment of coking plants under the assistance of the Dominion Government, for the coking of Canadian coal, would go far towards solving the coal problem in the Maritime Provinces."

The Domestic Fuel Act of 1927 was, therefore, designed for the two-fold purpose of assisting the Canadian coal mining industry and at the same time relieving the domestic fuel situation. Under the Act an annual subsidy payment of 4 per cent (or in some cases 5 per cent) of the capital cost of a coking plant would be paid by the Government, provided that at least 70 per cent of the coal used was of Canadian origin and that the amount did not exceed one dollar per ton of Canadian coal used in the production of coke sold for domestic use. If less than 70 per cent, but more than 50 per cent, of the coal thus used was Canadian, smaller amounts would be paid.

Three coking plants have been built or re-built under the Act. They are the plants of the Nova Scotia Light & Power Company at Halifax, the Quebec Power Company of Quebec, and the British Columbia Electric Power & Gas Company at Vancouver. These plants are still in operation. Up to March 31, 1946, subsidy payments to them under this Act totalled $737,608, covering the use of 748,981 tons of Canadian coal of which 139,450 tons was used at Halifax, 187,196 tons at Quebec, and 422,335 tons at Vancouver.

It is now abundantly clear that the high hopes of those who advocated the Domestic Fuel Act have not been realized. This was frankly admitted by the 1932 Nova Scotia Commission on the coal mines of that province, again under the chairmanship of Sir Andrew Rae Duncan. The largest domestic coke and gas plant in central Canada, that of the Montreal Coke and Manufacturing Company, was built after the Act came into effect, but did not apply for aid under it because the operators did not believe that they could use even 50 per cent Canadian coal. The construction of the two plants at Halifax and Quebec has provided neither a large market for Canadian coal nor a large source of domestic coke, and thus the Act has contributed little to solving the coal problem in the Maritime Provinces or to improving the domestic fuel situation in central Canada. The largest payment under the Act has been that to the Vancouver plant. This assistance has undoubtedly increased the market for Vancouver Island coal, but, inasmuch as no anthracite was used in British Columbia previously, it has not affected in any way our reliance on United States sources of anthracite.

Assistance Under Various Orders in Council

The failure of the Domestic Fuel Act and the experience of the coke plant at Montreal indicated that if a stimulus was to be given to domestic coke manufacture in central Canada, it would have to be done in such a way that plants using Canadian coal, but in amounts less than 50 per cent, could benefit. Therefore, Order in Council P.C. 944, of 1932, provided assistance on Canadian coal so used up to the difference in the laid-down cost at the coke plant between Canadian and imported coal with a maximum of one dollar per ton. This Order in Council was designed particularly to encourage the use of Nova Scotia coal in the Montreal coke plant and it was successful in providing a pre-war movement of about 170,000 tons of Nova Scotia coal per year to that plant at a cost to the Government of just under one dollar per ton. Under the same Order in Council there have been small movements of coal to the plants of the Ottawa Gas Company and Shawinigan Chemicals. Under other but similar Orders in Council there were small movements of Nova Scotia coal to the plant of the Hamilton By-Product Coke Ovens Limited during 1936 and 1937. In the thirteen years up to the end of 1945, about 1,700,000 tons of Nova Scotia coal have moved under Order in Council assistance to coke plants. Since the assistance has been given on the principle of equalizing laid-down costs, the assistance is of benefit to the coal industry rather than to the coke plants.

Under P.C. 944 and various other Orders in Council more than 700,000 tons of western Canadian coal have moved into the Winnipeg Electric Company's coke ovens. The tonnage moved has fluctuated considerably from year to year, but has on occasion been important, particularly in that much of it has been slack coal. As in central Canada, assistance given to this movement benefited mine operators rather than the coke plant.

Tariff Assistance and The Coke Bounties Act

Since 1907 there has been a measure of assistance given to the coke and gas industry in Canada through the remission of a portion of the duty paid on coal imported for use in coke and gas plants when the coke made is used for certain specified purposes. The details of these arrangements may be found in the chapter Subventions and Other Aid. The most interesting of these provisions is that in effect since 1934, allowing a withdrawal of 99 per cent of the duty paid on imported coal where the coke made is sold for use as a fuel in other than a coke or gas plant, provided that not less than 35 per cent of the bituminous coal used was mined in Canada. The effect of this provision has been that a plant such as that of the Montreal Coke and Manufacturing Company Limited, when using at least 35 per cent Canadian coal, can import foreign coal almost duty free. In the case of that plant, this provision has provided the incentive to take advantage of P.C. 944.

The 1926 Federal Royal Commission on Maritime Claims suggested that the 99 per cent drawback allowed on imported coal, when the coke produced from it is used for metallurgical purposes, amounted to a subsidy and that a similar subsidy should be paid on Canadian coal used in the steel industry. This recommendation was given effect by the Coke Bounties Act of 1930. Under this Act a bounty of 49.5 cents per ton is paid on bituminous coal mined in Canada and used to produce coke for the steel industry. In the fiscal years 1930 to 1945 inclusive, $3,913,000 in bounties has been paid on approximately 7,900,000 tons of coal, all of it mined in Nova Scotia.

GENERAL CONSIDERATIONS AFFECTING THE COKE AND GAS INDUSTRY AND ITS FUTURE

The future of that section of the coke and gas industry which produces principally for the steel industry will, of course, depend largely on the future of the steel industry. In metal smelting coke acts at the same time as both a fuel and a chemical reducing agent and no adequate substitute for it in this dual role is available. For the subsequent working of metal, whereas coke is widely used, it is meeting increasing competition from other fuels and from hydro-electric power. Generally speaking, however, the coke requirements of the metal industries will depend upon the level of activity in those industries.

One of the outstanding features of modern by-product coke ovens is their flexibility. Ovens which normally produce good metallurgical coke can also supply good domestic coke. When the requirements of the steel industry fall off, the makers of metallurgical coke usually prefer to turn to domestic coke rather than to close down, and their offerings consequently increase competition in the market for domestic coke. This circumstance is a considerable deterrent to the development of plants built primarily to supply domestic coke, for the operators must face the prospect of periodic invasions of such market as they may develop by surplus coke from metallurgical plants.

Coke has many advantages as a domestic fuel. The experience of those who have been engaged in developing the domestic market for coke indicates clearly, however, that if it is to compete successfully in the domestic fuel market, the coke offered must be of high quality. This fact has led coke manufacturers to lay greater and greater emphasis on obtaining the most suitable coals. The exact specifications for coal to be used for domestic coke have made it increasingly difficult to supply coal from Nova Scotia mines. There is no evidence that these specifications can be relaxed, for the domestic fuel market promises to continue to be highly competitive. Anthracite will continue to be available and the pressure from oil promises to increase. In the domestic market there is a distinct trend towards automatic equipment which will probably militate against the use of coke, for coke is unsuitable for such equipment. Bituminous Coal Research in the United States is endeavouring to develop domestic heating equipment in which high volatile coal may be burned without smoke. Should its efforts be successful, bituminous coal may become much more strongly competitive in the domestic market to the disadvantage of coke and other domestic fuels.

The successful commercial operation of a by-product coke plant depends equally as much on an adequate market for gas as it does on an adequate market for domestic coke. The capital cost of a gas distribution system is necessarily high and, therefore, manufactured gas can only be distributed in large urban areas. Gas manufactured from coal is limited in its ability to compete with other fuels for space heating because of the seasonal character of the load. It is therefore used most successfully where the seasonal factor is insignificant such as for cooking, water heating and specific industrial purposes. Within that market gas is under strong competition from electricity, for in many areas in Canada hydro-electric power is relatively cheap. In the areas where natural gas is available, gas from coal is not competitive.

The use in recent years of liquefied petroleum gas is a further instance of competition with gas derived from coal. The petroleum and natural gas industries have to deal with considerable amounts of hydrocarbons which are gaseous under ordinary conditions of temperature and pressure, but which may be liquefied under comparatively low pressures, and can, therefore, be distributed in suitable tank cars and light cylinders. Liquefied petroleum gas is particularly suitable for supplying the intermittent heat requirements of urban and rural and small urban communities. The gas, which has a very high heat value, is also used to supplement supplies of natural or other manufactured gas. This gas, however, is relatively costly.

CONVERSION OF COAL TO SYNTHETIC LIQUID FUELS

Much popular interest has been aroused in the synthetic production of petroleum from coal. Prior to the war, it was commonly known that there was a sizable and expanding industry in Germany and that one full-scale plant had also been built in England. Two synthetic processes were used, both having been originally developed through technical research in Germany. These are commonly known by the names of their respective inventors, high pressure hydrogenation having been invented by Bergius and hydrocarbon synthesis by Fischer and Tropsch. The first process is applicable to coal or to such heavy liquids as tar and natural bitumen, while the Fischer-Tropsch synthesis can start either with coal or with natural gas.

With the exception of some small plants in Japan and France, the bulk of synthetic petroleum, prior to and during World War II, was produced in Germany and England; there were only small-scale research plants in the United States. When Germany was invaded in 1945, the synthetic oil industry was one of the first to be investigated. It was found that the major part of the synthetic oil was produced by the high pressure hydrogenation process. The total capacity of both processes was of the order of 40,000,000 barrels per year. The total production in Germany from all sources, including both natural and synthetic production, was about 56,000,000 barrels per year. The Government of Great Britain, following the advent of Hitler's leadership in Germany, established one high-pressure hydrogenation plant at Billingham, capable of producing 3,500 barrels of high octane gasoline daily, not a large production when measured with the total needs of modern war, and yet large enough to make a significant contribution to the supply of aviation fuel. The oil-from-coal industry can, therefore, be said to have reached major proportions in Germany and to have been established on a full scale in England. It should be emphasized, however, that none of this production was economically competitive with natural petroleum.

The major research effort in the United States at present is being made by the Bureau of Mines which was authorized by Congress to make expenditures over a period of five years up to the amount of $30,000,000. The program is already well under way and is divided into several branches. The main research laboratory is to be located at Bruceton, Pa., near Pittsburgh, where experimental equipment for the study of both high pressure hydrogenation and the Fischer-Tropsch type of synthesis, on a small scale, will be undertaken. Demonstration plants for large scale work, again following both of the fundamental methods, are being established at Louisiana, Mo. An experimental plant at

Rifle, Col., is to study methods for the recovery of shale oil. Other experimental work is being carried out on production of water gas from coal at Morgantown, W.Va. The oil companies in the United States are interested in a modification of the Fischer-Tropsch method with a view to converting natural gas to gasoline. Quite apart from the experiments being conducted by the United States Bureau of Mines, some of the commercial companies have already made considerable experimental progress along this line. The foregoing information with respect to research in the United States is set out in some detail, partly to illustrate the present status of the industry and also to emphasize that, notwithstanding the large coal resources of that country, no attempt has yet been made to proceed with commercial scale production as has been done in Germany and Great Britain.

It has been suggested that further research be undertaken in Canada in the field of synthetic liquid fuels. Small-scale experiments have been conducted by the Division of Fuels of the Bureau of Mines. The field is a large one and much research is currently being undertaken in the United States. Accordingly, it is desirable that any activities in Canada in this direction should be intensive and complementary to the work being done there, since it is assumed that these two countries can co-operate in the future as they have done in the past.

Interest in the subject has in part been due to the fact that most of the petroleum consumed in Canada is imported. The value of imported petroleum is more than $100,000,000 per year. Taking a broader view, the petroleum supply of the world as a whole is not inexhaustible and, when the rate of production cannot be maintained at as high a level as the rate of consumption, the price of petroleum will rise to a point where substitutes will be able to compete economically. Another factor contributing to interest in the possibility of producing oil from coal has been the desire for security in wartime when the supply of petroleum from foreign sources may be interrupted. The coal mining industry is especially concerned because it would be profoundly affected by any major substitution of coal for petroleum as the source of material for liquid fuels. Assuming that 0.6 tons of coal can be converted to the equivalent of one barrel of petroleum, the following table indicates the amount of coal that would be required to replace various proportions of the total petroleum consumption of Canada:

Percent Replaced by Coal	Coal Requirements (millions of tons)
100	34.0
50	17.0
10	3.4

These figures are, of course, arbitrary and approximate and apply to bituminous coal. If low rank coals were used, the requirement would be greatly increased.

A technical treatment of the subject follows.

METHODS

The methods that must be employed in order to convert coal to liquid hydrocarbons are indicated in a general way by comparing the chemical composition of the raw material with that of the product. The hydrogen content of coal is about 6 per cent and that of gasoline about 14 per cent; there are substantial quantities of oxygen, nitrogen and sulphur in coal and practically none in gasoline; and coal has a very high and indefinite molecular weight and gasoline a much smaller average molecular weight. To convert coal into gasoline three changes must be made, hydrogen must be added, oxygen, sulphur and nitrogen removed, and the large molecules broken down into smaller ones. The hydrogen required for the conversion is usually made from coke and steam by a process absorbing thermal energy, which is also produced from coal, so that, considering the overall conversion and neglecting minor products, coal and water go into a series of reactions and gasoline and carbon dioxide are produced.

Although the overall conversion is defined by the chemical compositions of the materials involved, two fundamentally different methods have been devised for carrying it out. One of these, called hydrogenation, brings about the chemical combination of hydrogen with coal through the agencies of high pressure and catalysis. The other, called indirect hydrogenation, or more commonly, the Fischer-Tropsch synthesis, converts the coal to water gas, adds hydrogen and converts the mixture of gases to hydrocarbons by passing it over a catalyst.

Direct Hydrogenation (*Bergius*)

It is difficult to give a concise description of the process of coal hydrogenation because of its complexity. The outline of the process that follows will, therefore, be confined as far as possible to fundamentals.

The conversion of coal to gasoline is accomplished in a series of separate stages. In the first stage, the coal is liquefied and yields as its principal net product a distillable middle oil. In the second stage, the middle oil is purified from compounds of nitrogen which would poison a catalyst that is used subsequently. In the third stage, the purified middle oil is converted to gasoline. All three stages have two conditions in common; first, a stream of hydrogen flowing through the reaction zone at a pressure of several thousand pounds per square inch, and second, the presence in the reaction zone of catalytic materials.

The manufacture of hydrogen can be considered as the starting point of the process. Of the numerous methods that have been developed for the production of hydrogen, the one most commonly used in Germany and in England is well known and has been employed for many years in the synthetic ammonia industry. In it hot coke is blown alternately with air and steam to produce water gas. The water gas is then passed over a catalyst with additional steam which converts most of the carbon monoxide to hydrogen and carbon dioxide. The chemical equations for these processes are as follows:

1. $C + H_2O = CO + H_2$
2. $CO + H_2 + H_2O = 2H_2 + CO_2$

The mixture of gases resulting from these reactions is compressed and the carbon dioxide and the carbon monoxide removed from it by selective solvents. The purified hydrogen is introduced into the re-circulating streams of hydrogen that flow through the reaction zones. About 250 to 300 cubic feet of hydrogen are required for the production of one gallon of gasoline from coal.

In preparation for the first stage of hydrogenation, the coal is dried and, if necessary, cleaned. Approximately half of the total coal is put through the liquefaction process, the remainder being required for fuel, hydrogen production, etc. Because of this division of the raw material, the high grade portion can be processed and the low grade portion used as fuel. The portion to be hydrogenated is pulverized and mixed with a heavy recycle oil and with a small amount of a compound of iron or tin as a catalytic material. The proportion of coal to recycle oil is usually about 45:55. When tin is used as the catalyst, its activity is increased by the presence of hydrochloric acid and the comparatively low pressure of about 4,500 pounds per square inch can be employed. When iron is used as the catalyst, the acid is not necessary but the pressure should be about 10,000 pounds per square inch. In the newer German plants, the trend has been towards the use of iron catalysts and higher pressures.

The paste of coal, oil and catalyst is injected into the high pressure system where it joins the stream of circulating hydrogen. The mixture of paste and hydrogen is passed through a heating system and into the reaction chambers where the temperature is about 900° F. There are usually four of these in series and a unit of four chambers, together with the heater and other auxiliary equipment, is called a "stall". The volume of reaction space in a stall is about 950 cubic feet and about 13 tons of coal are liquefied per hour in each stall. The product from the reaction chambers is collected, cooled and let down to atmospheric pressure. It is distilled and otherwise processed to yield a heavy oil which is mixed with fresh coal and recycled through the first stage. The other product is a light oil boiling between 32° and 600° F., which is passed on to be processed in the second stage.

The purpose of the second stage of hydrogenation is to remove nitrogen compounds from the light fraction produced in the first stage. If these are not removed, they react with the catalyst that is used in the third stage and greatly reduce the length of time that it is effective. The equipment employed in the second stage is similar to that of the first stage and the pressure is usually of the order of 4,500 lbs. per square inch but the temperature is lower, about 750° F., and the catalyst is tungsten sulphide. The catalyst is not finely powdered and mixed with the feed stock as in the first stage but is in the form of pellets that remain in fixed position in the reaction chamber. The throughput of middle oil is about 19 tons per stall per hour. Fewer stalls are required in any given plant for the second than for the first stage; for instance, at Leuna there were 10 first stage, 5 second-stage and 3 third-stage stalls.

The function of the third stage is to convert the purified oil from the second stage into gasoline. The equipment, pressure and temperature employed in the third stage are similar to those of the second but the catalyst most commonly used consists of tungsten sulphide mixed with an activated clay. This catalyst produces gasoline of a fairly high octane number. The rate of throughput of feed stock is about 22 tons per stall per hour. About 40 per cent of the product has a boiling range above that of gasoline and this fraction is mixed with fresh feed stock and recycled through the third stage when the net liquid product is to be entirely gasoline.

In addition to the three-stage process as outlined above there are, in some plants, dehydrogenation, polymerization, and alkylation units similar to those employed by the petroleum industry. The purpose of these is to prepare base and blending stocks of especially high octane number for the manufacture of aviation gasoline.

Regarding the nature of the coals that are suitable for direct hydrogenation, it has been established by extensive experimentation that, in general, coals of a rank below medium volatile bituminous are readily liquefiable. Above that rank too large a proportion remains unliquefied for successful technical operation. There is no lower limit to the rank that can be liquefied as is evidenced by the extensive use in Germany of different types of brown coal. Within a given rank there is some variation in amenability to liquefaction depending on the proportions of the various petrographic constituents. The dependence of yield on petrographic composition has been intensively studied by the United States Bureau of Mines and, where petrographic analyses are available, yields can be predicted with sufficient precision to eliminate some coals that might otherwise be subjected to pilot plant assays. Thirdly, the ash and moisture contents of the coals are factors to be taken into consideration. A coal high in ash not only contains less liquefiable matter but also the ash has to be removed from the heavy recycle oil in order to prevent accumulation and this involves a loss of oil roughly equal to the weight of the ash.

Only a relatively small proportion of all Canadian coals are of too high rank to be considered for hydrogenation. In order to choose the most suitable coal for this purpose a preliminary selection would, therefore, be made on the basis of grade and cost. Since few petrographic analyses have been made for Canadian coals, it would be necessary to make extensive laboratory tests and, after narrowing the field on a basis of their results, to conduct pilot plant tests.

The following table taken from the Bureau of Mines Publication No. 798 summarizes the results of laboratory tests on a series of Canadian coals. The yields indicated do not, of course, include the coal that would be required for fuel, etc., in a commercial-scale plant.

—	—	Imp. Gals. of primary oil per 2000 lbs. dry and ash-free basis
Crowsnest	Medium-volatile bituminous	124
Vancouver Island	High-volatile bituminous A	134
Sydney	High-volatile bituminous A	154
Saunders	High-volatile bituminous C	107
Drumheller	Sub-bituminous B	125
Edmonton	Sub-bituminous C	115
Bienfait	Lignite	113

The main product of coal hydrogenation in any of the existing commercial plants is gasoline. In both Germany and Great Britain, the gasoline was largely finished to aviation specifications. The finished gasoline is very similar to that produced for the same purpose from petroleum and, in fact, it was only with considerable difficulty that the origin of gasoline in captured enemy equipment could be determined. In Germany, motor gasoline, diesel oil and fuel oil were also made from coal by direct hydrogenation. Lubricants were prepared by secondary processing of oils from hydrogenation. Contrary to the general impression, Germany was not handicapped by the quality of the petroleum substitutes produced from coal.

In this report, unless otherwise stated, the yields are based on the total coal requirement, including fuel. The variation of yield with changing rank is especially pronounced if the amount of coal used is expressed on the as-mined basis including water. Less important variations are due to differences in methods of processing and in the nature and quality of the products obtained. In order to specify the yield with precision it is, therefore, necessary to fix all of these variable conditions. As an approximation to be used in rough estimating, it can be assumed that the overall yield is about one barrel of gasoline from 0.6 tons of bituminous coal, or from 1.8 tons of lignite containing 50 per cent moisture. In order to make an accurate estimate for any given coal and processing procedure, it is necessary to determine certain factors by actual test in a pilot plant.

HYDROGENATION COSTS*

LEUNA WORKS

—	†RM/Hour	Cents/Gal.	Per Cent of Total
A. *Materials*—			
1. Raw Materials: Brown Coal	972.00	1.8265	7.065
Brown Coal Tar	1,248.00	2.3452	9.072
2. Other Materials—			
Make-up Gas (96 per cent H_2)	6,753.60	12.6911	49.094
Red Earth (dried)	306.00	.5750	2.224
Catalyst and other chemicals	144.80	.2721	1.053
3. By-Products (Credits)—			
Butane	*910.25*	*1.7105*	*6.617*
Propane	*1,131.43*	*2.1261*	*8.224*
Ethane	*315.70*	*.5933*	*2.295*
Hydrogenation Gas	*1,386.00*	*2.6045*	*10.075*

*Capital costs are included in each item.
† Reichsmarks.

HYDROGENATION COSTS*—*Concluded*

LEUNA WORKS—*Concluded*

—	†RM/Hour	Cents/Gal.	Per Cent of Total
B. *Running Costs*—			
Coal, steam drying of	185.90	.3493	1.351
Coal, gas-fired drying of	747.85	1.4053	5.436
Paste preparation	467.67	.8788	3.399
Paste injection	207.79	.3905	1.511
Coal stalls	931.76	1.7509	6.773
Heavy oil let down centrifuges	125.25	.2345	.910
Heavy oil let down kilns	801.51	1.5061	5.826
Tar centrifuges	113.70	.2137	.827
Liquid phase distillation	288.10	.7293	2.821
Gas washing plant	173.57	.3262	1.262
Circulation	274.66	.5161	1.996
Vapour phase injection	128.11	.2407	.931
Vapour phase stalls	613.61	1.1531	4.461
Vapour phase distillation	283.49	.5327	2.061
Petrol wash	26.14	.0491	.190
Depropanizing plant	67.40	.1267	.490
Liquid phase, rich gas purification	286.22	.5379	2.081
Liquid phase, rich gas fractionation	524.18	.9850	3.810
Petrol testing	6.26	.0118	.046
Liquid phase intermediate storage	152.23	.2861	1.107
Vapour phase intermediate storage	41.43	.0779	.301
Hydrogenation, drain water treatment	60.96	.1145	.443
Hydrogenation, phenol separation	9.02	.0169	.065
Hydrogenation, phenol washing	20.61	.0387	.150
C. *Loading and Evaporation*	217.20	.4082	1.579
D. *Additional Costs* (I. G. direction, research, etc.)	1,220.66	2.2938	8.873
Total	13,756.31	25.9	100.0

*Capital costs are included in each item.
†Reichsmarks.

Although there are numerous statements in the technical literature regarding the cost of hydrogenation of coal, there are only two organizations that have outstanding technical knowledge of the subject; source material for most of the statements has originated with the I. G. Farbenindustrie in Germany or Imperial Chemical Industries in England. As in the case of yields, the costs vary widely depending on the particular raw material, product and process modification selected. The most recent and detailed cost that has been published was obtained by a team of technical investigators at the Leuna plant of the I. G. Farbenindustrie. This team was sponsored by the British Ministry of Fuel and Power, the United States Petroleum Administration for War, and the United States Bureau of Mines. These costs are summarized in the table concluded above. Although these figures apply to brown coal, other more approximate figures based on bituminous coal are of the same order of magnitude. It will be noted that, taking the reichsmark at its nominal value of 40 cents, the cost of motor gasoline is about 26 cents per gallon. It will be well to bear in mind in converting German to Canadian costs that the relative value of the reichsmark is uncertain.

The capital cost for coal hydrogenation plants also varies considerably depending on the exact conditions for which the plant was designed and it is safe to say that there is no plant in existence which would exactly fit conditions in Western Canada. The capital costs for the Leuna plant were not given in the reference that has been quoted but a rough approximation has been given in the report of the Falmouth Committee published in 1938. This applied to English conditions at that time and, of course, does not take into consideration improvements that were developed in Germany during the war. The cost of a plant to produce 150,000 long tons per year of motor gasoline was given as £8,000,000 (approximately $40,000,000) which is equivalent to about $11,400 per barrel per day of gasoline producing capacity. A rough value for estimating can, therefore, be taken as $10,000 per barrel per day but any such estimate must be used with the understanding that it indicates only the order of magnitude of the cost.

Fischer-Tropsch Process

In this report a distinction is made between the Fischer-Tropsch process as established in Germany and the developments along the line of hydrocarbon synthesis that are now in progress in the United States. These are both based on catalytic synthesis of hydrocarbons from carbon monoxide and both are commonly referred to as the Fischer-Tropsch synthesis. In some respects, however, they are fundamentally different and there would be less confusion if the newer developments were distinguished by a different name. In this report the name Fischer-Tropsch is applied exclusively to the process that was established in Germany. The newer work that is now in the development stages in the United States is referred to as the Improved Fischer-Tropsch Synthesis.

Unlike the hydrogenation process, there is relatively little variation in the design of the Fischer-Tropsch plants. There were nine of these in Germany and one in France, all of which followed closely two basic designs. These designs were developed by the Ruhrchemie A.G. The plants were built between 1933 and 1939 and were operated without any major addition or alteration until they were put out of operation by bombing in 1944-45.

The general chemistry of the process can be reduced to simple equations. First, water gas is produced from coke according to the equation: $C + H_2O = CO + H_2$. Secondly, the ratio of hydrogen to carbon monoxide is increased to 2:1. This is usually done by separating one-third of the water gas, converting the carbon monoxide in it to hydrogen according to the equation: $CO + H_2 + H_2O = CO_2 + 2H_2$ and adding the hydrogen to the remaining two-thirds of the original water gas. The carbon dioxide is removed by solution in a selective solvent. This part of the process is similar to the preparation of hydrogen for the hydrogenation process. The amount of hydrogen that has to be made separately is also of the same order of magnitude, about 300 cubic feet per gallon of primary hydrocarbons produced. The total requirement of synthesis gas, including the separately-prepared hydrogen, is about 1,000 cubic feet per gallon of primary hydrocarbons. Finally, the synthesis gas, consisting principally of hydrogen and carbon monoxide in the ratio of 2:1, is passed over a catalyst and is converted to hydrocarbons according to the equation $CO + 2H_2 = -CH_2- + H_2O$. The molecular unit $-CH_2-$ shown in this equation readily combines with others to form various hydrocarbons.

As in hydrogenation, the production of water gas is the first step. This is ordinarily carried out by the conventional reaction between steam and coke that has already been described. Although there are numerous other means of producing water gas, the Humphreys-Glasgow process was the one favoured in Germany. The crude water gas contains considerable amounts of sulphur both as hydrogen sulphide and as organic sulphur compounds. This would poison the sensitive catalyst that is used in the synthesis stage and it has to be removed almost completely. The hydrogen sulphide is taken out first by passing the gas over iron oxide at ordinary temperature. The organic sulphur is then taken out by further treating the gas with a mixture of iron oxide and soda at a temperature of about 400° F. After the sulphur has been removed, the ratio of hydrogen to carbon monoxide is adjusted by reacting one-third of the gas with steam over an iron-containing catalyst. The gas after this stage is called synthesis gas and it is either sent directly to the reaction chambers or is compressed to about 150 pounds per square inch, and then passed to the reaction chambers.

The synthesis reaction takes place on the surface of a catalyst at 360° to 400° F., and the temperature must be closely controlled to avoid rapid deterioration of the catalyst and undesired side reactions. Control of temperature is difficult because of the large amount of heat that is liberated by the reaction. It was found that, with a granulated catalyst in a fixed position, no part of the catalyst should be farther than about one-quarter of an inch from a heat-absorbing surface. This condition defined the fundamental nature of the reaction chambers. One design, used when the reaction is carried out at atmospheric pressure, consists of steel plates placed 0.29 of an inch apart with the catalyst between them. The plates were cooled by water pipes in contact with them as well as with the catalyst. A reaction chamber consists of 555 vertical plates and 630 horizontal water pipes and weighs, when empty, about 46 tons. The other design, employed for the medium pressure synthesis, uses banks of double concentric tubes with the catalyst placed between them and with water both inside the inner tube and outside the outer tube. About 2,000 double tubes comprise one chamber which weighs about 49 tons. The steam generated by the heat of reaction amounts to about 5 pounds per pound of hydrocarbon oils produced and is used in the plant for the manufacture of water gas, power, etc.

The catalyst used in all the German plants was composed of cobalt, thoria, magnesia and keiselguhr in the proportions of 30:1.5:2.5:66. The same catalyst was used for both low and medium pressure synthesis. It was made only by the Ruhrchemie in a separate part of their main plant at Holten and was shipped out in special rail cars to the various plants. Spent catalyst from the other plants was returned to Holten for reconversion into fresh catalyst. A charge of catalyst weighs about three tons, occupies about 350 cubic feet and lasts for three to four months. Synthesis gas is passed over the catalyst at a rate of about 100 cubic feet per cubic foot of catalyst per hour. At this rate each reaction chamber produces approximately one barrel of primary hydrocarbons per hour.

Contact with the catalyst converts a large part of the synthesis gas into hydrocarbons which range in molecular size all the way from methane to hard paraffin wax. Some of the wax remains on the catalyst and is periodically dissolved off; the heavier oils condense when the gases, leaving the chamber, are cooled and the lighter oils are absorbed from the residual gases by activated charcoal. Usually the residual gases are subjected to a second pass through another stage of chambers, absorbers, etc. The residual gas leaving the second stage is used for fuel. The raw products are refined first by distillation, which yields motor fuel and diesel oil, and secondly, by various chemical processes for the preparation of marketable waxes, lubricants, edible fats, etc.

The raw materials that can be used for the Fischer-Tropsch synthesis are theoretically any which can produce water gas. This, of course, is a very wide range, and in theory includes all carbonaceous materials. On the other hand, in Germany the range of coals that were considered suitable was narrow. With the exception of two of the plants, all used high temperature coke prepared from bituminous coal and there is some doubt concerning the successful operation of the two exceptional plants using the other raw materials. There is a possibility that materials with a high proportion of volatile matter, when gasified, produce a gas containing entrained minute drops of tar which deposit on the iron oxide mass that is used for sulphur removal and inhibit its activity. This permits sulphur to pass through to the synthesis catalyst, poisoning it. It is not certain whether the preference in Germany for high temperature coke as a raw material was due to this or some other technical reason or whether it was purely a matter of economics. In our present state of knowledge, however, if a Fischer-Tropsch plant were to be established in this country to convert coal to hydrocarbons, some risk would be involved in using any other material than high temperature coke. Active development work is now in progress directed towards invention of new and relatively cheap methods for production of water gas from a wide range of coals including lignites, sub-bituminous and bituminous coals. Should this work indicate the possibility of producing a satisfactory synthesis gas for the Fischer-Tropsch process, the conclusion given above, which was based on German practice, would have to be entirely changed.

The nature of the products produced by the Fischer-Tropsch process is not in any way affected by the original raw material. The products are almost entirely hydrocarbons belonging to the paraffin and olefin series. The hydrocarbons are principally of the straight chain type and, for this reason, the gasoline product has a very low octane number. As previously stated, the molecular size of the products varies widely from methane to the very large molecules that comprise paraffin wax. At the Holten plant of Ruhrchemie, the distribution of products according to boiling range from both atmospheric and medium pressure operation is shown in the following table:

—	Product	Per Cent by Weight	
		Atmospheric Pressure	Medium Pressure
Propane, butane	Treibgas	13	9
Boiling range 35—160° C	Light naphtha	45	36
Boiling range 160—230° C	Diesel oil	18	16
Boiling range 230—320° C	Gas oil	16	18
Boiling range 320—400° C	Soft wax	5	12
Boiling range 400—460° C	Table paraffin	1	2
Boiling range above 460° C	Hard wax	2	7

Referring to the table, the propane, butane fraction called treibgas by the Germans was used as a motor fuel. It was carried in cylinders under pressure on the tops of motor vehicles. The light naphtha fraction was used as a constituent of motor gasoline although its octane number was only about 50. The diesel oil is of good quality especially as regards its cetane number, which is above 100. The higher boiling fractions were for the most part not used as fuels but were converted by further processing into lubricants, hard and soft waxes, alcohols which were used in the manufacture of detergents, edible fats, etc. The trend in Germany appeared to be towards the use of medium pressure synthesis and other conditions which would increase the fraction of higher boiling constituents. It was thought that the best use for the Fischer-Tropsch process lay in the production of chemical raw materials rather than in the production of fuels.

The yields that are obtainable by the Fischer-Tropsch process are indicated by a theoretical study of the chemistry involved. Considering the equation $CO + 2H_2 = -CH_2- + H_2O$ it can be shown that 1,077 cubic feet of completely pure synthesis gas can yield at most 14 pounds of hydrocarbons which, converted to other units, shows that 539 cubic feet can produce about one Imperial gallon of primary products. However, this first approximation does not take into consideration the formation of methane and ethane and, in practice, it is usually found that 750 cubic feet of ideal synthesis gas are required per Imperial gallon of hydrocarbon products. Further, in actual practice synthesis gas is not entirely pure but contains carbon dioxide, nitrogen and other impurities and, after it has passed two stages of synthesis, the concentration of impurities is increased so that a considerable proportion must be discarded. Taking as an example an actual flow sheet, that of the Krupp Treibstoffe Werke, 60,000 cubic metres of water gas produce 7.33 metric tons of total product including propane and butane or 6.66 metric tons of liquid and solid products. This works out to 955 cubic feet of water gas per Imperial gallon of total primary product including wax and propane and butane, or considerably more than

1,000 cubic feet if only liquid products are considered. In normal practice with the standardized type of water gas generator, one ton of coke produces about 60,000 cubic feet of water gas, and, assuming that a ton of coke is produced from 1.5 tons of coal, the overall yield of primary products from one ton of coal is 40 gallons or, put in another way, one barrel of primary products is produced from 0.875 tons of coal. If the major product is to be gasoline, a further reduction in yield is introduced by the losses from cracking of the high boiling fractions of the primary product. These losses, according to Denig, reduce the volume of gasoline to 80 per cent of the volume of the primary product so that one barrel of gasoline would be produced from about 1.1 tons of bituminous coal. From this quantity of coal there are, in addition to the synthetic products, the by-products, tar and gas, that are produced in the gasification step.

Numerous estimates of the cost of the Fischer-Tropsch process were made before the end of the war on the basis of partial information that had been given out by the Ruhrchemie prior to 1939. Among these were the report of Sir David Rivett to the Australian Government, the submission of R. P. Russell to the United States Senate Committee on Bill 1243 in 1943, the submission of Mr. Fred Denig of the Koppers Company to the same Committee and the report of the Falmouth Committee in Britain in 1938. The more recent data obtained by interrogation of Dr. Friedrich Martin, President of the Ruhrchemie, since the war, has indicated that prices for gasoline as given in these previous reports were somewhat too low as was also the capital cost of the plants. The cost of the primary products was given by Martin as 300 reichsmarks per metric ton which, taking the reichsmark at its nominal value of 40 cents, would give a cost of 40 cents per gallon of primary product and a considerably higher cost if the heavier fractions were processed to gasoline. Martin also stated that the capital investment cost for Fischer-Tropsch plants was generally figured at 800 reichsmarks per metric ton of annual production capacity of primary products exclusive of land and utilities. Reducing this to the same basis that was used for the hydrogenation costs given previously in this report, the cost works out to $13,600 per barrel of daily capacity to which must be added the cost of land and utilities. It will be seen that both the capital cost and the cost per unit of hydrocarbon product are considerably higher than was the case for high pressure hydrogenation, which fact is consistent with the German policy for development of synthetic fuels which extended the hydrogenation industry during the war but did not extend the Fischer-Tropsch industry.

Improved Fischer-Tropsch Synthesis

From the foregoing section on the European Fischer-Tropsch process, it is apparent that this process has three major faults, namely, the high cost of producing water gas by conventional methods; the large and expensive heat transfer equipment that is necessary; and the nature of the products, most of which require extensive processing in order to be marketable. Beginning before the war, a group of United States oil interests energetically attacked the problem of eliminating these faults. At present their efforts are primarily directed towards a process to be applied to natural gas but, as a long term project, they are also considering coal as a source material. The United States Bureau of Mines is also working on the same problem, especially as regards production of cheap synthesis gas from coal. No full scale synthesis plant is yet in operation but pilot plants on a scale of 10 to 20 barrels per day have been built and, based on the operation of these, some cost estimates have been worked out.

As a means of correcting the first fault, the high cost of synthesis gas, it is proposed to employ fluidized gasification. In this method a bed of pulverized coal is blown with oxygen and steam to produce a synthesis gas. The pulverized fuel is violently agitated by the gaseous streams flowing through it and has many of the properties of a true fluid, hence the name. Because the coal has uniform temperature distribution and can be easily transported in the fluidized state, the process can be operated continuously in a steady state condition. The economic advantage of this method is expected to be that it can use coal rather than coke as a raw material and that it can operate in units of very large capacity. It is not known how far experimental development along this line has been carried up to the present.

The United States Bureau of Mines, in collaboration with other agencies, is experimenting on a large scale with another method of gasification that has been invented and partially developed by Dr. V. F. Parry. This method is applicable only to sub-bituminous and other low rank coals. It is a continuous process by which the coal is heated through a metal wall by gas that is generated from the residual char from the process. The coal is first carbonized and then reacted with steam in one continuous operation. Tars and other volatile products of carbonization are reacted with steam in a hot zone of the retort so that substantially complete gasification is achieved with good heat economy.

Associated oil interests also propose to use the technique of fluidizing solids for the synthesis step of the process. In the European Fischer-Tropsch process, the removal of heat from the catalyst is accomplished by large steel heat transfer surfaces so that a reaction chamber producing less than one barrel per hour of primary product weighed about 50 tons. The United States interests propose to pulverize the catalyst and pass a stream of synthesis gas through it at such a rate that the catalyst is maintained in the fluidized condition. The space velocity is increased at least tenfold by this procedure and the temperature of the catalyst is almost perfectly uniform. Even more important, the coefficient of heat transfer is increased so that much smaller heat transfer surfaces can be employed. It would appear, therefore, that the amount of steel in the reaction chambers can be greatly decreased by employing the fluidizing technique. Pilot plants are stated to have demonstrated its feasibility. Another approach to the problem of reaction chamber design is being made by the United States Bureau of Mines. They now have an experimental chamber in which the cooling of the catalyst is accomplished by addition of a volatile oil fraction which vapourizes at the desired temperature of reaction and, in vapourizing, absorbs heat. This technique is at present being used with a fixed cobalt catalyst but it is also applicable to other conditions of catalyst, including the fluidized condition described above.

The third major fault of the European process, the nature of the products, can also possibly be corrected. The gasoline produced in the German plants had an octane number of 40 to 50 because it was composed largely of straight-chain paraffin hydrocarbons. Moreover, the yield of gasoline amounted to only about 40 per cent of the total product. By using an iron catalyst and a temperature of about 550° to 600° F., a product can be made which is olefinic and the gasoline fraction of it has an octane number of about 70 which can be increased by adding polymers produced from the gaseous products. About 85 per cent of the total primary product is gasoline and the remainder can largely be converted to gasoline by cracking.

The ranks of coal that are suitable for the Improved Fischer-Tropsch Synthesis depend entirely on the method that will be selected for the primary gasification. Although there are no published data, it is believed that practically any coal can be gasified without technical difficulty by the fluidized process. The Parry process is limited to those coals that produce a char having a high reactivity. This is necessary in order to have the reaction between steam and char proceed at a low enough temperature to allow a metallic heat transfer surface to be used. In general only sub-bituminous coals and lignites can meet this qualification and it may be necessary to differentiate between the more and less reactive varieties within a given rank. Because the newer gasification processes are only in the development stages, it is not possible at present to make any reliable generalization concerning the rank of Canadian coals that would be most suitable.

The nature of the product is independent of the source material so that it is possible to use, as applying to coal, the data that have been given out on conversion of natural gas to gasoline as well as the extremely meagre information that can be obtained on the conversion of coal to gasoline by improved synthesis. Although an iron catalyst is used in conjunction with a higher temperature than in the European Fischer-Tropsch process, the products still have predominantly the straight-chain structure. The principal difference between the older and the improved process is in the degree of unsaturation and in the newer process a very large proportion of the product is olefinic. Because of the high temperature, there is also a considerable proportion of oxygenated compounds in the product consisting principally of ethyl alcohol but containing also small amounts of propyl and butyl alcohols and methyl and ethyl ketones. The boiling range of the primary product is such that about 85 per cent distils in the gasoline range. The remaining 15 per cent is a diesel oil having a cetane number of about 65 which can be used as diesel fuel or can be cracked to yield more gasoline. The primary gasoline has an octane rating by the motor method of 70. When the gaseous products are polymerized and added to the primary gasoline, its octane number is raised to 72 or 73 and, by the addition of 1.2 cubic centimetres of tetraethyl lead per Imperial gallon, the octane number can be raised to 80.

The yield of gasoline and other products that can be obtained from coal by the Improved Fischer-Tropsch Synthesis has been estimated from unpublished data made available to the Commission. For a plant to produce 10,100 barrels per day of synthetic crude oil which is equivalent to 9,900 barrels per day of gasoline, 6,120 tons of coal having a heating value of 13,000 B.t.u. per pound are required. Stated on the same basis that was used for the other processes, 0.62 tons of coal are required to produce one barrel of gasoline. However, in the Improved Fischer-Tropsch Synthesis process as estimated, there would be produced as a by-product a considerable amount of fuel gas and, if this is not sold but is used for fuel, the coal requirement is decreased to about 0.41 tons of coal per barrel of gasoline.

The estimated costs for production of gasoline from coal by the Improved Fischer-Tropsch Synthesis appear to be much lower than those of the European Fischer-Tropsch and hydrogenation processes. The following costs have been supplied for a projected plant.

Plant Capacity—

10,100 bbls. per day....Synthetic Crude (87 per cent Gasoline and 13 per cent Gas Oil)
or
9,900 bbls. per day....Gasoline by cracking Gas Oil
using
6,120 tons per day.....Bituminous Coal (13,000 B.t.u.)

Estimated Capital Cost—

$43,000,000............(including $1,000,000 for cracking plant)

	Per Calendar Day	Per Barrel Gasoline
Estimated Operating Cost—		
Labour, Supplies and Maintenance	$10,600	$1.06
Gas oil, Cracking Cost	1,010	0.10
Depreciation at 8 per cent	17,000	0.95 (est.)
Other Overhead and Administration		0.77 (est.)
Coal (6,120 tons at $2.50 per ton)	15,300	1.54
Total	$43,910	$4.42
By-Product Credits—		
Tail Gas at 9½ cents per million B.t.u	$ *4,800*	*$0.48*
Oxygenated Compounds at 8 cents per barrel Gasoline produced (mainly ethyl and propyl alcohol)	*800*	*0.08*
Total By-Product Credit	$ *5,600*	*$0.56*
Cost of Producing Gasoline—		
(Operating Cost less By-Product Credits)	$38,310	$3.87

Gasoline Cost of $3.87 per barrel = 9.2 cents per U.S. Gallon = 11.1 cents per Imperial Gallon.

It may be well to add the caution that many of the features of this plant have still to be tested, that it exists on paper only and that the costs apply to United States conditions and are in United States funds. Again recalling the fact that about 1,000 cubic feet of synthesis gas are required for production of one gallon of primary product, it will be seen that the cost figures given above imply a revolutionary improvement in the manufacture of water gas from coal. The improved water gas generator was stated to be based on the fluidizing principle but again was on paper only.

PRESENT INDUSTRY IN OTHER COUNTRIES

The synthetic liquid fuel industry based on coal has, up to the present, been too expensive to compete with natural petroleum on an open market. Where it has been employed, it has been subsidized for the purpose of security in wartime or in order to adjust an unfavourable balance of trade.

Germany

Germany is the only country in which the industry has been extensive enough to approach self-sufficiency. Both the hydrogenation and Fischer-Tropsch processes were invented in Germany and have been in course of development for about 30 years. The first high pressure hydrogenation plant was put into operation in Germany about 1927 and there has been a gradual growth of this industry ever since. The war greatly accelerated the rate at which the hydrogenation industry was expanded. The first full scale Fischer-Tropsch plants were built between 1933 and 1936 and there was considerable expansion of this industry up until 1939. It has remained static during the war with no increase in the capacity of the plants excepting that which was due to improved operating technique.

During 1944 and the early months of 1945, intensive bombing badly damaged all of these plants so that practically no production was obtainable from them. In the British zone of occupation, they have not been repaired for use as fuel producing plants, although their conversion to the manufacture of synthetic ammonia and base materials for the production of edible fats, detergents, etc., has been authorized in some cases. The status of the plants that are in the Russian zone of occupation is not known.

In addition to the full scale plants, there were in Germany numerous research and development organizations devoted to the improvement of the synthetic fuel processes. Of these perhaps the three outstanding organizations were the I. G. Farbenindustrie staff at Ludwigshaven, the Ruhrchemie at Holten and the Kaiser Wilhelm Institute for Coal Research at Mulheim. The Kaiser Wilhelm Institute is the only one that was not damaged by bombing, and since the war, it has continued uninterrupted in its study of water gas synthesis and closely related subjects. On the other hand, the laboratories of the I. G. Farbenindustrie and the Ruhrchemie, which were the sources of information on industrial scale development of hydrogenation and Fischer-Tropsch synthesis, were destroyed and their staffs dispersed so that for some time no valuable information on these processes can be expected from them.

Great Britain

In Britain a synthetic oil industry was not absolutely essential to national security and only one coal hydrogenation plant has been established. This has a capacity of about 3,500 barrels per day of gasoline when coal is used as the raw material. The plant was built by Imperial Chemical Industries and is on the site adjoining their chemical works at Billingham. The plant was protected by a preferential tariff. It operated until 1939 on both coal and tar oils. As planned, about two-thirds of the gasoline production was from coal and the other third from tar oils. At the beginning of the war, it was converted entirely to the use of tar oils because when these were used as raw materials the capacity of the plant was considerably increased. The product during the war was entirely aviation gasoline.

In addition to this plant, a second hydrogenation plant was built in 1940 at Heysham near Lancaster which also produced aviation gasoline but which used imported petroleum as the raw material. The hydrogenation process was employed because it gives the maximum possible quantity of aviation gasoline from a given quantity of crude oil.

There are no industrial scale Fischer-Tropsch plants in Britain, although small and intermediate scale experiments have been conducted. Perhaps the greatest part of the British research and development work was carried out by Imperial Chemical Industries who had access also to the German and United States data through their association in the International Hydrogenation Patents cartel. Aside from this research, the British Fuel Research Board has conducted small and intermediate scale experimental work on both hydrogenation and Fischer-Tropsch processes beginning in about 1921 and continuing up to the present.

The consensus of opinion in Britain at present is that the industry should not be expanded for the purpose of producing gasoline. This is largely for the reason that coal in Britain is too expensive. There is, however, at the British Fuel Research Board, considerable interest in both processes as a means for producing base chemicals.

France

In France, the synthetic fuel industry was not developed to any great extent. During the 1930's, research and development were carried out, principally by Valette, on a modified hydrogenation process. A large pilot plant was operated according to this process at Bethune in the Pas de Calais area by the Societe des Carburante Synthetiques des Mines de Bethune. The results of this test do not seem to have been encouraging for no larger plant following this process was built.

A Fischer-Tropsch plant was erected at Harnes in 1937 by Etablissement Kuhlmann. This plant was designed to have a capacity of about 600 barrels of primary products per day but achieved a production of somewhat less than 400 barrels per day. It was a conventional atmospheric pressure plant licensed from the Ruhrchemie and operated as described in the section under the Fischer-Tropsch process.

Aside from these two, which cannot be considered as more than large scale experimental or demonstration plants, there has been no development in France. Moreover, there has been less fundamental research on synthetic fuels than in other large, highly industrialized nations. Insofar as is known, there is no important development in progress in France at the present time.

Japan

Japan, like other nations with insufficient oil supplies, made efforts to establish a synthetic fuel industry and there are numerous references in the technical literature to experimental and development work that has been conducted in that country. Moreover, both the I. G. Farbenindustrie and the Ruhrchemie sent technical advisers to Japan to assist in putting synthetic oil plants into operation during the war. It is expected that very soon reports will be available on the industry in Japan but, up to the present, all that is known is that there were several plants using both hydrogenation and Fischer-Tropsch processes in that country. From information obtained in Germany, however, it is believed that these plants were small, were not entirely successful and were based on German design with little or no original Japanese modification.

United States

In the United States, there are no industrial scale synthetic oil plants based on coal. The Standard Oil Development Company, however, made an agreement with I. G. Farbenindustrie in 1927 regarding applications of hydrogenation to various phases of petroleum refining and in 1930 erected two plants at Bayway, New Jersey, and Baton Rouge, Louisiana, respectively, for refining of lubricants and other processes involving hydrogenation. During the war, the Baton Rouge plant is believed to have been used for the production of aviation gasoline from petroleum stocks.

Beginning in 1935, the United States Bureau of Mines undertook research on hydrogenation of coals and has increased the scope of this work continuously since that time. More recently a parallel investigation of the Fischer-Tropsch type of synthesis has also been conducted. In 1943, the United States Bureau of Mines considered that the pace of these investigations should be greatly accelerated because it was realized that, within foreseeable time, the United States might be dependent upon imported petroleum. For this reason a Bill, No. 1243, was passed by Congress authorizing the Bureau of Mines to spend $30,000,000 on an investigation of means for producing petroleum substitutes from coal, oil-shale, and other materials.

In addition to the interest of Government organizations, the oil industry is also active in development work on substitute liquid fuels. At present the greatest activity is in the field of production of gasoline from natural gas by hydrocarbon synthesis, but, as a longer term project, the oil industry is also studying means of utilizing coal as a primary raw material. Part of this work has been summarized briefly in the previous section under Improved Fischer-Tropsch Synthesis.

Italy

In Italy, there were no synthetic oil plants based on coal, but two full scale oil hydrogenation plants were built, one at Bari on the Adriatic, and the other at Leghorn. These plants were both built to designs supplied to the Italian company by the I. G. Farbenindustrie.

COMPETITIVE RAW MATERIALS

Natural Petroleum

Indigenous

Of the raw materials that are competitive with coal as sources of liquid fuels, petroleum is, of course, the most important. Statistics on Canadian requirements and production of petroleum are in the chapter Sources of Energy. Summarizing them very briefly, in 1944 the requirement of petroleum for all of Canada was roughly 180,000 barrels per day, and Canadian production was 27,420 barrels per day. Canadian production is practically all from the Prairies and Northwest Territories.

During the war years, there was unusually intensive exploration in Alberta, but this did not result in the discovery of any major field. Exploration is expected to continue but, of course, there is no reliable method of predicting what its result will be. Indigenous petroleum, therefore, is not now the major competitor with coal as a source material for liquid fuels. If, for any reason, it should be necessary or desirable to place Canada in an independent position as regards liquid fuels, the industry, failing new discoveries, would have to be based on some raw material other than petroleum.

Foreign

In 1944, more than 150,000 barrels per day of crude petroleum were imported into Canada. In the chapter Sources of Energy, there is a brief review of the fields from which this petroleum came, and of the proven reserves in various parts of the world. It appears that within the near future, the United States will become on balance an importer of petroleum, and Canada will probably have to turn more and more to other countries for her requirements. If there is free access to the fields in South America and the Middle East, no major readjustment in the Canadian petroleum industry would appear to be necessary. However, the possibility that the North American continent may soon be less than self-sufficient with respect to petroleum raises consideration of future security, which might in time justify the establishment of a synthetic petroleum industry on a subsidized basis.

One possible development in the petroleum industry is the application of the hydrogenation process to increase the yield of gasoline from crude petroleum. It is argued in some quarters that it may be more practical to convert petroleum almost entirely to gasoline and light fuel oils and to substitute coal directly for heavy fuel oil than to convert coal to gasoline. This possibility was emphasized in the hearings on Bill 1243 before the United States Senate Committee. The effect of a policy based on this consideration would be to delay somewhat the development of a synthetic liquid fuel industry based on coal.

Natural Gas

The second raw material to be considered in competition with coal for the production of liquid fuels is natural gas. As mentioned earlier, the United States oil industry is now developing a method based on hydrocarbon synthesis for conversion of natural gas to gasoline. The United States oil industries claim to have developed a new process for hydrocarbon synthesis to the point where a full scale plant can be built. The main features of the process appear feasible, and the cost estimates are lower than for any other synthetic method, but the process cannot be accepted without reserve until it has been established on a full scale, or until complete details have been made available for criticism. If, as seems possible, the process should be technically and commercially successful, it will be necessary to find and allocate to this use a sufficient quantity of natural gas.

The reserves and production of natural gas in Canada are discussed in the chapter Sources of Energy. Only in Alberta are the reserves of natural gas sufficient to warrant consideration of a synthetic liquid fuel industry based on them. It appears that there is at present a good deal of interest in the feasibility of such an industry in that Province. It is important to recognize, however, that irrespective of its local importance, such an industry could not contribute a very large proportion of Canada's liquid fuel requirements unless the volume of natural gas made available to the industry becomes very much greater than is thought at present to be available. If the total production of natural gas in Alberta, including gas which was wasted, were diverted to a synthetic fuel industry, it could supply a plant having a capacity of some 11,000 barrels per day, that is, it could supply only about 7 per cent of Canada's liquid fuel requirements. It is probable that at the present time proven reserves in

Alberta would justify a plant not much larger than 5,000 barrels per day. Whether a synthetic liquid fuel industry based on natural gas will develop in Alberta is, of course, highly uncertain.

Bitumen

The bituminous sands of the McMurray area in Alberta are a third raw material to be taken into consideration as a possible competitor with coal in the production of liquid fuels. These are beds of sand, the grains of which are coated with an extremely heavy asphaltic oil. Unlike most oil-bearing sands, the McMurray occurrences are partly at, or near, the surface. The sand can be mined by open-cut methods and the bitumen removed from it by washing with hot water or by other means. The separated bitumen can be converted to an equal volume of gasoline by hydrogenation, and to fuel oils, asphalts, etc., by other processing methods.

The bituminous sands have attracted wide-spread interest, chiefly because of their large quantity. The amount of bitumen in the whole occurrence has been estimated at 100 to 200 billion barrels, a figure the magnitude of which can best be grasped by comparison with the world's known petroleum reserve which is 50 billion barrels. Although the magnitude of the quantity is impressive, it is, however, entirely without commercial significance unless the bitumen can be produced and refined to marketable products at competitive costs. Commercial ventures in mining and separation have not, up to the present, been successful financially, or completely successful even technically. Nevertheless, improved methods of mining and recovery, and also of refining and transportation, may bring costs of gasoline and other products from bitumen down to the point where they can compete with those from petroleum imported into the Prairie area from long distances or with synthetic products made from coal. There is not enough reliable information on methods of recovery of bitumen from the sand or on refining methods to make a satisfactory assessment of its future possibilities and further development work in both these fields is needed.

POSSIBLE FUTURE OF SYNTHETIC LIQUID FUELS FROM COAL

Improvement of Methods

None of the process modifications that have been established on a commercial scale has been able to produce gasoline from coal at a cost that is competitive with that of petroleum-produced gasoline. The question arises, therefore, of the possibility that technological improvements in the existing processes or invention and development of radically new methods will make it possible to produce gasoline from coal in competition with petroleum at its present price.

To answer this question, let us first examine the energy conversion of the more efficient of the established processes. When 0.6 tons of bituminous coal is converted to one barrel of gasoline, the energy conversion is somewhat less than one-third; that is to say, two-thirds of the energy of the raw materials are lost in the process of making gasoline from coal. In this respect, therefore, there is theoretically much room for improvement.

Secondly, considering the influence of the cost of the raw material upon the cost of the final product, the table below gives the part of the cost of gasoline that is chargeable to coal as a function of cost and rank of the coal. In preparing the table, it is assumed that, to produce one barrel of gasoline, the total requirement including fuel, etc., was 0.6 tons of bituminous, or 1.0 ton of sub-bituminous coal or 1.4 tons of lignite (30 per cent moisture) or 1.8 tons of brown coal (50 per cent moisture). These assumptions are, of course, somewhat arbitrary and correspond roughly to hydrogenation practice in Europe. They set bituminous coal at $5.00 per short ton as equivalent to sub-bituminous coal at $3.00, lignite at $2.12 and brown coal at $1.67.

Cost of Coal $. per Short Ton	Costs Chargeable to Coal in Cents per Imperial Gallon of Gasoline			
	Bituminous	Sub-bituminous	Lignite (30 Per Cent Moisture)	Brown Coal (50 Per Cent Moisture)
1	1.7	2.9	4.0	5.1
2	3.4	5.7	8.0	10.3
3	5.1	8.6	12.0	15.4
4	6.9	11.4	16.0	
5	8.6	14.3		
6	10.3			

It will be seen from these considerations of energy efficiency and cost of coal that it would be incorrect to dismiss the possibility that some improved process may be able to make gasoline from coal as cheaply as it is now made from petroleum, on the grounds of raw material cost alone.

Technical difficulties, however, are another matter and it is well to bear in mind that the synthetic fuel industry has been undergoing constant development for more than thirty years by some of the best technical organizations in the world, whose expenditures for development in Germany and elsewhere, are in the order of hundreds of millions of dollars. It is, therefore, difficult to make any satisfactory estimate of the probability that future processes will be improved enough to make coal competitive with petroleum at its present price as a source material for liquid fuels.

Significance of a Deficiency of Petroleum

If it is assumed that coal will never be able to produce gasoline and other liquid fuels as cheaply as they are now made from petroleum, the next question to be considered is how long the cost of petroleum products will remain at the present level. Although there are many factors that have to be taken into consideration in answering this question, the central one is undoubtedly the question of the world's resources of petroleum. It has been shown that the total proven reserve for the whole world as of 1945 was about 50 billion barrels and that in 1945 daily consumption was 7,580,000 barrels. If the world reserve were an accessible reservoir that could be tapped at any desired rate, if no more discoveries were made, and if production remained constant at the level of 1945, the present reserve would be completely exhausted in about 18 years. However, oil fields cannot be tapped beyond a certain optimum rate so that if no more oil were discovered a shortage would be imminent. On the other hand, there is a high probability that extensive new fields will be discovered, especially in the Middle East. In the face of this situation, any course of action that is taken must be based upon uncertainty rather than on the assumption either of continuing sufficiency or imminent deficiency.

In considering the cost of petroleum, the cost of transportation to the consumer must be added to the price at the well. If, for any reason, the supply of petroleum were even slightly inadequate, the general price level would rise to the point where substitutes could compete to make up for the deficiency. Where substitute raw materials are available, the competition would be with the total cost of petroleum including transportation charges. For this reason, the first truly economic use of substitute fuels will be in an area deficient in petroleum and into which the transportation cost is high. Such an area exists in the Prairie Provinces, especially in Alberta, although in Alberta the situation is complicated by the presence of natural gas and bitumen in addition to coal as substitute raw materials. However, establishment of a synthetic fuel industry in an area where it would be protected by a high transportation cost involves the economic risk that a new oil field might be discovered in the area after the synthetic industry had been established in it. This risk is especially great in the Canadian midwest where much of the territory is potentially oil-bearing.

In wartime, or time of similar crisis, a different set of conditions arises; transportation may be not only costly but completely obstructed and at the same time the value of petroleum products is enhanced. There are, however, three major shortages which always attend wartime economy which would render it difficult, if not impossible, to establish a major synthetic fuel industry or a major addition to one already existing after hostilities had begun. The first shortage to be considered is steel. The presently existing synthetic oil processes require approximately 10 tons of steel per barrel per day of gasoline-producing capacity. To replace 10 per cent of Canada's requirement—180,000 tons of steel would, therefore, be required. As a further example, considering the position of the United States, Dr. H. H. Storch, of the United States Bureau of Mines, has estimated that "...to fabricate all of the plants necessary to produce the equivalent of our present petroleum consumption of 1.4 billion barrels per year, would require about 10 years of work by all of the fabricating companies now in existence in the United States...it is, of course, impractical to use the entire fabricating capacity of the United States for synthetic fuel plant construction, and it is, therefore, apparent that 30 to 40 years may be required for the completion of all the necessary plants...". Secondly, in wartime, there is always a labour shortage and it is extremely doubtful that a sufficient force of skilled labour could be provided to construct and erect a synthetic fuel industry of any significant size within a reasonable time. Thirdly, in wartime, the need for a synthetic industry would be urgent and even granted ample supplies of steel and of labour, a single synthetic oil plant of commercial scale cannot be planned, designed and erected in less than 2 or 3 years. For these reasons, therefore, if synthetic oil is to be available during a war, the condition of deficiency must be foreseen long in advance and the industry must be established gradually and slowly over a long period of years in peacetime.

Combination with Coke and Gas Industries

In attempting to forecast the future course of the synthetic liquid fuel industry, it has been suggested that there are possible combinations of synthetic processes with the already established gas and carbonization industries that might improve the economic outlook for both. One such suggestion is that a gas plant employing total gasification of coal be operated in the winter to supply gas for domestic heating and in the summer to supply water gas to a hydrocarbon synthesis plant. This combined operation does not appear to be economically sound because of the high capital cost of the synthesis plant. If a winter peak load must be met by a gas plant, it would be cheaper to have excess gas manufacturing capacity which would be idle in summer than to erect a more expensive synthesis plant which would be idle in winter.

Another suggestion is that hydrogenation and coking be combined in such a way that the coke oven gas is used for manufacture of hydrogen, the coal tar in addition to raw coal is converted to gasoline and the heavy pitch, which is one of the products from the first stage of hydrogenation, is carbonized with coal. This combination appears to offer numerous advantages over simple hydrogenation, but is subject to the fundamental fault that two major products are made, namely, coke and gasoline, and the size of the plant would be limited by the market for coke. Even overlooking this disadvantage, it does not seem probable that a flow sheet could be worked out which would enable this process to compete with natural petroleum under present conditions. This type of combination, however, merits study.

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General Conclusions

This concludes a technical and economic review of problems relating to the production of synthetic petroleum from coal by the three processes that are now recognized, viz., high pressure hydrogenation, the European Fischer-Tropsch process and the Improved Fischer-Tropsch Synthesis. It is obviously a subject that should continue to receive consideration by the public generally, and at least selective research (having regard to the magnitude of the cost of comprehensive research) must be a matter for consideration.

The principal economic factors governing the commercial development of a synthetic liquid fuel industry are the cost of the raw material, the size of the market, and the price of gasoline. It is desirable to emphasize at this point that low cost coal is of primary importance in the development of a synthetic fuel industry based on coal and that any developments in this field will not relieve the mine operators from the need to improve the efficiency and cut the cost of coal production. The low productivity and high costs of Maritime coals are serious impediments to the development of a synthetic liquid fuel industry based on coal in that area. The prospects of synthetic fuel production, not necessarily based on coal, are somewhat more favourable in the Prairie Provinces than in the Maritimes. The price of gasoline is relatively high, the cost of raw materials is moderate and the market, while restricted, might be sufficient for a small industry. Any such development presupposes that there will be no discovery of new large oil fields in this area, which is by no means certain. Moreover, if a synthetic fuel industry does develop it may be based on raw materials other than coal. If the natural gas reserves of Alberta and Saskatchewan prove adequate, these may be used rather than coal. Failing this, the industry may be based on the bituminous sands of Alberta. Consideration of alternative raw materials emphasizes the necessity of increased efficiency in coal production if a synthetic fuel industry based on coal is to develop. In any event, further technical research is required before any synthetic fuel industry can be developed on a commercial scale in Canada.

CHEMICAL INDUSTRIES BASED ON PRODUCTS FROM COAL

As stated in the introduction to the chapter, this section deals with those industries which are based on products from coal. These industries are distinguished by two salient facts—*(a)* their main products are not used as fuels, *(b)* they use coal products as a raw material from which they produce or process chemicals containing carbon. For convenience of discussion, the industries concerned may be subdivided into main groups and sub-groups as follows:

(1) Industries based on the use of coke as a raw material.
- *(a)* Electro-thermal industries,
- *(b)* The synthetic chemical industries.

(2) Industries based on by-products arising from the coking of coal.
- *(a)* The chemical aspects of the gas and coke industry,
- *(b)* The coal tar distillation industry,
- *(c)* The synthetic coal tar chemical industries.

The value of the coal products as a raw material for all these industries lies in the fact that these coal products are a convenient source of carbon or of chemicals containing carbon. As a building product for the chemical industries, coal products may be utilized in the following ways:

(1) As Coke—Coke is one of the main raw materials in the electro-thermal industries, where it may play the role of a reducing agent or may actually enter into the final product. It is also a source of carbon monoxide.

(2) As Carbon Monoxide—Carbon monoxide is an important raw material in the synthetic chemical industry. It is an indirect source of hydrogen and ammonia. It is a direct source of synthetic methyl alcohol and other similar chemicals.

(3) As By-products in the Manufacture of Coke—Coal tars are the source of creosote and pitch, as well as some organic products, such as naphthalene and carbolic acid. The light oils provide substantial amounts of benzene, toluene and xylene, from which many organic chemicals are synthesized. Ammonium sulphate, for use as a fertilizer, is also obtained from this source.

The non-fuel use of coke from coal in the chemical industries in Canada accounts for less than 1 per cent of the total coal consumption. Less than one half of the coke so used is made from Canadian coal. It is therefore apparent that the non-fuel coal requirements of the chemical industries are almost negligible.

In the manufacture of organic chemicals there are two main sources of raw material other than coal or its derivatives. All three sources are competitive, for most compounds can be made from any one of the sources of carbon. The sources alternative to coal are petroleum products, including natural gas, and vegetable matter. In Canada the synthetic rubber industry is based on petroleum products, and one large synthetic ammonia plant is based on the use of natural gas. There is also a large fermentation industry which produces organic solvents, including ethyl alcohol, butyl alcohol, and acetone. Many synthetic chemicals are derived from these products. Likewise there exists a wood distillation industry which produces organic chemicals.

Acetone provides a good example of a chemical which may be produced from several alternative raw materials. It can be manufactured

(a) from refinery gases
(b) from calcium carbide produced from coke
(c) by fermentation of corn
(d) from ethyl alcohol produced from molasses
(e) by wood distillation.

All the industries are naturally dependent on the existence of markets for their products. In most cases these markets are world-wide markets and the products must meet world-wide competition. Canada is not a large user of chemicals and there is, therefore, an insufficient domestic market for the products. Another factor affecting the marketing of the products of these industries is the fact that in the production of a desired product there are frequently inevitable by-products which must also be marketed to allow the industry to survive. In the synthetic chemical industries, both those based on coke and coking by-products, the carbon which enters into the finished product is but one of many raw materials which are required. Adequate supplies of these other raw materials must be available to permit the establishment of these industries. Typical other raw materials required are chlorine, limestone, ammonia, soda ash, caustic soda, et cetera. Cheap power may also be considered as a raw material and is essential to the operation of most of these industries. The size of the industries based on by-products of coking depends upon the size of the coke and gas industry. The very large coke and gas industry in the United States, based largely on the demand for metallurgical coke, permits a much larger by-product chemical industry than is possible in Canada. These economic factors are of fundamental importance. The mere availability of coal, coal products, and coal by-products is by no means sufficient in itself to warrant the establishment of any of these industries.

INDUSTRIES BASED ON COKE AS A RAW MATERIAL

Electro-thermal Industries

The electro-thermal industries process coke in electric furnaces to produce such carbon compounds as calcium carbide, silicon carbide, graphite, etc. These industries also use coal products in the form of electrodes required for electric furnace operation.

The industries which produce calcium carbide and calcium cyanamide and their derivatives are among the largest units of the chemical industry in Canada. Calcium cyanamide is not itself produced in an electric furnace, but because it is made from calcium carbide it will be discussed here.

Calcium carbide is formed by the reaction of lime and carbon in an electric furnace. The commercial manufacture of calcium carbide requires a large supply of low cost electrical power and, therefore, its production is usually carried on adjacent to hydro-electric power sites. Carbide was first produced in Canada in 1904, and its manufacture has been a steadily expanding industry. Manufacture in Canada is largely centred at Shawinigan Falls, P.Q., but there is also a small production at Welland, Ontario. Calcium carbide reacts with water to form acetylene, which was originally used for illuminating purposes and for oxy-acetylene welding. It continues to be used for these purposes, but large quantities of acetylene are now converted to other chemicals. During World War I acetylene was used to produce acetone, which was required as a solvent in explosives manufacture. From this original operation an increasingly wide range of chemical products has been produced. Among the important chemicals produced from acetylene prior to 1939 were acetone, acetic acid, acetic anhydride, ethyl acetate, acetylene black, trichlorethylene, and an important series of resins used in the production of plastics. As a result of the war, facilities for the production of these products were expanded and manufacture of butanol, polyvinyl chloride and hexachlorethane and other products was undertaken in Canada.

Based upon low cost hydro-electric power and the resulting low cost carbide, a large export market was developed prior to the war for both carbide and the chemicals derived from acetylene. As a result of the war, this export market was greatly expanded. It seems probable that a substantially larger post-war domestic and export market might develop. On the other hand, synthetic chemicals based on the by-products of the petroleum industry are providing increasing competition, and while this competition is not yet an important factor in the domestic market, it has affected the export market and may eventually make itself felt in the domestic field.

The operations at Shawinigan Falls have in the past provided a market for from 50,000 to 100,000 tons annually of Nova Scotia coal. Shawinigan Chemicals Limited, at Shawinigan Falls, has developed a low cost method of making coke from bituminous coal for use in their carbide furnaces. Their plants use either coal coke, petroleum coke, or bituminous coal, depending on current price and availability. The Electro-Metallurgical Company of Canada at Welland, Ontario, depends on United States supplies.

Calcium cyanamide, commonly known as cyanamide, is manufactured from calcium carbide by passing nitrogen from the air through ground carbide under carefully controlled conditions. Until the development of the synthetic ammonia processes, cyanamide was the chief source of fertilizer containing nitrogen obtained from the air. The plant of the North American Cyanamid Company, at Niagara Falls, Ontario, was first established in 1909 and since that date has been the sole producer of cyanamide in North America and in the British Empire. In 1944 this plant used about 100,000 tons of coke as raw material, nearly one-quarter of which was petroleum coke. In addition to its use as a fertilizer, cyanamide has been for some years one of the main sources of cyanide used in the extraction of gold from its ores. More recently, a number of important chemicals has been developed from cyanamide as a raw material, among these being melamine, an important synthetic resin. As part of the war programme, manufacture of dicyandiamide, guanidine nitrate, and nitroguanidine were undertaken at Niagara Falls, Ontario, using cyanamide as a raw material. While manufacture of the latter, an important military explosive, has ceased, the production of the other two is being maintained, mainly for export to the United States for the production of melamine. Expansion of the use of cyanamide as a chemical raw material will be largely dependent upon export markets for the resulting chemical products. The continued use of cyanamide as a fertilizer will be largely dependent upon its ability to compete with other synthetic fertilizers.

Silicon carbide, known as carborundum, is produced by heating coke and sand in an electric furnace. Carborundum is practically as hard as diamond and is, therefore, extensively used as an abrasive. Other abrasives, such as aluminum oxide (alundum), do not contain carbon, although carbon is used in their manufacture—principally in the form of electrodes. There are in Canada three plants using carbon in the manufacture of abrasives—two in the Niagara district and one at Shawinigan Falls. The industry consumes about 25,000 tons of coke per year (not all of it from coal) and is dependent on low cost hydro-electric power.

Artificial graphite is made in an electro-thermal furnace by heating coke to a very high temperature. The ash is volatilized and the remaining product is pure carbon in the form of graphite. The best known use for graphite is as a dry lubricant.

Synthetic Chemical Industries

These industries are based on synthesis gases produced by the controlled combustion of coke or natural gas. The synthesis gases are mainly mixtures of carbon monoxide and nitrogen, or of carbon monoxide, nitrogen and hydrogen, depending upon the method of production. From synthesis gases a wide range of chemicals can be made, among those commercially feasible being ammonia and synthetic methanol (wood alcohol).

These synthetic chemical industries owe their existence to the work done by the Germans prior to World War I. In 1913 the Badische Anilin and Soda Fabrik installed the first commercially successful plant for the manufacture of synthetic ammonia. The ammonia was used to produce nitric acid which is essential to the manufacture of high explosives. Thus the development of synthetic ammonia in Germany is credited with enabling that country to wage World War I.

Ammonia is produced by the reaction of three parts of hydrogen and one part of nitrogen passed at high pressure over a suitable catalyst. The hydrogen required may be produced by the electrolysis of water or by the decomposition of steam using coke or natural gas. Nitrogen may be obtained either from producer gas or by the liquefaction of air. When the production of ammonia is based on coke, about 1.3 tons of coke are used per ton of ammonia produced. The current trend in the synthetic ammonia industry is towards the use of natural gas rather than coke.

Prior to World War II the synthetic ammonia capacity of Canadian plants was about 35,000 tons per year, all of it based on electric power. In 1945 the rated capacity was about 180,000 tons of which 30 per cent was based on coke (equivalent to a maximum of 80,000 tons of coke per year), 40 per cent was based on natural gas and the remaining 30 per cent was based on electrical energy. The largest ammonia plants in Canada are situated at Trail, Calgary and Welland. The Trail plant uses coke and electrical energy, the Calgary plant uses natural gas and the Welland plant uses coke.

The main peacetime use of ammonia is to make ammonium nitrate for use as a fertilizer. Plant capacity in Canada was expanded substantially during World War II to provide ammonia for explosives but at present the plants must rely principally upon an export market for fertilizer.

Methanol is synthesized by the reaction of carbon monoxide and hydrogen in a process similar to that used for production of ammonia. There is no plant in Canada producing synthetic methanol. Very high capital costs and large volume production are essential to the establishment of these synthetic industries. The urgency of wartime demands justified the great expansion of the synthetic ammonia industry and provided essential markets. Such has not been the case with regard to methanol production. Its synthetic production in Canada must await more favourable conditions.

INDUSTRIES BASED ON BY-PRODUCTS ARISING FROM THE COKING OF COAL

Three different types of industries are concerned in the recovery and refining of the by-products arising from the coking of coal. They are:

(1) The gas and coke industries.

(2) The coal tar distillation industry.

(3) The synthetic coal tar chemical industries.

In 1845 Hofman proved the existence of benzene in the light oil derived from coal tar. It was this discovery which first established coal tar as a chemical raw material and laid the foundation for the so-called coal tar chemical industry that was to follow. It was not until after 1876 that benzene was discovered in coal gas and the recovery of light oil as a source of benzene was commenced. Although light oil subsequently replaced coal tar as the principal source of benzene, coal tar continued to receive the credit for being the source, not only of benzene, but of other light oil constituents such as toluene and xylene and all organic compounds derived from these components of light oil. Today, about 60 per cent of all so-called coal tar synthetic organic chemicals are derived from benzene, toluene, and xylene, and, although these parent substances come almost entirely from light oil and not from coal tar, they are regularly classified as coal tar chemicals.

Chemical Aspects of the Gas and Coke Industry

The main by-products of the coke and gas industry are ammonia, light oils, and coal tar, which are now recovered from some 80 to 85 per cent of the coal coked in Canada. The gases from the coking operation are first cooled by spraying water into the gas-collecting mains. This cooling causes the separation of some tar from the gas and also dissolves part of the ammonia in the spray water. Further cooling is carried out in equipment known as primary coolers where the gases are passed over water-cooled tubes or subjected to further water sprays. Final traces of tar in the gases leaving the primary coolers are removed by mechanical or electrical means. Any ammonia remaining in the gas may be removed by further water-washing or by reaction with sulphuric acid to produce ammonium sulphate. Nearly all the ammonia produced by the coking industries is recovered as ammonium sulphate. The tar and water which has been accumulated in the collecting mains and coolers is run to storage tanks where the tar and aqueous layers are separated. The aqueous layer is treated for recovery of ammonia and the tar is sold to tar distillers or is burned as a fuel.

After removal of ammonia and tar, the gases are passed through towers countercurrent to a stream of "wash oil". The wash oil is usually a heavy petroleum oil. This operation removes the light oils from the gas. These light oils are a mixture of benzene, toluene, and xylene, which are all soluble in the wash oil. It may be desirable to purify the gases further by the removal of other impurities such as sulphur, and this is sometimes done, though none of these further by-products is recovered in Canada. With or without this final purification, the gas is used as an industrial and domestic fuel.

The light oils, benzene, toluene, and xylene, may be removed from the wash oil by distillation. The wash oil is then ready for further use. By re-distillation the constituents of light oil may be separated one from another to whatever degree of purity is justified by market conditions.

The by-products of the Canadian coke and gas industry for 1939 and 1943 were as follows:

—	Coal Tar	Light Oils	Ammonia
1939	27 million gallons	7 million gallons	8 thousand tons
1943	36 million gallons	8 million gallons	9 thousand tons

These by-products represent about 8 to 10 per cent of the weight of the coal coked. The ammonia was almost entirely converted to ammonium sulphate and sold as fertilizer. The light oils were refined and sold as benzol, toluol, xylol, and solvent naphthas. The main outlet for these refined light oils is the synthetic chemical industry. Thus, the coke and gas industry produces ammonium sulphate as a finished product and coal tar and refined light oils as raw materials for other industries.

THE COAL TAR DISTILLATION INDUSTRY

Coal tar is a black, fairly viscous, liquid. Its chemical composition depends on the manufacturing methods which produced it. The size and type of coal coked, the type of oven or retort in which the coal is carbonized, the temperature prevailing during the coking operation, have far reaching effects on the nature of the tar produced. The composition and geographical location of various tars will naturally determine the products to be obtained and the processing methods to be used.

The first step in coal tar refining is the distillation of the crude coal tar to produce refined tars or pitch, and distillate products. The percentage of the volatile constituents distilled off is determined by the type of crude tar used and the type of tar or pitch residue desired. Preliminary refining equipment is generally a simple batch still—that is, a closed vessel which is partially filled with tar and then heated to distil off low-boiling products until the tar or pitch residue has reached the required consistency or melting point. The tar or pitch residue is then drawn off from the still and cooled. The distillates are condensed to oily liquids. The oils distilled off at different temperatures may be collected in separate tanks where they are available for further processing. In this further processing the economically recoverable chemicals are removed. The remaining distillates are blended to specifications and sold as creosote oil.

The main chemicals which are recoverable from coal tar in commercial quantities (pre-supposing the removal of ammonia and the light oils) are naphthalene, phenanthrene, anthracene, tar acids, and tar bases. Of these, only naphthalene and tar acids are recovered in Canada. All these chemicals constitute not more than 15 to 20 per cent of the tar. The tar, in turn, represents not more than about 5 per cent by weight of the coal coked, so that the production of coal tar chemicals from coal would be at best in the order of 0.75 per cent to 1 per cent of the coal coked. The inclusion of ammonia and the light oils would raise the percentage of recovery of chemicals from coal to about 2 per cent.

The production of chemicals is not an essential part of the coal tar distillation industry. As a matter of fact, in Canada and the United States at least 95 per cent of the products produced from coal tar are sold as crude distillates or residues.

The Canadian production of coal tar is insufficient to supply the needs of the industry. In 1939 it was necessary to import over 3,000,000 gallons of tar and in 1943 over 6,000,000 gallons from the United States.

In 1943 over 9,000,000 gallons of creosote were supplied to creosoting plants for the preservation of railway ties, telegraph and telephone poles and structural timber. Over 85,000 tons of pitches were produced. A very large proportion of these pitches was used in the manufacture of electrodes for the production of aluminum. Additional amounts were used for roofing. Some 16,000 tons of pitch coke were supplied for the manufacture of abrasives and 180,000 gallons of tar acids and over 6,000 tons of naphthalene were recovered.

Tar acids are a complex mixture of acidic chemicals, of which the best known is carbolic acid. The tar acids are used either directly for manufacturing disinfectants or as raw materials for products made by the synthetic coal tar chemical industries. Phenol is also used for the purification of lubricating oil. Naphthalene was once important as a moth repellant. Its main use now is as a raw material for the manufacture of other chemicals.

Coal tar distillation plants are operated in Canada by the following three companies: Dominion Tar and Chemical Company Limited at Sydney, Montreal, Toronto, Sault Ste. Marie and St. Boniface, the Barrett Company at Montreal and Toronto, and Currie Products Limited at Ottawa and Hamilton. Barrett Company and Currie Products Limited produce mainly road tars, roofing pitch, paving tars, and saturants for building products. No chemicals are recovered from the small amount of distillates. Dominion Tar and Chemical Company refines most of the tar processed in Canada. Creosote, pitches, road tars, and pitch coke are the main items produced. This Company is the only one equipped for the extraction of coal tar chemicals.

Synthetic Coal Tar Chemical Industries

These are the industries which use benzene, toluene, xylene, tar acids, naphthalene, and other chemicals directly recoverable from light oils or coal tar as raw materials for the production of new chemicals. It is to be noted that these raw materials obtained from coal are by-products of the gas and coke industries and that it is not economically feasible to coke coal for the specific purpose of producing these chemical raw materials. It has already been pointed out that the complete recovery of the chemical by-products of coal would amount to not more than 2 per cent of the weight of coal coked. Furthermore, a large number of other raw materials provided by other chemical industries must be available before the synthetic chemical industries can produce the dyes, pharmaceuticals, disinfectants, resins, insecticides, plastics, et cetera, which we commonly hear spoken of as being obtainable from coal. In many cases a number of intermediate products must be manufactured before obtaining the desired final product.

A typical example of the complexity of these operations and their relationship to the coal by-product chemicals is the manufacture of synthetic rubber as made by the Polymer Corporation at Sarnia. Benzene and ethylene are reacted to form ethyl benzene, which is in turn converted to styrene. Butane, a petroleum product, is converted to butylene and thence to butadiene. The styrene and butadiene are reacted together to produce synthetic rubber as Buna S. Thus, the benzene is but a fraction of the raw material required and is many operations removed from the final product.

The manufacture of nylon provides another example of the complexity of producing a final product from a raw material which is originally obtained from coal. Nylon can be produced from phenol, which is obtainable from coal tar, but there are a number of intermediate steps, involving complex and expensive operations. To make nylon, phenol is first converted to cyclohexanol which is converted to adipic anhydride, from which adipic acid is produced. Adipic acid is one of the direct raw materials for making nylon. The other one is hexamethylenediamine, which is made by treating adipic acid with ammonia to form a dinitrile, which is then converted to hexamethylenediamine. The two raw materials are then reacted together to give nylon, which must then be processed into the form of a fibre before it is available to the textile trade. Thus, no less than five intermediate products must be manufactured and processed to acquire even the raw materials for making nylons. The complexity and scale of the direct and subsidiary operations required to produce nylon are such that it is not commercially feasible in Canada. The only part of these operations carried on in Canada is the production of nylon textiles from imported crude nylon.

The existence of these synthetic industries has practically no effect on the amount of coal coked. They merely provide a market for by-products which are inevitably produced when coal is coked for the purpose of obtaining coke or gas.

GENERAL CONSIDERATIONS

We have stressed that the nature of the chemical industry in any area depends upon the available sources of carbon and of other necessary raw materials and upon adequate markets. Variations in these factors explain the differences in the chemical industries in different countries.

Britain's chemical industry is, for the most part, based on coal and the traditional fermentation and distillation processes. The high cost of coal has encouraged the search for alternative sources of carbon, and because of the lack of large amounts of surplus agricultural products there has been a trend towards increasing reliance on imported petroleum products as raw materials.

Germany's whole chemical economy was based on coal. The huge steel and coke industry assured the country of large supplies of coal tar and other by-products as chemical raw materials. Lacking petroleum products and having barely enough foodstuffs to feed the population, the country turned increasingly to coal as a source of liquid fuels, textiles, edible fats, synthetic rubber, and many other products.

United States has virtually all the raw materials for a successful chemical industry—petroleum products, coal, coal tar, agricultural products, sulphur, salt and many others. The United States synthetic rubber programme was based primarily on petroleum derivatives with supplementary supplies of other raw materials, notably alcohol from corn fermentation and acetylene and acetaldehyde from calcium carbide. The tendency to-day appears to be to manufacture organic chemicals from petroleum products. This is governed by purely economic considerations. The ammonia, methanol, and formaldehyde industries are strongly entrenched behind cheap coal. The availability of large amounts of coal tar and other by-products from the coke industry is a determining factor in the American production of synthetic organic chemicals.

The Canadian chemical industry has been handicapped by a small domestic market, but it has taken advantage of the availability of cheap hydro-electric power and of certain raw materials to secure export markets in specialized lines. The size of the chemical industries based on the by-products of coking is, of course, limited by the size of the coke and gas industry. This industry is not large in Canada, and there is no prospect of it being substantially expanded. The future development of the chemical industries in Canada will depend very largely on export markets, and it is unfortunately true that the areas most suited for cheap manufacture of chemicals are not well situated for export. The chemical industries using coal products as raw materials have not so far been important users of coal, and there seems little prospect that they will become so. The chemical industries most likely to expand are those based on either natural gas or imported petroleum products.