CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

INVESTIGATIONS OF FUELS AND FUEL TESTING

(Testing and Research Laboratories)

1927

PART I

PART II

No. 696

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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Annual reports on Mines Branch investigations are now issued in four parts, as follows:—

Investigations of Mineral Resources and the Mining Industry.

Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories).

Investigations of Fuels and Fuel Testing (Testing and Research Laboratories).

Investigations in Ceramics and Road Materials (Testing and Research Laboratories).

Other reports on Special Investigations are issued as completed.

MINES BRANCH INVESTIGATIONS OF
FUELS AND FUEL TESTING, 1927

GENERAL REVIEW OF INVESTIGATIONS

B. F. Haanel, *Chief of Divison of Fuels and Fuel Testing*
R. E. Gilmore, *Superintendent of Fuel Testing Laboratories*

The technical staff of the Division of Fuels and Fuel Testing was engaged during 1927 in conducting testing and research work on Canadian fuels with the object of assisting in the economic utilization and development of the country's fuel resources. Investigations under way during the year included carbonization tests at both high and low temperatures, coking index experiments on Canadian bituminous coals, special laboratory work relating to oil shales and bituminous sands and developments in oil refining practice with special reference to lubricating oil and synthetic liquid fuels. Considerable attention was also paid to plans for a new building to be known as the Department of Mines—Fuel Research Laboratories, and to the selection of some of the technical scale equipment for the same. Although a large amount of the work cannot be put in report form, certain investigations are sufficiently far advanced and of such a nature that the results can be published at this time. Accordingly, the annual Investigations of Fuels and Fuel Testing, 1927 is comprised of six papers which are reported in two parts containing four and two papers respectively. In addition to a short paper on the use of coke for household heating purposes, and the regular annual analyses of solid fuels examined during the year, Part I includes the results of coking tests on coals from western Canada, which results are reported in two sections, viz., (1) box coking tests in commercial by-product ovens, and (2) laboratory by-product carbonization tests. The box coking tests, which were conducted in the ovens of the Winnipeg Electric Company, were made possible by the co-operation of the officials of that company, and of the coal companies supplying the coal samples for test purposes, to all of whom grateful appreciation is acknowledged. The two papers comprising Part II concern the annual gasoline survey, and methods for the laboratory assay of bituminous sands respectively. The ready co-operation of various officers of the Department of Health in the collection of samples of gasoline is also herewith acknowledged. A general review of the contents of the papers and results obtained follows:

PART I

The Use of Gas and By-Product Cokes for Domestic Heating Purposes: by E. S. Malloch and C. E. Baltzer. This paper shows briefly the extent to which coke was used during the year 1926 as a domestic fuel, and outlines the main differences between the two cokes in common use, viz. retort or gas house coke and oven or by-product coke. Types of domestic furnaces most commonly used in Ontario and Quebec are also described, and instructions given for economically burning coke in them. The paper includes also directions for the detailed use of draughts and dampers on both the hot-air furnace and the hot-water boiler when burning coke, as well as remarks and cautions for burning coke in general.

Coking Tests on Coals from Western Canada: by R. E. Gilmore and R. A. Strong. This paper is a report of coking tests on nine bituminous coals—six from Alberta, and three from British Columbia—and represents a continuation of a high-temperature survey begun in 1924 (on coals from the Maritime Provinces). Its objective is to make available reliable information for the use of the coal producers and to provide a suitable guide for the operators of by-product oven and gas plants in the selection of Canadian coals which will meet their requirements for both coke and gas. The investigation reported here was conducted in two stages, viz., box coking tests in commercial by-product ovens at Winnipeg on fairly large samples of the nine representative western Canadian coals, followed by by-product carbonization tests in a special Sperr and Rose carbonization apparatus in the laboratories at Ottawa. Notwithstanding the fact that the laboratory tests are conducted on small samples of coal the results are quite reliable inasmuch as the apparatus is employed in the laboratories of the Koppers Company to predict the commercial yields of coke, gas, and other by-products. The success of the test, which is entirely empirical, depends on the rigid control of operating conditions by specially trained and experienced engineering chemists, together with frequent comparison with actual plant yields on given coals.

The results of the tests show that three of the nine coals examined, namely, Coal Creek and Michel coals from British Columbia and Mountain Park coal from Alberta, are suitable individually for the production of high quality coke and commercial yields of gas and other by-products and that the remaining six coals will each produce a satisfactory domestic coke when blended with a high quality coking coal. The low sulphur content and comparatively high ash fusibility temperature of all nine coals tested are factors in their favour; but for the higher ash coals, a considerable reduction in ash is seemingly necessary before they can be seriously considered for use in by-product oven plants and especially in plants such as Winnipeg, where no facilities are as yet available for charging more than one grade of coal at a time, or, in other words, where blending is not practised.

Low-temperature Carbonization—Continuation of Tests on Canadian Bituminous Coals: by R. A. Strong. This paper comprises the results of tests on four coals, namely, Minto and Stellarton from New Brunswick and Nova Scotia respectively, and on Luscar and Mountain Park coals from Alberta, which results are supplementary to those on the ten coals reported in 1926. The tests were conducted on the five-pound scale in the special electrically heated lead bath apparatus according to the standard low-temperature carbonization method described in Investigations of Fuels and Fuel Testing for 1925. Photographs of the cokes produced are shown and from the results, which are reported in detail in a series of eleven tables, the amenability of the coals tested to low-temperature carbonization treatment may be judged.

Analyses of Solid Fuels: compiled by J. H. H. Nicolls. This compilation comprises analyses of coals, cokes, and solid fuels examined in the Fuel Testing Laboratories during 1927. The results are tabulated in three sections, viz.:—

1. *Analyses of solid fuels native to Canada as follows:*

Nova Scotia and New Brunswick	12 samples of coal
Quebec	2 " peat
Saskatchewan	1 sample of coal
Alberta	23 samples of coal
British Columbia	18 " "

2. *Coal samples submitted by Department of Soldiers' Civil Re-establishment.* This section contains 55 analyses of composite samples submitted during 1927 by the D.S.C.R., and is similar to that published in Investigations of Fuels and Fuel Testing for 1925 and 1926. The results of analyses as reported are important in that they were used to determine the degree to which the coal delivered varied from the contract grade in respect to moisture, ash, and calorific values, and furnished the data on which the contract price was subject to bonuses or penalties.

3. *Miscellaneous solid fuels comprising the following:*

Pennsylvania anthracite	28 samples
Welsh anthracite	15 "
Low-volatile bituminous coals	13 "
Bituminous coals	9 "
Charcoal, briquettes, etc	4 "

The coke and anthracite samples reported represent an analyses survey of these household fuels as sold in Ottawa during the winter of 1927-28 and may be considered as a follow-up of the coke analyses survey reported in the Investigations of 1926. (*See also* " Examinations of Typical Cokes Sold in Canada " in the Investigations of Fuels and Fuel Testing for 1925). In addition to the usual proximate analyses, calorific values, etc., the screen analyses of most of the anthracite and coke samples examined are shown in this section.

PART II

The Gasoline Survey for 1927: by P. V. Rosewarne and R. J. Offord. This is the fifth annual analyses survey of the gasoline sold in Canada conducted by the Fuel Testing Laboratories. A total of 83 samples collected in 13 different cities by inspectors of the Department of Health was examined. The tables show the " unsaturates, the aromatics, the naphthenes, and the paraffins " for all the samples examined, which, it is to be noted, are in addition to the usual specific gravity, distillation range, and index values reported in former surveys. The results of the analyses show that the average gasoline marketed during 1927, although not quite so good as that marketed during 1926, was of good quality and superior to that sold during the same season in the United States.

The Assay of Bituminous Sands: by R. E. Gilmore, A. A. Swinnerton, and G. P. Connell. The subject-matter is treated in three sections as follows:

1. Tentative methods for the determination of (*a*) the bitumen in bituminous sands, and (*b*) the sulphur content of the bitumen.
2. The use of carbon disulphide versus benzol as solvents for extracting the bitumen from bituminous sands in respect to the sulphur content of the extracted bitumen and fractions thereof.
3. Comparison of laboratory extraction and distillation methods for the examination of the bitumen from bituminous sands as a source of petroleum oil products.

The tentative methods for the determination of the bitumen have been found to be serviceable for the rapid examination of samples of bituminous sands, either in the laboratory or in the field. The method described for the determination of the sulphur, which is a modification of the sodium peroxide method, affords a means of ascertaining the sulphur content of the bitumen without prior solvent extraction of the bitumen and removal of the solvent. The results are comparative rather than absolute, and the method is especially suitable for a series of core samples from drilling operations to show variation in the quality of the bituminous sands in respect to total sulphur.

The results of the study as to comparative merits of benzol and carbon disulphide as solvents show that carbon disulphide is comparatively easy to remove and that its use does not contaminate nor give high results in respect to the sulphur content of the extracted bitumen. Another finding confirmed is that when the extracted bitumen is distilled, the sulphur tends to concentrate progressively in the higher boiling fractions and pitch residue. A comparison of three laboratory extraction and distillation methods for the examination of the products showed interesting results. Preference is indicated for the method consisting of extraction by solvent, fire-still distillation and fractionation of the distillate, in that it affords threefold results, viz.: (*a*) the yield, specific gravity, etc., of the extracted bitumen; (*b*) criteria in respect to the different oil fractions by ordinary distillation; and (*c*) the yield of distillate suitable for pressure cracking along with indicated yields of coke and gas products.

PART I

I

THE USE OF GAS AND BY-PRODUCT COKES FOR DOMESTIC HEATING PURPOSES

E. S. Malloch and C. E. Baltzer

Inasmuch as the Dominion Fuel Board has consistently advocated the more general utilization of coke fuels for domestic heating purposes as a partial solution of the domestic fuel problem in the central part of Canada, this paper has been prepared by the Engineering section of the Division of Fuels and Fuel Testing, in order to provide information of general interest on the subject.

In view of the Board's recommendation it is gratifying to note the marked increase, during the past few years, in the use of coke fuels for domestic heating purposes. Although comparative statistics of the annual consumption of coke for this particular purpose are not to hand, the consumption in Ontario and Quebec during the year 1926, was as follows:

Consumption of Coke Fuels in Ontario and Quebec for Domestic Heating Purposes during the Calendar Year 1926

Item	Ontario		Quebec	
	Consumption in short tons		Consumption in short tons	
Gas coke—				
Produced in Canada	96,240		34,136	
Imported	768		1,936	
Total gas coke		97,008		36,072
By-product coke—				
Produced in Canada	203,088		66,276	
Imported	399,082		10,455	
Total by-product coke		602,170		76,731
Total coke consumed		699,178		112,803

In general it may be said that of all the fuels that are available, or may be made so, as substitutes for American anthracite, coke is, in so far as is known at present, the best for Canadian conditions when all the factors concerned are taken into consideration. It is a clean fuel; more readily adapted to use in present house-heating equipment than any other substitute; and, contrary to general opinion, will last as long in a fire as the same weight of anthracite coal, requiring no more attention than an anthracite fire when it is properly used.

Coke is a solid residue resulting from the dry distillation of soft coal of certain classes, and is produced either in retorts or ovens. Retort coke is sometimes called gas house coke, or more commonly gas coke; while oven coke, which is produced either in beehive or by-product ovens, is commonly called metallurgical or by-product coke. In every town and city where gas is made by the retort method, gas coke is produced, a certain amount of which is available for domestic use. Generally speaking, with this process, gas is the primary product, and the resultant coke is really a by-product which is usually disposed of locally. On the other hand, with the beehive or the by-product oven process, coke is the primary objective, and the gas and other products are incidental to the production of coke.

Although coke made by these various processes from any given coal will be chemically very similar, there exists a difference in physical characteristics, which is of great importance. Absence of volatile matter in coke fuels makes them harder to ignite than bituminous or semi-bituminous coals; but due to the harder and denser characteristics of by-product coke it is more difficult to ignite than gas coke. These properties also enable by-product coke to withstand considerable handling without appreciable breakage and production of fines, and to hold a fire for a longer period than gas coke. Furthermore, in the use of gas coke closer furnace regulation will be required than with by-product coke. In general, however, these two cokes, though having slightly different weights per cubic foot, behave in exactly the same manner when burned in the ordinary domestic furnace, with the exception that gas coke will ignite a little more readily and will burn more freely than by-product coke.

The two types of furnace heater most commonly used for domestic heating purposes in the central provinces of Canada are the hot-air furnace and the hot-water boiler. Both types are used extensively in urban centres and probably in the ratio of three of the former to one of the latter, since the former type predominates in the smaller size houses and in those more cheaply built for purposes of renting or where first cost is the main consideration.

The hot-air furnace consists of a fire-pot, which is capped with a radiation dome, surrounded by an annular ring through which the products of combustion pass on their way to the chimney, the whole being enclosed in a sheet-iron casing. Gravity circulation sends the cool air from the house through cold air registers and ducts down to the bottom of the casing where it is warmed in passing up over the hot surfaces of the fire-pot, radiation dome, and annular ring. The air so warmed then passes up through the hot-air pipes to registers in the various rooms of the house.

The hot-water boiler consists of a water-jacketed fire-pot resting upon an enclosed ash-pit which also supports the grate bars, together with a series of three or four water sections placed one above the other, over the fire-pot. These sections are so arranged that the products of combustion generated in the fire-pot take a staggered path through ports in the sections on their way to the flue pipe. The water spaces in the sections and the water-jacketed portion of the fire-pot are connected in parallel with each other. The water-jacketed portion of the fire-pot, the water sections and the radiators, together with the piping connecting these various units, form the circulating system of the boiler. Gravity circulation sends the cooler water of the circulating system to the bottom of the water-jacketed portion of the fire-pot; here it is heated and passes up to the water sections above, where it takes up more heat. The water, after becoming heated in the water passages of the boiler, passes through pipes to the radiators located in the various rooms of the house.

Figure 1 shows a sectional view of a hot-air furnace and a hot-water boiler. It will be noted that the draught controls are similar in both, with the exception that the hot-air furnace has the additional direct damper " E ". In general, when building a fire, all draughts should be open and after the fire has been built up, closed to the degree necessary to support combustion at the rate desired. (*See* Figure 1.)

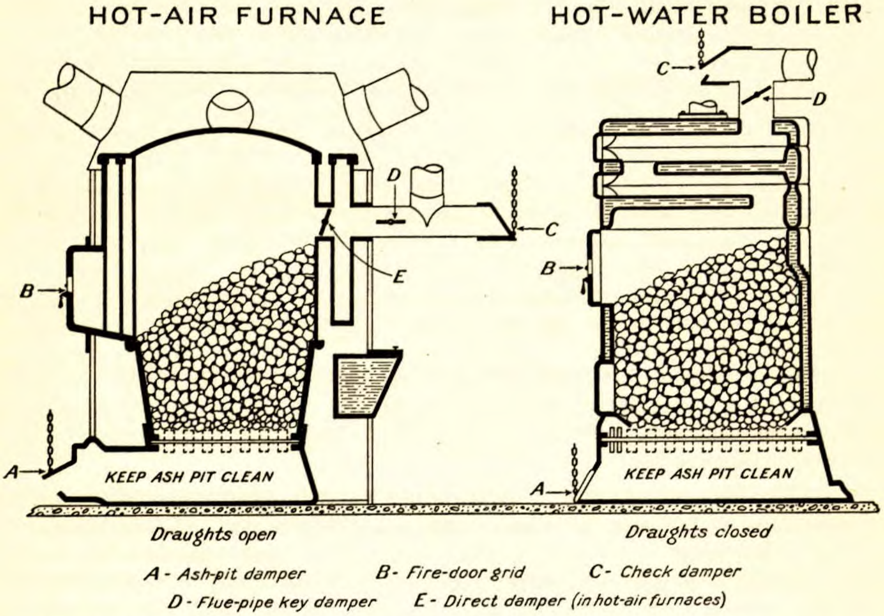

Figure 1. Draught controls on a typical hot-air furnace and hot-water boiler.

The purpose of the various dampers may be briefly described as follows. Combustion in the incandescent part of the fuel bed is maintained by the air which is drawn through the ash-pit damper " A " and combustion will be more or less rapid according to the amount this damper is opened or closed. Combustible gases given off the top of the fuel bed must combine with the secondary air drawn through the fire-door grid " B ", in order that they may be burned. Check-damper " C " and flue-pipe key damper " D " act as a check on combustion, according to the amount they are opened and closed respectively, whereas direct damper " E " (in the hot-air furnace) is only used to provide a direct passage for the products of combustion from the fire-pot to the flue, and is used temporarily when lighting up a fresh fire. At all other times it remains closed.

Although there are many different makes of hot-air furnaces and hot-water boilers on the market, the essential features of all are the same as described above.

Coke is a light porous fuel, its apparent specific gravity being a little more than half that of American anthracite, and its calorific value is about the same as the grade of anthracite now being sold in Ontario. It is evident, therefore, that in order to supply the same amount of heat the volume of coke charged to the furnace at one time must be about twice that of anthracite. Coke fuel ignites much more readily than anthracite, and when once burning freely, requires less draught through the fuel bed to support combustion. Furthermore, it might be said that the characteristics of coke fuel just mentioned have a very definite bearing on the design and upkeep of the furnace in which it is to be burnt.

On account of the large volume of coke fuel which it is necessary to charge into the furnace at one time, the hot-air furnace is better suited for burning this fuel than the hot-water boiler, since the main difference between the two heaters, in so far as the burning of coke is concerned, is that in the hot-air furnace, with a high radiation dome above the fire-pot, there is more space for fuel than in the hot-water boiler which has the first water section resting directly on top of the fire-pot, in which position it is close to the top of the fire. Furnaces which are equipped with a coil over the fire-pot for heating the domestic hot-water supply should have this coil removed, or placed as high as possible above the fuel bed, before an attempt is made to burn coke in them, otherwise there will not be sufficient room to charge the quantity of fuel required for one 8-hour fire-period.

When using either gas or by-product coke the same general method of procedure is followed as when burning anthracite coal, except that the draughts are kept more nearly shut and a thin layer of ashes, 3 or 4 inches thick, is allowed to remain on the grates in order to protect them and still further reduce the draughts through the fuel bed. When building a coke fire all draughts should be opened wide until the coke is burning freely, then closed until there is just sufficient air passing through to support combustion at the desired rate. Coke is nearly twice as bulky, weight for weight, as American anthracite; therefore, in order that a coke fire will last for a long time it is necessary to completely fill the fire-pot and combustion space with coke. Since no two furnaces have exactly the same operating characteristics, no hard and fast rule can be given for the draught settings. Therefore, some experimentation is necessary in order to determine the proper settings for each installation. However, by using a little care the most suitable conditions can readily be found for each installation. The following directions have been found to give satisfactory results, and can, therefore, be used as a general guide for burning coke fuels in either hot-air furnaces or hot-water boilers.

Building the Fire. Cover the bare grates with a layer of ashes 3 or 4 inches thick, and on top of the ash build a wood fire in the usual manner. When it is burning freely charge four or five shovelfuls of coke on top of the fire, being careful to leave the draughts, especially the fire-door grid, wide open until this coke becomes incandescent. Then completely fill the fire-pot with coke, as illustrated in Figure 1. As soon as blue flames appear over the fuel bed, or immediately when the first sign of red shows through the fuel bed, close all draughts and open the check damper to the degree necessary to support combustion at the desired rate. The fire-door grid may be closed or left slightly open, according as experience dictates. This fire should then burn from six to eight hours without further attention.

Replenishing the Fire. When the fire needs replenishing open all draughts; shake the grates until a red glow shows in the ash-pit; again fill the fire-pot with coke, and proceed as before. If there is very little live fuel left on the grates after they have been shaken it may be necessary to first fire a few shovelfuls of coke and leave the draughts open for a short while before firing the main charge of fresh fuel, but on no account leave them fully open after the first sign of red shows through the final fuel charge.

Arrangement of Draughts. The furnace ash-pit should be tightly fitted to the floor and fire-pot, so that the only air which will pass to the fire will come through the ash-pit damper. The draught should be regulated preferably by the flue-pipe dampers, and for ordinary operation the flue-pipe key damper should be kept partly closed; the check damper in the flue-pipe one-quarter to three-quarters open; the fire-door grid one-quarter open, and the ash-pit damper closed. Such an arrangement will ensure a steady consumption of fuel at uniform rate and, therefore, an even temperature will be maintained in the house. In very severe weather the ash-pit damper may be opened slightly and the grid in the fire-door closed; then regulate with the flue-pipe dampers so that the fire will burn at the desired rate. This will cause a more rapid combustion of fuel and, therefore, give out heat to the house at a faster rate.

Shaking the Grates. The grates should be shaken but once a day, usually in the morning, although in very severe weather it may be advantageous to shake each time before charging fresh fuel. In any event the shaking should be done carefully and at no time continued after the first red glow is seen in the ash-pit. Two or three inches of ashes should be left on the grates. It is very important to keep the ash-pit empty, otherwise, the grates will warp and may burn out.

Clinkers. Good coke of uniform size, when fired with moderate care, should give no clinker trouble, unless the fire is forced. Clinker trouble is the direct result of making a fire so hot that the ash fuses and solidifies on the grates. Clinkers may form right across the grates or in one or two spots in the fuel bed. In the latter case they are caused by stirring the fuel bed needlessly with the poker, or building the fire with coke of irregular size and quality. If clinkers form they may be pried off the grates with a slice bar and lifted out through the fire-door.

Banking the Fire. For banking the fire the fines or ashes should be used. This ensures a denser fuel bed, thus retarding the draught through the fire, and by this means it may be maintained at a slow rate of burning for a long period. The fire-door grid should be left open, the ash-pit damper tightly closed, the check damper in the flue-pipe open wide, and the flue-pipe key damper nearly closed.

Early Morning Procedure. Close the draughts and shake the grates as previously directed; remove clinkers, if any, then place a heavy charge of coke on the fire. Leave the dampers open for from 10 to 30 minutes, depending on the amount of chimney draught. Care must be taken to check the fire when blue flames appear over the surface of the fuel bed, or immediately on the first appearance of red in the fuel bed, as experience dictates. On no account leave the draughts fully open until the fresh coke has all been burnt to redness, because the rate of combustion will be too rapid, clinkers may form, and more fuel will have to be added.

General Rules

If the following simple rules are followed with ordinary care the use of coke should give complete satisfaction.

(1) Buy only clean, uniformly-sized coke of the same grade—never mix different grades.

(2) When firing, carry a deep fuel bed; completely fill the fire-pot.

(3) After the fire is started use as little draught as possible, consistent with the combustion rate necessary for the prevailing weather conditions.

(4) Keep two or three inches of ashes on the grates, and in mild weather increase the depth of this layer. This serves to protect the grates and also to reduce the draught through the fuel bed.

(5) Do not overshake or overpoke the fire. Generally, one shaking a day is sufficient.

(6) Keep the ash-pit clear of ashes to protect the grates from being warped or burned out.

(7) Provide means for supplying moisture to the atmosphere of the house. This may be done with hot-air furnaces by keeping the waterpan filled with water; with hot-water boilers other means must be provided, such as placing pans of water on the radiators.

Remarks and Cautions

Remember that coke is a clean, smokeless fuel, having approximately the same heating value as present-day American anthracite, and a much greater useful heating value than soft coal, peat, lignite, wood, etc., when used in the average hot-air furnace or hot-water boiler. In addition, coke may be purchased at a lower price than anthracite, and this fact will enable the winter's fuel bill to be reduced. Tests conclusively show that coke has an equivalent useful heating value to anthracite and is superior to many other fuels when used in domestic furnaces. Coke fuel is bulky and, therefore, if it is required to operate the furnace for eight hours without attention, a large amount of fuel must be fired. If it is required to operate the furnace for twelve hours without attention the fire-pot should be completely filled. In storing coke fuel a bin about double the size of that for the same weight of anthracite will be required. Difficulty may at first be experienced in controlling the fire; either it will burn through too quickly, or else it will go out because of too little draught. The proper draught settings commensurate with the proper combustion rate for the weather conditions prevailing at the time can be determined only by trial. Within limits, it may be said that the smaller the size of coke the more easily the fire can be controlled.

II

COKING TESTS ON COALS FROM WESTERN CANADA

R. E. Gilmore and R. A. Strong

Within recent years coke has become an important factor in the domestic fuel market in Canada as a substitute for imported anthracite. Coking plants that formerly either produced coke solely for metallurgical purposes or as a by-product in the manufacture of city gas are now producing "domestic" coke as the main product. Statistics show a steady decrease of anthracite importations since 1923, and according to the tabulation[1] shown below, the coke consumed (in central Canada) for domestic heating in 1927 was three times that in 1923. Indications, therefore, are that coke will continue to displace increasingly greater amounts of anthracite for household and other fuel purposes.

Ontario and Quebec

—	1923	1927
	Net tons	Net tons
Imports of American anthracite	4,753,873	3,073,033
Imports of British anthracite	207,282	720,203
Coke consumed for domestic heating	270,000	812,000
Low volatile coals	180,000	386,000

During recent years the Department of Mines, in conjunction with the Dominion Fuel Board, has recommended the use of coke as a household fuel in place of anthracite and has published considerable literature[2] on the subject.

However, for the manufacture of domestic coke in Canada the proportion of Canadian coal employed is still comparatively small, most of the coal used for this purpose being imported from the United States. This practice of using foreign coals in the coking industry is due, to a large extent, to the lack of knowledge which prevails as to the merits of Canadian coals in this connexion, as well as to adverse economic factors. The Carbonization Section of the Fuel Testing Laboratories has conducted tests on Canadian coals for the purpose of determining their suitability for the manufacture of domestic coke. Accordingly, this report describing coking tests on coals from western Canada is part of a comprehensive, high-temperature carbonization survey of the country's bituminous coal resources.

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[1] Second Progress Report, 1923-28, p. 15; Dominion Fuel Board.

[2] "Coke as a Household Fuel in Central Canada," Mines Branch, Dept. of Mines, Canada, Rept. No. 630 (Dominion Fuel Board Rept. No. 5), and other reports of the Dept. of Mines.

During 1924 a series of coking tests[1] was conducted on coals from the Maritime Provinces. This investigation comprised coking tests on four representative coals—three from Nova Scotia and one from New Brunswick—in the by-product ovens of the Hamilton By-Product Coke Ovens, Limited, and was preceded by an analysis survey of the coals of these two provinces. The burning properties of the cokes so produced were also tested in standard domestic furnaces and, in addition, laboratory washing and coking tests were made on certain New Brunswick coals which are characterized by their high ash and sulphur content. The Hamilton tests and subsequent laboratory experiments dealt mainly with the coke-producing qualities of the coals, as was the case in former tests[2] on Canadian coals. In the tests on coals from western Canada here reported, attention has been paid to the yield and quality of gas, tar, and other by-products as well as the coke. Accordingly, the results of examination of the coals by a standard laboratory high-temperature carbonization method, in addition to box coking tests in by-product ovens, are included. Inasmuch as the investigation was conducted in two stages, viz. the collection of fairly large samples and the testing of these samples by the box coking method as the first stage, followed by special examination in the laboratory, the results are reported here in two parts: Section 1 dealing with the coking tests in by-product ovens in Winnipeg and subsequent examination of the cokes produced; and Section 2 describing the laboratory carbonization apparatus used, together with a discussion of the results obtained.

The purpose of the above-mentioned high-temperature carbonization survey is to make available reliable information for the use of the coal operators of western Canada and to provide a suitable guide for the superintendents of gas plants in the selection of a coal which will meet their requirements for both coke and gas. The immediate objective was the possible use of one or more of these coals in the gas plant at Winnipeg, and in view of this it was first considered necessary to determine the conditions at this particular plant which would have a bearing on the selection of a suitable coal. The situation in Winnipeg is somewhat unique in that an abundance of low-priced electrical energy is available and as cooking by this means is largely used, the gas load is smaller than is usually the case in cities of its size. On the other hand, severe winter weather conditions make for a big demand for domestic fuel, and as coke is very satisfactory for this purpose no difficulty is met with in disposing of all the coke produced. The yield of a large volume of gas with a consequent lowered coke yield is, therefore, not essential in this particular locality, but the coal must produce a suitable coke for domestic purposes and possess a fairly low ash content of relatively high fusibility. The sulphur content is an important item, as low sulphur coals are readily available from the United States and it is not desirable to increase the gas purification costs.

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[1] "Coking Experiments on Coals from the Maritime Provinces", by R. E. Gilmore and B. F. Haanel; Mines Branch, Dept. of Mines, Canada. Invest. of Fuels and Fuel Testing, 1924, Rept. No. 644, pp. 1-20.

[2] "An Investigation of the Coals of Canada", by Porter, Durley, Stansfield, and others; Mines Branch, Dept. of Mines, Canada, Rept. No. 83 (1912).

Grateful acknowledgment is herewith made to the different coal mining companies for their hearty co-operation in supplying the coals for testing purposes; to the officers of the Winnipeg Electric Company for permission to conduct box coking tests in their by-product ovens, and particularly to Messrs. McNair, Dunderdale, and Torpey for their co-operation and personal attention during the tests. G. P. Connell assisted with the box coking tests at Winnipeg, and E. J. Burrough carried out the laboratory examination of the original coals according to the recently adopted standard high-temperature carbonization method.

DESCRIPTION OF COALS USED

Coal Creek coal from the Crow's Nest Pass Coal Company, Fernie, B.C. The sample was supplied from their Coal Creek colliery. This coal, which is comparatively low in ash, is the coal used in their beehive ovens for the manufacture of metallurgical coke.

Michel coal from the Crow's Nest Pass Coal Company's colliery at Michel, B.C. This coal is used for the production of metallurgical coke in the company's beehive ovens at Fernie, B.C. It is notably low in ash and sulphur and may be termed a medium volatile matter content coal.

Mountain Park coal from the Mountain Park Collieries, Limited, located in the Mountain Park area in Alberta. The 100-pound sample supplied by the company had a fairly high volatile matter content, was reasonably low in ash and sulphur, and was said to be the same as that used for the manufacture of metallurgical coke in by-product ovens at Anyox, B.C., where it is blended with Vancouver Island coal.

Hillcrest coal from the mine of the Hillcrest Collieries, Limited, at Hillcrest, Alberta, in the Crownest Pass area. As shown by the analysis of the 100-pound sample supplied, this coal possessed a comparatively high volatile matter content and was low in sulphur.

Greenhill coal from the mine of that name operated by the West Canadian Collieries, Limited, located at Blairmore in the Crowsnest Pass area of Alberta. The colliery is equipped with a pneumatic cleaning plant which is capable of effecting a considerable reduction in the ash as required.

McGillivray Creek coal from the mine of the McGillivray Creek Coal and Coke Company, Limited, located at Coleman, Alberta, also in the Crowsnest Pass area. This mine is equipped with a pneumatic cleaning plant for ash reduction, and produces a medium volatile matter content coal similar to Greenhill coal.

Denison coal from the mine of that name operated by the International Coal and Coke Company, Limited, located at Coleman, Alberta, in the Crowsnest Pass area. This colliery is also equipped with a pneumatic cleaning plant. The coal, of medium to low volatile matter content, has been used for the manufacture of metallurgical coke in beehive ovens, but is not being used for this purpose at the present time.

Corbin coal from the Corbin Coals, Limited, at Corbin, B.C., in the Crowsnest Pass area. This colliery is equipped with a washery using Elmore jigs for ash reduction.

Luscar coal from the Luscar Collieries, Limited, located at Mountain Park, Alberta, in the Mountain Park area. The sample received was comparatively low in volatile matter and possessed an exceptionally low sulphur content.

SUMMARY

All of the above listed coals are to be classed as bituminous with varying volatile matter contents as indicated. Before use at Winnipeg each coal was sampled, the analyses of which are shown in Table III. For the purpose of obtaining in advance some idea of the quality of the different coals, mainly in respect to coking properties, small samples of each shipment were forwarded from the mines to Ottawa. These samples were analysed and their coking properties as judged by the residue in the platinum crucible used in the volatile matter determination noted, the results being shown in Table I.

SECTION 1

BOX COKING TESTS IN COMMERCIAL BY-PRODUCT OVENS AT WINNIPEG

The box coking tests were made in the Koppers ovens of the Winnipeg Electric Company. In these ovens, known as the Becker Improved Type Combination Ovens, the distinctive feature is the possible use of preheated producer gas as fuel by means of split regenerators. By means of regulable ports it is also possible to use coal gas when the gas load is low. This arrangement allows of great flexibility in gas production and is obviously an ideal design for localities such as Winnipeg. At the time this battery consisting of seventeen ovens was constructed, it was connected to the then existing by-product equipment which served for the retorts previously in use, and consequently no provision is made for recovery of light oils. Ammonium sulphate is not recovered as no market for it exists in the west at present. The tar has a ready market locally and commands a fair price. No provision for blending coal was made when the plant was constructed, and crushing of the coal prior to charging is consequently dispensed with. This arrangement, while tending to reduce costs, does not allow of a wide range of selection in the coal used, and as shown later in this report, it also militates against the general use of Canadian coals, a considerable number of which might be used with blending, the number being appreciably reduced when it is required to use them alone.

The gas plant of the city of Winnipeg had been formerly manufacturing gas in horizontal retorts and as the plant was both old and inadequate to the demands, it was apparently decided to take cognizance of this situation and construct a new by-product coke plant which could manufacture a coke fuel for domestic heating as well as gas. Accordingly, the present battery of Koppers ovens was installed together with a coke crushing and sizing plant capable of making a high quality domestic coke of suitable sizes to meet the popular demand. Owing, it seems, to the lack of definite information regarding the suitability of western bituminous coals for the production of a domestic coke, this plant selected a high gas coal from the United States and has continued its use.

It was therefore considered advisable to carry out experiments at this plant on such Canadian coals as were within reasonable distance and which, if satisfactory, would be available. To this end a program of investigation involving nine Canadian coals was drawn up and arranged for. The character of the investigation included the testing of the selected coals in iron boxes placed in the ovens, together with the regular charge, which could be recovered when the oven was pushed. As each coal was crushed and prepared for the boxes, a very careful sampling was made, the sample being forwarded to the Laboratories of the Fuel Testing Division for subsequent determination of yields of gas, tar, and other by-products as described in Section 2 of this report. The resulting coke was examined physically and graded according to domestic coke standards, also as foundry coke, after which density and shatter tests were made as well as chemical analyses.

The original plan of the investigation included, first, the coking of the Canadian coals alone in order to determine their individual behaviour in the ovens and the quality of the coke produced; and, second, a series of tests in which each Canadian coal was blended with varying proportions of the imported coal now in use at the plant, to be followed by a series of blends using two selected Canadian coals. Due mainly to the difficulty of using the boxes more than once, the entire program was not completed. The first part, however, and part of the second was carried out, i.e. coking of the nine Canadian coals alone and a blend of the Canadian and imported coal in the proportion of 25 per cent of the domestic and 75 per cent of the imported coal. The coking of the Canadian coals alone had particular reference to the operation at Winnipeg as in this plant the entire coke production is sold for domestic use and under such conditions it is not necessary to blend. When a high volatile coal is used in a plant of this description it tends to produce a coke smaller in size than would be the case when a medium volatile coal is employed. As the coke has to be crushed and sized for domestic use, this is an advantage rather than otherwise. The blending tests were important inasmuch as the usual practice in by-product coke plants is to manufacture both metallurgical and domestic coke and in such cases the oversize, over 3 inches, is sold as foundry coke and the undersize as domestic. As foundrymen require a large size coke and are prepared to pay a premium price on size, it is customary to blend coals of lower volatile content in proportions up to 30 per cent with high volatile coals in order to obtain a volatile percentage in the blend approximately equivalent to 25. This tends to improve the coke size as well as the coke structure as desired for foundry work.

The chief purpose of box coking tests is to determine the quality of coke produced from a certain coal and its behaviour in the oven. When it is suspected that a given coal will not shrink sufficiently to allow of its being readily pushed from the oven, it is customary to employ a box test. The procedure is to fill a metal box with a given quantity of prepared coal and place it in an oven which has just been pushed. The regular charge is then placed in the oven on top and immediately surrounding the box. On completion of the coking period, the charge is pushed and the box recovered from the mass of hot coke in the coke car. The appearance of the coke in the box after quenching is a ready guide to the behaviour of a full oven charge and if the test is unfavourable the expense of a full-scale test as well as possible damage to an oven has been avoided. However, it must not be considered that a box test is final as it is very easy for an inexperienced observer to misinterpret the results as obtained from this type of test. A skilled operator is, however, able to obtain very reliable information as to the quality and suitability of coke which can be produced from a coal.

The tests as conducted at Winnipeg were made in specially designed boxes capable of holding from 80 to 100 pounds of coal. They were made of sheet metal of No. 16 gauge, the joints being welded. A cover is provided which rests on top of the coal mass and is loosely held in place by bolts which move in slots in order to take care of the expansion. The gas escapes through the space between this cover and the sides of the box.

The coal used for the experiments was forwarded from the mine in bags and was in all cases freshly mined as very little time elapsed from the time of shipment until the test. The preparation of the sample for coking consisted of crushing the coal to the desired fineness in an electrically driven Sturtevant crusher with automatic sampler, during which operation a sample was collected for analysis. In the case of blends, each coal was first crushed separately, the two coals were then thoroughly mixed and sampled by the cone and quartering method. After being filled and the covers fitted in place, the boxes were placed on the oven platform on the coke side and, immediately after the oven was discharged and prior to the recharging of the oven with fresh coal, they were pushed along the bottom of the oven by means of a long bar so that they were approximately eight feet from the door, where they remained during the regular coking period. They were subsequently recovered from the hot discharged coke by means of long bars with hooks, after which they were cooled by spraying with an ordinary hose instead of remaining in the coke during the regular quenching operation. When cool, the coke was weighed to determine its yield although it was not possible to attach much importance to this result in view of the difficulty in obtaining a completely dry sample. The recovered coke was bagged, properly labelled and forwarded to the Fuel Testing Laboratories for examination. Prior to bagging and shipping, the various cokes produced were graded, according to the Winnipeg plant standards, as both foundry and domestic coke, the results of which are given in Table II.

In addition to the usual proximate analysis, along with the determination of calorific value and sulphur content, the various cokes resulting from the box coking tests were examined as to apparent specific gravity and shatter properties. The apparent specific gravities were determined on 25-pound lots according to the method described in the Gas Chemists' Handbook, and the shatter test according to the standard A.S.T.M. method using approximately 50-pound lots of coke as specified.

DISCUSSION OF RESULTS OF BOX COKING TESTS

The results of the box coking tests are summarized in Tables II and III; the former showing the grading of the various cokes; and the latter the analyses of the coals used and the cokes produced, together with the apparent gravity of the cokes and their shatter index.

Coke Grading

The grading of the coke for foundry and domestic purposes as reported in Table II was made on the basis of appearance and structure solely without any reference to chemical properties. Representative pieces of the coke were selected for photographing and these are shown in Plates I to IX.

It will be noted that both cokes from the Crow's Nest Pass Company's mines, i.e. Coal Creek and Michel, show a very small amount of either longitudinal or cross fracture. The cell structures are uniform in both these cokes and the cells are very small in dimension. These cokes have been graded as excellent and have not been improved upon by blending. The photographs showing typical pieces of the coke produced by blending both Coal Creek and Michel coals with the imported coal used at the plant indicate a considerable enlargement of the cells in the case of Coal Creek and a decided increase in the fracture lines in the case of Michel.

Mountain Park coke, as shown in Plate III, also possesses a small amount of fracture lines and a uniform cell structure. The cells are, however, considerably larger than in the case of the two previously mentioned coals. This coke was graded as good and the addition of imported coal failed to improve its quality to a marked degree. The photograph of a typical specimen of the blended coke indicates a slight increase in cross fracture and an enlargement of the cells.

Hillcrest coal produced a large blocky coke with very irregular cell structure and a medium amount of fracturing, and was graded as fair only. The blend, however, decidedly improved the physical characteristics of this coke, the cell structure being more uniform and the fracture less pronounced.

Greenhill coal produced a rather small fingery coke with a decidedly uniform cell structure and few fracture lines. It was graded as fair to good for foundry purposes, although the percentage of foundry coke would be low. As a domestic coke, however, the grading is regarded as good on account of the small size of the cells and the absence of cross fracture. The result of the blending in this case was to increase the size of the coke cells as well as to increase the cross fracture and from a physical standpoint, therefore, could not be considered an improvement.

PLATE I

(Lab. No. 4536) (Lab. No. 4547)

Cokes from box coking tests on Coal Creek coal: No. 4536 when coked alone, and No. 4547 with 75 per cent Chilton coal.

PLATE II

(Lab. No. 4537)

(Lab. No. 4548)

Cokes from box coking tests on Michel coal: No. 4537 when coked alone, and No. 4548 with 75 per cent Chilton coal.

PLATE III

(Lab. No. 4538) (Lab. No. 4549)

Cokes from box coking tests on Mountain Park coal: No. 4538 when coked alone, and No. 4549 with 75 per cent Chilton coal.

PLATE IV

(Lab. No. 4539) (Lab. No. 4550)

Cokes from box coking tests on Hillcrest coal: No. 4539 when coked alone, and No. 4550 with 75 per cent Chilton coal.

PLATE V

(Lab. No. 4540) (Lab. No. 4551)

Cokes from box coking tests on Greenhill coal: No. 4540 when coked alone, and No. 4551 with 75 per cent Chilton coal.

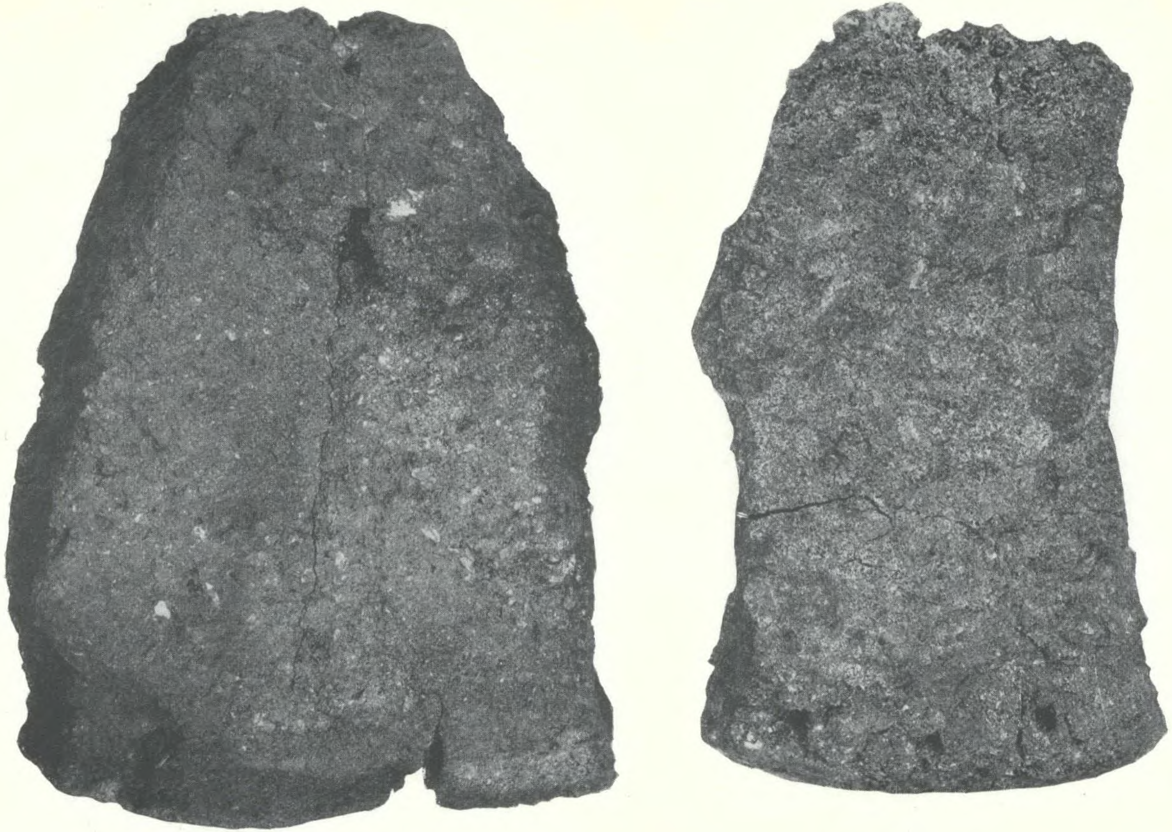
PLATE VI

(Lab. No. 4541)

(Lab. No. 4552)

Cokes from box coking tests on McGillivray coal: No. 4541 when coked alone, and No. 4552 with 75 per cent Chilton coal.

PLATE VII

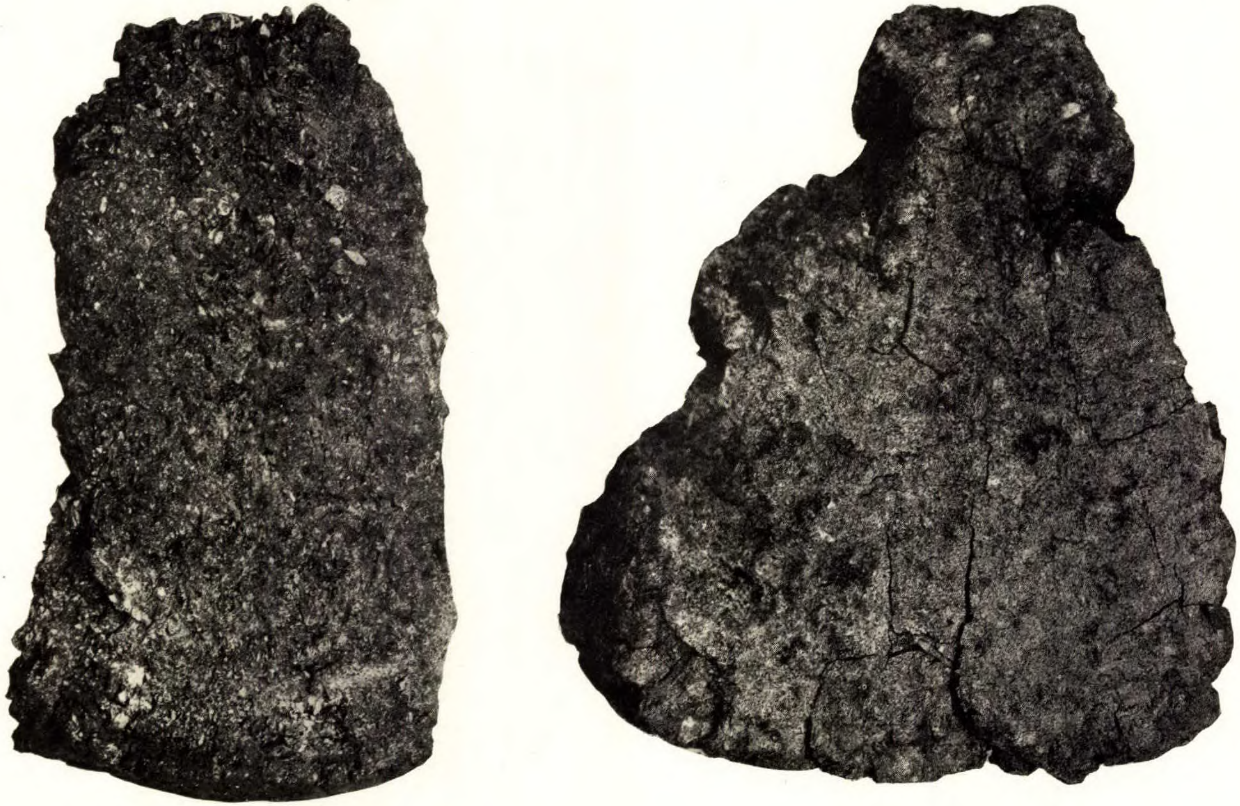


(Lab. No. 4542)

(Lab. No. 4553)

Cokes from box coking tests on Denison coal: No. 4542 when coked alone, and No. 4553 with 75 per cent Chilton coal.

PLATE VIII



(Lab. No. 4543)

(Lab. No. 4554)

Cokes from box coking tests on Corbin coal: No. 4543 when coked alone, and No. 4554 with 75 per cent Chilton coal.

PLATE IX

(Lab. No. 4544)

(Lab. No. 4546)

No. 4544: Coke from box coking tests on Luscar coal. No. 4546: Regular coke from Chilton coal as produced at Winnipeg.

McGillivray coal produced a large blocky coke with a large amount of cross fracture. The cell structure was rather irregular and the coke was graded as fair only. Blending in this case raised the grading to good. The cell structure was decidedly improved, being quite uniform, and both longitudinal and cross fracture reduced.

Denison coal produced a large blocky coke with very irregular cell structure. Cross fracture was very small and the longitudinal fracture was of medium amount. The coke could be graded as fair only. Blending in this case improved the quality of the coke considerably and while a small amount of cross fracture is evident from the photograph, the longitudinal fracture is very small and the cell structure is quite uniform.

Corbin coal when coked alone does not produce a very high quality coke. As will be noted in Plate VIII particles of the coal that have been unaltered are in evidence, which indicates poor agglutinating properties. Blending has decidedly improved this and the result is a good coke of fairly uniform cell structure and with medium amount of fracture.

Luscar coal produced a poor quality coke both for foundry and domestic purposes. In the case of this coal, the blend was not made owing to a shortage of boxes, but it may be presumed that a blend of Luscar coal with the imported coal in the proportions used in the other tests would result favourably.

Analyses of Coals

The results of analyses of the coals employed in the coking tests are shown in Table III.

It will be noted that all of these coals are remarkably low in sulphur, a most important feature when they are to be used for the production of coke, especially for foundry purposes. The volatile matter is, with two exceptions, of medium content, so that if the ash were sufficiently low they could be satisfactorily employed for the production of coke without the necessity of blending. Unfortunately, most of the coals tested possess too high an ash content to make a satisfactory coke without blending. It may be possible, however, to lower the ash of these coals considerably as a number of the collieries possess washeries. Some of the coals have a sufficiently low ash to be used alone or as the basis of a blend with some of the other high ash coals, and when used alone produce from the standpoint of chemical analysis a coke of high quality.

Ash fusibility, while not shown in the table, has a most important bearing on the selection of coals for the production of domestic coke. The western coals used in the box tests at Winnipeg all possess a relatively high fusion ash[1] and can carry a fairly high ash content without causing trouble from clinkering.

Analyses of Cokes

The results of chemical analysis of the various cokes obtained from the box tests are shown in Table III. It will be noted that in the majority of cases where the coal has been used alone, the ash results are too high to warrant their use for either foundry or domestic purposes.

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[1] Rept. No. 14; Scientific and Industrial Research Council of Alberta (1925).

Examination of typical by-product and gas cokes on the market (in central Canada) has shown that in order to have a heating value at least equal to average Pennsylvania anthracite, a coke must have at least 2 per cent less ash content, along with 2 per cent less moisture; that is, the maximum specifications for an average domestic coke are 11 per cent ash and 1 per cent moisture. Reference to Table III shows that of the nine Canadian coals coked alone, only three, namely, Coal Creek, Michel, and Mountain Park complied with these specifications. The cokes produced in the blending tests using 25 per cent Canadian coal with 75 per cent of the imported coal, however, showed gratifying results in that the ash content of six of the cokes ranged from 10·4 to 11·8 per cent with an average of 11·1 per cent, and three of the cokes obtained had ash contents below 10 per cent with an average of, roughly, 9 per cent.

Shatter Index and Apparent Specific Gravity

The shatter index indicates the percentage of the coke remaining on a 2-inch screen after four drops in the shatter test apparatus. As shown in Table III, the shatter index values for the nine Canadian coals coked alone ranged from 71 to 88, which may be considered as generally satisfactory for domestic coke. It is to be noted, however, that the shatter index values do not agree uniformly with the grading according to appearance and other properties. The coke, therefore, with the highest shatter index value is not necessarily the best coke. It may, however, serve to grade a coke in respect to presence of fracture lines in the coke lumps. It is also to be observed that the shatter index values for the cokes obtained when the Canadian coals were blended with 75 per cent of imported coal, were generally lower than when these coals were coked alone, despite the fact that in most cases blending improved the quality of the coke obtained.

The apparent specific gravity figures as shown in Table III ranged from 0·93 to 1·12 for cokes from the nine Canadian coals, which compared favourably with the range of 0·84 to 1·02 for typical by-product cokes on the market. The effect of blending, it will be observed, was generally to reduce slightly the apparent density of the cokes. As with the shatter index, the apparent density values for cokes produced in box coking tests must, however, not be stressed, as it is quite improbable that these values could be duplicated in full-size oven operation. The values shown in Table III are, therefore, comparative only, and indicate rather than show what may be expected in commercial practice.

TABLE I

Analyses of Advance Samples of Western Canadian Coals used in the Box Coking Tests at Winnipeg

Name of coal (as used in this report)	Laboratory No.	Proximate Analysis				Sulphur	Coking properties of coal[1]
		Moisture	Ash	Volatile matter	Fixed carbon		
		%	%	%	%	%	
Coal Creek	4353	1·2	6·3	25·6	66·9	0·45	Good
Michel	4352	2·4	4·8	25·6	67·2	0·60	"
Mountain Park	4357	1·7	9·1	29·9	59·3	0·50	"
Hillcrest	4356	1·4	10·8	29·4	58·4	0·60	"
Greenhill	4354	1·0	10·6	24·8	63·6	0·50	"
McGillivray[2]	4573	1·4	16·0	24·1	58·5	0·90	Fair
Denison	4355	1·4	12·3	23·6	62·7	0·60	"
Corbin	4367	1·2	12·6	23·6	62·6	0·25	"
Luscar	4358	1·1	11·5	20·5	66·9	0·33	"

[1] Coking properties as judged by the appearance of the coke button produced in the volatile matter determination and checked by laboratory coking tests on a one-pound scale in a fireclay crucible in a gas-fired furnace. Such a grading is comparative and an indication only as to whether the coal being tested is non-coking, whether it agglomerates, or possesses poor, fair, or good coking characteristics.

[2] The sample of McGillivray coal reported here was from a shipment sent to Winnipeg, and not from advance sample forwarded to Ottawa.

TABLE II

Box Coking Tests

(Grading of cokes produced from the nine Canadian coals when coked alone and then blended with 75 per cent Chilton coal.)

Canadian coal used	Coked alone, or blended with Chilton coal	Grading according to appearance	
		As foundry coke	As domestic coke
Coal Creek	Alone	Excellent	Very good
25% Coal Creek	75% Chilton	"	"
Michel	Alone	Excellent	Very good
25% Michel	75% Chilton	"	"
Mountain Park	Alone	Good	Good
25% Mountain Park	75% Chilton	"	"
Hillcrest	Alone	Fair	Fair
25% Hillcrest	75% Chilton	Good	Good
Greenhill	Alone	Fair to good	Good
25% Greenhill	75% Chilton	Good	"
McGillivray	Alone	Fair	Fair
25% McGillivray	75% Chilton	Good	Good
Denison	Alone	Fair	Fair
25% Denison	75% Chilton	Good	Good
Corbin	Alone	Poor	Fair
25% Corbin	75% Chilton	Good	Good
Luscar	Alone	Poor	Poor

TABLE III

Analyses of Coals used and Cokes produced in Box Coking Tests at Winnipeg

Name of Canadian coal coked alone or blended with 75 per cent Chilton coal	Laboratory No. of coal	Coal used						Laboratory No. of coke	Moisture	Ash	Volatile matter	Cokes produced				
		Proximate analyses, calorific value, coking properties, etc.										Proximate analyses, apparent specific gravity, shatter index, etc.				
		Moisture	Ash	Volatile matter	Fixed carbon	B.T.U. per pound	Sulphur					Fixed carbon	B.T.U. per pound	Sulphur	Apparent Sp. gr.	Shatter index
		%	%	%	%		%		%	%	%	%		%		
Alone																
Coal Creek	4568	1·2	4·8	26·6	67·4	14,500	0·4	4536	0·2	7·7	2·1	90·0	13,262	0·5	0·93	81
Michel	4569	1·9	4·3	25·2	68·6	14,485	0·6	4537	0·6	6·1	1·2	92·1	13,246	0·6	0·96	81
Mountain Park	4570	1·5	7·8	30·5	60·2	14,085	0·5	4538	0·3	11·2	1·6	86·9	12,695	0·5	0·94	80
Hillcrest	4571	1·1	12·0	29·1	57·8	13,290	0·6	4539	0·1	15·0	1·1	83·7	12,206	0·5	1·00	71
Greenhill	4572	0·8	10·5	25·4	63·3	13,637	0·5	4540	0·2	14·9	1·4	83·5	12,195	0·5	1·06	78
McGillivray	4573	1·4	16·0	24·1	58·5	12,521	0·9	4541	0·1	22·0	1·2	76·7	11,110	0·7	1·12	78
Denison	4574	1·2	12·7	23·7	63·0	13,209	0·6	4542	0·2	15·8	1·2	82·8	12,020	0·5	1·08	78
Corbin	4575	1·2	12·3	24·3	62·2	13,155	0·3	4543	0·1	15·8	1·4	82·7	12,098	0·3	1·05	72
Luscar	4576	0·9	11·1	20·3	67·7	13,816	0·3	4599	0·2	14·1	1·4	84·3	12,278	0·4	1·04	88
Blended																
Coal Creek	4578	1·8	6·1	30·6	61·5	14,188	0·7	4547	0·2	8·6	1·0	90·2	13,192	0·5	0·92	74
Michel	4579	2·0	6·3	31·0	60·7	14,132	0·8	4548	0·2	9·0	1·0	89·8	13,007	0·5	0·96	70
Mountain Park	4580	2·1	6·3	32·0	59·6	14,136	0·7	4549	0·1	10·4	0·8	88·7	12,861	0·6	0·94	73
Hillcrest	4581	1·8	6·8	31·4	60·0	14,053	0·8	4550	0·2	9·9	1·0	88·9	12,865	0·6	0·97	74
Greenhill	4582	2·0	6·9	30·2	60·0	14,024	0·7	4551	0·2	11·3	1·4	87·1	12,682	0·5	0·97	75
McGillivray	4583	2·0	8·2	30·3	59·5	13,777	0·8	4552	0·1	11·6	0·8	87·5	12,604	0·6	1·01	68
Denison	4584	1·8	7·4	30·1	60·7	13,972	0·8	4553	0·1	10·7	1·2	88·0	12,758	0·6	0·97	78
Corbin	4585	2·0	8·3	31·9	57·8	13,773	0·7	4554	0·2	10·7	1·0	88·1	12,722	0·5	0·98	71

TABLE IV

Summary of High-temperature Carbonization Tests

(Yields of products per ton of dry coal)

Laboratory No.	4568	4569	4570	4571	4572	4573	4574	4575	4576
Name of coal	Coal Creek	Michel	Mountain Park	Hillcrest	Greenhill	McGillivray	Denison	Corbin	Luscar
Coal—									
Proximate Analysis (dry basis)—									
Ash per cent	4·8	4·8	7·7	10·7	11·0	16·0	12·1	12·3	11·5
Volatile matter "	27·7	25·8	31·9	30·1	26·0	25·1	24·0	24·7	20·6
Fixed carbon "	67·5	69·4	60·4	60·2	63·0	58·9	63·9	63·0	67·9
Sulphur "	0·4	0·6	0·5	0·6	0·5	0·9	0·6	0·3	0·3
Calorific Value—									
B.T.U. per pound (calculated)	14,685	14,700	14,330	13,625	13,080	12,730	13,485	13,330	13,895
Coke—									
Percentage of coal	75·4	75·5	71·9	73·2	77·2	77·7	79·0	77·9	81·7
Pounds per ton	1,508	1,510	1,438	1,464	1,544	1,554	1,580	1,558	1,634
Proximate Analysis (dry basis)—									
Ash per cent	6·4	6·3	10·7	14·6	14·3	20·6	15·3	15·8	14·1
Volatile matter "	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5
Fixed carbon "	92·1	92·2	87·8	83·9	84·2	77·9	83·2	82·7	84·4
Sulphur "	0·5	0·6	0·5	0·5	0·5	0·7	0·5	0·3	0·4
Calorific Value—									
B.T.U. per pound (calculated)	13,480	13,300	12,810	12,280	12,310	11,325	12,120	12,110	12,310
Tar—									
Imperial gallons per ton	7·2	7·1	8·8	9·2	7·1	6·5	5·8	5·7	5·3
Light oils—									
Imperial gallons per ton	2·8	2·2	3·3	2·4	2·4	2·2	2·0	2·0	1·4
Ammonium sulphate (lb. per ton)	17·7	22·6	19·2	26·6	10·9	18·8	20·6	20·8	17·1
Hydrogen sulphide, grains per 100 cu. ft.	54	171	182	153	108	249	122	67	55
Gas—									
Cu. ft. per ton (including light oils)	10,965	10,404	10,867	10,095	9,889	9,837	9,305	9,786	9,906
B.T.U. per cu. ft.	590	545	587	555	567	529	850	523	523
Cu. ft. per ton (debenzolized)	10,846	10,313	10,727	9,993	9,787	9,746	9,221	9,702	9,846
B.T.U. per cu. ft.	558	519	549	525	537	501	523	498	505
Density (air=1) (exclusive of CO_2 and O_2)	0·34	0·33	0·35	0·35	0·32	0·33	0·30	0·33	0·30

SECTION 2

LABORATORY BY-PRODUCT CARBONIZATION TESTS

This section comprises a series of high-temperature carbonization tests made in the laboratories at Ottawa, the purpose of which was to obtain information as to the yield of coke, gas, and other by-products obtainable from the coals used in the box coking tests.

CARBONIZATION METHOD EMPLOYED

The laboratory carbonization tests here reported were conducted in a special apparatus according to a prescribed method, using a small sample of coal; this method furnishes results from which the commercial yield of by-products may be predicted. The apparatus used was that developed by Messrs. Sperr and Rose of the Koppers Company, the special feature being the patented electric furnace chamber for heating the coal. The coal, pulverized to pass a 60-mesh screen and previously oven-dried, is placed in a pyrex glass tube closed at one end so that the coal occupies a length equal, approximately, to one-half the width of a coke oven. On the open end of the tube, which protrudes through the end of the horizontal furnace, is attached a gas condensing and scrubbing train, along with a calibrated gasometer for collecting the by-products and determining the yields. Coking begins in that part of the charge toward the open end and continues progressively towards the closed end at such a rate that the rate of progression of heat into a coke-oven charge is duplicated. As stated by Mr. Rose[1], this method is both rapid and reliable, and is employed in the laboratories of the Koppers Company with entire satisfaction. The success of the test, which is entirely empirical, "depends upon the rigid control of test conditions by chemists experienced in this work, together with a frequent comparison with actual plant yields on the same coals."

Realizing the importance of this laboratory apparatus, arrangements were made to employ it in the high-temperature carbonization survey of Canadian bituminous coals already under way. Accordingly, by the courtesy of the Koppers Company, a duplicate of the above described special electric tube furnace, as used in their laboratories at the Mellon Institute, Pittsburgh, has been installed in the Fuel Testing Laboratories. In order to obtain concordant results, the operation of the oven has been assigned to engineering chemists specially trained in its operation, hence it is with utmost confidence that the yields of by-products from the coals tested, as reported in Tables V to VIII and summarized in Table IV are herewith presented. With this apparatus, the practice is to make a carbonization test according to a definite time schedule, the temperatures at which the different parts of the tube in which the coal is being carbonized and the rate of heating having been standardized to give from a standard coal corrected gas yields equal to the average obtainable from the same

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[1] Fuel in Science and Practice, vol. V, No. 12 (Dec. 1926) page 562, and also January and February, 1927.

coal in commercial by-product oven practice. The yield of coke obtainable in the laboratory has been found to approximate the plant yield of the total coke including the breeze, and likewise the yields of tar and ammonium sulphate afford a prediction of the commercial results to be obtained. The light oil yield obtained in the laboratory, however, is regarded as the maximum, in other words, a goal to which the plant operator may aspire.

COMPARISON OF BY-PRODUCT YIELDS

As to the yields of by-products obtainable in commercial practice, the writers hesitate to say what are high, low, or even average yields. For a given coal, the gas and other by-product yields may vary considerably, depending on the condition of the coal, on the rate of carbonization, on the total time the coke is allowed to remain in the oven or coking chamber before discharging, on leakages, etc. In vertical retorts, for example, where steaming is possible, the gas yield may be increased to as high as 2,000 cubic feet or more over and above the normal yield without steaming, and in by-product ovens where steaming is not practised the gas yield may be varied considerably according to will. Among the factors affecting the results, in addition to those just mentioned, are the extent to which tar is broken up into permanent gas and the amount of dilution of the make-gas with flue-gas, both of which, along with certain controlled variations in the rate of heating the charge, can be utilized to produce high gas yields when desired. The calorific value of the gas, which will vary according to variations in the yield, is dependent on the pressure within the oven and changes in this pressure can, therefore, be utilized to change both the quantity and quality of the gas. For example, from a coal yielding, under normal conditions, say 10,500 cubic feet of gas analysing 575 B.T.U. per cubic foot, a yield of 11,000 cubic feet of about 550 B.T.U. gas, and even as high as 12,000 cubic feet of 500 B.T.U. gas, can be produced by changes in operation without appreciably increasing the quantity of inerts in the gas. Increasing the gas yield by this method will, however, result in a noticeable decrease in the benzol yield recoverable from the gas.

With domestic coke as the main product, but with a normal yield of high heating value gas being of equal importance, the yield of commercial products to be expected per ton of a medium volatile matter content coal or coal mixture when carbonized in a standard (horizontal) by-product oven may be considered, for purposes of comparison, as follows:—

Coke, including breeze, at least 70 per cent by weight		1,400	pounds
Gas, 575 B.T.U. per cubic foot		10,500	cu. ft.
Ammonium sulphate (approximately)		20	pounds
Tar, water-free	(10 U.S. gallons)	8	Imp. gals.
Light oils from the gas	(3 U.S. gallons)	*2½	" "

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* With this light oil yield, the heating value of the gas would drop from 25 to 35 B.T.U. per cubic foot with a decreased gas yield of approximately 100 cubic feet per ton.

Accepting these yields as average and terming them "desired optimum" or " adopted standard ", a series of comparisons of the yields from the nine western Canadian coals, one with another and with the above standard may be made, as in Tables V to VIII inclusive.

TABLE V

Coke Results

(Comparison of yield, sulphur content, and calorific value of the cokes from the nine Canadian coals tested)

Coal used	Coke obtained				
	Yield		Calculated analysis		
	Weight %	Pounds per ton	Ash %	Sulphur %	B.T.U. per lb.
Adopted standard..........	70	1,400	10% or less	Less than 1·25%	13,000 or more
Coal Creek..............................	75·4	1,510	6·4	0·5	13,480
Michel..................................	75·5	1,510	6·3	0·6	13,300
Mountain Park...........................	71·9	1,440	10·7	0·5	12,810
Hillcrest...............................	73·2	1,465	14·6	0·5	12,280
Greenhill...............................	77·2	1,545	14·3	0·5	13,310
McGillivray.............................	77·7	1,555	20·6	0·7	11,320
Denison.................................	79·0	1,580	15·3	0·5	12,120
Corbin..................................	77·9	1,560	15·8	0·3	12,110
Luscar..................................	81·7	1,635	14·1	0·4	12,310

As just shown, the yield of coke from all nine Canadian coals exceeded the desired optimum of 1,400 pounds. This is accounted for by reason of the lower volatile matter contents of the coals used. With the last six coals, however, the increased coke yield was due in part to the higher ash contents.

TABLE VI

Gas Results

(Comparison of yield and heating value of the gas both with and without light oil recovery and also the hydrogen sulphide content of the unpurified gas)

Coal used	Volatile matter of dry coal %	Yield and B.T.U. per cu. ft. gas				Hydrogen sulphide grains per 100 cu. ft.
		Without light oil recovery		With light oil recovery		
		Cu. ft. per ton	B.T.U. per cu. ft.	Cu. ft. per ton	B.T.U. per cu. ft.	
Adopted standard.....	25 to 33	10,500	575	10,400	550	less than 300
Coal Creek.......................	27·7	10,970	590	10,850	560	84
Michel...........................	25·8	10,400	545	10,310	520	171
Mountain Park....................	31·9	10,870	585	10,730	550	182
Hillcrest........................	30·1	10,100	555	9,990	525	153
Greenhill........................	26·0	9,890	565	9,790	535	108
McGillivray......................	25·1	9,840	530	9,750	500	249
Denison..........................	24·0	9,310	550	9,220	525	122
Corbin...........................	24·7	9,790	525	9,700	500	67
Luscar...........................	20·6	9,910	525	9,850	505	55

Comments to be made on the results shown in Table VI concern the relation of the gas yield obtained to the volatile matter of the coals used and also the low hydrogen sulphide of the scrubbed gas. The gas yield, it is to be noted, was far from uniform for coals of equal volatile matter even when the volatile matter and gas yields are calculated to an equal ash or pure coal basis. Furthermore, Coal Creek and Mountain Park coals, with roughly 28 and 32 per cent volatile matter respectively, each showed gas yields in the neighbourhood of 10,900 cubic feet per ton in comparison with the 10,500 figure adopted as standard. The figures for the hydrogen sulphide content of the unpurified gas ranging from 55 to 249 grains per 100 cubic feet for the nine Canadian coals tested are also to be noted as coming below the minimum allowable quantity from standard gas coals, and indicate a saving in the cost of purifying the gas from these coals when coked alone or when blended either with one another or with imported coals. The analyses of the gases with their respective calculated densities are shown in Table VII, which results are on the basis of the gas exclusive of carbon dioxide and oxygen.

TABLE VII

Gas Analyses

(Exclusive of CO_2 and O_2)

Coals	Illuminants %	CO %	H_2 %	CH_4	N_2	Density (air=1)
Coal Creek	4·2	4·6	54·9	33·4	2·9	0·34
Michel	2·9	6·2	57·1	29·7	4·1	0·33
Mountain Park	4·1	7·8	54·4	32·3	1·4	0·35
Hillcrest	3·9	7·6	55·1	29·4	4·0	0·35
Greenhill	3·1	6·5	57·8	31·3	1·3	0·32
McGillivray	2·6	6·5	57·9	28·1	4·4	0·33
Denison	2·7	6·5	60·1	29·3	1·1	0·30
Corbin	2·5	7·7	57·9	28·0	3·9	0·33
Luscar	2·3	6·0	61·5	27·1	3·1	0·30

TABLE VIII

Comparison of the Tar, Light Oil, and Ammonia Yields from the Nine Canadian Coals Tested

Coal used	Tar		Light Oils		Ammonia as $(NH_4)_2SO_4$ lb. per ton
	Gallons per ton		Gallons per ton		
	Imp.	U.S.	Imp.	U.S.	
Desired optimum	8	10	2·5	3·0	20
Coal Creek	7·2	8·6	2·8	3·4	18
Michel	7·1	8·5	2·2	2·6	23
Mountain Park	8·8	10·5	3·3	4·0	21
Hillcrest	9·2	11·0	2·4	2·9	30
Greenhill	7·1	8·5	2·4	2·9	12
McGillivray	6·5	7·8	2·2	2·6	21
Denison	5·8	7·0	2·0	2·4	23
Corbin	5·7	6·8	2·0	2·4	23
Luscar	5·3	6·4	1·4	1·7	19

Reference to Table VIII shows that two of the Canadian coals gave tar yields higher than the adopted standard, while the average for all nine coals tested was only a little over one gallon less. As to light oils, two coals, viz., Coal Creek and Mountain Park, showed yields greater than the 2·5 (Imperial) gallons desired, while the yields from the other coals, with one exception, ranged from 2·0 to 2·4 gallons. In respect to yield of ammonium sulphate, it will be noticed that the average for eight out of the nine coals tested was over 20 pounds per ton, the figure adopted as standard.

COMPARATIVE VALUE OF SMALL- AND LARGE-SCALE COKING TESTS

The coke button produced in the volatile matter determination using a platinum crucible, although indicating whether a coal is non-coking, feebly coking, or strongly coking, is often at variance with the coke obtained on a larger scale in the laboratory and in commercial practice. Box coking tests in full-size ovens serve the double purpose of confirming laboratory indications of the coking properties of the coal or coals under examination, and for obtaining information as to how the coal will act in actual oven practice in respect to its swelling properties during the coking period and the subsequent shrinking properties of the coke. Thus, preliminary box tests are advisable for a coal which it is suspected will produce coke that will not shrink sufficiently to permit ready pushing from the oven. If the results are definitely unfavourable, the expense of a full-size oven test is thus eliminated and possible damage to the oven walls and consequent interference with plant operation avoided. Box coking tests, which are to be recommended when only small quantities of coal are available, cannot take the place of full-scale oven tests, when an accurate determination of the physical properties of the coke is required, as very erroneous ideas may be obtained from incorrectly conducted box tests. When properly made, however, box coking tests are considered by practical coke-oven operators to be of considerable value, and when correlated with the results of the laboratory tube test, afford the experienced observer a definite idea of the character and coking possibilities of the coal being tested.

SUMMARY

According to the grading as given in Section 1, p. 18, four of the nine coals tested produced a coke better than fair when coked alone; while all produced a good domestic coke when blended with 75 per cent of the imported coal used at that time at the Winnipeg plant. To this grading, which was according to appearance only, certain revisions are to be made when other criteria, such as (a) apparent specific gravity and shatter index, (b) ash content and fusibility of ash, and (c) yield of coke and other by-products as predicted by the laboratory tube test, are taken into account. The apparent specific gravity and shatter index figures for the cokes produced in the box tests, indicate that all the cokes obtained were good, which grading, however, is comparative only and subject to confirmation on a larger scale than allowable in the box tests.

Considering the average yields as shown in Section 2, p. 26, and bearing in mind that these yields may be varied according to different methods of operation as outlined above, the combined results of the box and laboratory coking tests on the nine Canadian coals tested may be summarized for each of the coals as follows:—

Coal Creek Coal. The yield of gas and coke from this coal was above the adopted standard, but the quantity of tar and ammonium sulphate was lower. The quantity of hydrogen sulphide in the gas was remarkably low and in this respect this coal is highly suitable for gas manufacture. The quality of the coke produced was exceptionally good and in respect to both physical and chemical properties equal to any coke at present in use in Canada for domestic purposes.

Michel Coal. The yields of gas and tar products from this coal were lower than optimum, but the quantity of coke obtained and the yields of ammonium sulphate were well above the adopted standard figure. The quantity of hydrogen sulphide present in the gas indicates low purification costs and is distinctly a factor in favour of the use of this coal. The quality of the coke produced from Michel coal was very good and equal to the best coke in use in Canada for domestic purposes. On account of the remarkably low ash in this coal it could also be used satisfactorily for blending purposes with higher ash coals to produce an average grade of coke.

Mountain Park Coal. The yield of coke from the sample tested, although not so high as from Coal Creek and Michel coals, was above the figure adopted as standard, and the gas and tar yields were well above the desired optimum. The sulphur in the gas was also notably low, as in the case of the previously mentioned coals. The physical properties of the coke produced were good and its quality, in general, equal to a number of cokes sold on the market for domestic use. From the results obtained it is evident that this coal would be suitable for coke and gas manufacture when coked alone, and the indications are that when blended with lower ash coals such as the two previously mentioned coals, it would produce highly satisfactory results.

Hillcrest Coal. The yield of gas from the sample tested was below the desired optimum, but the tar and sulphate yields were considerably above. The coke yield was well above the figure adopted as standard, but the quality of coke produced could be considered as fair only. This was in a large measure due to the ash content which was above that allowable in good quality domestic coke. Ash reduction in the coal prior to coking or blending would be necessary in order to employ this coal for coke manufacture. The results of blending with a low ash imported coal were highly satisfactory, the coke produced being within the desired chemical and physical specifications.

Greenhill Coal. The yields of by-products from the sample of this coal tested were considerably lower than the desired optimum, but a much greater coke yield was obtained. The structure of the coke produced was satisfactory, but its ash content was high. Preliminary reduction of the ash in the coal to 7 per cent would, however, produce a satisfactory domestic coke in respect to both physical and chemical characteristics. The quality of coke produced by blending this coal with the imported coal was good, but the ash was higher than allowable in high quality domestic coke.

McGillivray Creek Coal. The yield of coke from the sample of this coal was considerably above the figure adopted as standard, but the yields of gas and other by-products were low. The quality of the coke produced by coking this coal alone was fair and this grading was increased to good by blending. In both cases, however, the ash was higher than desired and it is evident that considerable additional reduction of ash is necessary for this coal to be used for a readily marketable domestic coke.

Denison Coke. The yields of gas and by-products from this coal were considerably lower than the desired optimum, but this was partly compensated for by the appreciably higher yield of coke. Denison coal when coked alone produced a rather high ash coke of fair quality, but when blended with a high-grade imported coal, a good quality coke of average ash content resulted.

Corbin Coal. The yields of gas and other by-products were considerably lower than the desired optimum, although the coke yield was considerably higher. The decidedly low figure for hydrogen sulphide in the gas indicates low purification costs and is a factor in favour of this coal. The high ash content and the poor agglutinating properties militate against the use of this coal alone for the production of a domestic coke, but the results of blending were quite favourable and show that proportions of this coal may be blended with a low ash coal to produce average quality coke for domestic use.

Luscar Coal. The coke yield from this coal was considerably greater than the figure adopted as standard, but both gas and by-product yields were low. This coal has an exceptionally low sulphur content which is a distinctly favourable characteristic. On account of its high ash content it is evident, however, that Luscar coal would not find extensive use for the production of by-product coke without blending, but when used in conjunction with a low ash coal, satisfactory results could be obtained.

CONCLUSIONS

The results of box coking tests in by-product ovens coupled with laboratory tests in a special high-temperature carbonization apparatus show that three of the nine western Canadian coals examined, viz., two from British Columbia and one from Alberta, are suitable individually for the production of high quality domestic coke and commercial yields of gas and other by-products. The results further indicate that the remaining six coals will each produce a satisfactory domestic coke when blended with a high quality coking coal. For use in plants where blending is not practised, however, a considerable further reduction in ash content is necessary before any of these (six) coals can be seriously considered for the commercial production of domestic coke, gas, and other by-products. The low sulphur content and the comparatively high ash fusibility temperature of all the nine coals tested are factors in their favour, and particularly in the case of the three coals referred to above, namely, Mountain Park coal from the Mountain Park area, Alberta, and Michel and Coal Creek coals from the Crowsnest Pass area, British Columbia.

III

LOW-TEMPERATURE CARBONIZATION—CONTINUATION OF TESTS ON CANADIAN BITUMINOUS COALS

R. A. Strong

Two previous papers on the subject of low-temperature carbonization of bituminous coals appeared in " Investigations of Fuels and Fuel Testing " for 1925 and 1926 respectively. The first paper, which dealt with three coals only, compared yields of products obtained at different temperatures using different methods, such as regular carbonization, carbonization in the presence of steam, and carbonization with circulation of hot gases. The second paper dealt with ten coals selected from the various bituminous fields of Canada, and carbonized according to the regular carbonization method. The present paper is a continuation of the second and includes four coals not previously examined, which were obtained at the same time as the ten Canadian coals just referred to, a list of which is as follows:—

Laboratory No.	Known in this paper as	Origin
4029A......	Stellarton coal*.........	From Acadia Coal Co., MacGregor seam, Albion Collieries Stellarton, N.S.
4030.......	Minto coal*............	From Rockwell Coal Co., Ltd., Minto, N.B.
4033.......	Luscar coal............	From Luscar Collieries, Ltd., Mountain Park, Alberta.
4035.......	Mountain Park coal.....	From Mountain Park Collieries, Ltd., Mountain Park, Alberta.

* The Stellarton and Minto coals, it will be noticed, bear the same names as two of those previously reported but in this case the samples were obtained from different seams.

APPARATUS AND METHOD EMPLOYED

The apparatus used in these tests was identical with that previously employed and described.[1] It consists essentially of a circular retort with a metal core for the purpose of limiting the thickness of the charge. The retort is immersed in a bath of molten lead, the temperature of which is carefully controlled so as not to exceed the required 600° C. A condensing train, meter, and gas holder complete the equipment, the layout of which is shown in Figure 2. The method employed for the tests was identical with that previously published and consisted of charging 2,000 grammes of coal in the retort, which is lowered into the previously heated lead bath. The temperature of the bath is then brought up to the required 600° C. as quickly as possible and held at this point until the completion of the run.

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[1] "Low-temperature Carbonization—Continuation of Tests on Canadian Bituminous Coals"; Invest. of Fuels and Fuel Testing, 1926, p. 12. Mines Branch, Dept. of Mines, Canada,

PLATE X

A

B

C

D

A. Coke from Stellarton coal.

B. Coke from Minto coal.

C. Coke from Luscar coal.

D. Coke from Mountain Park coal.

Duplicate runs were made on all coals and the products obtained joined and analysed. The tar was first dehydrated and weighed and reported as dry tar, after which it was treated as outlined in the two former reports, the details of which are shown in Figure 3.

The results obtained are shown in Tables IX to XIX. Table IX contains analyses of the general samples taken from the lot shipment of each sample as obtained from the mines and includes a proximate analysis, both on the " as received " and " dry basis." The sulphur content, calorific value, and ultimate analysis of each sample are shown. Table X is a summary of the tests and includes a proximate analysis of the sample as charged, an analysis of the coke, the quantity and heating value of the gas obtained, the amount of tar and light oils together with their gravities, and the ammonium sulphate yields. Tables XI and XII are weight and heat balances respectively of the products expressed as percentages, while the analyses of the tars and gases are shown in Tables XIII and XIV. Table XV shows the percentage of tar acids, pyridine bases, and washed neutral oil available from each of the tar fractions, as obtained

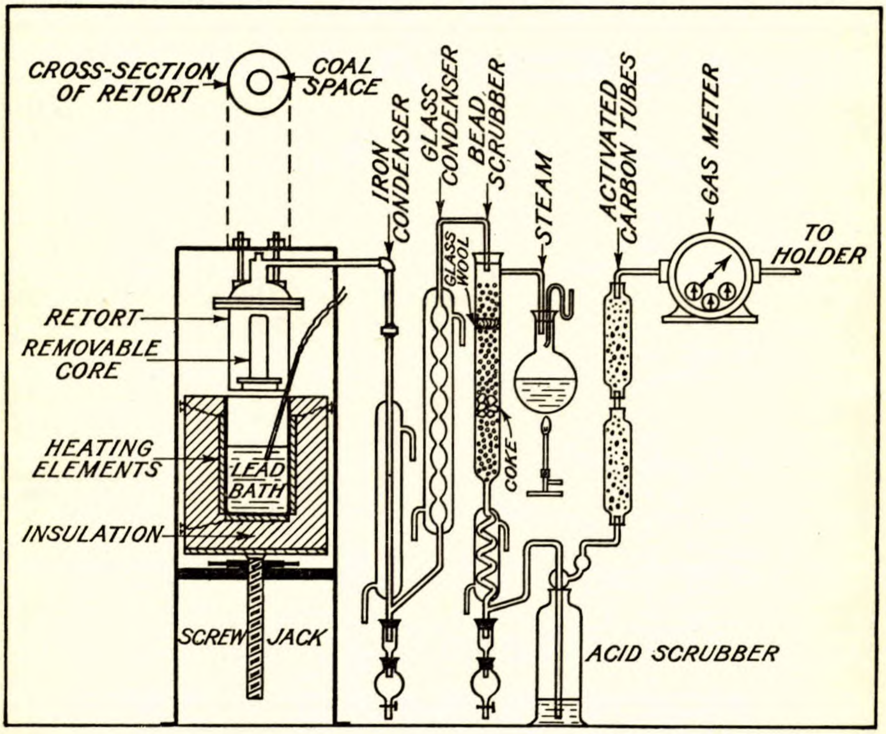

Figure 2. Diagrammatic sketch of lead bath apparatus for low-temperature carbonization.

from the distillation of the tar. The distillation ranges of these combined tar acids and neutral oils are shown in Tables XVI and XVII. The remaining two tables, i.e. XVIII and XIX, show the yield, specific gravity, etc., of the neutral oil fractions and the amount of these products as percentages of the total tar obtained.

DISCUSSION OF RESULTS

The cokes obtained varied considerably in appearance as is indicated in Plates XA to XD. In the case of Minto and Mountain Park coals, the charge in the retort after heating was very much swollen and the coke fairly porous. The other two coals, namely Stellarton and Luscar, contracted considerably during carbonization and the coke appeared to be dense and quite hard. In both cases small particles which apparently had not fused were present, from which it is evident that neither of these coals would produce as good a low-temperature coke in respect to structure as that obtainable from the other coals tested.

The analyses of the various cokes are shown in Table X. As will be noted all the cokes were quite high in ash and it would be necessary to reduce the ash content of all these coals by washing before they could be considered suitable for the production of a coke for domestic use. The volatile matter remaining in the coke averaged 6·7 per cent, varying from 6·2 to 7·4 per cent.

The following table compares the volatile matter contents of the coal and coke and also shows the yield in pounds per ton.

Coke used	Volatile matter		Yield of coke (lb. per ton)
	Coal	Coke	
Stellarton	28·1	6·8	1,522
Minto	31·3	6·9	1,480
Luscar	21·2	7·4	1,700
Mountain Park	29·8	6·2	1,500

The calorific value of the cokes in all cases was less than that of the coal from which it was produced. On account of the high ash, these cokes are considerably lower in heating value than the average gas or by-product coke usually sold for domestic purposes. The following table compares the calorific value of the coal and coke.

Coal used	Calorific value, B.T.U. per pound		Difference	Decrease
	Coal	Coke		
Stellarton	12,767	12,248	−519	4·1
Minto	12,699	12,043	−656	5·2
Luscar	13,367	12,535	−832	6·2
Mountain Park	13,158	12,418	−740	5·6

EXAMINATION OF TAR OILS

The tars obtained from the distillation of the coals were treated according to the method outlined in the two previous reports mentioned above, the flow-sheet of the method being shown in Figure 3. The tar was first completely dehydrated and then distilled at atmospheric pressure in a Hempel flask to 275° C. with one cut at 225° C. A second distillation was then made on the residue under reduced pressure, i.e. 40 mm., to 300° C. The three fractions from the complete distillation were treated for the removal of the tar acids and pyridine bases, and the resulting neutral oils distilled.

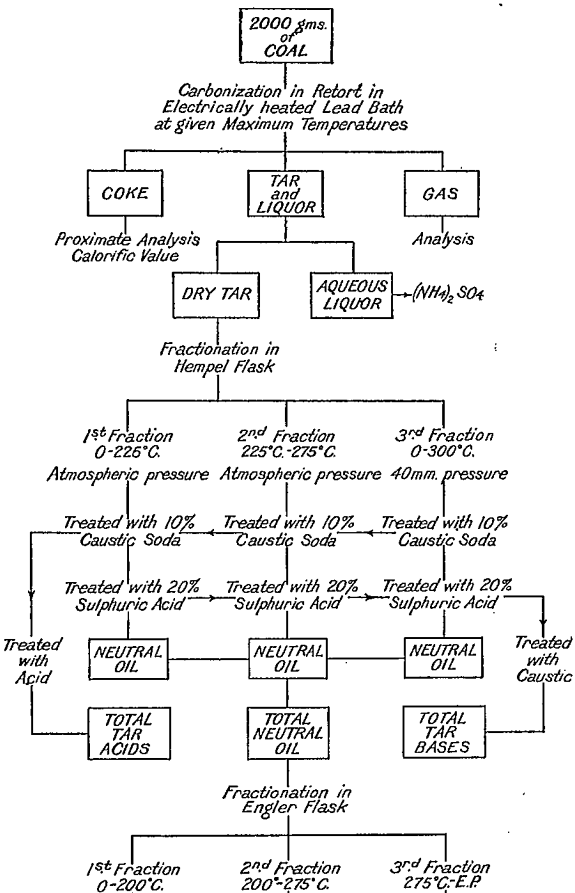

Figure 3. Flow-sheet of products from low-temperature carbonization.

The yields of tar from the four coals examined were, with one exception, low; this agrees with the results previously reported from ten Canadian bituminous coals, from which it would seem that the field for low-temperature carbonization from the standpoint of oil yield is decidedly limited in Canada. The following table shows the yields from the four coals tested.

Coal used	Tar oils obtained		
	Per cent	Imp. gallons per ton	Specific gravity at 60° F.
Stellarton	7·1	14·1	1·007
Minto	11·4	22·1	1·033
Luscar	4·2	8·1	1·041
Mountain Park	9·6	18·5	1·038

In all cases, the tar obtained was typical low-temperature tar in respect to colour, fluidity, and odour, and the gravity of all four tars was greater than 1·000.

The light oils were stripped from the gas by scrubbing with activated charcoal and were later recovered by distilling the charcoal with glycerine. The table given below shows the quantity of light oils obtained from each coal, in gallons per ton, and their gravities.

Coal used	Per cent	Gallons per ton	Specific gravity at 15·5° C.
Stellarton	0·9	2·5	0·709
Minto	0·8	2·1	0·705
Luscar	0·5	1·3	0·698
Mountain Park	0·6	1·6	0·701

EXAMINATION OF GAS

The gas from the tests was collected in a holder and an average sample taken, representative of the duplicate runs. The analyses were made with the Burrell gas-analysis apparatus, using the combustion method with oxygen for the determination of hydrogen and methane. The yield of gas varied from 3,450 to 4,250 cubic feet per ton with heating values from 570 to 650 B.T.U. per cubic foot. The methane content of the gas varied from 40 to 55 per cent, the lowest result being obtained with Mountain Park coal, which had a correspondingly high hydrogen content, i.e. 39 per cent. The hydrogen content of the gases from the other three coals varied from 19 to 29 per cent. The following table gives the volatile content of the coal with its gas yield together with the various percentages of methane and hydrogen.

Coal used	Volatile matter content of coal, %	Gas obtained		
		Cu. ft. per ton	Methane, %	Hydrogen, %
Stellarton	28·1	4,234	53·0	24·9
Minto	31·3	3,468	55·2	18·8
Luscar	21·2	3,458	52·1	29·2
Mountain Park	29·8	4,251	39·6	38·8

AQUEOUS DISTILLATE

The aqueous distillate, when separated from tar, was, as previously explained, joined with the acid from the scrubber and, after making up to a definite volume, a sample was taken for ammonia determination. The results showed a variation in ammonium sulphate from 4·3 to 19·1 pounds per ton of coal carbonized, the highest yield being obtained from the Stellarton coal. Although this sample was taken from the MacGregor seam, it conforms with the results previously obtained on Stellarton coal from the Foord seam, and it is, therefore, quite apparent that a comparatively high ammonia yield is a characteristic of the Stellarton coal. The ammonia yield from the other three coals was low.

TREATMENT OF LOW-TEMPERATURE TAR OILS

The method adopted for the treatment of the tar oils was identical with that described in previous reports. The specific gravity of the three fractions obtained was determined, after which they were treated with caustic potash for removal of the tar acids, and with dilute sulphuric acid for the extraction of the pyridine bases. The remaining neutral oil fractions were joined and distilled in an Engler flask using a 100 c.c. portion, cuts being made at 200° and 275° C. The tar acids were removed from the caustic solution and where sufficient was obtainable, a distillation was made. The detailed results of the tar distillation are shown in Table XIII, and of the neutral oils and tar acids in Tables XVI and XVII respectively.

The following table compares the distillation results of the tar from the four coals showing the yield and gravity of the different fractions.

Coal used	Fraction up to 225° C.		Fraction 225° to 275° C.		Fraction up to 300° C. (vacuum)	
	%	Sp. gr. at 60° F.	%	Sp. gr. at 60° F.	%	Sp. gr. at 60° F.
Stellarton	33·3	0·877	12·6	0·962	27·4	1·040
Minto	23·0	0·887	13·7	0·972	14·7	1·018
Luscar	23·8	0·879	13·5	0·969	13·5	1·034
Mountain Park	21·0	0·879	15·0	0·958	18·3	1·010

Tar Acids

The quantity of tar acids recovered was measured, and the specific gravity determined after which a distillation was made, the results of which are shown in detail in the appended tables. The following table shows the yield of tar acids and their respective gravities.

Coal used	Tar acids	
	Volume of original tar	Sp. gr. at 60° F.
	%	
Stellarton	18·5	1·066
Minto	13·3	1·051
Luscar*	10·0	....
Mountain Park	13·0	1·052

*In the case of the tar from Luscar coal, an insufficient quantity was recovered for proper determination of either gravity or boiling range.

Pyridine Bases

The small amount of bases present in the low-temperature tar oils examined did not warrant their recovery and examination. The oils were treated with a 20 per cent solution of sulphuric acid and the contraction due to pyridine bases noted. The results are shown in Table XV.

Neutral Oils

The various fractions obtained from the distillation of the tar were each, as indicated, treated with caustic soda and sulphuric acid and the resulting neutral oils joined and fractionated in an Engler flask, as previously described. The distillation ranges of neutral oils as obtained from these four coals are shown in Table XVI. It will be noted that the Minto coal yields a different result from that previously obtained.[1] The Luscar coal yielded such a small quantity of tar that only 50 c.c. of neutral oil was available for distillation and the figures submitted are, therefore, not entirely comparable. The remaining two coals, i.e. Stellarton and Mountain Park, conform in the neutral oil distillation results to the average results obtained on the various bituminous coals previously tested. The yields of the various fractions from the distillation of the neutral oils are shown in Table XIX. The following table compares the total neutral oil content as obtained from the tars of the four coals examined.

Coal used	Neutral oil	
	Volume of original tar	Imp. gals. per ton
	%	
Stellarton	52·1	7·4
Minto	36·4	8·1
Luscar	36·5	3·0
Mountain Park	38·7	7·2

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[1] "Low-temperature Carbonization of Bituminous Coals"; Invest. of Fuels and Fuel Testing, 1925, p. 80; Mines Branch, Dept. of Mines, Canada.

Unsaturated Compounds

The fractions obtained from the distillation of the neutral oils were treated with concentrated sulphuric acid in order to determine the quantity of " unsaturates " present, the results obtained being shown in Table XVIII. From 60 to 75 per cent of the light oil fraction, i.e. 0° to 200°C., was found to be insoluble in the acid solution. The fraction boiling between 200° and 275°C. shows a variation of 56 to 79 per cent insoluble, while the heavy oil fraction, i.e. 275° to the end point, varies from 29 to 56 per cent.

TABLE IX

Analyses of Coals: Low-temperature Carbonization Tests

Name of coal carbonized	Stellarton	Minto	Luscar	Mountain Park
Laboratory No.	(4029A)	(4030)	(4033)	(4035)
Proximate Analysis (as received)—				
Moisture per cent	1·8	1·0	0·7	1·7
Volatile matter "	27·2	31·8	20·5	29·4
Ash "	12·7	14·5	13·3	12·1
Fixed carbon "	58·3	52·7	65·5	56·8
Calorific value, B.T.U. per lb.	12,897	12,892	13,288	13,259
Proximate Analysis (dry basis)—				
Volatile matter per cent	27·7	32·1	20·6	29·9
Ash "	12·9	14·7	13·4	12·4
Fixed carbon "	59·4	53·2	66·0	57·7
Calorific value, B.T.U. per lb.	13,135	13,023	13,383	13,493
Ultimate Analysis (dry basis)—				
Carbon per cent	73·6	70·6	76·8	75·7
Hydrogen "	4·7	4·9	4·2	4·8
Ash "	12·9	14·7	13·4	12·4
Nitrogen "	1·8	0·8	1·1	1·2
Sulphur "	1·8	6·2	0·3	0·7
Oxygen (by difference) "	5·2	2·8	4·2	5·2

TABLE X

Summary of Low-temperature Carbonization Tests

(Yields per 2,000 pounds of coal as charged)

Name of coal carbonized	Stellarton	Minto	Luscar	Mountain Park
Coal—				
Proximate Analysis (as charged)—				
Moisture per cent	2·4	1·2	1·2	1·9
Volatile matter "	28·1	31·3	21·2	29·8
Ash "	12·6	14·8	12·9	12·1
Fixed carbon "	56·9	52·7	64·7	56·2
	100·0	100·0	100·0	100·0
Sulphur "	1·7	6·2	0·3	0·7
Calorific value, B.T.U. per lb.	12,767	12,699	13,367	13,158
Coke—				
Percentage of coal carbonized	76·1	74·0	85·0	75·0
Proximate Analysis—				
Volatile matter per cent	6·8	6·9	7·4	6·2
Ash "	16·8	19·8	16·2	16·7
Fixed carbon "	76·4	73·3	76·4	77·1
	100·0	100·0	100·0	100·0
Sulphur "	1·6	5·0	0·3	0·6
Calorific value, B.T.U. per lb.	12,248	12,043	12,535	12,418
Gas—				
Cubic feet per ton	4,234	3,468	3,458	4,251
B.T.U. per cu. ft. (calculated)	645	655	638	570
Density (air=1)	0·58	0·63	0·52	0·47
Tar (water-free)—				
Imperial gallons per ton	14·1	22·1	8·1	18·5
Specific gravity at 15·5° C.	1·007	1·033	1·041	1·038
Light Oils—				
Imperial gallons per ton	2·5	2·1	1·3	1·6
Specific gravity at 15·5° C.	0·709	0·705	0·698	0·701
Liquor (aqueous)—				
Imperial gallons per ton	14·2	9·2	7·4	13·6
Ammonium sulphate, pounds per ton	19·1	4·3	7·9	10·5

TABLE XI

Weight Balance—Low-temperature Carbonization Tests

(Parts by weight per 100 parts of coal charged)

Name of coal carbonized	Stellarton	Minto	Luscar	Mountain Park
Products—				
Coke	76·1	74·0	85·0	75·0
Tar	7·1	11·4	4·2	9·6
Light oil	0·9	0·8	0·5	0·6
Liquor	7·1	4·6	3·7	6·8
Gas	9·3	8·3	6·8	7·5
Loss	+0·5	0·9	+0·2	0·5

TABLE XII

Thermal Balance—Low-temperature Carbonization Tests

(Thermal value of products as percentages of that in coal as charged)

Name of coal carbonized	Stellarton	Minto	Luscar	Mountain Park
Products—				
Coke	73·0	70·2	79·7	70·8
Tar	9·3	15·2	5·1	12·4
Gas	0·7	8·9	8·3	9·2
Loss	17·0	5·7	6·9	7·6

ERRATA

Table XII, under "Stellarton" should read—

Coke	73.0
Tar	9.3
Gas	10.7
Loss	7.0

TABLE XIII

Analyses of Tars: Low-temperature Carbonization Tests

Name of coal carbonized.........	Stellarton			Minto			Luscar			Mountain Park		
Tar (water-free)—												
Specific gravity at 15·5° C......	1·007			1·033			1·041			1·037		
B.T.U. per pound..............	16,798			16,884			16,308			17,032		
	% Volume		Specific gravity at 60° F.	% Volume		Specific gravity at 60° F.	% Volume		Specific gravity at 60° F.	% Volume		Specific gravity at 60° F.
	Fractional	Cumulative		Fractional	Cumulative		Fractional	Cumulative		Fractional	Cumulative	
Distillation at atmospheric pressure—												
First drop at..................	45° C.	....	....	50° C.			48° C.	....	....	60° C.	....	....
Fraction cut at 75° C..........	3·0	3·0	....	1·8	1·8	....	1·5	1·5	....	0·7	0·7	....
" 100° C..........	1·3	4·3	....	1·3	3·1	....	6·4	7·9	....	1·6	2·3	....
" 125° C..........	1·7	6·0	....	1·4	4·5	....	0·3	8·2	....	0·5	2·8	....
" 150° C..........	5·7	11·7	....	2·8	7·3	....	1·2	9·4	....	2·3	5·1	....
" 175° C..........	4·8	16·5	....	4·0	11·3	....	4·7	14·1	....	4·0	9·1	....
" 200° C..........	6·8	23·3	....	5·0	16·3	....	4·4	18·5	....	4·9	14·0	....
" 225° C..........	10·0	33·3	0·877	6·7	23·0	0·887	5·3	23·8	0·879	7·0	21·0	0·879
" 250° C..........	5·0	38·3	....	6·5	29·5	....	5·9	29·7	....	7·0	28·0	....
" 275° C..........	7·6	45·9	0·962	7·2	36·7	0·972	7·6	37·3	0·969	8·0	36·0	0·958
Distillation at 40 mm. pressure—												
Fraction cut at 175° C..........	2·2	2·2	....	....	....	....	....	....	....	....	....	....
" 200° C..........	5·2	7·4	....	....	....	....	....	....	....	....	....	....
" 225° C..........	4·8	12·2	....	....	....	....	....	....	....	....	....	....
" 250° C..........	5·6	17·8	....	1·0	1·0	....	0·9	0·9	....	1·8	1·8	....
" 275° C..........	2·2	20·0	....	5·7	6·7	....	3·8	4·7	....	3·8	5·6	....
" 300° C..........	7·4	27·4	1·040	8·0	14·7	1·018	8·8	13·5	1·034	12·7	18·3	1·010
Pitch (by weight) per cent.......	29·8			51·3			49·1			48·9		

TABLE XIV

Analyses of Gases—Low-temperature Carbonization Tests

Name of coal carbonized		Stellarton	Minto	Luscar	Mountain Park
Density (air=1)		0·58	0·63	0·52	0·47
Carbon dioxide	per cent	4·2	10·2	4·2	2·8
Illuminants	"	1·7	2·0	0·8	1·9
Oxygen	"	1·1	1·9	3·7	2·5
Carbon monoxide	"	2·5	3·2	2·9	5·8
Methane	"	53·0	55·2	52·1	39·6
Hydrogen	"	24·9	18·8	29·2	38·8
Nitrogen	"	12·6	8·7	7·1	8·6
B.T.U. per cu. ft.—					
Net		577	587	569	508
Gross		645	655	638	570

TABLE XV

Crude Tar Acids, Bases and Neutral Oil Content of Tars from Low-temperature Carbonization Tests

Name of coal carbonized		Stellarton	Minto	Luscar	Mountain Park
Fraction I: 0°–225° C. (atmos. pressure)—					
Tar acids by alkali treatment	per cent	26·6	25·0	24·7	27·0
Pyridine bases by acid treatment.	"	1·7	1·5	3·7	1·6
Washed neutral oil	"	71·7	73·5	71·6	71·4
Fraction II: 225°–275° C. (atmos. pressure)—					
Tar acids by alkali treatment	per cent	29·4	30·0	17·4	28·9
Pyridine bases by acid treatment.	"	2·9	2·5	13·0	4·4
Washed neutral oil	"	67·7	67·5	69·6	66·7
Fraction III: 0°–300° C. (40 mm. pressure)—					
Tar acids by alkali treatment	per cent	21·6	25·0	13·0	16·4
Pyridine bases by acid treatment..	"	6·8	2·3	13·0	9·1
Washed neutral oil	"	71·6	72·7	74·0	74·5

TABLE XVI

Distillation Range of Neutral Oils from Low-temperature Carbonization Tests

Name of coal carbonized	Stellarton	Minto	Luscar*	Mountain Park
Specific gravity at 15·5° C.	0·906	0·909	0·924	0·913
Distillation range—	° C.	° C.	° C.	° C.
1st drop	85	60	75	90
10 per cent vol.	132	110	125	147
20 " "	160	137	147	178
30 " "	188	161	170	205
40 " "	220	190	190	228
50 " "	253	220	225	254
60 " "	278	245	252	270
70 " "	307	257	268	285
80 " "	340	277	282	305
90 " "	368	309	313	332
End point	398	330	325	370

* Only 50 c.c. available for this distillation—100 c.c. generally used.

TABLE XVII

Distillation Range of Tar Acids from Low-temperature Carbonization Tests

Name of coal carbonized	Stellarton	Minto	Mountain Park
Specific gravity at 15·5° C.	1·066	1·051	1·052
Distillation range—	° C.	° C.	° C.
10 per cent volume	205	198	210
20 " "	210	211	212
30 " "	215	216	214
40 " "	224	222	217
50 " "	232	229	222
60 " "	253	244	224
70 " "	299	256	234
80 " "	339	272	266
90 " "	359	303	284
End point	360	315	290
Specific gravity of tar acids	1·061	1·051	1·057

TABLE XVIII

Yield, Specific Gravity, Etc., of Neutral Oil Fractions

Name of coal carbonized	Stellarton	Minto	Luscar	Mountain Park
Light oil (0°–200° C.) per cent	34·0	45·0	42·0	28·0
Specific gravity at 15·5° C.	0·817	0·834	0·850	0·831
Insolubility in conc. H_2SO_4 per cent	60	60	61	74
Middle oil (200°–275° C.) per cent	25·0	34·0	33·0	36·0
Specific gravity at 15·5° C.	0·901	0·937	0·949	0·904
Insolubility in conc. H_2SO_4 per cent	56	62	68	79
Heavy oil (275° C.–E.P.) per cent	39·5	19·5	22·0	34·5
Specific gravity at 15·5° C.	0·985	0·988	1·009	0·969
Insolubility in conc. H_2SO_4 per cent	29	35	42	56

TABLE XIX

Yields of Crude Tar Oils and Fractions

Name of coal carbonized	Stellarton		Minto		Luscar		Mountain Park	
	Tar (vol.)	Imp. gals. per ton	Tar (vol.)	Imp. gals. per ton	Tar (vol.)	Imp. gals. per ton	Tar (vol.)	Imp. gals. per ton
	%		%		%		%	
Crude dry tar oil	....	14·1	....	22·1	....	8·1	....	18·5
Fraction (0°–225° C.)	33·3	4·7	23·0	5·1	23·8	1·9	21·0	3·9
Fraction (225°–275° C.)	12·6	1·8	13·7	3·0	13·5	1·1	15·0	2·8
Fraction (0°–300° C. vacuum)	27·4	3·9	14·7	3·2	13·5	1·1	18·3	3·4
Neutral oil—								
Fraction (0°–225° C.)	23·9	3·4	16·7	3·7	17·1	1·4	15·0	2·8
Fraction (225°–275° C.)	8·6	1·2	9·0	2·0	9·4	0·8	10·0	1·9
Fraction (0°–300° C. vacuum)	19·6	2·8	10·7	2·4	10·0	0·8	13·7	2·5
Tar acids from all three fractions	18·5	2·6	13·3	2·9	10·0	0·8	13·0	2·4
Tar acids (recovered)	17·8	2·5	12·8	2·8	8·5	0·7	13·0	2·4
Tar bases from all three fractions	3·1	0·4	1·0	0·2	4·4	0·4	2·7	0·5
Light neutral oil (0°–200°C.)	14·3	2·0	16·4	3·6	15·3	1·2	10·8	2·0
Middle neutral oil (200°–275° C.)	10·5	1·5	12·4	2·7	12·0	1·0	13·9	2·6
Heavy neutral oil (275°–E.P.)	16·6	2·3	7·1	1·6	8·0	0·6	13·4	2·5

IV

ANALYSES OF SOLID FUELS

Compiled by J. H H. Nicolls

The solid fuel analyses compiled here are tabulated under the three following group headings:—

(1) Solid fuels occurring in Canada.
(2) Coal samples submitted by the Department of Soldiers' Civil Re-establishment.
(3) Miscellaneous solid fuels.

The first group of fuels (Table XX) contains a number of "mine" or "prospect" samples, collected by technical officers of either the Federal or Provincial governments. The "mine" samples were procured from deposits already under development; the "prospect" samples from deposits as yet undeveloped. A large number of "commercial" samples occur in the first group; each of these is considered to be representative of the corresponding product as shipped from the mine.

As a general rule "mine" and "prospect" samples contain less ash and have higher calorific values than would the corresponding "commercial" samples. This is due to the fact that, in ordinary mining practice, it is very difficult to exclude impurities as thoroughly as would be done in collecting the small "mine" samples. Therefore, in using the tables following in connexion with the sale or purchase of coal, care should be taken to note whether the samples are "mine" or "commercial" (which general term includes "slack", "run-of-mine", and the various sizes of screened coal), and to judge therefrom whether any particular coal as shipped from the mine could reasonably be expected to have as good an analysis as that given in the table. It should also be realized that, generally speaking, "slack" coal will contain more moisture and ash and have a lower calorific value than the corresponding screened coal, and that "run-of-mine" coal will be intermediate between the two.

The second group of fuels (Table XXI) consists entirely of bituminous coals purchased by the Department of Soldiers' Civil Re-establishment for use in the heating plants of their various hospitals. These include both Canadian and United States coals. They are all "commercial" samples, and consist principally of "slack" coal. The samples were collected entirely by the engineers at the various heating plants, following instructions sent out by their headquarters after consultation with the staff of the Fuel Testing Laboratories. According to the procedure employed in reporting these samples to the D.S.C.R., only the moisture contents (which may vary with weather conditions) are shown on the "as-received" basis, the remainder of the analyses being reported on the "dry" basis in order to simplify comparisons between the different coal samples.

The third group of fuels (Table XXII) consists of imported coals, such as are sold by local dealers either for private residences or public buildings. In addition, it includes a considerable number of cokes recently obtained from various Ottawa dealers, most of which were made in Canada, though nearly all with coals from the United States. These are all " commercial " samples. In addition, the third group contains some processed fuels and a sample of hardwood charcoal such as is used for kindling.

Tables XXIII and XXIV contain the screen analyses of a large number of the samples belonging to the third group of fuels. There is a certain ambiguity as to the exact definition of the sizes named, but it is believed that the screen sizes as used in the headings of the tables are approximately correct. Wherever possible, the sizes to which the various samples are supposed to correspond are given, and it will be seen that the nomenclature is somewhat erratic. This is particularly noticeable in the coke samples. Not only do the designated samples fail in many cases to correspond with the screen sizes accepted here as standard, but also they do not agree among themselves.

Wherever possible, the exact date of sampling is given, or at least the month during which the sample was taken. However, in some few cases this information was not available, and the dates upon which the samples were received at the laboratory are shown.

The following notes explain abbreviations in the tables, and may be of assistance in studying them.

(*a*) Figures in columns " R " refer to fuels as received; in columns " AD " to air-dried fuels; and in columns " D " to those dried at 108° C. It may be generally accepted that the fuels were analysed as received, except in the instances where the " AD " columns are included. In such cases the fuels were analysed following air-drying in the standard apparatus.[1] The analyses of the high moisture " slack " coals do not include the " AD " column, since this information was not considered to be of any particular interest, although it is obvious that the fuels could not have been ground for analysis without previous drying.

(*b*) In certain instances more than one sample number will be observed at the head of a column. In such cases the analysis shown is the average of the analyses of the samples enumerated.

(*c*) The " coking properties " described were obtained by heating one-gramme samples in closed platinum crucibles during the determination of volatile matter. These serve only as indications of the cokes to be expected from commercial ovens, and may occasionally be somewhat misleading.

The analyses reported below were carried out under the supervision of the writer, according to the general directions of the Superintendent of the Fuel Testing Laboratories. The samples were prepared for analysis by W. Kritsch, laboratory assistant, who also carried out the screen analyses. Proximate analyses for moisture, ash, and volatile matter were made by C. B. Mohr, G. E. LeWorthy, K. W. Bowles, and C. J. Coleman; sulphur determinations by C. B. Mohr and G. E. LeWorthy; and calorific value and nitrogen determinations principally by J. L. Bowlby. C. B. Mohr also assisted in checking the results of the analyses and in the reporting of the same.

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[1] Report of Scientific and Industrial Research Council of Alberta, 1923, p. 39.

TABLE XX

Analyses of Solid Fuels Occurring in Canada

	Dominion Coal Co., Ltd. (Besco), Glace Bay, Nova Scotia																	
—	Supplied to Ottawa Public School Board				Supplied to Fuel Testing Station through Department of Public Works												Supplied to Ottawa Civic Hospital	
Sample No.	4342		4343		4154		4432		4481		4528		4719		4739		4174	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																		
Moisture........per cent	2·8	....	3·6	....	3·0	....	4·9	....	5·1	....	6·0	....	5·6	....	9·1	....	2·8	....
Ash "	8·5	8·8	7·9	8·2	9·1	9·4	8·9	9·3	9·1	9·6	8·7	9·2	8·5	9·0	8·2	9·0	8·8	9·1
Volatile matter "	33·3	34·2	36·7	38·1	32·6	33·6	32·5	34·2	32·0	33·7	32·2	34·3	32·3	34·3	30·9	34·0	34·0	34·9
Fixed carbon "	55·4	57·0	51·8	53·7	55·3	57·0	53·7	56·5	53·8	56·7	53·1	56·5	53·6	56·7	51·8	57·0	54·4	56·0
Ultimate Analysis—																		
Sulphur........per cent	2·9	2·9	2·4	2·5	2·9	3·0	3·5	3·6	3·4	3·5	3·2	3·4	2·9	3·1	3·1	3·5	3·1	3·2
Calorific Value—																		
Calories per gramme, gross	7,450	7,670	7,380	7,660	7,380	7,610	7,180	7,560	7,160	7,550	7,230	7,690	7,230	7,660	6,940	7,640	7,380	7,600
B.T.U. per pound, gross	13,410	13,800	13,280	13,780	13,280	13,700	12,930	13,600	12,890	13,590	13,010	13,840	13,010	13,780	12,500	13,760	13,290	13,680
Fuel ratio	1·65		1·40		1·70		1·65		1·70		1·65		1·65		1·70		1·60	
Coking properties	Good		Good		Fair to good		Fair to good		Fair to good		Good		Fair to good		Good		Good	
Designation of coal	Run-of-mine				Run-of-mine												Slack	
Kind of sample	Commercial				Commercial; 10 or 12 tons monthly												Commercial	
Taken by	Public School Board officials				Staff of Fuel Testing Laboratories												Hospital engineers	
Date of sampling	August, 1927				During April, 1927		During Oct., 1927		During Nov., 1927		During Dec., 1927		During Jan., 1928		During Feb., 1928		April, 1927	

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

——	Coal from 3 miles north of Belmont station, Colchester county, Nova Scotia		Coal from near Newcastle Bridge, Queens county, New Brunswick		Coal from near Albrite, Sunbury county, New Brunswick		Peat from Tourbe, Ltée., Garneau, Quebec				Manitoba and Saskatchewan Coal Co., Ltd., Bienfait, Saskatchewan, sec. 10, tp. 2, R. 6, W. 2 mer.		
							Oven-dried		Air-dried and oven-dried				
Sample No.	4156		4327		4328		4223		4223A		4168		
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	AD	D
Proximate Analysis—													
Moisture per cent	1·4	....	2·0	....	5·2	....	12·4	....	11·6	....	33·8	20·1	....
Ash "	33·8	34·3	11·9	12·1	7·5	7·9	3·0	3·4	2·2	2·5	7·0	8·4	10·5
Volatile matter "	28·8	29·2	32·6	33·3	34·2	36·1	58·1	66·3	58·7	66·4	27·0	32·6	40·8
Fixed carbon "	36·0	36·5	53·5	54·6	53·1	56·0	26·5	30·3	27·5	31·1	32·2	38·9	48·7
Ultimate Analysis—													
Sulphur per cent	5·8	5·8	5·2	5·3	1·5	1·6	0·2	0·2	0·2	0·2	0·5	0·6	0·7
Calorific Value—													
Calories per gramme, gross	5,050	5,130	....	....	....	....	5,150	5,880	4,960	5,610	4,070	4,920	6,150
B.T.U. per pound, gross	9,090	9,230	....	....	....	....	9,270	10,580	8,930	10,090	7,330	8,850	11,070
Fuel ratio	1·25		1·65		1·55		0·46		0·47		1·20		
Coking properties	Poor to fair		Fair to good		Poor						Non-coking		
Softening temperature of ash			2,000° F. (1,090° C.)		2,410° F. (1,320° C.)								
Designation of fuel											Nut		
Kind of sample			Prospect								Commercial		
Location in deposit	5½-ft. seam, 40 ft. from surface. 250 ft. from level opening.												
Taken by	Private individual.		Sent by Development Branch, Canadian National Railways.				R. E. Gilmore				Official of Lignite Utilization Board		
Date of sampling	May 4, 1927		Aug. 25, 1927				Aug., 1927				May 16, 1927		

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

—	Peerless Carbon Collieries, Stopp mine, No. 115, Carbon, Alberta, sec. 12, tp. 29, R. 23, W. 4 mer.			Coal samples from Sentinel No. 1 well, L.S. 14, sec. 8, tp. 20, R. 2, W. 5 mer.												Coal from Spooner No. 1 well, L.S. 12, sec. 13, tp. 20, R. 3, W. 5 mer.	
Sample No.	4484			4216		4217		4218		4219*		4430		4220			
Moisture condition	R	AD	D	R	D	R	D	R	D	R	D	R	D	R	D		
Proximate Analysis—																	
Moisture, per cent	16·9	14·9	....	4·6	....	4·7	....	5·0	....	4·5	....	3·6	....	1·3	....		
Ash, "	12·1	12·4	14·6	39·6	41·5	6·6	6·9	7·3	7·7	54·0	56·6	5·8	6·0	31·9	32·3		
Volatile matter, "	29·7	30·4	35·7	25·1	26·3	39·5	41·5	37·0	38·9	21·2	22·2	37·5	38·9	28·7	29·1		
Fixed carbon, "	41·3	42·3	49·7	30·7	32·2	49·2	51·6	50·7	53·4	20·3	21·2	53·1	55·1	38·1	38·6		
Ultimate Analysis—																	
Sulphur, per cent	0·4	0·4	0·5	0·4	0·5	1·3	1·3	0·7	0·7	1·0	1·1	0·6	0·6	17·6	17·8		
Calorific Value—																	
Calories per gramme, gross	5,200	5,330	6,260	4,210	4,420	7,100	7,450	7,110	7,480	3,000	3,140	7,420	7,690	5,080	5,140		
B.T.U. per pound, gross	9,360	9,590	11,260	7,580	7,950	12,790	13,410	12,790	13,470	5,400	5,660	13,350	13,850	9,140	9,260		
Fuel ratio	1·40			1·25		1·25		1·35		0·96		1·40		1·35			
Coking properties	Non-coking			Tendency to agglomerate		Fair		Fair		Non-coking		Fair to good		Poor to fair			
Designation of coal	"Pea and nut"																
Kind of sample	Commercial			Prospect		Prospect		Prospect		Prospect		Prospect		Prospect			
Location in deposit				1,220 ft.		1,330 ft.		1,600 ft.		1,700 ft.		2,500 ft.		3,470 ft.			
Taken by	Staff of Northwest Territories and Yukon Branch, Calgary, Alberta																
Date of sampling	Nov. 29, 1927			July, 1927								Oct., 1927		July, 1927			

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* It is believed that there has been an error in numbering, and that No. 4219 represents the 1,220-ft. sample, No. 4216 the 1,330-ft. sample, and so on through the series.

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

—	Mohawk Bituminous Mines, Ltd., No. 133, Bellevue, Alberta, sec. 21, tp. 7, R. 3, W. 5 mer.								Hillcrest Collieries, Ltd., No. 40, Hillcrest, Alberta, sec. 18, tp. 7, R. 3, W. 5 mer.		West Canadian Collieries, Ltd., Greenhill or No. 396 mine, Blairmore, Alberta, sec. 2, tp. 8, R. 4, W. 5 mer.		International Coal and Coke Co., Ltd., Denison or No. 88 mine, Coleman, Alberta, sec. 16, tps. 7 and 8, R. 4, W. 5 mer.	
Sample No.	4392		4393		4501		4500		4356		4354		4355	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture per cent	1·8	....	3·3	....	2·4	....	1·8	....	1·4	....	1·0	....	1·4	....
Ash "	25·8	26·3	20·5	21·2	22·0	22·6	16·7	17·0	10·8	10·9	10·6	10·7	12·3	12·4
Volatile matter "	24·2	24·6	25·7	26·6	24·7	25·3	26·4	26·9	29·4	29·8	24·8	25·1	23·6	24·0
Fixed carbon "	48·2	49·1	50·5	52·2	50·9	52·1	55·1	56·1	58·4	59·3	63·6	64·2	62·7	63·6
Ultimate Analysis—														
Sulphur per cent	0·8	0·8	0·5	0·6	0·5	0·5	0·6	0·6	0·6	0·6	0·5	0·5	0·6	0·6
Calorific Value—														
Calories per gramme, gross	5,940	6,050	6,230	6,440	6,280	6,440	6,840	6,970	7,480	7,590	7,570	7,640	7,370	7,480
B.T.U. per pound, gross	10,690	10,880	11,220	11,600	11,310	11,590	12,320	12,540	13,470	13,660	13,620	13,760	13,270	13,460
Fuel ratio	2·00		1·95		2·05		2·10		2·00		2·55		2·65	
Coking properties	Poor		Poor		Fair		Fair		Good		Fair to good		Poor	
Designation of coal					Representative tipple sample.									
Kind of sample	Commercial delivery				Commercial		Mine							
Location in mine					From screens immediately below dump.		From face of main entry; intrusion of bone and slate omitted according to mine practice.							
Taken by	Officials of Northwest Territories and Yukon Branch.				Provincial inspector of mines				All by mine operators, as representing output					
Date of sampling	October, 1927				December 13, 1927				All during August, 1927					

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

—	Mountain Park Collieries, Ltd., No. 282, Mountain Park, Alberta, sec. 33, tp. 45, R. 23, W. 5 mer.		Luscar Collieries, Ltd., No. 905, Luscar, Alberta, sec. 23, tp. 47, R. 24, W. 5 mer.		Blue Diamond Coal Co., Ltd., No. 429, Brulé Mines, Alberta, sec. 16, tp. 52, R. 27, W. 5 mer.					
Sample No.	4357		4358		4215		4234		4235	
Moisture condition	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—										
Moisture per cent	1·7	....	1·1	....	0·7	....	1·2	....	1·0	....
Ash "	9·1	9·3	11·5	11·6	15·3	15·4	13·2	13·4	11·4	11·5
Volatile matter "	29·9	30·4	20·5	20·8	19·3	19·4	21·1	21·4	26·8	27·1
Fixed carbon "	59·3	60·3	66·9	67·6	64·7	65·2	64·5	65·2	60·8	61·4
Ultimate Analysis—										
Sulphur per cent	0·5	0·5	0·3	0·3	0·5	0·5	0·5	0·5	0·5	0·5
Calorific Value—										
Calories per gramme, gross	7,720	7,850	7,640	7,730	7,230	7,290	7,400	7,490	7,470	7,540
B.T.U. per pound, gross	13,890	14,130	13,750	13,910	13,020	13,120	13,330	13,480	13,440	13,580
Fuel ratio	2·00		3·25		3·35		3·05		2·25	
Coking properties	Good		Fair to good		Fair		Fair to good		Good; much swollen.	
Designation of coal							Run-of-mine		Lump	
Kind of sample					Commercial delivery.		Commercial; tipple.		Picked sample; tipple	
Location in mine							No. 2 seam			
Taken by	All by mine operators, as representing output				Fire ranger, Board of Railway Commissioners.		B. R. MacKay, Geological Survey			
Date of sampling	All during autumn of 1927				June, 1927		July 14, 1927			

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

—	Blue Diamond Coal Co., Ltd., No. 429, Brulé Mines, Alberta, sec. 16, tp. 52, R. 27, W. 5 mer.						Corbin Coals, Ltd., Corbin, British Columbia.				Crow's Nest Pass Coal Co., Ltd., Fernie, British Columbia, Michel colliery.			
Sample No.	4236		4237		4238		4367		4486		4162		4352	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture.....per cent	1·4	....	0·9	....	0·9	....	1·2	....	1·1	....	0·9	....	2·4	....
Ash "	18·8	19·0	12·1	12·2	9·6	9·7	12·6	12·8	11·8	11·9	4·8	4·8	4·8	4·9
Volatile matter "	18·2	18·5	19·7	19·9	26·3	26·5	23·6	23·9	23·6	23·9	25·7	26·0	25·6	26·3
Fixed carbon "	61·6	62·5	67·3	67·9	63·2	63·8	62·6	63·3	63·5	64·2	68·6	69·2	67·2	68·8
Ultimate Analysis—														
Sulphur.....per cent	0·4	0·4	0·5	0·5	0·5	0·5	0·3	0·3	0·4	0·4	0·4	0·4	0·6	0·6
Calorific Value—														
Calories per gramme, gross	6,830	6,930	7,540	7,610	7,680	7,750	7,280	7,370	7,340	7,420	8,150	8,230	8,010	8,210
B.T.U. per pound, gross	12,300	12,480	13,580	13,700	13,820	13,940	13,110	13,270	13,220	13,360	14,670	14,810	14,410	14,770
Fuel ratio	3·40		3·40		2·40		2·65		2·70		2·65		2·60	
Coking properties	Poor		Good		Good; swollen		Poor		Poor		Good		Good	
Designation of coal	Run-of-mine......		Lump, principally "grey" coal.		Lump, "grey" coal.		....		....		....		....	
Kind of sample	Commercial; tipple.		Picked samples; tipple........				....		Commercial delivery.		....		....	
Location in mine	No. 3 seam.......		No. 3 seam, 2-ft. bench.		No. 2 seam, 2-ft. bench.		....		....		No. 1 seam.....		....	
Taken by	B. R. MacKay, Geological Survey........						Mine operators, as representative.		Fire ranger, Board of Railway Commissioners.		Mine operators, as representative....			
Date of sampling	July 19, 1927........						Sept., 1927........		Nov., 1927........		April, 1927......		Sept., 1927.........	

TABLE XX—*Continued*

Analyses of Solid Fuels Occurring in Canada—*Continued*

	Crow's Nest Pass Coal Co., Ltd., Fernie, British Columbia													
	Michel colliery								Coal Creek colliery					
Sample No.	4186		4187		4188		4189		4176		4177		4178	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture.......per cent	1·1	....	1·1	....	1·8	....	2·0	....	0·7	....	0·5	....	0·6	....
Ash "	5·8	5·9	4·2	4·2	3·6	3·7	4·1	4·2	7·4	7·4	8·1	8·1	7·5	7·5
Volatile matter "	24·6	24·9	25·1	25·4	27·3	27·8	26·8	27·3	27·6	27·8	27·4	27·5	27·2	27·4
Fixed carbon "	68·5	69·2	69·6	70·4	67·3	68·5	67·1	68·5	64·3	64·8	64·0	64·4	64·7	65·1
Ultimate Analysis—														
Sulphur.......per cent	0·7	0·7	0·5	0·5	0·5	0·5	0·6	0·6	0·4	0·4	0·4	0·4	0·4	0·4
Calorific Value—														
Calories per gramme, gross	8,060	8,140	8,260	8,350	8,130	8,290	8,050	8,220	8,050	8,110	8,020	8,070	8,050	8,100
B.T.U. per pound, gross	14,500	14,660	14,870	15,030	14,640	14,920	14,450	14,800	14,490	14,590	14,440	14,520	14,490	14,580
Fuel ratio	2·80		2·75		2·45		2·50		2·35		2·35		2·40	
Coking properties	Good; swollen		Good		Good		Good		Good; swollen		Good; swollen		Good; swollen	
Designation of coal	"Mine-run"		"Slack"		"Mine-run"		"Slack"		"Round coal"		"Mine-run"		"Slack"	
Kind of sample	Commercial; tipple								Commercial; tipple					
Location in colliery	No. 3 mine tipple				No. 8 mine tipple				No. 1 seam					
Taken by	Provincial inspector of mines								Provincial inspector of mines					
Date of sampling	May 30, 1927								May 26, 1927					

TABLE XX—*Concluded*

Analyses of Solid Fuels Occurring in Canada—*Concluded*

—	Crow's Nest Pass Coal Co., Ltd., Fernie, British Columbia, Coal Creek colliery								Middlesboro Collieries, Ltd., Middlesboro, Merritt, British Columbia						From Lake Kathlyn, British Columbia	
Sample No.	4179		4180		4181		4353		4170			4171			4391	
Moisture condition	R	D	R	D	R	D	R	D	R	AD	D	R	AD	D	R	D
Proximate Analysis—																
Moisture per cent	0·9	....	0·6	....	0·6	....	1·2	....	4·4	3·6	....	4·5	3·7	...	12·5	....
Ash "	2·7	2·7	2·8	2·8	4·2	4·2	6·3	6·4	9·0	9·1	9·4	7·9	7·9	8·3	2·5	2·8
Volatile matter "	23·4	23·7	21·9	22·0	22·0	22·1	25·6	25·9	32·5	32·8	34·0	32·7	33·0	34·2	6·3	7·2
Fixed carbon "	73·0	73·6	74·7	75·2	73·2	73·7	66·9	67·7	54·1	54·5	56·6	54·9	55·4	57·5	78·7	90·0
Ultimate Analysis—																
Sulphur per cent	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·1	0·2
Calorific Value—																
Calories per gramme, gross	8,490	8,560	8,480	8,530	8,350	8,390	8,120	8,210	7,180	7,240	7,510	7,240	7,300	7,580	6,460	7,380
B.T.U. per pound, gross	15,280	15,410	15,260	15,360	15,020	15,110	14,610	14,780	12,930	13,030	13,520	13,040	13,140	13,650	11,630	13,290
Fuel ratio	3·10		3·40		3·30		2·60		1·65			1·70			12·45	
Coking properties	Good; swollen		Good; swollen		Good		Good		Poor to fair			Poor to fair			Non-coking	
Designation of coal	"Round coal"		"Mine-run"		"Slack"										Best grade showing	
Kind of sample	Commercial; tipple								Commercial delivery						Prospect	
Location in mine	No. 2 seam								Both from No. 2 seam						Frank seam	
Taken by	Provincial inspector of mines						Mine operators, as representative.		Fire ranger, Board of Railway Commissioners						D. Lay, provincial district resident engineer	
Date of sampling	May 26, 1927						Sept., 1927		May, 1927						Season of 1927	

TABLE XXI

Analyses of Coal Samples submitted by Department of Soldiers' Civil Re-establishment

—	Described as "Dominion" or Glace Bay, Nova Scotia, "slack" coal												
	Delivered to Camp Hill Hospital, Halifax				Delivered to Ste. Anne de Bellevue Hospital								
Sample No.	4161	4561	4728	4741	4148	4157	4172	4197 4200	4226	4227 4242	4326 4329	4351 4361 4372	4365
Moisture (as received)...per cent	2·6	4·0	5·4	5·0	2·1	4·8	6·8	4·1	3·4	3·9	3·2	4·8	3·4
Dry Basis—													
Ash “	6·3	7·4	9·2	9·1	6·9	10·7	11·2	12·0	11·2	11·5	8·9	11·8	9·1
Volatile matter “	34·8	34·0	32·7	33·3	34·7	33·0	33·5	33·1	35·3	34·2	35·0	34·5	33·6
Fixed carbon “	58·9	58·6	58·1	57·6	58·4	56·3	55·3	54·9	53·5	54·3	56·1	53·7	57·3
Sulphur “	2·8	2·7	3·2	3·4	3·5	3·3	3·2	3·2	3·0	2·6	3·0	2·5	3·0
Calories per gramme, gross	7,850	7,830	7,670	7,580	7,880	7,480	7,390	7,340	7,450	7,370	7,690	7,310	7,670
B.T.U. per pound, gross	14,130	14,090	13,800	13,640	14,190	13,460	13,310	13,200	13,410	13,260	13,830	13,150	13,800
Number of tons as represented by sample	172	183	211	25	134	116	209	290	204	430	....	518	251
Date of delivery	April 1 to 30, 1927	Dec. 1 to 31, 1927	Jan. 1 to 31, 1928	Feb. 1 to 15, 1928	April 11 and 12, 1927	April 24 to May 1	May 4 to 18	June 14 to 26	July 30 to Aug. 3	Aug. 3 to 19	Aug., 1927	Aug. 26 to Sept. 10	Sept. 15 to 19

—	Described as "Dominion" or Glace Bay, Nova Scotia, "slack" coal; delivered to Ste. Anne de Bellevue Hospital.									Described as Minto, New Brunswick, "run-of-mine" coal, from mine of Miramichi Lumber Co., Ltd; delivered to Lancaster Hospital, St. John, New Brunswick.				
Sample No.	4374	4397 4398	4476	4450	4457	4458	4478 4491	4492	4499	4222	4370	4438	4560	4732
Moisture (as received)...per cent	3·6	4·1	5·5	5·1	5·2	5·0	6·0	4·7	7·0	1·9	1·1	2·4	1·1	2·6
Dry Basis—														
Ash “	10·9	9·8	13·1	11·7	11·1	10·3	12·7	12·2	10·3	18·7	14·7	20·6	12·4	18·9
Volatile matter “	33·2	33·6	34·0	34·9	35·6	35·3	34·3	34·1	33·4	30·6	31·6	30·9	33·5	30·4
Fixed carbon “	55·9	56·6	52·9	53·4	53·3	54·4	53·0	53·7	56·3	50·7	53·7	48·5	54·1	50·7
Sulphur “	3·3	3·2	2·7	2·5	2·7	2·7	2·7	2·8	3·2	6·1	7·9	6·5	7·0	6·9
Calories per gramme, gross	7,440	7,610	7,210	7,330	7,400	7,510	7,260	7,320	7,550	6,840	7,160	6,670	7,460	6,800
B.T.U. per pound, gross	13,400	13,720	12,980	13,200	13,320	13,510	13,070	13,180	13,590	12,310	12,880	12,000	13,430	12,240
Number of tons represented by sample	299	251	165	295	248	190	373	239	245	48	50	33	78	47
Date of delivery	Sept. 22 to 26, 1927	Oct. 10 to 18	Oct. 25 to 27	Oct. 27 to Nov. 2	Nov. 5 to 8	Nov. 12 to 14	Nov. 17 to 30	Dec. 1 to 5	Dec. 9 to 13, 1927	July 26 and 27, 1927	Sept. 17 to 19	Oct. 17 to 19	Dec. 6 to 22, 1927	Jan. 16 to 20, 1928

TABLE XXI—*Concluded*

Analyses of Coal Samples submitted by Department of Soldiers' Civil Re-establishment—*Concluded*

—	Described as "run-of-mine" coal from International Coal and Coke Co., Ltd., Coleman, Alberta.					Described as "slack", coming from the Pittsburgh seam in Monongalia or Marion counties, West Virginia, U.S. from "Byrne No. 1" mine at Scottdale, near Louisville.			Described as "slack" coming from the Pittsburgh seam in Marion county, West Virginia, from "Jamieson Nos. 8 and 9" mines at Farmington, near Underwood.					
	Delivered to Deer Lodge Hospital, Winnipeg.			Delivered to Vetcraft Shops, Winnipeg.		Delivered to Christie Street Hospital, Toronto								
Sample No.	4389	4532	4724	4562	4729	4395	4456	4468	4482	4487	4489	4525	4529
Moisture (as received) per cent	2·2	1·3	2·2	3·7	3·9	1·8	2·7	3·1	4·8	3·9	4·8	3·2	3·3
Dry Basis—													
Ash "	13·8	14·5	14·9	13·2	13·7	10·0	9·7	8·5	11·2·	9·6	11·4	10·3	9·7
Volatile matter "	23·2	24·8	26·9	25·2	27·8	36·7	35·8	35·4	35·5	36·3	39·3	35·4	36·7
Fixed carbon "	63·0	60·7	58·2	61·6	58·5	53·3	54·5	56·1	53·3	54·1	49·3	54·3	53·6
Sulphur "	0·7	0·7	0·5	0·8	0·5	2·8	2·7	2·4	2·7	2·7	2·4	3·1	2·9
Calories per gramme, gross	7,340	7,190	7,130	7,380	7,230	7,640	7,640	7,750	7,540	7,640	7,490	7,580	7,630
B.T.U. per pound, gross	13,210	12,940	12,840	13,280	13,020	13,760	13,760	13,950	13,580	13,760	13,480	13,650	13,730
Number of tons represented by sample	45	50	31	29	30	49	280	130	230	180	120	250	350
Date of delivery	Aug. 15 to Oct. 6, 1927	Dec. 1 to 31, 1927	Jan. 1 to 31, 1928	Dec. 1 to 31, 1927	Jan. 1 to 31, 1928	Oct. 20 1927	Nov. 8 to 12	Nov. 18	Nov. 24 to 26	Dec. 1 to 5	Dec. 5	Dec. 16 to 22	Dec. 31, 1927

—	Described as "slack" coming from the Pittsburgh seam in Marion county, West Virginia, U.S., from "Jamieson Nos. 8 and 9" mines at Farmington, near Underwood; delivered to Christie Street Hospital, Toronto.					Described as "slack" coming from the Pittsburgh seam in Marion county, West Virginia, from "Mona" mine at Morgantown, near Grenville, or "Connellsville No. 1" mine at Pursglove; delivered to Westminster Hospital, London, Ontario.									
Sample No.	4534	4566	4721	4725	4733	4206	4213	4221	4240	4337	4364	4371	4380	4396	4455
Moisture (as received) per cent	3·5	3·4	2·9	2·6	3·8	1·6	2·3	3·0	2·3	2·4	1·8	2·3	1·7	2·9	1·4
Dry Basis—															
Ash "	8·4	9·1	7·7	7·5	8·0	9·4	10·5	10·1	10·6	10·1	9·7	8·9	9·0	10·2	9·8
Volatile matter "	37·6	35·1	37·7	37·8	37·6	34·6	33·9	34·3	33·4	34·5	35·5	35·6	36·7	36·5	35·6
Fixed carbon "	54·0	55·8	54·6	54·7	54·4	56·0	55·6	55·6	56·0	55·4	54·8	55·5	54·3	53·3	54·6
Sulphur "	2·4	1·3	2·2	2·3	2·3	3·0	3·2	3·2	3·1	3·3	3·1	3·2	3·3	3·4	3·3
Calories per gramme, gross	7,740	7,630	7,800	7,810	7,760	7,690	7,570	7,610	7,550	7,580	7,660	7,720	7,730	7,640	7,660
B.T.U. per pound, gross	13,940	13,730	14,040	14,060	13,970	13,850	13,630	13,700	13,590	13,650	13,790	13,900	13,920	13,750	13,790
Number of tons represented by sample	190	250	160	130	180	245	346	396	554	341	374	382	375	375	524
Date of delivery	Jan. 6 to 9, 1928	Jan. 12 to 17	Jan. 24 to 28	Feb. 2 to 4	Feb. 15 to 17, 1928	July 11 to 15, 1927	July 19 to 23	July 28 to Aug. 4	Aug. 8 to 17	Aug. 22 to 30	Sept. 1 to 13	Sept. 14 to 22	Sept. 24 to Oct. 5	Oct. 7 to 13	Oct. 18 to 28, 1928

TABLE XXII

Analyses of Miscellaneous Solid Fuels

—	Welsh anthracitic coal														
Sample No.	4159		4160		4173		4198		4421		4433		4461		
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	AD	D
Proximate Analysis—															
Moisture per cent	2·0	....	2·7	....	1·9	....	2·1	....	1·9	....	2·1	....	5·1*	2·0	....
Ash "	3·7	3·8	2·9	3·0	5·0	5·1	5·6	5·7	5·8	5·9	5·8	5·9	5·8	6·0	6·1
Volatile matter "	8·3	8·5	7·8	8·0	8·6	8·8	7·6	7·8	7·8	7·9	7·4	7·6	8·1	8·4	8·6
Fixed carbon "	86·0	87·7	86·6	89·0	84·5	86·1	84·7	86·5	84·5	86·2	84·7	86·5	81·0	83·6	85·3
Ultimate Analysis—															
Sulphur per cent	0·6	0·7	0·9	0·9	0·8	0·8	1·0	1·0	0·7	0·8	1·1	1·1	0·8	0·8	0·9
Calorific Value—															
Calories per gramme, gross	8,080	8,250	8,060	8,280	7,960	8,120	7,860	8,030	7,890	8,040	7,860	8,020	7,650	7,900	8,060
B.T.U. per pound, gross	14,550	14,850	14,510	14,910	14,330	14,610	14,150	14,450	14,200	14,470	14,140	14,440	13,770	14,210	14,510
Fuel ratio	10·30		11·15		9·85		11·15		10·90		11·35		9·95		
Designation of coal	....		....		"Stove"		Big Vein, Aberpergwm, "Cobbles" or "French nuts"		Seven Sisters, Onllwyn collieries, "Cobbles"		"Cobbles"		"Cobbles"		
Kind of sample	From dealers' stocks				Delivered coal		All from dealers' stocks								
Date of sampling	May 6, 1927		May 10		May 26, 1927		June 27, 1927		Oct. 25, 1927		Nov. 2, 1927		Nov. 18, 1927		

* Sample contaminated with snow.

Sample No.	4485		4526		4708			4726		4158		4164 4165		4192	
Moisture condition	R	D	R	D	R	AD	D	R	D	R	D	R	D	R	D
Proximate Analysis—															
Moisture per cent	1·5	....	7·4	....	16·0	2·2	....	1·1	...	1·8	...	1·9	....	2·3	...
Ash "	6·2	6·3	4·4	4·8	4·9	5·7	5·8	6·2	6·2	11·6	11·8	5·9	6·0	11·2	11·5
Volatile matter "	7·8	7·9	8·3	8·9	7·9	9·2	9·4	9·0	9·1	9·7	9·9	9·2	9·4	13·2	13·5
Fixed carbon "	84·5	85·8	79·9	86·3	71·2	82·9	84·8	83·7	84·7	76·9	78·3	83·0	84·6	73·3	75·0
Ultimate Analysis—															
Sulphur per cent	0·9	1·0	1·0	1·1	0·8	1·0	1·0	....	....	0·8	0·8	0·8	0·9	0·8	0·8
Calorific Value—															
Calories per gramme, gross	7,890	8,010	7,600	8,210	6,790	7,900	8,080	....	....	7,340	7,470	7,860	8,010	7,390	7,560
B.T.U. per pound, gross	14,200	14,420	13,680	14,780	12,220	14,230	14,550	....	....	13,210	13,450	14,140	14,420	13,300	13,610
Fuel ratio	10·80		9·65		9·00			9·35		7·95		9·00		5·55	
Designation of coal	"Buckwheat"		"Screenings"		"Screenings"			....		"Cobbles"		"Cobbles"		Briquettes made by NeathAbbey Patent Fuel Co. from coal from Neath Abbey colliery.	
Kind of sample	Delivered coal		Dealer's stock		Delivered coal					From dealers' stocks					
Date	Dec., 1927		Dec. 30		Jan. 27, 1928			Feb., 1928		May 5, 1927		May 13		June 21, 1927	

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	Pennsylvania anthracite coal													
Sample No.	4151		4495		4462		4463		4464		4736		4439	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture per cent	4·0	....	3·8	....	3·6	....	4·4	....	4·2	....	4·2	....	2·5	....
Ash "	13·4	14·0	12·8	13·3	11·1	11·5	11·7	12·3	10·9	11·4	12·8	13·4	10·6	10·8
Volatile matter "	7·6	7·9	5·2	5·4	5·9	6·1	5·6	5·8	5·6	5·8	5·7	5·9	6·9	7·1
Fixed carbon "	75.0	78·1	78·2	81·3	79·4	82·4	78·3	81·9	79·3	82·8	77·3	80·7	80·0	82·1
Ultimate Analysis—														
Sulphur per cent	0·6	0·7	0·6	0·6	0·9	1·0	0·8	0·8	0·8	0·9	0·9	1·0	0·8	0·9
Calorific Value—														
Calories per gramme, gross	6,790	7,080	6,950	7,230	6,950	7,210	6,810	7,120	7,140	7,450	6,860	7,170	7,220	7,410
B.T.U. per pound, gross	12,230	12,740	12,510	13,010	12,510	12,980	12,250	12,810	12,850	13,400	12,350	12,910	13,000	13,330
Fuel ratio	9·90		15·00		13·50		13·95		14·10		13·65		11·60	
Designation of coal	....		"Red ash"—"stove"		"D. and H."—"egg"		"D. and H."—"stove"		"D. and H."—"nut"		"D. and H."—"nut"		"D. and H."—"special buckwheat"	
Kind of sample	Delivered in central Ontario.		From dealers' stocks								Delivered in S.W. Ontario.		Delivered in Ottawa.	
Date	April 23, 1927		Dec. 13, 1927		Nov. 18, 1927						Feb. 25, 1928		Season 1926-27	

Sample No.	4440		4465		4564 4712		4441		4524		4422		4434		4435	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																
Moisture per cent	2·6	.....	7·8	....	4·8	....	3·2	....	7·8	....	4·2	....	4·1	....	3·6	....
Ash "	17·6	18·0	12·4	13·5	16·0	16·8	12·1	12·5	15·6	16·9	12·2	12·7	11·8	12·3	12·6	13·1
Volatile matter "	6·7	7·6	5·3	5·7	6·1	6·4	7·1	7·3	5·9	6·4	5·9	6·2	6·4	6·7	5·8	6·0
Fixed carbon "	73·1	74·4	74·5	80·8	73·1	76·8	77·6	80·2	70·7	76·7	77·7	81·1	77·7	81·0	78·0	80·9
Ultimate Analysis—																
Sulphur per cent	0·8	0·8	0·7	0·7	1·6	1·7	0·8	0·8	1·0	1·0	0·6	0·7	0·5	0·6	0·8	0·8
Calorific Value—																
Calories per gramme, gross	6,580	6,760	6,660	6,230	6,570	6,900	7,000	7,230	6,400	6,940	6,990	7,290	6,940	7,240	6,860	7,120
B.T.U per pound, gross	11,850	12,160	11,990	13,010	11,820	12,420	12,600	13,020	11,520	12,490	12,580	13,130	12,490	13,030	12,340	12,810
Fuel ratio	10·85		14·05		11·90		10·95		11·90		13·15		12·15		13·40	
Designation of coal	"D. and H."—"No. 1 buckwheat."		"D. and H."—"No. 1 buckwheat".		"D. and H."—"No. 1 buckwheat".		"D. and H."—"screenings"		"D. and H."—"rice"		"Lehigh Valley"—"stove" from Hazleton, Luzerne county.		"Lehigh Valley" and "Scranton"—"stove".		"Lehigh Valley" and "Scranton"—"chestnut".	
Kind of sample	Delivered in Ottawa,		Dealer's stock.		Delivered in Ottawa				Dealers' stocks							
Date	Season 1926-27		Nov. 18, 1927		Jan., 1928		Season 1926-27		Dec. 21, 1927		Oct. 25, 1927		Nov 2, 1927			

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	Pennsylvania anthracite coal													
Sample No.	4436		4437		4426		4427		4428		4429		4563 4707	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture per cent	4·5	....	5·3	....	3·9	....	3·9	....	4·5	....	4·2	....	3·4	....
Ash "	12·7	13·3	15·1	16·0	9·7	10·1	11·7	12·2	11·6	12·2	10·0	10·4	16·6	17·2
Volatile matter "	6·0	6·3	6·2	6·6	6·1	6·4	5·7	5·9	5·8	6·1	5·6	5·8	5·7	5·9
Fixed carbon "	76·8	80·4	73·4	77·4	80·3	83·5	78·7	81·9	78·1	81·7	80·2	83·8	74·3	76·9
Ultimate Analysis—														
Sulphur per cent	0·9	1·0	1·0	1·1	0·9	1·0	0·9	0·9	1·1	1·1	0·9	0·9	0·9	0·9
Calorific Value—														
Calories per gramme, gross	6,890	7,210	6,480	6,840	7,200	7,490	6,970	7,260	6,960	7,290	7,180	7,490	6,610	6,830
B.T.U. per pound, gross	12,400	12,980	11,670	12,320	12,970	13,490	12,540	13,060	12,520	13,120	12,920	13.490	11,890	12,300
Fuel ratio	12·85		11·80		13·10		13·80		13·40		14·30		12·90	
Designation of coal	"Scranton"—"pea"		"Scranton"—"No. 2 buckwheat"		"D.L. & W."—"egg"		"D. L. & W."—"stove"		"D. L. & W."—"nut"		"D. L. & W."—"pea"		"D. L. & W."—"No. 1 buckwheat"	
Kind of sample	From dealers' stocks												Delivered in Ottawa.	
Date	Nov. 2, 1927				Oct. 21, 1927								January, 1928.	

Sample No.	4167		4210		4480		4193		4194		4195	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture per cent	4·7	....	4·5	....	4·6	....	4·4	....	4·3	....	4·8	....
Ash "	11·9	12·5	9·7	10·1	9·7	10·1	12·1	12·7	12·1	12·6	11·3	11·9
Volatile matter "	5·2	5·4	6·4	6·7	5·6	5·9	5·8	6·0	6·6	6·9	6·1	6·4
Fixed carbon "	78·2	82·1	79·4	83·2	80·1	84·0	77·7	81·3	77·0	80·5	77·8	81·7
Ultimate Analysis—												
Sulphur per cent	0·8	0·8	0·9	1·0	0·9	0·9	0·6	0·6	0·6	0·7	0·5	0·5
Calorific Value												
Calories per gramme, gross	6,740	7,070	7,130	7,470	7,140	7,490	6,880	7,200	6,810	7,120	6,930	7,280
B.T.U. per pound, gross	12,130	12,730	12,830	13,450	12,850	13,480	12,390	12,960	12,260	12,820	12,480	13,110
Fuel ratio	15·20		12·40		14·35		13·50		11·70		12·65	
Source of coal	Jeddo-Highland Coal Company, Jeddo, Luzerne county.		South Penn Collieries Company, Von Storch mine, Scranton.				Frontier Mining Company, West Nanticoke.					
Designation of coal	"Pea"		"Pea"				"Red ash"—"egg"		"Red ash"—"stove"		"Red ssh"—"nut"	
					(All four coals washed by Chance sand flotation process.)							
Kind of sample	All from dealers' stocks											
Date	May 20, 1927		July 26, 1927		Nov. 29, 1927		June 21, 1927					

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	By-product coke made in Koppers ovens by Dominion Iron and Steel Company (Besco), Sydney, from washed "Dominion' coal, from Glace Bay, Nova Scotia.		Gas coke made in Glover-West retorts by Ottawa Gas Company, Ottawa, Ontario.						By-product coke made in Semet-Solvay ovens by Hamilton Gas and By-Products Company, Limited, Hamilton, Ontario.							
Sample No.	4412		4473		4474		4533		4734		4415		4416		4737	
Moisture condition	R	D	R	D	R	D	AD	D	R	D	R	D	R	D	R	D
Proximate Analysis—																
Moisture per cent	0·8	....	0·4	...	0·4	....	0·9*	....	2·4	....	1·2	....	3·3	....	3·3	....
Ash "	7·6	7·6	10·4	10·5	9·9	9·9	10·4	10·5	7·4	7·6	7·4	7·5	7·4	7·6	7·3	7·5
Volatile matter "	1·4	1·5	0·9	0·9	1·0	1·0	1·2	1·2	2·1	2·1	1·3	1·3	1·7	1·8	1·4	1·5
Fixed carbon "	90·2	90·9	88·3	88·6	88·7	89·1	87·5	88·3	88·1	90·3	90·1	91·2	87·6	90·6	88·0	91·0
Ultimate Analysis—																
Sulphur per cent	1·7	1·8	0·9	1·0	0·8	0·8	0·9	0·9	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·6
Calorific Value—																
Calories per gramme, gross	7,260	7,310	7,030	7,060	7,080	7,100	7,010	7,080	7,270	7,450	7,300	7,380	7,180	7,430	7,260	7,500
B.T.U. per pound, gross	13,060	13,160	12,650	12,700	12,740	12,780	12,620	12,740	13,090	13,410	13,130	13,290	12,930	13,370	13,060	13,500
Specific gravity (apparent)	0·835		0·705		0·745		......		......		0·890		0·885		......	
Designation of coke	"Crushed"		"Large"		"Crushed"		Mixed sizes		"Furnace"		"Stove"		"Nut"		"Nut"	
Kind of sample	From dealers' stocks						Delivered in Ottawa.		Delivered in southwestern Ontario.		From dealers' stocks				Delivered in southwestern Ontario.	
Date	Oct. 21, 1927		Nov. 25, 1927				Jan. 9, 1928		Feb. 25, 1928		Oct. 21, 1927				Feb. 25, 1928.	

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* Sample contained abnormally high moisture when received, and was dried before grinding.

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	By-product coke made in Wilputte ovens by Steel Company of Canada, Hamilton, Ontario.								"Oto" by-product coke, designated as made by Algoma Steel Corporation, Sault Ste. Marie, Ontario.					
Sample No.	4400		4403		4407		4408		4406		4410		4401	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture ... per cent	1·8	....	1·8	....	2·2	....	2·8	....	2·1	....	0·3*	....	0·6*	....
Ash ... "	10·7	10·9	10·9	11·1	10·3	10·5	10·6	10·9	10·9	11·2	11·5	11·5	10·7	10·8
Volatile matter ... "	2·0	2·0	1·7	1·7	1·8	1·9	2·0	2·0	1·6	1·6	1·2	1·2	1·7	1·7
Fixed carbon ... "	85·5	87·1	85·6	87·2	85·7	87·6	84·6	87·1	85·4	87·2	87·0	87·3	87·0	87·5
Ultimate Analysis—														
Sulphur ... per cent	0·8	0·8	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·7	0·8
Calorific Value—														
Calories per gramme, gross	6,890	7,020	6,940	7,070	6,960	7,110	......	....	6,890	7,040	6,920	6,940	6,960	7,000
B.T.U. per pound, gross	12,410	12,630	12,490	12,730	12,520	12,800	......	....	12,410	12,670	12,460	12,500	12,530	12,600
Specific gravity (apparent)	0·890		0·890		0·900		0·880		0·915		0·970		0·895	
Designation of coke	"Stove"		"Stove"		"Stove"		Mixed		"Stove"		"Stove"		"Nut"	
Kind of sample	All from dealers' stocks													
Date	All Oct. 20, 1927													

* Sample contained abnormally high moisture when received, and was dried before grinding.

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	"Oto" by-product coke, designated as made by Algoma Steel Corporation, Sault Ste. Marie, Ontario.				By-product coke made in Koppers ovens by Winnipeg Electric Company, Limited, Winnipeg, Manitoba.						"Connellsville" coke, made in beehive ovens at Pittsburgh, Pennsylvania**					
Sample No.	4404		4411		4445		4446		4447		4413		4414		4417	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																
Moisture.................per cent	3·0	...	0·3*	....	0·7	....	0·8	....	1·6	....	0·9	....	0·7*	....	0·8	....
Ash "	10·6	10·9	11·7	11·7	7·6	7·7	8·7	8·8	9·0	9·2	8·9	9·0	16·2	16·3	15·6	15·7
Volatile matter "	1·6	1·7	1·5	1·5	1·0	1·0	1·0	1·0	0·9	0·9	1·3	1·3	1·2	1·3	1·5	1·5
Fixed carbon "	84·8	87·4	86·5	86·8	90·7	91·3	89·5	90·2	88·5	89·9	88·9	89·7	81·9	82·4	82·1	82·8
Ultimate Analysis—																
Sulphur..................per cent	0·9	1·0	0·9	0·9	0·5	0·5	0·5	0·5	0·5	0·5	1·0	1·0	1·0	1·0	1·0	1·0
Calorific Value—																
Calories per gramme, gross	6,900	7,120	6,900	6,920	7,270	7,320	7,170	7,230	7,050	7,170	7,120	7,190	6,570	6,620	6,610	6,660
B.T.U. per pound, gross	12,430	12,810	12,420	12,450	13,090	13,180	12,910	13,020	12,690	12,900	12,820	12,940	11,830	11,920	11,890	11,990
Specific gravity (apparent)	0·870		0·915		0·940		0·975		0·940		0·900		0·980		0·815	
Designation of coke	"Nut"		"Nut"		"Stove"		"Nut"		"Pea"		"Egg" and "large stove"		"Small stove" and "nut"		"Forked"	
Kind of sample	All from dealers' stocks															
Date	Oct. 20, 1927				Nov. 4, 1927						Oct. 21, 1927					

** This information may not be correct in every detail, but is believed to be nearly so.

* Sample contained abnormally high moisture when received, and was dried before grinding.

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	Coke made in works of United States Steel Corporation, Clairton, Penn., supplied by Gillies-Guy Corporation, Buffalo, N.Y.		By-product coke made in Semet-Solvay ovens								By-product coke made in Ford plant, near Detroit, Michigan.	
			Made in Buffalo, New York				Made in Detroit, Michigan					
Sample No.	4405		4418		4419		4409		4402		4565	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture per cent	0·5	....	1·0	....	0·5*	....	1·9	....	1·3*	....	0·5*	....
Ash "	10·5	10·5	8·7	8·8	9·4	9·4	8·9	9·0	11·0	11·2	9·6	9·6
Volatile matter "	0·9	0·9	1·5	1·5	1·1	1·1	1·3	1·4	2·3	2·3	1·4	1·4
Fixed carbon "	88·1	88·6	88·8	89·7	89·0	89·5	87·9	89·6	85·4	86·5	88·5	89·0
Ultimate Analysis—												
Sulphur per cent	0·9	0·9	0·6	0·7	0·7	0·7	0·6	0·7	1·1	1·1	0·5	0·5
Calorific Value—												
Calories per gramme, gross	6,950	6,980	7,180	7,250	7,160	7,200	7,140	7,280	6,960	7,050	7,150	7,190
B.T.U. per pound, gross	12,510	12,570	12,930	13,060	12,890	12,960	12,850	13,100	12,520	12,690	12,880	12,940
Specific gravity (apparent)	1·000		0·875		0·910		0·845		0·975		0·865	
Designation of coke	"Nut"		"Egg"		"Nut"		"Egg" and "stove"		"Pea"		"Nut"	
Kind of sample	All from dealers' stocks											
Date	Oct. 20, 1927		Oct. 21, 1927				Oct. 20, 1927				Jan. 19, 1928	

* Sample contained abnormally high moisture when received, and was dried before grinding.

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

	Semi-bituminous or "smokeless" coals from the United States													
—	"Black Knight" coal from Beckley seam, mine of Raleigh Coal and Coke Company, Raleigh, West Virginia.		"Miltrena" coal from Smokeless Fuel Company, Charleston, West Virginia.		"Pocohontas" coal from West Virginia									
					Designated as coming from Pocohontas No. 3 seam, from Arlington mine of Arlington Coal and Coke Company, in McDowell county.								—	
Sample No.	4185		4459		4191		4344 4345 4346		4347 4348		4349 4350		4340	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture...per cent	1·1	....	1·0	....	3·0	....	1·6	....	1·7	....	1·5	....	1·1	....
Ash "	5·4	5·5	4·4	4·5	6·8	7·0	8·5	8·6	8·8	8·9	9·4	9·5	4·9	5·0
Volatile matter "	20·1	20·3	18·1	18·2	20·2	20·8	19·5	19·8	19·5	19·8	20·1	20·4	18·8	19·0
Fixed carbon "	73·4	74·2	76·5	77·3	70·0	72·2	70·4	71·6	70·0	71·3	69·0	70·1	75·2	76·0
Ultimate Analysis—														
Sulphur...per cent	0·9	0·9	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·6	0·7	0·7	0·7
Calorific Value—														
Calories per gramme, gross	8,130	8,220	8,330	8,410	7,860	8,110	7,840	7,970	7,810	7,950	7,770	7,880	8,220	8,320
B.T.U. per pound, gross	14,640	14,790	14,990	15,130	14,160	14,600	14,120	14,340	14,060	14,310	13,980	14,190	14,800	14,970
Fuel ratio	3·65		4·25		3·50		3·60		3·60		3·45		4·00	
Coking properties	Good, swollen, coke		Good		Good		Good coke, much swollen		Good, swollen, coke		Good		Good	
Designation of coal	"Smithing"......		"Smithing"......		"Run-of-mine"...								....	
Kind of sample	From dealers' stocks...				Delivered to Ottawa Public Schools...								Delivered in southwestern Ontario.	
Date	June 14, 1927......		Nov. 17, 1927.....		June 21, 1927......		September 12, 1927...						....	

TABLE XXII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

Semi-bituminous or "smokeless" coals from the United States

—	"Pocohontas" coal from No. 3 seam, No. 3 mine, Caples, McDowell county, West Virginia.		"Sonman" coal from Pennsylvania				"Old Keystone" or "Lilly" coal from lower Kittanning seam, Lilly Coal Company, Cambria county, Pennsylvania.		"Smoke Run" coal from lower Kittanning seam, Smoke Run Smokeless Coal Company, Clearfield county, Pennsylvania.			
Sample No.	4740		4142		4137		4184		4204		4239	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture, per cent	1·2	....	1·0	....	0·9	....	1·2	....	1·3	....	1·6	....
Ash, "	9·1	9·2	7·2	7·3	7·0	7·0	6·2	6·2	12·2	12·4	12·4	12·6
Volatile matter, "	15·5	15·7	20·1	20·3	21·1	21·3	22·4	22·7	18·9	19·1	18·5	18·8
Fixed carbon, "	74·2	75·1	71·7	72·4	71·0	71·7	70·2	71·1	67·6	68·5	67·5	68·6
Ultimate Analysis—												
Sulphur, per cent	1·1	1·2	1·1	1·1	1·2	1·2	1·0	1·0	3·3	3·4	3·3	3·3
Calorific Value—												
Calories per gramme, gross	7,790	7,880	8,050	8,130	8,060	8,140	8,120	8,220	7,450	7,540	7,400	7,520
B.T.U. per pound, gross	14,030	14,190	14,490	14,630	14,510	14,650	14,620	14,800	13,410	13,580	13,320	13,530
Fuel ratio	4·80		3·55		3·40		3·15		3·60		3·65	
Coking properties	Fair		Good coke, very much swollen		Good coke, very much swollen and friable.		Good coke, very much swollen		Good, swollen, coke		Good, swollen, coke	
Designation of coal	"Stove"		"Smithing"—"Piper-Sonman"		"Smithing"—probably "Piper-Sonman"		"Smithing"		....			
Kind of sample	From dealers' stocks								Delivered to Ottawa schools			
Date	Feb. 29, 1928		April 11, 1927		April 4, 1927		June 10, 1927		July 15, 1927		Aug. 19, 1927	

TABLE XXIII—*Continued*

Analyses of Miscellaneous Solid Fuels—*Continued*

—	"Norstar" coal from Chilton seam, Boone mine, Boone county, West Virginia.		From Chilton seam, Logan county, West Virginia.		Monsarrat Mining Company, Bemis, West Virginia.		"Federal No. 3" mine, Pittsburgh seam, Lowsville, Monongalia county, West Virginia.		No. 2 mine of Pittsburgh Terminal Coal Corporation, Pittsburgh seam, Castle Shannon, Allegheny county, Penn.		"Criterion" mine, Pittsburgh seam, Rilltown, Westmoreland county, Penn.		Graceton Coal and Coke Company, upper Freeport seam, Indiana county, Pennsylvania.	
Sample No.	4341		4488		4454		4143		4145		4146		4163	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture.........per cent	2·2	....	1·8	....	0·9	....	1·3	....	2·0	....	1·4	....	1·0	....
Ash "	4·3	4·4	5·9	6·0	4·5	4·6	6·1	6·2	4·2	4·3	5·7	5·8	13·1	13·2
Volatile matter "	35·9	36·7	32·8	33·4	23·9	24·1	38·8	39·3	37·6	38·4	34·6	35·1	25·6	25·9
Fixed carbon "	57·6	58·9	59·5	60·6	70·7	71·3	53·8	54·5	56·2	57·3	58·3	59·1	60·3	60·9
Ultimate Analysis—														
Sulphur.........per cent	0·7	0·7	0·7	0·8	0·5	0·5	1·9	2·0	1·1	1·2	1·0	1·0	4·5	4·5
Calorific Value—														
Calories per gramme, gross	7,970	8,150	7,890	8,040	8,300	8,380	7,890	8,000	7,910	8,070	7,920	8,040	7,350	7,430
B.T.U. per pound, gross	14,350	14,670	14,210	14,480	14,950	15,090	14,210	14,400	14,240	14,530	14,260	14,470	13,230	13,370
Fuel ratio	1·60		1·80		2·95		1·40		1·50		1·70		2·35	
Coking properties	Fair to good		Good		Good		Good		Fair to good		Good		Fair to good	
Designation of coal	....		....		....		"¾ lump"........		....		....		....	
Kind of sample	Delivered in southwestern Ontario.		Used for making coke in Winnipeg		Small sample, probably picked coal.		From dealers' stocks........							
Date	Sept. 12, 1927.....		Nov., 1927........		Nov. 11, 1927....		April 11, 1927........						May 13, 1927......	

TABLE XXII—*Concluded*

Analyses of Miscellaneous Solid Fuels—*Concluded*

—	"Hallston" mine, middle Kittanning seam, Hallston Coal Company, Claytonia, Butler county, Pennsylvania.		"Standard No. 1" mine, B or lower Kittanning seam, Dias, Indiana county, Pennsylvania.		Coal designated as coming from Indian, Washington, through Pacific Coast Coal Company of Seattle, Washington.		Hardwood charcoal, as retailed in Ottawa.		Briquettes made with carbonized Bienfait, Saskatchewan, lignite and "Cohesite" binder by Tapping Cohesives of Birmingham, England		"Fuelite" coke, manufactured at Tondu, South Wales.	
Sample No.	4144		4731		4722		4224		4738		4175	
Moisture condition	R	D	R	D	AD	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture per cent	3·0	...	2·9	....	7·7*	....	4·7	....	3·9	....	0·3	....
Ash "	7·3	7·5	10·4	10·7	10·8	11·7	4·8	5·1	14·4	15·0	6·5	6·5
Volatile matter "	36·1	37·2	24·6	25·4	38·1	41·3	19·9	20·8	18·4	19·2	1·8	1·8
Fixed carbon "	53·6	55·3	62·1	63·9	43·4	47·0	70·6	74·1	63·3	65·8	91·4	91·7
Ultimate Analysis—												
Sulphur per cent	0·8	0·9	3·8	3·9	0·4	0·5	0·1	0·1	1·3	1·3	0·8	0·8
Calorific Value—												
Calories per gramme, gross	7,490	7,730	7,520	7,730	6,330	6,860	7,240	7,600	6,710	6,980	7,450	7,470
B.T.U. per pound, gross	13,490	13,910	13,530	13,920	11,400	12,340	13,040	13,680	12,080	12,570	13,410	13,450
Fuel ratio	1·50		2·50		1·15		3·55		3·45		....	
Coking properties	Fair		Good		Non-coking		....		....		....	
Specific gravity (apparent)	....		....		....		....		1·165		1·340	
Designation of fuel	....		"Smokeless, run-of-mine"		....		....		....		Made from 2/3 non-coking "dry" Welsh steam "duff" and 1/3 strongly-coking coal.	
Kind of sample	From dealer's stock		Delivered in southwestern Ontario.		Delivered in western Canada.		From dealer's stock		....		....	
Date	April 11, 1927		Feb. 17, 1928		Feb. 3, 1928		Aug. 9, 1927		Feb. 28, 1928		June, 1927	

* This sample was very dry when received, and actually absorbed moisture under standard air-drying conditions.

TABLE XXIII

Screen Analyses of Anthracites

(Wire screens with square openings)

Sample No.	Description	Size designated	On 3" (Lump)	3" to 2" (Egg)	2" to 1½" (Stove)	1½" to ¾" (Nut)	¾" to ½" (Pea)	Through ½" (Screenings)
Welsh anthracitic coals								
4421	Seven Sisters, Onllwyn	Cobbles	16·0	18·5	23·0	21·0	9·0	12·5
4433		“	6·5	34·0	40·5	16·5	1·5	1·0
4461		“	41·0	35·0	15·5	4·5	2·0	2·0
Pennsylvania anthracite coals								
4462	D. and H.	Egg	0·0	78·5	19·0	1·5	0·5	0·5
4426	D. L. and W.	“	0·0	64·5	29·5	5·0	0·5	0·5
4463	D. and H.	Stove	0·0	9·0	76·0	14·0	0·5	0·5
4422	Lehigh Valley	“	0·0	17·0	63·0	15·0	3·0	2·0
4434	Mainly D. L. and W.	“	0·0	11·0	68·0	19·5	1·0	0·5
4427	D. L. and W.	“	0·0	15·0	72·5	11·5	0·5	0·5
4464	D. and H.	Nut	0·0	0·0	0·0	69·5	28·5	2·0
4435	Mainly D. L. and W.	“	0·0	0·0	0·0	58·5	36·5	5·0
4428	D. L. and W.	“	0·0	0·0	0·0	48·0	41·0	11·0
4436	D. L. and W.	Pea	0·0	0·0	0·0	0·0	11·0	89·0
4429	D. L. and W.	“	0·0	0·0	0·0	1·0	23·5	75·5
4439	Probably D. and H.	Special Buckwheat	0·0	0·0	0·0	5·5	27·0	67·5
—	—	—	On 0·525"	0·525" to 0·371"	0·371" to 0·263"	0·263" to 0·131"	0·131" to 0·065"	Through 0·065"
4440	Probably D. and H.	No. 1 Buckwheat	0·5	27·0	52·0	19·5	0·5	0·5
4465	D. and H.	“ “	0·0	40·5	42·0	16·0	1·0	0·5
4712	D. and H.	“ “	0·5	29·5	46·0	22·0	1·5	0·5
4707	D. L. and W.	“ “	0·0	28·0	50·0	21·0	1·0	0·0
4437	D. L. and W.	No. 2 Buckwheat	0·0	22·5	50·5	24·5	2·0	0·5
4441	Probably D. and H.	Screenings	1·5	4·5	10·0	32·5	27·5	24·0

TABLE XXIV

Screen Analyses of Cokes

(Wire screens with square openings)

Sample No.	Description	Size designated	On 3" (Lump)	3" to 2" (Egg)	2" to 1½" (Stove)	1½" to ¾" (Nut)	¾" to ½" (Pea)	Through ½" (Screenings)
4473	Ottawa Gas	Large	0·0	40·0	52·5	6·5	0·5	0·5
4734	Hamilton By-product—Solvay	Furnace	4·0	47·5	40·5	7·0	0·5	0·5
4418	Solvay-Buffalo	Egg	0·0	21·5	71·5	6·0	0·5	0·5
4413	Connellsville	Egg and large stove	8·0	68·5	22·5	0·5	0·0	0·5
4409	Solvay—Detroit	Egg and stove	0·0	23·0	72·0	4·0	0·5	0·5
4412	Besco—Koppers	Crushed	0·0	39·0	27·5	17·0	8·5	8·0
4474	Ottawa Gas	"	0·0	0·0	62·0	36·5	1·0	0·5
4415	Hamilton By-product—Solvay	Stove	0·0	9·5	79·5	10·5	0·0	0·5
4400	"Stelco", Hamilton—Wilputte	"	0·0	4·0	74·0	21·0	0·5	0·5
4403	" "	"	0·0	11·5	83·0	4·5	0·0	1·0
4407	" "	"	0·0	1·5	54·5	35·0	8·0	1·0
4406	"Oto"	"	0·0	1·5	53·0	41·5	3·0	1·0
4410	"	"	0·0	0·0	47·5	48·5	2·0	2·0
4445	Winnipeg—Koppers	"	0·0	12·5	67·5	18·5	0·5	1·0
4414	Connellsville	Small stove and nut	0·0	0·0	0·0	69·5	27·5	3·0
4417	" —beehive	Mixed	0·0	0·0	6·5	82·0	8·5	3·0
4416	Hamilton By-product—Solvay	Nut	0·0	0·0	23·5	73·0	2·5	1·0
4737	" " "	"	0·0	7·0	13·0	65·0	14·5	0·5
4401	"Oto"	"	0·0	0·0	29·0	60·0	10·0	1·0
4404	"	"	0·0	0·0	47·0	52·5	0·0	0·5
4411	"	"	0·0	0·0	7·5	74·5	16·5	1·5
4446	Winnipeg—Koppers	"	0·0	0·0	0·0	72·5	24·5	3·0
4405	Clairton	"	0·0	1·5	20·5	65·5	11·5	1·0
4419	Solvay—Buffalo	"	0·0	0·0	10·5	78·0	9·5	2·0
4565	Ford—Detroit	"	0·0	2·0	53·0	43·0	1·5	0·5
4447	Winnipeg—Koppers	Pea	0·0	0·0	0·0	0·0	77·5	22·5
4402	Solvay—Detroit	"	0·0	0·0	0·0	22·0	68·5	9·5

PART II

I

GASOLINE SURVEY FOR 1927

P. V. Rosewarne and R. J. Offord

An annual survey of the gasoline sold in Canada has been conducted by the Fuels and Fuel Testing Division of the Mines Branch during the past four years.[1] This report covers a similar survey for 1927. During the latter part of August, 83 samples were collected[2] from wholesalers or distributors in the following cities: Halifax, St. John, Quebec, Montreal, Ottawa, Toronto, London, Winnipeg, Regina, Calgary, Edmonton, Vancouver, and Victoria. These samples were tested for distillation range and specific gravity. The distillation range was determined according to the method recommended by the United States Bureau of Mines.[3] From the results so obtained, a weighted index number was calculated after the method advocated by Gruse,[4] with the difference that the index numbers were calculated from temperatures of the distillation range expressed in °F. instead of from temperatures expressed in °C. as was done by Gruse. The specific gravities were obtained by the Westphal balance at room temperature and the results calculated[5] to 60°F.

In addition to the above, each sample was analysed to determine the relative amounts of unsaturates, aromatics, naphthenes, and paraffins present. The method chosen was that outlined by Egloff and Morrell.[6] The results obtained by the method were good, reproducible values being given consistently on repetition of the work on any sample.

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[1] Mines Branch, Dept. of Mines, Canada, Investigations of Fuels and Fuel Testing, 1923 to 1926 inclusive.

[2] The hearty support and co-operation of the Department of Health in taking the samples is gratefully acknowledged.

[3] U. S. Bureau of Mines, Technical Paper 323A.

[4] Chemical and Metallurgical Engineering, vol. 29, No. 22, p. 970.

[5] Mines Branch, Dept. of Mines, Canada. Investigations of Fuels and Fuel Testing, 1923, p. 53.
U. S. Bureau of Standards, Circular 57.

[6] Industrial and Engineering Chemistry, vol. 18, No. 4, p. 354.

TABLE XXV

Results of Analyses

Sample No.	Brand	Distillation Range								Index No. °F.	Specific gravity	Hydrocarbons			
		1st Drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery			Unsat-urates %	Aro-matics %	Naph-thenes %	Paraf-fins %
	HALIFAX, N.S.														
1	Red Seal *(a)*....................	122	188	222	278	324	380	430	97·5	1822	0·7565	2·75	5·31	24·70	67·24
2	Premier *(b)*....................	128	189	218	284	328	400	450	97·0	1869	0·7575	5·00	4·72	24·30	65·98
3	White Rose (*a*)..................	97	144	170	248	294	370	431	97·0	1657	0·7265	2·90	2·41	19·90	74·79
	Average....................	116	174	203	270	315	383	437	97·2	1783	0·7468	....	....	....	....
	SAINT JOHN, N.B.														
4	Premier *(b)*....................	120	182	212	270	310	368	416	97·0	1758	0·7530	3·26	5·29	27·45	64·00
5	Fundy *(c)*......................	94	133	158	233	281	357	408	96·0	1570	0·7265	3·77	3·14	24·80	68·29
6	White Rose (*a*)..................	106	160	190	268	316	371	420	97·5	1725	0·7395	4·73	5·14	21·40	68·73
	Average....................	107	158	187	257	302	365	415	96·8	1684	0·7397	....	....	....	....
	QUEBEC, QUE.														
7	Aviation *(d)*....................	100	140	163	232	279	340	395	97·0	1549	0·7240	2·76	1·98	26·72	68·54
8	Peerless *(e)*....................	96	140	170	242	292	364	406	95·5	1614	0·7230	2·86	3·21	22·10	41·83
9	Premier *(b)*....................	125	178	207	272	314	363	420	98·0	1754	0·7510	3·25	4·50	27·00	65·25
10	Super-Power *(e)*................	112	165	198	268	310	371	420	97·0	1732	0·7460	3·34	4·47	25·10	67·09
11	Ethyl *(b)*......................	119	170	197	254	298	354	402	97·5	1675	0·7555	3·13	7·72	29·00	60·15
12	Red Seal *(a)*....................	110	166	198	270	312	371	426	97·0	1743	0·7455	4·28	4·77	24·50	66·45
	Average....................	110	160	189	256	301	361	412	97·0	1678	0·7408	....	....	....	....

MONTREAL, QUE.

13	Aviation *(d)*	98	142	164	230	275	336	394	98·0	1541	0·7255	3·36	1·99	26·52	68·13
14	Blue Sunoco *(f)*	110	174	202	273	318	383	436	98·0	1786	0·7635	3·67	5·58	40·43	50·32
15	Ethyl *(b)*	108	160	185	264	302	350	399	98·0	1660	0·7430	1·79	4·11	28·85	65·25
16	Super-Power *(e)*	100	154	180	256	294	362	427	97·0	1673	0·7385	2·65	2·85	27·10	67·40
17	Peerless *(e)*	106	158	180	234	266	320	382	97·5	1540	0·7245	2·59	2·42	26·62	68·37
18	Premier *(b)*	106	166	196	270	320	371	426	98·0	1749	0·7495	2·54	3·25	28·52	65·69
19	Tidioute *(g)*	110	154	176	238	284	354	410	97·5	1616	0·7240	2·58	0·61	21·00	75·81
20	Shell *(d)*	97	145	184	250	296	353	396	96·0	1624	0·7325	4·11	4·72	24·40	66·77
	Average	104	157	183	252	294	354	409	97·5	1649	0·7376				

OTTAWA, ONT.

21	Premier *(b)*	116	174	204	264	306	363	412	97·5	1723	0·7480	2·79	6·45	27·60	63·16
22	Ethyl *(b)*	110	155	184	260	302	355	398	96·5	1654	0·7405	2·31	4·43	28·30	64·96
23	Peerless *(e)*	111	157	180	233	269	325	381	97·0	1545	0·7245	3·29	3·26	25·10	68·35
24	British Motor *(e)*	122	182	207	268	307	367	420	97·0	1751	0·7495	1·39	4·56	25·10	68·95
25	Aviation *(d)*	100	148	179	258	310	378	427	96·5	1700	0·7420	4·23	7·98	22·60	65·19
26	Shell *(d)*	102	152	181	264	320	382	427	96·0	1726	0·7480	4·77	9·86	27·80	57·57
27	White Rose *(a)*	97	143	176	263	314	391	427	95·0	1714	0·7315	5·76	3·90	19·65	70·69
28	Red Seal *(a)*	120	177	206	268	310	367	425	97·5	1753	0·7480	1·50	3·67	27·20	67·63
29	Marathon *(h)*	101	148	176	244	295	370	413	96·0	1646	0·7265	1·95	2·42	23·70	71·93
30	Cyclo *(j)*	101	140	168	263	344	399	423	96·0	1737	0·7610	15·01	10·44	26·50	48·05
31	Frontenac *(j)*	116	172	200	266	306	364	420	97·0	1728	0·7470	2·75	3·23	27·50	66·52
32	Supertest (H.C.) *(k)*	110	152	172	224	260	328	406	97·0	1542	0·7275	2·86	None	30·10	67·04
33	Supertest *(k)*	120	175	202	262	306	364	424	97·5	1733	0·7480	1·88	4·54	29·61	63·97
34	Sunoco (H.T.) *(f)*	100	154	176	238	279	352	430	98·0	1629	0·7185	0·89	2·05	15·95	78·12
35	Sunoco (L.T.) *(f)*	106	155	184	242	288	364	434	96·5	1667	0·7240	2·64	3·29	15·95	78·12
36	Beach (S.Q.) *(l)*	108	156	174	226	262	328	409	97·0	1555	0·7265	2·59	0·41	28·72	68·28
37	Super-Service *(m)*	110	154	174	224	262	327	398	97·0	1539	0·7255	4·48	0·40	28·10	67·02
38	Cities-Service (H.T.) *(n)*	101	142	166	220	257	315	376	97·5	1476	0·7155	5·21	Trace	25·81	68·98
39	Cities Service (L.T.) *(n)*	110	160	186	244	284	348	408	97·0	1630	0·7355	2·76	1·62	28·50	67·12
	Average	108	158	184	249	294	357	414	96·8	1655	0·7362				

TABLE XXV—*Continued*

Results of Analyses—*Continued*

Sample No.	Brand	Distillation Range								Index No. °F.	Specific gravity	Hydrocarbons			
		Ist drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery			Unsat-urates %	Aro-matics %	Naph-thenes %	Paraf-fins %
	TORONTO, ONT.														
40	Premier *(b)*......................	109	160	195	272	320	380	428	97·5	1755	0·7475	1·37	4·97	28·90	64·76
41	Light *(o)*.........................	100	156	188	258	294	356	420	97·0	1672	0·7265	4·12	4·39	15·80	75·69
42	Perfection *(p)*..................	100	148	170	236	277	340	402	97·0	1573	0·7245	3·13	5·00	21·90	69·97
43	Blue Sunoco *(f)*.................	100	140	166	238	292	376	421	96·5	1633	0·7635	8·18	6·94	28·82	56·06
44	City Service *(n)*................	96	150	178	260	310	368	414	97·0	1680	0·7330	5·27	7·56	21·12	66·05
45	Marathon *(h)*.....................	97	146	182	276	336	394	421	96·5	1755	0·7385	8·21	6·46	20·80	64·53
46	White Rose *(a)*..................	88	129	159	257	312	389	430	95·0	1676	0·7245	5·53	3·14	20·08	71·25
47	Aviation *(d)*......................	105	156	183	246	289	339	370	97·0	1583	0·7285	3·55	2·00	25·78	68·67
	Average......................	99	148	178	255	304	368	413	96·7	1666	0·7358	....	....	....	....
	LONDON, ONT.														
48	Red Seal *(a)*.....................	118	182	215	282	322	374	419	97·5	1794	0·7485	5·15	10·37	20·75	63·73
49	Marathon *(h)*.....................	96	148	170	230	272	336	394	97·0	1550	0·7225	2·34	0·41	26·23	71·02
50	Aviation *(d)*......................	94	144	170	240	282	334	371	96·5	1541	0·7235	2·85	1·60	26·10	69·45
51	High Test..........................	106	158	194	280	332	392	434	96·5	1790	0·7400	8·65	6·46	20·65	64·24
52	Super-Power *(e)*................	114	173	200	269	312	365	412	97·2	1731	0·7415	4·01	7·27	21·30	67·42
53	Shell *(d)*...........................	96	154	184	252	298	354	386	97·0	1628	0·7320	2·39	2·88	25·62	69·11
54	Premier *(b)*......................	110	171	199	270	312	365	411	97·0	1728	0·7400	6·38	7·84	21·00	64·78
55	Supertest *(k)*....................	124	190	217	285	322	373	418	97·0	1806	0·7495	4·20	9·76	21·45	64·59
	Average......................	107	165	194	264	307	362	406	97·0	1696	0·7372	....	....	....	....

WINNIPEG, MAN.

56	White Rose *(a)*	96	140	168	252	304	378	436	96·5	1678	0·7375	3·90	4·38	23·76	67·96
57	British Motor *(e)*	110	172	200	270	312	366	414	97·0	1734	0·7405	4·37	8·80	19·05	67·78
58	North Star *(q)*	99	146	172	236	276	330	379	97·0	1539	0·7210	2·39	nil	25·90	71·71
59	Fyre Drop *(r)*	108	169	198	265	306	360	410	97·2	1708	0·7385	4·06	6·46	21·00	68·48
60	Ethyl *(b)*	110	167	194	258	295	347	400	97·2	1661	0·7390	7·08	10·80	20·32	61·80
61	Buffalo *(s)*	92	136	162	242	302	382	428	96·0	1652	0·7230	6·92	3·13	24·30	65·65
	Average	102	155	182	254	299	361	411	96·8	1662	0·7333	....	....	....	....

REGINA, SASK.

62	British Motor *(e)*	100	170	199	273	17	382	432	97·2	1773	0·7470	5·18	9·86	20·20	64·76
63	Maple Leaf *(t)*	118	178	205	290	340	400	436	97·0	1849	0·7505	4·80	2·01	20·82	72·37
64	White Rose *(a)*	98	130	158	244	296	372	438	96·0	1638	0·7230	3·99	3·58	24·20	68·23
65	Imperial *(b)*	116	177	204	274	318	386	442	97·0	1801	0·7465	4·31	10·06	21·52	64·11
	Average	108	164	192	270	318	385	437	96·8	1765	0·7418	....	....	....	....

CALGARY, ALTA.

66	Union *(u)*	106	166	195	266	311	379	428	97·0	1745	0·7545	1·79	5·75	38·85	53·61
67	Maple Leaf *(w)*	116	178	204	286	338	398	432	97·5	1836	0·7490	3·46	1·41	21·35	73·78
68	Sun Shine *(x)*	130	182	204	268	313	378	432	97·7	1777	0·7410	1·31	0·83	21·00	76·86
69	Premier *(b)*	102	160	192	278	322	384	426	97·0	1762	0·7465	6·28	11·85	18·70	63·17
	Average	114	172	199	275	321	385	430	97·3	1780	0·7478	....	....	....	....

EDMONTON, ALTA.

70	North Star *(q)*	100	160	191	280	328	385	422	97·2	1766	0·7465	5·78	11·55	19·13	63·54
71	British Motor *(e)*	108	164	196	282	332	388	430	97·0	1792	0·7470	3·32	11·42	18·65	66·61
72	White Rose *(a)*	116	169	188	244	280	345	409	98·0	1635	0·7285	1·49	trace	21·95	76·56
73	Premier *(b)*	106	166	200	279	326	380	420	97·0	1771	0·7475	4·09	11·85	19·95	64·11
	Average	108	165	194	271	317	375	420	97·3	1741	0·7424	....	....	....	....

TABLE XXV—*Concluded*

Results of Analyses—*Concluded*

Sample No.	Brand	Distillation Range								Index No. °F.	Specific gravity	Hydrocarbons			
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery			Unsat-urates %	Aro-matics %	Naph-thenes %	Paraf-fins %
	VANCOUVER, B.C.														
74	Premier *(b)*	116	175	200	250	296	366	420	97·5	1707	0·7575	1·30	3·32	15·45	79·93
75	Union *(u)*	104	164	202	272	317	385	432	97·0	1772	0·7573	5·60	7·12	36·15	51·13
76	Shell *(d)*	112	172	203	260	304	360	402	97·0	1701	0·7535	1·75	4·56	39·25	54·44
77	Northern Light *(y)*	110	168	190	256	306	373	415	97·0	1708	0·7485	2·20	2·91	35·65	59·24
78	General *(z)*	99	162	201	271	321	387	425	96·5	1767	0·7580	2·39	5·54	38·10	53·97
	Average	108	168	199	262	309	374	419	97·0	1731	0·7550	....	....	....	....
	VICTORIA, B.C.														
79	Union *(u)*	96	154	187	265	313	379	424	96·5	1722	0·7520	2·14	6·95	36·43	54·48
80	Premier *(b)*	106	164	191	258	302	371	423	97·5	1709	0·7535	3·96	4·37	40·00	51·31
81	Shell *(d)*	114	181	206	265	307	360	399	97·0	1718	0·7580	2·17	4·13	38·45	55·25
82	Victory Gas	114	183	206	283	327	379	415	97·5	1793	0·7630	2·32	4·97	37·60	55·11
83	Associated Gas	120	188	214	284	324	380	420	98·0	1810	0·7645	2·29	4·56	40·15	47·00
	Average	110	174	201	271	315	374	416	97·3	1750	0·7582	....	....	....	....

(a) Canadian Oil Companies, Limited.
(b) Imperial Oil, Limited.
(c) Canadian Independent Oil, Limited.
(d) Shell Oil Company, Limited.
(e) British American Oil Company, Limited.
(f) Sun Oil Company, Limited.
(g) Tidioute Refining Company, Limited.
(h) McColl Bros., Limited.
(j) Frontenac Oil Company.
(k) Supertest Petroleum Corporation.
(l) Beach Motors.
(m) Hull Iron and Steel.
(n) Cities Service Oil Company, Limited.
(o) Union Oil of Pennsylvania (Canadian Division).
(p) Perfection Petroleum Company, Limited.
(q) North Star Oil and Refining Company, Limited.
(r) Western Oil Company.
(s) Prairie City Oil Company.
(t) Puritan Oil Company.
(u) Union Oil Company, Limited
(w) Maple Leaf Oil and Refining Company, Limited.
(x) Alberta Refining Company, Limited.
(y) Vancouver Oil Company, Limited.
(z) General Oil Company, Limited.

TABLE XXVI

Average Results of Analyses by Cities

District	Distillation Range								Index No. °F.	Specific gravity
	1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery		
Halifax, N.S............	116	174	203	270	315	383	437	97·2	1783	0·7468
St. John, N.B...........	107	158	187	257	302	365	415	96·8	1684	0·7397
Quebec, Que.............	110	160	189	256	301	361	412	97·0	1678	0·7408
Montreal, Que...........	104	157	183	252	294	354	409	97·5	1649	0·7376
Ottawa, Ont.............	108	158	184	249	294	357	414	96·8	1655	0·7362
Toronto, Ont............	99	148	178	255	304	368	413	96·7	1666	0·7358
London, Ont.............	107	165	194	264	307	362	406	97·0	1696	0·7372
Winnipeg, Man...........	102	155	182	254	299	361	411	96·8	1662	0·7333
Regina, Sask............	108	164	192	270	318	385	437	96·8	1765	0·7418
Calgary, Alta...........	114	172	199	275	321	385	430	97·3	1780	0·7478
Edmonton, Alta..........	108	165	194	271	317	375	420	97·3	1741	0·7424
Vancouver, B.C..........	108	168	199	262	309	374	419	97·0	1731	0·7550
Victoria, B.C...........	110	174	201	271	315	374	416	97·3	1750	0·7582
Average*............	107	161	189	259	304	366	416	97·0	1693	0·7406

* This is the average value for all samples tested.

COMPARISON OF RESULTS

It is quite interesting to compare the above figures with others obtained in somewhat the same way. Table XXVII gives the average results of 88 samples collected in Canada, presumably in 1916, and reported by the laboratories of the Department of Inland Revenue[1]; the average of 48 samples collected in Canada during 1923[2]; the average of 59 samples collected during 1924[3]; the average of 73 samples collected during 1925[4]; the average of 76 samples collected in 1926[5] the average of 83 samples collected during 1927; the average of 131 samples collected in the United States during July, 1927; and reported by the U. S. Bureau of Mines[6]; and the essential features of the specification for motor gasoline adopted by the Specification Board of the United States[7] for the use of the various departments and independent establishments of the United States Government. It will be observed that the gasoline sold in Canada during the present year shows an average of good quality when judged by the distillation range which is the ordinarily accepted standard.

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[1] Department of Inland Revenue, Canada: Bulletin 362 ("Gasoline").
[2] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923.
[3] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1924.
[4] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1925.
[5] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1926.
[6] U.S Bureau of Mines, Report of Investigations, Serial No. 2827.
[7] U.S. Bureau of Mines, Technical Paper 323A.

TABLE XXVII

Average Results for Comparison

—	Distillation Range								Index No. °F.	Specific gravity	Iodine value
	1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery			
Canada, 1916.......	125	170	192	237	270	330	380	....	1579	0·732	17
Canada, 1923.......	120	170	193	255	296	358	423	97·1	1695	0·737	19
Canada, 1924.......	113	173	195	249	288	347	410	97·4	1662	0·736	18
Canada, 1925.......	116	174	199	258	299	359	412	97·0	1701	0·739	18
Canada, 1926.......	110	164	191	256	300	360	410	97·4	1681	0·739	21
Canada, 1927.......	107	161	189	259	304	366	416	97·0	1693	0·741	......
United States, July, 1927..............	102	......	193	267	......	381	417	96·4	......	0·748	......
U.S. Federal Specification..........	131	......	221	284	......	293	437	....	......	....	......

TABLE XXVIII

Ten Per cent of Samples having Maximum End Point

Sample No.	Brand	Distillation Range								Index No. °F.	Specific gravity
		1st drop °F.	10% F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery		
2	Premier............	128	189	218	284	328	400	450	97·0	1869	0·7575
65	Imperial............	116	177	204	274	318	386	442	97·0	1801	0·7465
64	White Rose.........	98	130	158	244	296	372	438	96·0	1638	0·7230
14	Blue Sunoco........	110	174	202	273	318	383	436	98·0	1786	0·7635
56	White Rose.........	96	140	168	252	304	378	436	96·5	1678	0·7375
63	Maple Leaf.........	118	178	205	290	340	400	436	97·0	1849	0·7505
35	Sunoco L.T.........	106	155	184	242	288	364	434	96·5	1667	0·7240
51	High Test..........	106	158	194	280	332	392	434	96·5	1790	0·7400
	Average........	110	163	192	267	316	384	438	96·8	1710	0·7428

TABLE XXIX

Ten Per Cent of Samples having Minimum End Point

Sample No.	Brand	Distillation Range								Index No. °F.	Specific gravity
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point	Re-covery		
47	Aviation............	105	156	183	246	289	339	370	97·0	1583	0·7285
50	Aviation............	94	144	170	240	282	334	371	96·5	1541	0·7235
38	Cities Service H.T.	101	142	166	220	257	315	376	97·5	1476	0·7155
58	North Star.........	99	146	172	236	276	330	379	97·0	1539	0·7210
23	Peerless............	111	157	180	233	269	325	381	97·0	1545	0·7245
17	Peerless............	106	158	180	234	266	320	382	97·5	1540	0·7245
53	Shell..............	96	154	184	252	298	354	386	97·0	1628	0·7320
13	Aviation............	98	142	164	230	275	336	394	98·0	1541	0·7255
	Average........	101	150	175	236	277	332	380	97·2	1549	0·7244

In order to estimate the variations in quality of the gasoline being sold, the average of the 8 samples (approximately 10 per cent of the total 83 samples) having the highest end point and the average of the 8 samples having the lowest end point were obtained as in preceding years. The results are as shown in Table XXVIII and Table XXIX.

TABLE XXX

Difference between Maximum and Minimum End Points

—	1916	August 1923	August 1924	August 1925	August 1926	August 1927
	°F.	°F.	°F.	°F.	°F.	°F.
Maximum 10 per cent............	432	446	459	458	437	438
Minimum 10 per cent............	322	381	358	366	379	380
Difference.......................	110	65	101	92	58	58

Table XXX shows the difference between the average end points of the maximum 10 per cent and minimum 10 per cent of samples collected in Canada in 1916[1], 1923, 1924, 1925, 1926, and 1927. The difference between the two averages has been used previously for the purpose of comparison, as a measure of the variation in quality. It will be observed that in 1927 the variation in quality when determined by the above method was the same as that obtained in the survey of 1926.

Accordingly, an attempt was made to obtain a figure which would indicate more exactly the variations in quality. For that purpose the index number was chosen because it represents an aggregate of several points in the distillation range rather than the arbitrarily chosen end point. The procedure adopted was the same as that used above, namely the average of ten per cent of the samples having the highest index numbers and the average of ten per cent of the samples having the lowest index numbers were calculated as shown in Tables XXXI and XXXII.

TABLE XXXI

Ten Per Cent of Samples having Maximum Index Numbers

Sample No.	Brand	Index No. °F.	Specific gravity	Distillation Range					
				10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point
2	Premier........................	1869	0·7575	189	218	284	328	400	450
63	Maple Leaf......................	1849	0·7505	178	205	290	340	400	436
67	Maple Leaf......................	1836	0·7490	178	204	286	338	398	432
1	Red Seal........................	1822	0·7565	188	222	278	324	380	430
83	Associated Gas..................	1810	0·7645	188	214	284	324	380	420
55	Supertest.......................	1806	0·7495	190	217	285	322	373	418
65	Imperial	1801	0·7465	177	204	274	318	386	442
48	Red Seal........................	1794	0·7485	182	215	282	322	374	419
	Average....................	1823	0·7528	184	212	283	327	377	431

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[1] Mines Branch, Dept. of Mines, Canada, Investigations of Fuels and Fuel Testing, 1923.

TABLE XXXII

Ten Per Cent of Samples Having Minimum Index Numbers

Sample No.	Brand	Index No. °F.	Specific gravity	Distillation Range					
				10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point
38	Cities Service (H.T.)............	1476	0·7155	142	166	220	257	315	376
37	Super-Service....................	1539	0·7255	154	174	224	262	327	398
58	North Star......................	1539	0·7210	146	172	236	276	330	379
17	Peerless........................	1540	0·7245	158	180	234	266	320	382
13	Aviation........................	1541	0·7255	142	164	230	275	336	394
50	Aviation........................	1541	0·7235	144	170	240	282	334	371
32	Supertest (H.C.)................	1542	0·7275	152	172	224	260	328	406
23	Peerless........................	1545	0·7245	157	180	233	269	325	381
	Average.....................	1518	0·7234	149	172	230	268	327	386

Similar calculations were made for samples collected and analysed in preceding years and these results are shown in Table XXXIII.

TABLE XXXIII

Difference between Maximum and Minimum Index Numbers

Year	1923	1924	1925	1926	1927
Maximum 10 per cent......................	1791	1806	1821	1815	1823
Minimum 10 per cent......................	1500	1428	1479	1524	1518
Difference.........................	291	378	342	291	305

It will be seen that the variation in quality by this method of calculation shows a reasonably good agreement with that determined by the previous method, but that the variation in quality was slightly greater during 1927 than that during 1926.

It will be further observed that the average index number of ten per cent of the samples having the highest index numbers of all those examined in 1927 was slightly higher than an average index number calculated in like manner from the samples examined in 1926. This indicates that the average volatility of that group of samples was less in 1927 than in 1926. Conversely, it is also to be noted that the average index number of ten per cent of the samples having the lowest index numbers of those examined in 1927 was slightly lower than an average index number calculated in like manner from the samples examined in 1926. For the same reason, this indicates that the average volatility of this group of samples was greater in 1927 than in 1926.

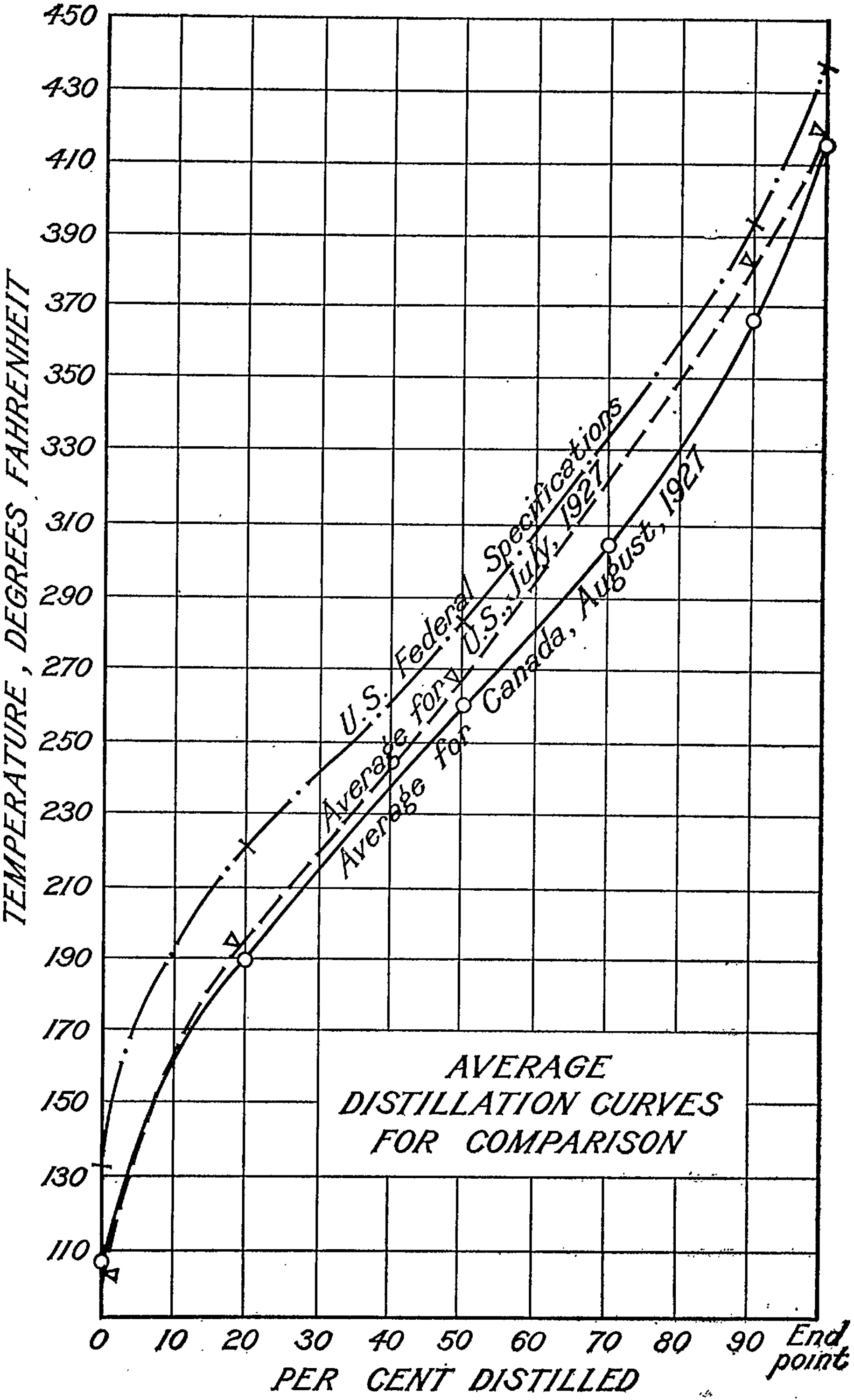

Figure 4. Average distillation curves.

SUMMARY

Eighty-three samples of gasoline were collected in August, 1927, from thirteen widely separated Canadian cities, and may be accepted, therefore, as representative of the gasoline sold in Canada at that time.

The analyses and detailed examination of these samples show that the average gasoline sold during 1927 was of good quality, but was not quite so good as that sold during 1926.

The average distillation curves show that the gasoline sold in Canada during August, 1927, was superior to that sold in the United States during July, 1927, and to the United States Federal specifications for the United States Government motor gasoline.

The variation in quality was slightly greater during 1927 than during 1926; the greater variation was due to the lower grades being less volatile and the higher grades being more volatile in 1927 than in 1926.

II

THE ASSAY OF BITUMINOUS SANDS

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The large amount of laboratory analytical work required in connexion with samples of bituminous sand sent in by Mines Branch field engineers and others has required considerable attention as to the best methods to follow in respect to their chemical and physical examination. Certain comparatively rapid methods for the extraction of the bitumen and the examination of the extracted bitumen and fractions derived therefrom have been worked out and found to be reliable and quite satisfactory. Accordingly, on the assumption that a description of the investigational work conducted would be welcomed by other investigators dealing with bituminous sands and related materials, a record of the methods used, along with comments on the results, is herewith offered. The material is presented in three parts or sections: The first section is an outline of analysis for the determination, in the laboratory and in the field, of the bitumen content of bituminous sands; the second section is a comparison of carbon disulphide and benzol as solvents for extracting the bitumen from bituminous sands in respect to the sulphur content of the extracted bitumen and the fractions thereof; and the third section is a comparison of laboratory extraction and distillation methods for the examination of the bitumen as a source of petroleum oil products. The first section also includes a modification of the adopted standard method for the rapid determination in the field of the bitumen content of control samples of bituminous sand mixtures at the scene of paving operations.

Tentative Method for the Determination of the Bitumen in Bituminous Sands and the Sulphur Content of the Bitumen

The method adopted in the Fuel Testing Laboratories involves (*a*) preliminary air-drying and preparation of the sample, (*b*) the determination of the water content, and (*c*) the extraction of the bitumen from the air-dried sample by means of a suitable solvent to obtain the weight of the dry sand. The bitumen content, which is obtained " by difference," is the total loss by extraction minus the moisture content, the result being calculated either on the as-received (wet) basis or on the dry bituminous sand basis.

Preliminary Air-Drying and Preparation of the Sample

Due to the non-uniformity of the material in the samples submitted, mainly in respect to water content, preliminary air-drying is necessary. This is accomplished by exposing weighed samples in shallow pans to the atmosphere in a warm room. For one-quarter to one-half pound samples, spread to a depth of not greater than one inch, the minimum time required is about 24 hours, although for very wet samples a longer time is necessary.

When air-dried to constant weight or nearly so, the pan and sample are weighed, the difference between this and the first weight representing the loss by air-drying, which may be calculated either to the as-received or to the dry bituminous sand basis. The air-dried sample, which is usually of a lumpy nature, is then prepared for further examination by breaking and mixing the lumps either with the fingers or by means of a mortar and pestle.

Water Determination

The water content is determined on air-dried sample, according to Dean and Starke (toluene) method as described in A.S.T.M. D-95-27, an outline of which follows: The apparatus, as illustrated in Figure 5, consists of a 500 c.c. round bottom, ring neck flask, a reflux condenser, a special (side neck) graduated receiver reading to one-tenth of a cubic centimetre, and an electric heater. One hundred grammes of the bituminous sand are weighed into the flask and 150 c.c. of toluene added; the different parts of the apparatus are connected and the heating started. The toluene and water vapours are driven off, both of which are condensed, the bulk of the toluene overflowing back into the flask while the water sinks to the bottom of the receiver. Heating is continued until no more water is collected, which usually requires about forty minutes. The volume of water in the graduated receiver is read, and from this the percentage of water in the sample is calculated.

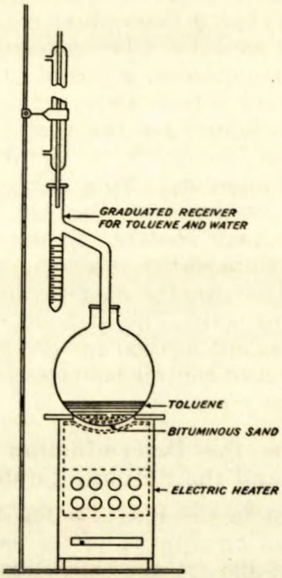

Figure 5. Apparatus for determining moisture in bituminous sand and bitumen.

Extraction with Solvent

A Dulin Rotarex centrifuge, as illustrated in Figure 6, is employed, and the solvent generally used is benzol. From 500 to 1,000 grammes of the prepared sample are placed in the bowl of the centrifuge and sufficient benzol added to cover the sample. The filter papers are then placed in position and the lid screwed down by means of the funnel as shown. After allowing the solvent to penetrate the sand, the motor is started slowly and the speed adjusted until the solution comes out of the exit pipe in a thin stream. An Erlenmeyer flask is used as collector.

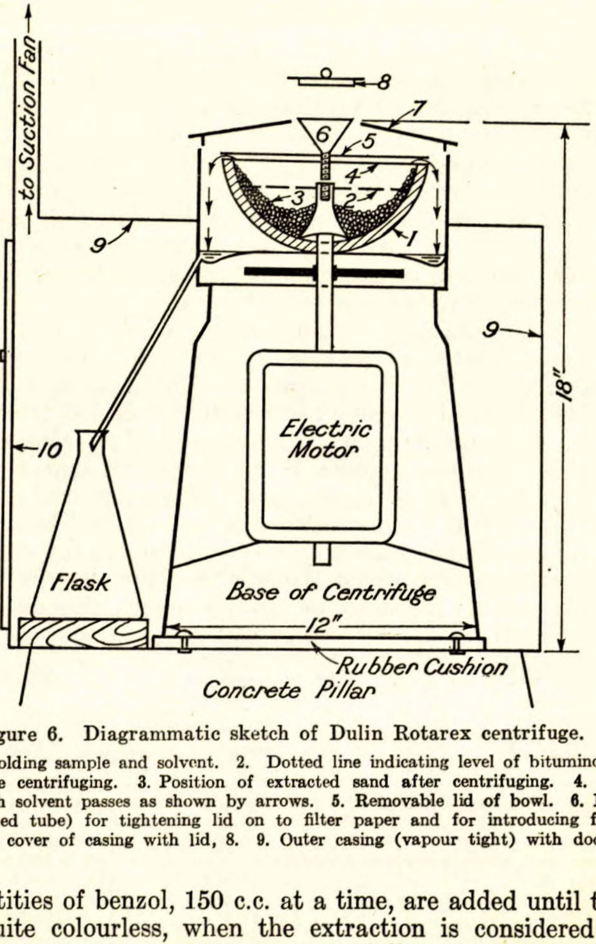

Figure 6. Diagrammatic sketch of Dulin Rotarex centrifuge.

1. Bowl for holding sample and solvent. 2. Dotted line indicating level of bituminous sand and solvent before centrifuging. 3. Position of extracted sand after centrifuging. 4. Filter paper through which solvent passes as shown by arrows. 5. Removable lid of bowl. 6. Funnel (with hollow threaded tube) for tightening lid on to filter paper and for introducing fresh solvent. 7. Removable cover of casing with lid, 8. 9. Outer casing (vapour tight) with door, 10.

Further quantities of benzol, 150 c.c. at a time, are added until the solvent comes out quite colourless, when the extraction is considered complete The lid is then opened up and the sand carefully transferred to a weighed pan and dried to constant weight in an oven at 105° C. After standing over night, the solvent with its extracted material is decanted, leaving in the bottom that portion which contains practically all the silty material that passed through the filter. This sediment is transferred to a filter paper (No. 42 Whatman) in a suitable glass funnel and washed with successive amounts of benzol to remove all traces of bitumen. After being dried, the fine material is brushed from the filter paper into the main bulk of the sand, the filter paper ignited, and the resulting ash also added. The total weight of the dry extracted sand is then obtained, and the difference between this and the weight of the original sample taken is the combined bitumen and water contents. The total loss by extraction minus the moisture content represents the bitumen content.

" Ashing " Method

In cases where the sample of bituminous sand submitted is not large enough for the centrifuge extraction, or where it is desired to roughly check the centrifuge results, an alternative method consisting of " ashing " the original sample and applying a loss of ignition correction, may be used. By this method 25 grammes or so are ignited in a porcelain crucible to constant weight, either over a gas burner or in an electric muffle furnace. The large size crucibles employed in the Eschka sulphur method for coal have been found suitable, and ignition at 700° to 750° C. in an electric muffle furnace according to the standard method used for coals and other solid fuels has been found satisfactory. Due to the loss in the sand material itself during the ignition period, in addition to that caused by the combustion of the bitumen, a " loss on ignition " correction must be made. This is determined on a duplicate sample of the extracted and dried sand obtained either from the centrifuge determination or from a specially extracted lot of the sample being examined. This ignition method of determining the bitumen content is obviously not suitable for samples containing insoluble organic matter such as woody or coal-like material in addition to the soluble bitumen, since the error caused by the combustion of such solid fuel material cannot readily be corrected for without resorting to solvent extraction for which the method here described is an alternative. The results of duplicate determinations by this method compared with those obtained by the centrifuge extraction method were as follows:

—	Ignition method			Centrifuge extraction method
	Test (1)	Test (2)	Test (3)	
Amount of sample taken, grammes	27·199	21·142	24·489	500
Weight after ignition, grammes	22·234	17·367	20·175	
Total loss by ignition, grammes	4·965	3·775	4·314	
Loss on ignition due to sand (per cent of dry sand), grammes	0·279	0·154	0·156	
Net loss, i.e. bitumen and moisture, grammes	4·686	3·621	4·158	
as per cent	17·2	17·1	17·0	17·2
moisture, per cent	0·3	0·3	0·3	0·3
Bitumen content of sample, per cent	16·9	16·8	16·7	16·9

Modification of the Solvent Extraction Method for Use in the Field

For samples taken at the scene of paving operations using bituminous sands, on which rapid determinations are necessary, certain modifications of the extraction method described above are required. The field method employed, and found serviceable as a control on the mixer used in connexion with the road paving operations at Jasper, Alberta, is as follows: A sample of about 25 pounds of the hot mix, taken from the heating and mixing machine at the time of its discharge, is well mixed while still hot, "quartered", and half of the total discarded. From the half retained, a grab sample weighing 1,000 grammes is placed in the bowl of the Dulin Rotarex centrifuge, and the bitumen extracted as above. The extracted "mineral aggregate" is dried to constant weight at 105° C. and a correction is added to compensate for the more or less constant loss of finely divided material—mostly filler—during extraction of the bitumen. The difference between this corrected weight and the sample taken represents the bitumen content of the sample of "hot mix" being tested. The correction to be applied to the weight of the dried extracted mineral aggregate is previously determined from a series of extractions carried out on mixtures containing various percentages of filler. The corrections to be used for different types of paving mixtures are tabulated below:

Sample of bituminous sand used......................1,000 grammes in each case.
Average dry sand content........................... 870 "

—	(1)		(2)	
Amount of Portland cement added as filler, grammes	43·85	43·85	87·70	87·70
Filler as percentage dry sand	5·0	5·0	10·0	10·0
Amount of fines found in solvent	3·5	3·8	3·9	4·1
Fines as percentage of mineral aggregate	0·38	0·42	0·41	0·43
Average correction factor	0·40		0·42	

DETERMINATION OF SULPHUR CONTENT OF THE BITUMEN

An obvious method of procedure for determining the sulphur content of the bitumen in bituminous sands would be to first extract the bitumen with a suitable solvent and then on an aliquot part of the extract, determine the sulphur content by the oxygen bomb method recommended for heavy oils. This method has been found to be quite satisfactory, but is long and tedious. In an endeavour to find a shorter and more reliable method, modifications of other more or less well known methods for the determination of sulphur were tried. The Eschka method using two to five grammes of the original bituminous sand of known bitumen content gave consistently low results when compared with the above method, due, apparently, to the loss of sulphur vapours during the roasting of the Eschka mixture. The determination of sulphur by the standard sodium peroxide method on the original bituminous sand was also tried, but abandoned on account of the length of time required to eliminate the silica resulting from the fusion of the sand, that is, before proceeding with barium chloride precipitation.

Comparison of Results by the Eschka, Sodium Peroxide, and Oxygen Bomb Methods

A sample of dehydrated (separated) bitumen gave the following results:

Method used	Sulphur, per cent	
	Individual determinations	Average
Eschka mixture	4·75 4·79 4·92	4·82
Oxygen bomb—400-pounds pressure	4·76 4·86	4·81
Oxygen bomb—600-pounds pressure	5·15 5·10	5·12
Sodium peroxide method	5·20 5·26 5·29	5·25

The close agreement of the results by the Eschka method and those obtained in the oxygen bomb at 400 pounds, the pressure used for calorific value determinations on coals, is to be observed. Since, however, the Eschka results are liable to be low as mentioned above, and as the results by the sodium peroxide method agree rather closely (although higher) with those obtained by the oxygen bomb method using 600 pounds pressure, the pressure stipulated in A.S.T.M.[1] standard method for sulphur in heavy oils, the sodium peroxide method is herewith recommended as a serviceable alternative method for the rapid determination of the sulphur content in the bitumen from bituminous sand samples.

Sodium Peroxide Method

Fifty grammes of well mixed bituminous sand is placed in a glass (or cork) stoppered graduated cylinder, and sufficient benzol solvent added so that the combined solvent and bitumen volume will amount to 250 c.c. The cylinder is vigorously shaken to ensure that the bitumen is completely dissolved after which the sand material is allowed to settle to the bottom; 20 c.c. of the supernatant liquid, in two successive 10 c.c. lots, are then drawn off by means of a pipette and transferred to the bottom cup of a Parr peroxide bomb, from which the solvent is evaporated by placing the bomb in a specially adapted steam bath. When the bitumen is free from the odour of the solvent, the potassium chlorate accelerator is added and mixed with the bitumen in the bomb by means of a glass stirring rod. In this operation, loss of bitumen is avoided by wiping the lower end of

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[1] A.S.T.M. D-129-27, viz., "Standard Method for Test for Sulphur in Petroleum Oils heavier than Illuminating Oils."

the rod with a pinch of filter paper held between the thumb and finger, after which the paper is dropped into the bomb. Sodium peroxide is then added, the cover put on, the screw clamp tightened and the charge exploded in the usual way. The bomb washing, sulphur precipitation, etc., are conducted according to standardized procedure.

NOTE

Care must be taken to see that the solvent is completely removed and that the amount of filter paper "wiper" used is not large, in order to avoid excessive carbon content to be exploded in the bomb; this care ensures that the pressure within the bomb at the time of explosion is not too great, and allows for longer life of the bombs employed.

For the evaporation of the solvent, an ordinary steam bath will do, but care should be taken during the latter part of the evaporation to have the bottom half of the bomb cup in the boiling water or steam proper so that the whole of the bomb comes to steam heat in order to drive off the solvent under uniform conditions in successive determinations. For this a water bath may be constructed from an ordinary low form gallon capacity tin can with removable lid, in which lid as many as seven holes of a diameter just large enough for the bomb cup to pass through may be cut. A wire screen or plate soldered or otherwise supported on the inside of the can proper serves adequately as a shelf on which the bomb cup may rest in a position so that at least half of the cup is below the cover level. Such an improvised water bath for use on a small electric hot plate has been found quite satisfactory. From 60 to 90 minutes are necessary for the evaporation of the two successive 10 c.c. lots of solution and at least an extra half hour should be allowed for the complete evaporation of the solvent.

Using 10 per cent for the average bitumen content, a recommendable procedure for adding sufficient solvent is to standardize the cylinder to be used by first placing 45 grammes of dry spent sand, preferably from the sample to be tested, in the cylinder, and then 250 c.c. of the solvent, thus to obtain a cylinder marking for future use representing the level to which solvent may be added to 50 grammes of sample to give without undue experimental errors a combined solvent-bitumen solution of 250 c.c. Where, however, the bitumen content varies considerably from 10 per cent, the above figures should be corrected accordingly. An aliquot part of 20 c.c. pipetted off for evaporation of the solvent in the bottom cup of the bomb would represent 4 grammes of the bituminous sand sample and 0·4 grammes of the bitumen in a 10 per cent bitumen sample. By this method the sulphur content can, therefore, be reported directly on the original bituminous sand basis, or by the use of the bitumen content figures obtainable by the extraction method given above can be calculated to water-free bitumen basis.

Where the solvent employed contains sulphur, the results obtained must be corrected. Comparative determination, with and without preliminary addition and evaporation of 20 c.c. of benzol in the peroxide bomb, on a standard sample of separated dehydrated bitumen (obtained without the use of solvents) gave the following results:

Sulphur by peroxide bomb method

Using 20 c.c. of commercial benzol (average of four determinations, 5·53, 5·45, 5·50, and 5·51 per cent)............................	5·50	per cent
Without benzol (average of three determinations).................	5·25	"
Correction for sulphur in benzol solvent................=	0·25	"

A typical data sheet for the laboratory assay of a sample of bituminous sands, according to the method described above, is as follows:

Air-drying

(Sample No. 70, Laboratory No. 4657.)

Sample and pan	2,024·5	grammes
Weight of pan	400·3	"
Sample taken	1,624·2	"
After drying to constant weight	2,002·2	grammes
Loss by air-drying, 2,024·5 − 2,002·2	22·3	"
Loss as per cent of sample taken	1·4	per cent

Moisture determination on air-dried sample

	(1)	(2)
Weight of sample taken, grammes	50	50
Aqueous distillate reading, c.c	0·7	0·4
Moisture content of air-dried sample, per cent	1·4	0·8
Average moisture content of air-dried sample, per cent	1·1	

Bitumen content of air-dried sample

	(1)	(2)
Weight of sample taken, grammes	500	500
Weight of dry extracted sand, grammes	430·9	435·0
Loss by solvent extraction, grammes	69·1	65·0
Loss by solvent extraction, per cent	13·8	13·0
Average loss by solvent extraction, per cent	13·4	
Average moisture content, per cent	1·1	
Average bitumen content, per cent	12·3	

Sulphur determination by Na_2O_2 method

Weight of air-dried sample taken, grammes	50
Benzol added to bring total volume of solvent and bitumen to 250 c.c	
Amount of benzol-bitumen solution used for sulphur determination, c.c	20
Bituminous sand in sample taken, grammes	4
Bitumen content at 12·3 per cent, grammes	0·492

	(1)	(2)
Weight of $BaSO_4$ obtained, grammes	0·1834	0·1775
Weight of sulphur (calculated), grammes	0·0252	0·0244
Sulphur as per cent of bitumen, per cent	5·12	4·95
Sulphur in blank (average), per cent	0·25	0·25
	4·87	4·70
Average sulphur content of bitumen to be reported to nearest 0·1, per cent	4·8	

Carbon Disulphide versus Benzol as Solvent in Respect to Sulphur in the Bitumen

Very little information is available regarding the sulphur content and the distribution of the same in the bitumen and fractions obtained therefrom by distillation when using different solvents for extracting the bitumen. Clark[1] gives the sulphur content of various samples of extracted bitumen and mentions that benzol was used for extraction instead of

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[1] "The Bituminous Sands of Alberta"; Rept. No. 18, p. 14.

carbon disulphide, as the bitumen was to be analysed for the sulphur content. He assumed, apparently, that sulphur from the carbon disulphide would contaminate the sample and vitiate the results of the analysis. J. H. Bateman and Charles Delp[1], in their recent paper on the examination of asphaltic mixtures, show that extraction with carbon disulphide and subsequent removal of the solvent actually reduces the sulphur content of the bitumen. As a result of these statements, it was decided to extract the bitumen from some bituminous sand both with benzol and carbon disulphide, fractionate the resulting samples of bitumen according to the Engler method, and determine the sulphur content of each fraction. By this means a comparison could be made of the effect of the solvent used on the sulphur content of the various fractions, and some information obtained as to the distribution of sulphur in the different fractions.

EXPERIMENTAL

Two lots of bitumen were obtained, one by extraction with carbon disulphide and the other by extraction with benzol. For the purpose of comparison a sample of bitumen was also obtained by distillation of the sand in a fire still. These three samples were fractionated according to the continuous Engler method and the sulphur content of each fraction determined according to the oxygen bomb method, as described in A.S.T.M. D-129-27.

Description of Methods

(1) EXTRACTION BY CARBON DISULPHIDE

One thousand grammes of bituminous sand were extracted in the Dulin Rotarex centrifuge, as described in the first part of this paper, using carbon disulphide as solvent. The mixture of bitumen and solvent was transferred to a large distilling flask connected to a condenser and a receiver and the solvent distilled off. Distillation at steam heat, with the flask immersed in boiling water, removed most of the solvent, but the raising of the bath temperature to 235° F. (112° C.) by means of an oil bath was necessary to ensure that practically all the carbon disulphide was distilled off. Subsequent heating for a long period, as shown below, gave only a slight further loss. One hundred c.c. of the extracted bitumen was then fractionated from a 250 c.c. Engler flask, cuts being made at 150° C., 300° C., and at E.P., viz., the end point; and sulphur determinations made on the bitumen and the different fractions therefrom. Using a sample of dry "unweathered" bituminous sand assaying 12·7 per cent bitumen, the following extraction results were obtained:

Weight of sample taken	1,000 grammes
Weight of dry (extracted) sand obtained	873·3 "
Weight of bitumen recovered at 235°F. (bath temp.)	126·7 "
Weight of bitumen after prolonged heating at 235°F	126·1 "

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[1] "The Recovery and Examination of the Asphalt in Asphaltic Paving Mixtures"; A.S.T.M. Proceedings, vol. 27, p. 465 (1927).

(2) EXTRACTION WITH BENZOL

The procedure was the same as in (1) using benzol instead of carbon disulphide. A temperature of 275° F. (135° C.) was used, with the system connected to a water vacuum pump to remove all but the last traces of the benzol solvent. Using a dry bituminous sand, similar to that used in (1), but from a different container, and assaying 14·1 per cent bitumen, the following results were obtained, employing benzol as solvent:

Weight of sample taken	1,000 grammes
Weight of dry (extracted) sand obtained	858·8 "
Weight of bitumen recovered at 275°F. (bath temp.)	141·2 "
Weight of bitumen after prolonged heating at 275°F	139·7 "

The extracted bitumen was then fractionated in an Engler flask as described above, and sulphur determinations made on the separate fractions, the results of which are shown in Table XXXIV.

(3) DESTRUCTIVE DISTILLATION WITHOUT THE USE OF A SOLVENT

For comparison, a sample of the same unweathered bituminous sand as used in (1) and (2) was destructively distilled in a large oil-shale assay retort, and the distillate fractionated in an Engler flask; subsequent sulphur determinations being made on the different fractions.

Weight of sample taken for destructive distillation	1,000 grammes
(Bitumen content, per cent weight, 13·5; water, per cent, 0·1.)	
Weight of distillate obtained	101·5 "
Weight of spent sand (ash content 96·0 per cent)	883·2 "
Sulphur content of spent sand, 0·24 per cent.	

TABLE XXXIV

Summary of the Sulphur Results

Method of extraction	Per cent sulphur in				
	Original bitumen or distillate	Fraction			Pitch residue
		Up to 150° C.	150° to 300° C.	300° C. to end point	
(1) Extraction with CS_2			1·85	2·97	6·85
(2) With benzol	5·03		2·62	3·47	6·90
(3) Destructive distillation		1·26	1·98	3·15	4·40

DISCUSSION OF RESULTS AND SUMMARY CONCLUSIONS

The uniformly higher sulphur content of the fractions of the bitumen obtained by extraction with benzol is more than likely due in part to the sulphur impurity in the solvent remaining in the different fractions, since as shown in the first section of this paper, the use of the commercial grade of benzol does give high results. In the absence of correction factors, which are not readily available on account of the shortage of both the particular lot of benzol employed and the standard sample of bituminous sands, the results are allowed to stand, subject to subsequent checking by the use of sulphur-free benzol as solvent.

As to the relative value of carbon disulphide and benzol for use as solvents one result is, however, outstanding, namely, that the use of carbon disulphide as a solvent does not contaminate nor give high results in respect to the sulphur content of the extracted bitumen and fractions therefrom. Instead of an increase of sulphur content, an actual decrease was observed. This agrees with the findings of Bateman and Delp, referred to above. Another observation to be made is that the sulphur tends to concentrate progressively in the higher boiling fractions and pitch residue, which agrees with the findings of Bjerregard[1] in respect to high sulphur crude oils.

It is to be further noted that the sulphur figures for the three different fractions, using carbon disulphide as solvent, agreed more closely with those obtained by destructive distillation which, coupled with the greater difficulty experienced in removing the last traces of benzol, makes the use of carbon disulphide as solvent preferable, especially when it is desired to obtain the light oil fractions free from solvent. When, however, time does not allow and when it is not necessary to remove the last traces of solvent from the bitumen, that is, where no great errors would be involved in subsequent determinations in allowing small amounts of solvent to remain, and especially where the amount is known, the use of benzol would have the preference for examinations in cases where the determination of sulphur alone is involved.

Comparison of Laboratory Extraction and Distillation Methods for the Subsequent Examination of the Bitumen

The bituminous sands of northern Alberta may be considered a source of two classes of products, one a water-proofing material for road building, roofing and other structural purposes, and the other a source of petroleum oil products, such as gasoline, fuel oil, etc. For the first class of products, it is the physical properties, such as ductility, tensile strength, penetration, etc., of the extracted bitumen that are of chief importance. Methods and apparatus for the determination of these physical properties have been fairly well standardized, having been derived for the most part from those already in use for the examination of coal tar and petroleum products.[2]

A review of the literature dealing with the laboratory examination of bituminous materials to ascertain their value as a source of substitutes for petroleum products, however, shows that no one standard method has seemingly as yet been adopted; methods heretofore used have varied in accordance with the preferences or inclinations of each particular investi-

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[1] Journal Ind. and Eng. Chem., vol. 17, p. 142 (1925).

[2] These methods are described in the various treatises on bitumen and asphaltic material, e.g. "Asphalts and Allied Substances," by Abraham; and "Laboratory Manual of Bituminous Substances," by Hubbard.

gator. There is, therefore, an apparent need for a standard method suitable for the examination of raw bituminous sands such as those found in Alberta. Such a standard method, in addition to showing the bitumen content of the sands, should also give an indication of its comparative value for (*a*) use for such as water-proofing material; and (*b*) as a source of petroleum oil products. The purpose of this paper is to show the comparative results of assaying a standard sample of bituminous sands by three different methods and to obtain data for the development and selection of a simple and reliable laboratory method for the examination of samples of bituminous sands.

The following short review of the literature on the bituminous sands illustrates the variety of methods used in examining bituminous sands. Ells[1] in 1913 distilled a number of samples of bitumen separated from the Alberta bituminous sand, using the apparatus and method as per A.S.T.M. PZO-18[2] except that heating was by a hot-air bath instead of direct. The average of all his results was:—

Total oil, including all fractions	69·0	per cent of original bitumen
Coke residue	23·7	" " "
Uncondensed fractions, loss, etc.	7·3	" " "
	100·0	per cent

Destructive distillation of a bituminous sand sample assaying 15 per cent bitumen in a retort designed at the Mellon Institute[3] gave a distillate yield of 19·3 Imperial gallons (sp. gr. 0·9191) equivalent to roughly 59 per cent of the original bitumen. Distillation of the crude oil in an Engler flask gave the following results:—

Fraction	Per cent by volume
Up to 150° C.	8·1
150°–300° C.	30·6
300°–325° C.	6·0
140°–325° C. at 8 mm.	47·0
Asphalt and loss	8·3

Kreible and Seyer[4] analysed the bitumen from Alberta bituminous sand by the Marcusson method and compared it with the Trinidad and Bermudez bitumens. Their method for recovering the bitumen consisted of extraction with petroleum ether. From the hydrocarbon oils extracted from the bitumen, on a sufficiently large scale for fractional distillation, they succeeded in isolating thirteen apparently pure hydrocarbons, belonging to the C_nH_{2n}, C_nH_{2n-2} and C_nH_{2n-4} series. They apparently were interested in studying the constitution of certain portions of the bitumen, rather than extracting and examining the total bitumen content of the sands.

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[1] Ells, S. C.: "The Bituminous Sands of Northern Alberta": Mines Branch, Dept. of Mines, Canada, Report No. 632, p. 107 (1926).

[2] By this method, which is the same as that described by Hubbard in "Laboratory Examination of Bituminous Materials," pp. 76–80, 100 c.c. are distilled from a 250 c.c. glass flask attached to a vertical glass condenser.

[3] Ells, S. C.: "The Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 108 (1926).

[4] "A Chemical Investigation of theAsphalt in the Tar Sand of Northern Alberta"; V. K. Kreible and W. E. Seyer, Jour. Amer. Chem. Soc., 1926, vol. 43, No. 6, pp. 1337–1349.

Clark[1] gives the following analysis of the crude distillate obtained by retorting Alberta bituminous sand but does not describe any particular apparatus or method.

Analysis of original sample

Water, by volume	3·2 per cent
Sediment, tarry residue	0·5 "
Oil, by volume	93·3 "
Specific gravity	19·5 Bé. (0·936)

Distillation of oil

70°–150° C.	9·7 per cent
150°–300° C.	27·3 "
300°–380° C.	55·6 "
Loss	7·4 "

His table showing the final products from the extracted bitumen was:

Refined products	45 per cent
Gas	5 "
Coke	25 "
Pitch	5 "
Refining losses	20 "

Abraham[2] gives an analysis of Alberta bitumen but it is restricted to the physical properties, penetration, consistency, etc. All these illustrate the lack of uniformity in the methods used for assaying Alberta bituminous sands and show the need of a standard method.

According to Ells[3], processes for the recovery of hydrocarbons from the bituminous sands may be grouped into three general classes.

1. Separation of associated bitumen through the leaching action of hot water, with or without the addition of various reagents.
2. Separation of the associated bitumen through the leaching action of organic solvents.
3. Recovery of the associated hydrocarbons by destructive distillation.

Methods 2 and 3, applying in particular to large-scale operations, have been kept in mind as a basis for laboratory extraction and distillation experiments.

EXPERIMENTAL

The bituminous sand used as standard sample was an " unweathered " sample furnished by S. C. Ells. It was a quite viscous, coarse, sandy material and was comparatively free from water. After receipt in the

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[1] Second Annual Report of the Scientific and Industrial Research Council of Alberta, pp. 54–59.

[2] Asphalts and Allied Substances, p. 106.

[3] Ells, S. C.: "The Bituminous Sands of Northern Alberta"; Mines Branch, Dept. of Mines, Canada, Rept No. 632, p. 173, et seq. (1926).

laboratory it was kept in a sealed container and was considered representative of the freshly obtained natural product. Three different laboratory methods were examined as follows:

1. Extraction of the bituminous sand with carbon disulphide, removal of solvent, followed by fractional distillation of the bitumen residue according to the continuous Engler method.[1]

2. Destructive distillation of the bituminous sand in an iron retort, followed by fractional distillation of the distillate in a glass (Engler) flask.

3. Extraction of the bituminous sand with carbon disulphide, removal of solvent, distillation of the extracted bitumen in an iron fire still, followed by fractional distillation in an Engler flask.

For future reference the following short titles will be used to designate the three methods just given.

1. Extraction plus Engler fractionation.
2. Destructive distillation plus Engler fractionation.
3. Extraction plus fire-still distillation plus Engler fractionation.

Description of Methods

1. EXTRACTION FOLLOWED BY ENGLER FRACTIONATION

The procedure for extracting the bitumen was the same as used for routine samples of bituminous sands submitted primarily for determination of bitumen content, a detailed description of which is given on page 85. The solvent employed in these experiments, however, was carbon disulphide instead of benzol. On account of its comparatively low boiling point it (CS_2) was used to simplify the removal of the solvent without loss of light oil content of the bitumen and in turn to ensure that the first light oil fraction when distilled is as free as possible from the solvent. A comparison of the results, in respect to sulphur contamination, using carbon disulphide and benzol respectively is given on page 92.

Extraction. One thousand grammes of the well-mixed bituminous sand were placed in the bowl of the (Dulin Rotarex) centrifuge, Figure 6, and sufficient carbon disulphide added to cover the sample. After the filter paper rings and lid are properly adjusted, the material is alternately centrifuged and new solvent added until the solvent is thrown out quite clear, indicating that the extraction is complete. Approximately five pounds of solvent were needed for each 1,000 grammes of bituminous

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[1] For a description of this Engler method, originally employed for fractional distillation of petroleum, see "A Treatise on Petroleum" by Redwood, vol. II, p. 204. In this method an Engler flask of specified dimensions, so called after its author, Dr. Engler, is used. The rate of distillation and the temperatures at which the different fractions are to be cut, viz., 150° C. and 300° C. etc., are specified. Alternative methods of operation, viz., intermittent and continuous fractionation, are practised. In the former, the temperature is brought up to the point at which the fraction is to be cut and then allowed to cool, this process being repeated until no more distillate is obtained; while in the latter the heating is continuous and the receivers changed at predetermined temperatures, according to the cuts desired.

sand extracted. The solvent with its (extracted) bitumen was then transferred to a large pyrex glass distilling flask, fitted with suitable condenser and receiver, and most of the solvent removed by means of a small electric heater. The removal of the solvent was completed by heating on a steam bath in the open flask until free from the odour of CS_2. After removal from the flask and the determination of specific gravity by means of a Sommer hydrometer, the bitumen was ready for subsequent destructive distillation.

Fractional Distillation and Examination of the Fractions. Approximately 100 c.c. of the solvent-free bitumen were weighed into a 250 c.c. Engler flask and distilled according to the continuous method. Temperature readings were taken at every 5 per cent distilled over and cuts made at 150° C., 300° C., and at the end point (E.P.). The amount of pitch remaining in the flask was then weighed. The specific gravities of the three fractions were determined by a Westphal balance and the percentage of saturates determined according to the solubility in concentrated sulphuric acid. For this test 5 c.c. of each fraction were shaken with equal quantities of concentrated H_2SO_4 (sp. gr. 1·84) in a 15 c.c. centrifuge tube adding the acid in small portions and keeping the mixture cool, either in ice water or holding under running tap water. After centrifuging, the volume of the upper layer was read off and the amount of insoluble saturated calculated.

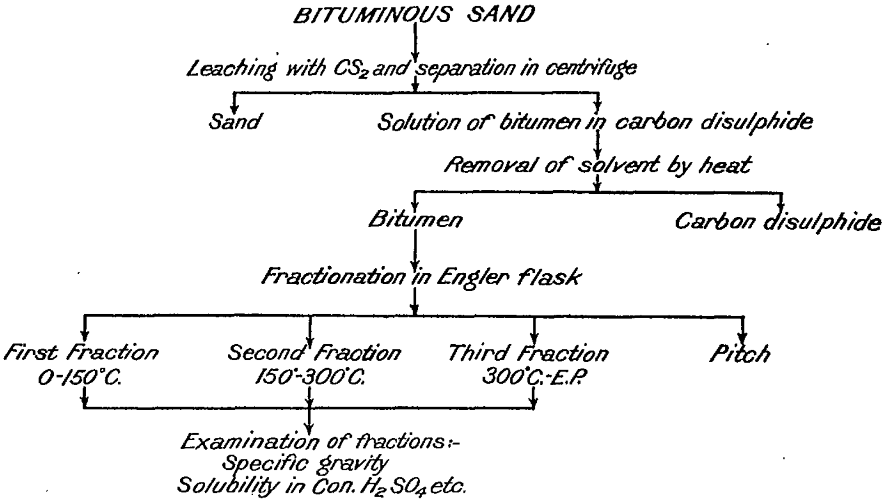

Figure 7. Flow-sheet of Method 1.

Typical Data Sheet for Method 1

Amount of sample used for extraction..............	1000	grammes
Weight of bitumen after removal of solvent........	140	"
Specific gravity of bitumen at 60°F................	1·015	"

Fractionation of Bitumen in Engler Flask

(Amount taken, 103·3 grammes = 101·7 c.c.)

Temperature	Fractions			
	c.c.	Per cent of volume	Sp. gr. at 60° F.	Insolubility Conc. H_2SO_4
				%
Up to 150° C.	0·9	0·9	....	....
150° to 300° C.	11·5	11·3	0·866	68
300° C. to end point	63·0	62·0	0·899	58

2. DESTRUCTIVE DISTILLATION FOLLOWED BY ENGLER FRACTIONATION

The procedure and apparatus employed in this method are the same as that used for the distillation of oil shales, viz.: a cast-iron retort, 1,000 grammes capacity, connected to condensers and receivers and gas meter.

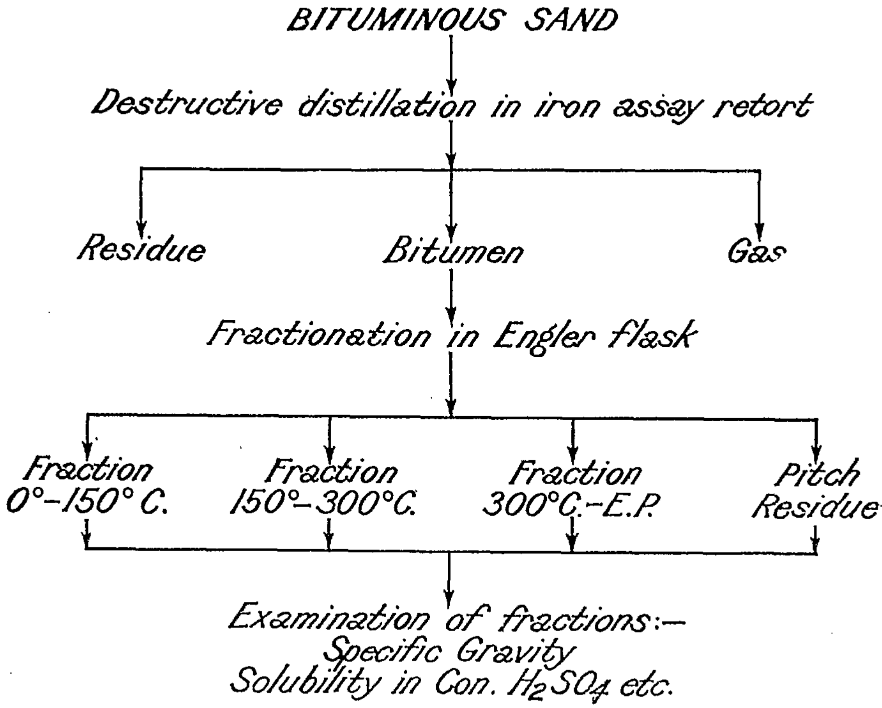

Figure 8. Flow-sheet of Method 2.

A description of this method was given on page 72 in the 1924 Investigations of Fuels and Fuel Testing. One thousand grammes of tar sand were placed in the retort, the lid screwed down tightly and the exit tube connected up with the condensing train. Heating was started slowly and regulated so that no tar fog appeared. Distillation was stopped when no further oil distilled off, the total time required being from 3½ to 4 hours. The distillate was then weighed, the water separated from the oil, and the yield of dry oil obtained. The pitch residue after being emptied from the retort was weighed and the weight of the gas in turn calculated from its volume and analysis. The fractional distillation was carried out according to the standard Engler method described above.

Typical Data Sheet for Method 2

Amount of sample used for distillation	1,200 grammes	
Products obtained—		% weight of bituminous sand
Oil-distillate (water-free)	119·1 grammes	9·9
Water	6·5 "	0·5
Gas (0·46 cubic feet)	11·1 "	0·9
Spent sand residue	1,054·5 "	87·9
Loss by difference		0·8
Ash content of residue	96·4 per cent	
Fixed carbon by difference	2·1 "	

Fractionation of Oil Distillate in Engler Flask

(Amount taken, 100 c.c.; specific gravity at 60° F., 0·925).

Temperature	Fractions		
	c.c.	Sp. gr. at 60° F.	Insolubility Con. H_2SO_4
			%
Up to 150° C	4·6	0·707	76
150° to 300° C	27·0	0·859	66
300° to end point	62·0	0·939	60

Pitch residue: 3·4 grammes = 3·7 per cent weight of distillate.

3. EXTRACTION, DISTILLATION OF THE EXTRACTED BITUMEN IN FIRE STILL, FOLLOWED BY FRACTIONAL DISTILLATION OF THE DISTILLATE

One thousand grammes of bituminous sands were extracted by centrifuging followed by removal of the solvent as in Method 1. The solvent-free bitumen was weighed and then transferred to an iron (fire) still, as used in Method 2. In this operation the extracted bitumen was distilled to coke as in the fire-still operations for certain asphaltic base petroleums in oil refineries. The distillate, that is the extracted bitumen minus the coke was then fractionally distilled as in Methods 1 and 2.

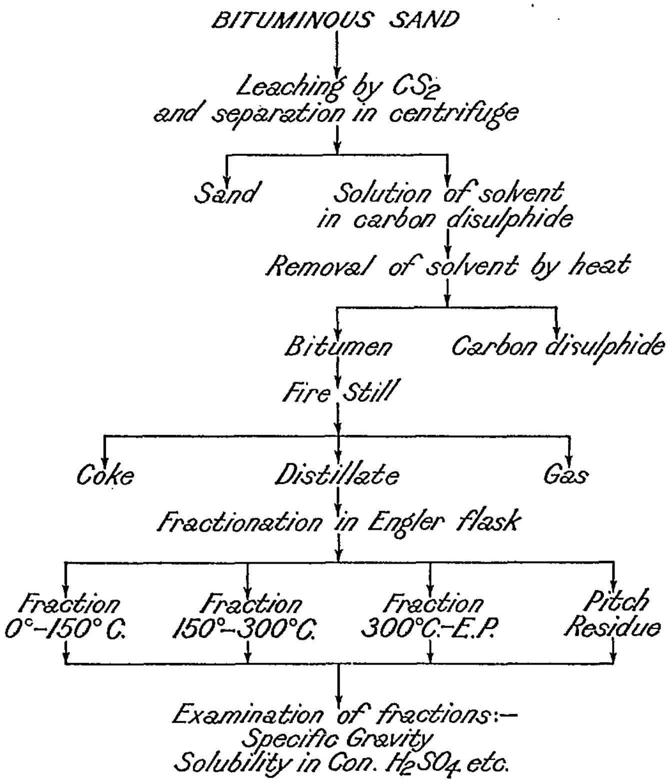

Figure 9. Flow-sheet of Method 3.

Typical Data Sheet for Method 3

Amount of sample used for extraction	2,000 grammes
Weight of bitumen after removal of solvent	281 "
Specific gravity of bitumen at 60° C	1·015
Weight of bitumen distilled in iron retort	190 grammes (187 c.c.)

Products obtained—

		Per cent weight of extracted bitumen
Oil distillate (water-free)	141·0 grammes	74·2
Coke residue	30·9 "	16·3
Gas (0·56 c.f.)	15·4 "	8·1
Loss by difference		1·4

Specific gravity of oil distillate at 60° F. = 0·913

Oil distillate as per cent of extracted bitumen = 82 per cent.

Fractionation of Distillate in Engler Flask

(Amount taken, 100 c.c.)

Temperature	Fractions			
	c.c.	Per cent of volume of extracted bitumen	Sp. gr. at 60° F.	Insolubility Con. H_2SO_4
				%
Up to 150° C.	8·0	6·6	0·740	76
150° to 300°C.	27·0	22·1	0·866	68
300° to end point	55·0	45·1	0·893	63

Pitch residue: 6·8 grammes = 5·5 per cent of weight of extracted bitumen.

TABLE XXXV

Summary of Results

——	Yields		
	Method 1	Method 2	Method 3
	Extraction and fractionation	Destructive distillation and fractionation	Extraction, distillation, and fractionation
Extracted Bitumen—			
Yield, % weight of bituminous sands	14·0	....	14·1
Specific gravity at 60° F.	1·015	....	1·015
Oil Distillate—			
Yield, % weight of bituminous sands	....	9·9	10·4
Specific gravity at 60° F.	....	0·925	0·913
Gas, % weight of bitumen	....	....	8·1
Coke (from fire still) % weight of bitumen	....	....	16·3
Coke (in spent sand), % weight of bituminous sands	....	18·5	....

Fractionation of extracted bitumen or of distillate:	Method 1	Method 2	Method 3	
	Per cent of extracted bitumen	Per cent of distillate	Per cent of	
			Distillate	Extracted bitumen
Up to 150° C. % volume	0·9	4·6	8·0	6·6
150°C. to 300° C. “ “	11·3	27·0	26·9	22·1
300°C. to end point “ “	62·0	62·0	55·0	45·1
Pitch residue “ “	27·6	3·7	7·4	5·4
Light oils, up to 300° C. “ “	12·2	31·6	34·9	28·7
Total oils to end point “ “	74·2	93·6	89·9	73·8
Total pitch and coke	27·6	3·7	....	21·7
Specific Gravity at 60° F.—				
Fraction up to 150° C.	*	0·71	0·74	
“ 150° to 300° C.	0·87	0·86	0·87	
“ 300° C. to end point	0·90	0·94	0·89	
Insolubility in Conc. H_2SO_4—				
Fraction up to 150° C.	*	76%	76%	
“ 150° to 300° C.	68%	66%	68%	
“ 300° C. to end point	58%	60%	63%	

* Sample too small for examination.

TABLE XXXV—*Concluded*

Summary of Results—*Concluded*

—	Yields as Imperial gallons or pounds per ton of bituminous sand		
	Method 1	Method 2	Method 3
Extracted bitumen	27·6 gal.	....	27·7 gal.
Specific gravity at 60° F	1·015	....	1·015
Oil distillate	....	21·4 gal.	22·8 gal.
Specific gravity at 60° F	....	0·925	0·913
Fraction up to 150° C	0·3 gal.	1·0 gal.	1·6 gal.
" 150° to 300° C	3·1 "	5·8 "	5·4 "
" 300° to end point	17·1 "	13·3 "	11·0 "
Pitch residue	15·0 lb.	7·0 lb.	15·0 lb.
Light oils up to 300°C	3·4 gal.	6·8 gal.	7·0 gal.
Total oils to end point	20·5 "	20·1 "	18·0 "
Total pitch and coke	77·0 lb.	7·0 lb.	61·0 lb.
Coke in spent sand	....	37·0 "	
Gas	....	350 cu. ft.	370 cu. ft.

DISCUSSION OF RESULTS

Individual data sheets and Table XXXV show that the results obtained by the three different methods varied considerably. Comparing Method 1 (extraction plus fractionation) and Method 2 (destructive distillation plus fractionation) although there is considerable variation in the yields of the three fractions going to make up the total, the yield of light oils up to 300° C. is practically the same, viz. 20·5 and 20·1 gallons per ton of bituminous sand treated respectively. The pitch yield in Method 1 is 77 pounds as compared with 7 pounds in Method 2. Adding to the 7 pounds, 37 pounds, representing the coke left in the spent sand in Method 2 after destructive distillation, a total of 44 pounds is obtained, part of the difference between this figure and 77 being accounted for by the gas amounting to 0·9 per cent of the weight of the bituminous sand, equal to 350 cubic feet per ton retorted. Where suitable extraction apparatus is not readily available, Method 2, viz., destructive distillation of the original bituminous sand, followed by fractional distillation of the distillate, has merits and may be used. However, since Method 1 involving extraction and subsequent fractionation of the extracted bitumen, affords information as to the yield and specific gravity of the bitumen, gives a yield of light oils comparable with that obtained in Method 2, and shows a high pitch yield, it is preferable to Method 2.

By Method 3, the maximum yields of both extracted bitumen and distillate and interpretable results concerning oil fractions, pitch, coke, and gas products are available. The light oil yield of 7·0 gallons compares favourably with the yield of 6·8 gallons in Method 2, and while the total yield is slightly less, it would no doubt be increased by running to coke instead of pitch in the fractional distillation. The yield of distillate obtained by distillation of the extracted bitumen to coke in the fire still is of special interest in that such distillate represents the amount of the bitumen available as cracking stock for pressure-cracking refining. Other products obtainable by this method are as just stated, fire-still coke and gas amounting to 46 pounds and 370 cubic feet per ton of the bituminous sand examined.

SUMMARY CONCLUSION

Inasmuch as Method 3—consisting of extraction by solvent, fire-still distillation and fractionation of the distillate—may be considered a combination of Methods 1 and 2, and affords valuable threefold results, viz., (*a*) the yield and quality of the extracted bitumen, (*b*) an indication of the yield of the different oil fractions to be expected by ordinary refining at atmospheric pressure, and (*c*) the yield and quality of distillate suitable for pressure-cracking stock, along with the yield of coke and gas products, it, i.e. Method 3, is to be recommended for the laboratory assay of samples of bituminous sand in respect to the examination of the bitumen as a source of petroleum oil products, in preference to the other two methods described.

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