

CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN MCLEISH, DIRECTOR

INVESTIGATIONS
OF
FUELS AND FUEL TESTING
(*Testing and Research Laboratories*)

1928

	PAGE
General review of investigations: by B. F. Haanel and R. E. Gilmore.....	1
I. Report of preliminary carbonization and briquetting tests on lignite from northern Ontario: by R. A. Strong.....	7
II. Report on oil-shale from Pictou county, Nova Scotia: by A. A. Swinnerton..	13
III. Laboratory notes: by J. H. H. Nicolls—	
(1) Under-water storage of Saskatchewan lignite.....	25
(2) Effects of prolonged weathering on the friabilities of certain coals....	27
(3) Observations concerning organic and other forms of sulphur in coals containing large amounts of sulphur.....	28
IV. Analyses of coals and other solid fuels: compiled by J. H. H. Nicolls and C. B. Mohr.....	36
V. Gasoline survey for 1928: by P. V. Rosewarne and R. J. Offord.....	57



No. 712

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928

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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, 1928

GENERAL REVIEW OF INVESTIGATIONS

B. F. Haanel, *Chief of Division of Fuels and Fuel Testing*

R. E. Gilmore, *Superintendent of Fuel Testing Laboratories*

The program of the Division of Fuels and Fuel Testing during 1928 was comprised largely of new work of a somewhat different nature from that of recent years. The new building of the Fuel Research Laboratories and the installation of equipment therein was brought nearer to completion, and a good beginning made on a comprehensive chemical and physical survey of the Phalen coal seam in Nova Scotia. This survey and other investigations begun during the year are not sufficiently advanced to be put in the usual report form, but a summary of the program and results obtained may be given. As an introduction to the general review of investigations, therefore, the writers desire to outline the activities of the technical staff of the division during the year. The investigations conducted are outlined in the Annual Report of the Department of Mines for the fiscal year ending March 31st, 1929, certain phases of which investigations may be amplified here.

The results of a series of experiments on the fire-setting propensities of clinkers dropped from oil-burning locomotives, conducted by E. S. Malloch and C. E. Baltzer, are worthy of special mention. These tests, which were conducted at the request of the Fire Inspection Department of the Board of Railway Commissioners, showed that slag and other firebox refuse on being heated to a temperature of 2,000° F. and dropped a distance of four feet into dry grass, leaves, etc., instantly set this inflammable material afire. It was further found that 1,500° to 1,600° F. was the minimum temperature at which the slag had to be heated to set fire to the inflammable material used. The results indicate that the dumping of hot slag, clinkers, and other firebox refuse from oil-burning engines is a dangerous practice where inflammable material is present in close proximity to a railway right-of-way.

Pulverized Coal. During the year visits to industrial pulverized fuel fired boiler plants throughout the country were made by C. E. Baltzer. The purpose of these visits was to make a survey of the pulverized fuel installations, make the acquaintance of the operators and their problems in the utilization of coal in powdered form, and in turn acquaint them with the proposed tests in the experimental pulverized fuel fired boiler installation at Ottawa. The objective of these tests is the greater utilization of Canadian coal for steam-raising purposes. At the several plants visited, notes taken included the different kinds of pulverizer units and burners used, and samples of the coal before and after pulverization were collected. The results of examination of these samples showed a wide variation in moisture content and degree of fineness of the pulverized coal, which indeed accounted for wide variations noted in the overall efficiencies. The moisture content of 10 different samples of raw coal charged varied

from 0.6 to 9.0 per cent and the percentages of the pulverized fuel passing a 200-mesh screen varied from 35 to 88 per cent. The corresponding figures for the proportion through a 100-mesh screen varied from 50 to 97 per cent, with an average of 85 per cent.

Phalen Seam Survey. This survey was a co-operative investigation in which the Geological Survey of the Department of Mines, the Provincial Government of Nova Scotia, and the Dominion Coal Company were interested. The work was of a preliminary nature and consisted mainly of taking underground samples. The purpose was to examine the seam at various locations in order to determine the variation in the quality of coal from top to bottom of the seam, and as the seam extended seaward. The first series of samples was taken from 13 different locations, 7 of which were "seaward" from the hoisting shafts, the remaining locations being "landward". The area sampled extended from No. 16 Colliery at New Waterford in a southeasterly direction to No. 6 Colliery at Caledonia and the seaward locations varied from one to three miles from the hoisting shaft. At each location a composite channel sample of the seam and from 20 to 24 sectional samples were taken. These sectional samples were cut out from the face of the seam, the original dimensions of each cubical section being approximately 4 inches square on the horizontal plane and varying from 2 to 8 inches in height. The sectional samples were taken in duplicate, one set of which was kept in reserve. A column or section of the face was cut out bodily and shipped intact to Ottawa for special "thin section" photomicrographic examination.

The composite and sectional samples were for proximate analysis, sulphur content, and fusibility of ash; and on selected samples special carbonization and other tests were to be made. Preliminary examination has shown a considerable variation in the quality of coal from top to bottom of the seam, and a study of the results indicates to what extent certain portions of the roof and floor might very well be left, in order to maintain the high quality of coal hoisted.

Carbonization Tests on the composite samples from different locations in the Phalen seam survey were made. These consisted of small-scale tests on 10 of the 13 samples, in the Sperr and Rose (Koppers) laboratory apparatus according to the standardized procedure outlined in a previous report.¹ Low-temperature carbonization tests on 5 of the 13 samples were also made by Messrs. R. A. Strong and E. J. Burrough, who took charge of the greater part of the underground sampling program.

Crude Oil and Natural Gas. The collection of representative samples of crude oil for a comprehensive analysis survey of the crude petroleum oils from wells in the different sections of the country was brought nearer completion. The crude oils on hand at the end of the year were as follows:

- Samples from the Petrolia field, Ontario.
- Samples from the Gaspé field, Quebec.
- Samples from the Turner Valley field, Alberta.

The program involved in the analyses of these samples comprised fraction-distillation according to both the standard Engler and Hempel methods,

¹ Mines Branch, Dept. of Mines, Canada; Invest. of Fuels and Fuel Testing, 1927, page 24.

specific gravity determinations of all fractional cuts, and the determination of viscosity on the heavier lubricating oil fractions. The sulphur content of the light, medium, and heavy oil fractions obtained in the "Hempel" distillation were also to be determined as well as the sulphur content and calorific value on the original crudes. The results of preliminary examination of these crude oils are on record, but their publication is being held over for the 1929 report of investigations, when it is hoped the results of complete analyses will be available on the Ontario and Quebec samples at least.

The crude oil and natural gas situation in the Turner Valley field in Alberta was investigated during the year by an officer of the division, namely, P. V. Rosewarne, and an inter-departmental report made. The methods of analysis employed for gasoline, kerosene, fuel oils, and lubricating oils were also compiled for later publication in bulletin form, which is to include the methods of analysis for solid and gaseous as well as for those of liquid fuels employed in the Fuel Research Laboratories.

Review of Investigations

The annual report "Investigations of Fuels and Fuel Testing, 1928," comprises five papers, two of which are the analyses of coals and other solid fuels examined during the year, and the annual gasoline survey respectively. The results of field and laboratory work on samples of oil shale from the Pictou area, Nova Scotia, comprise the third paper. Notes on some minor small-scale laboratory investigations thought worthy of publication concerning the comparative friability of certain solid fuels after continued weathering, the under-water storage of Saskatchewan lignite, and some observations on the determination of the forms of sulphur; and a report of small-scale carbonization and briquetting tests on lignite from northern Ontario, constitute the two remaining papers. A general review of the contents of these papers and the results obtained follows:

Report of Preliminary Carbonization Experiments on Ontario Lignite: by R. A. Strong. This paper comprises tests on selected lumps of lignite coal submitted by the Ontario Department of Mines. A description and results of examination of the 500-pound lot of coal obtained from an outcrop on the Abitibi river are given in the annual report¹ of that Department and need not be further described here. The lumps selected for carbonization and briquetting tests were from laboratory sample No. 5331, which represented the better quality proportion of the total outcrop sample. The moisture content of the fresh lumps examined was in the neighbourhood of 40 per cent, which along with other criteria, indicates that this northern Ontario lignite is similar, though of a lower rank, to lignites of the Estevan area in Saskatchewan, which range from 33 to 35 per cent in moisture content in the freshly mined condition.

By carbonization at 600° C., a carbonized residue or char with a calorific value of 12,860 B.T.U. per pound was obtained, which is more than

¹Annual Report of the Ontario Department of Mines, vol. 38, Part IV, pages 34-40, "Lignite Coal from Blacksmith Rapids, Abitibi River," by R. E. Gilmore.

double the calorific value in the freshly mined or slightly air-dried condition, and is an appreciable increase over that of the coal when dried at 105° C. The yield of carbonized residue, however, was only 37 per cent, which means that from $2\frac{1}{2}$ to $2\frac{3}{4}$ tons of raw coal are required to produce a ton of char. The laboratory yields of tar oils varied from $5\frac{1}{2}$ to 6 Imperial gallons per ton, and the gas yield was in the neighbourhood of 3,300 cubic feet per ton of raw coal carbonized. The tar oils representing the sum of the dried tar from the total liquid distillate, and the light oils scrubbed from the gas—with a specific gravity of 1.060—had a phenolic content of nearly 50 per cent, the balance being neutral oil, pitch, etc.

Small-scale briquetting tests in a plunger press showed that the char was amenable to briquetting; satisfactory briquettes have been produced with 9 per cent of binder, asphalt being used. The ash content and calorific value of the briquettes produced were roughly 15 per cent and 12,700 B.T.U. respectively on a 2 per cent moisture basis, which analysis corresponds favourably with the analysis of Pennsylvania anthracite marketed in central Canada.

Report on Oil Shale from Pictou County, Nova Scotia: by A. A. Swinerton. This report comprises the results of field work in the Pictou area, which work is supplementary to that of W. A. Bell, of the Geological Survey, in 1923, and of Prof. A. E. Flynn, of the Nova Scotia Technical College, in 1926. Five different outcrops, located along the course of McLellan brook in the vicinity of New Glasgow, were opened up and sampled. After preparing an unweathered face, a series of different sections of the seam at each location was collected, and from two of the richer seams large samples were taken for future large-scale retorting tests. Retorting tests on eighteen different samples were made according to standardized laboratory procedure described in the appendix to the report.

Of the five different outcrops sampled, two, viz. beds B and C, having a thickness of 11 and $13\frac{1}{2}$ feet respectively, had oil contents of only 8.5 and 6.0 Imperial gallons per ton, with no section of either seam showing over 11 gallons of crude oil. As judged by the outcrops, these two beds are, therefore, not of high economic value. Bed A, $4\frac{1}{2}$ feet in thickness, showed an average oil content of 17.5 gallons, different sections of the seam ranging from 12.0 to 30.5 gallons. Since, however, the thickness of the seam showing over 20 gallons was only one foot, the relative value of this bed is not high.

A bed, to be worthy of commercial development, should show an oil yield of at least 20 Imperial gallons per short ton, and as the laboratory yield is likely to be consistently higher than the commercial yield, the figure of 25 gallons per ton as the laboratory assay yield is a preferable value to judge the commercial possibilities of a given oil shale deposit. As judged by the outcrop samples only two of the five beds sampled, viz. beds AB and D, show up to advantage. Bed AB, having a thickness of 5 feet, showed an average oil yield of roughly $26\frac{1}{2}$ gallons, while bed D, also 5 feet thick, averaged $28\frac{1}{2}$ gallons. Different sections of the latter bed, located near the junction of McLellan brook and McLellan Mountain road, varied from 19 to 48 gallons per ton, which indeed makes this outcrop the most promising of any examined in the Pictou area.

Laboratory Notes: by J. H. H. Nicolls and E. Swartzman. These notes are in three sections or parts, the first two dealing with laboratory investigations conducted by the senior author and the third (main) section relating to results of some analytical work conducted by the junior author under the guidance of J. H. H. Nicolls.

(1) *Under-water storage of Saskatchewan lignite.* This paper deals with the storage of lignite coal to prevent oxidation and other chemical changes during continued laboratory examination rather than advocating the commercial storage of such lignite under water, although it is shown that this method of storage would prevent the slacking and disintegration that takes place when it is stored in piles in the open.

(2) *Effect of prolonged weathering on the friabilities of certain coals:* is a continuation of former friability experiments and the results reported here are to be considered as supplementary to those reported in Investigations of Fuels and Fuel Testing, 1924 and 1925.

(3) *Observations concerning organic and other forms of sulphur in coals containing large amounts of sulphur.* This paper also should be read in relation to "forms of sulphur work" reported in former publications. As the title suggests, it deals specially with high sulphur coals and raises the question as to reliability of the results obtained by difference for organic sulphur when using the standard laboratory procedure.

Analyses of Coals and Other Solid Fuels: compiled by J. H. H. Nicolls and C. B. Mohr. This compilation is comprised of three parts, as in previous years.

(1) *Analyses of coal and peat native to Canada, originating as follows:*

Nova Scotia.....	27 samples of coal.
Ontario.....	7 samples of peat and 2 samples of lignite.
Saskatchewan.....	2 samples of lignite.
Alberta.....	35 samples of coal.
British Columbia.....	1 sample of coal.

(2) *Analyses of coals submitted by Department of Pensions and National Health.* This section contains 50 individual analyses, each analysis being the average of two or more samples of the same lot of coal, and in many cases a single analysis represents the coal from as many as six carloads. Half of the total analyses reported (i.e. 25 analyses) is for coals mined in Canada, the other half being for coals imported from the United States. These analyses are for coals delivered to the hospitals operated by the Department, and are important in that the price paid was adjusted for bonuses and penalties based on the variation of the moisture, ash, and calorific values of the coal delivered from that guaranteed as "contract" grade.

(3) *Analyses of miscellaneous solid fuels, comprising the following:—*

Bituminous (steam) coals from U.S.A.....	12 samples
Scotch and Russian anthracite.....	4 "
Cokes: domestic by-product oven sizes.....	10 "
Briquettes, hardwood charcoal, etc.....	5 "

Gasoline Survey for 1928: by P. V. Rosewarne and R. J. Offord. This is the sixth annual analysis survey of the gasoline marketed in Canada, conducted by the Fuel Testing Laboratories. By the hearty co-operation of the officials and inspectors of the Department of Health, 75 samples from 13 different cities were collected and sent in. Continuing the innovation started in the 1927 survey, the "unsaturates, aromatic, naphthene and paraffin" contents of the gasolines were determined in addition to the usual specific gravity, distillation range, index values, etc., reported in former years. It is of interest to note that the gasoline sold during 1928 was of good quality and was again superior to that sold during the same period in the United States.

I

REPORT OF PRELIMINARY CARBONIZATION AND BRIQUETTING TESTS ON LIGNITE FROM NORTHERN ONTARIO

R. A. Strong

The Ontario Department of Mines submitted samples from what appears to be a commercial deposit of brown coal or lignite in northern Ontario to the Fuel Research Laboratories for analysis and carbonization tests. The samples were taken from an outcrop on the Abitibi river and although not entirely representative of the deposit, owing to weathering, the importance of the find in a province where no coal deposits exist warranted preliminary testing of the samples as submitted.

The analytical work consisted of proximate analysis, sulphur, and calorific value determinations. Carbonization experiments were carried out in a small laboratory apparatus on a 20-gramme scale and also in the standard lead bath apparatus on a 2,000-gramme sample, the results being shown in the series of tables appended. The char as obtained from the carbonization tests in the lead bath apparatus after being sampled for analysis was briquetted in a hand hydraulic press with several different binders.

CARBONIZATION EXPERIMENTS

The laboratory apparatus used for the carbonization experiments, known as the "tube test", is a product of the Koppers Laboratories, and was designed by Messrs. Sperr and Rose of that organization for determining by-product yields by high-temperature carbonization. This particular apparatus has been previously described by Rose¹, and has been discussed by the senior writer in a former report² on western Canadian coals. In the present instance, the apparatus was operated at low temperatures, i.e. approximately 600° C., this figure having been adopted by the Fuel Research Laboratories as a standard for low-temperature carbonization. In the operation of the apparatus the charge is dried at 105° C. prior to carbonizing and in the collection of by-products the H₂S and the CO₂ are absorbed, the gas being collected free of these two constituents. The tar is collected in a filter maintained at steam heat, and is therefore dry, and the light oils are absorbed in paraffin oil. The results of the test are shown in Tables I to V, the yields having been calculated to the basis of the lignite as received. The gas is shown free of oxygen, but including the carbon dioxide.

The lead bath apparatus as used in the second experiment has been fully described and illustrated in former reports³ by these Laboratories. The apparatus consists essentially of an iron retort which is immersed in a bath of molten lead previously heated to the desired temperature. The molten lead has been found to be a highly suitable medium for constant

¹ "Fuel in Science and Practice," vol. V, No. 12 (December, 1926, and also January and February, 1929).

² "Coking Tests on Coals from Western Canada"—Investigations of Fuels and Fuel Testing, 1927, p. 24.

³ Investigations of Fuels and Fuel Testing, 1926 and 1927.

temperature and this apparatus has, therefore, been tentatively adopted by the Fuel Research Laboratories as a standard for low-temperature carbonization tests. The chief advantage of this apparatus over the smaller type is the quantity of charge, i.e. 2,000 grammes, which when tests are run in duplicate allows of the recovery of a sufficient quantity of the by-products for subsequent examination. The tar is condensed by passing the gas through a condenser and scrubber and as recovered usually contains a considerable quantity of water, but weighings are made after separation and distillation, so that the dry weight of tar recovered is obtained. The light oils are absorbed in activated carbon and are later recovered by distilling the carbon with glycerine. The gas is metered and stored in a holder, a sample being taken for analysis at the end of the run. The main difference in procedure in this test as compared to other small-scale methods is that in the lead bath apparatus the yields of products are all obtained by actual weights, whereas in the other methods referred to, the gas weight is determined by difference, and, therefore, is subject to all the errors in the run. It is customary to charge the retort with the coal as received, but the large quantity of water in the samples submitted prevented the collection of sufficient tar, so that the samples were air-dried to about 10 per cent moisture before charging. The results obtained have been calculated to the as-received basis and are shown in Tables I to V inclusive.

BRIQUETTING EXPERIMENTS

Briquettes were made from the char in a hand press as previously mentioned, using binders consisting of (a) asphalt, (b) asphalt and flour, (c) sulphite liquor, (d) sulphite liquor and flour. The press contains a mould 2 inches in diameter and 5 inches long, around which is a steam jacket. Dies of any desired shape are placed in the mould and pressures up to 30,000 pounds per square inch can be applied. Tests in this type of press are indicative only and should not be considered as having a direct commercial significance.

In making a laboratory test, a definite quantity of the fuel to be tested is weighed out, along with a given percentage of binder. The coal is heated in the presence of steam and the binder, which has also been previously heated, is slowly added, the mass being thoroughly mixed and kneaded; a portion is then placed in the press mould and the pressure applied. The briquette is allowed to remain under pressure for a period of one minute, after which it is removed from the press, cooled, and dried.

No attempt was made to make sufficient briquettes for a burning test, as the quantity of char was insufficient. The briquettes were, however, examined as to hardness and breakability by drop test; and in the case of the asphalt briquettes an analysis was made.

Previous experience in laboratory briquetting tests has indicated that one per cent of flour will displace practically twice that amount of bitumen and the tests carried out on the Abitibi River lignite char were no exception to this. It was found that, when used alone, about 9 per cent of asphalt was required to make a briquette which would withstand the drop test and which was sufficiently hard to withstand normal handling. Sulphite liquor when used as a binder is usually calculated to the basis of

solids or cell pitch. On this basis it was necessary to use between 10 and 12 per cent in order to make a satisfactory briquette. The sulphite liquor and flour binders do not make a waterproof briquette unless subsequently treated by a baking process and must, therefore, be stored under cover; for this reason neither of these binders are used to any extent in commercial practice. The binder most commonly used commercially is asphalt, and as in all probability any plant which was established to briquette Abitibi lignite char would use this material, an analysis was made of the briquettes made with the asphaltic binder, the results of which are given below.

	Per cent
Moisture.....	2.0
Ash.....	15.2
Volatile matter.....	13.7
Fixed carbon.....	69.1
Sulphur.....	4.0
B.T.U. per pound.....	12,720

It will be observed that this analysis is quite comparable with the imported anthracite coal now used as the standard domestic fuel in Ontario and Quebec both as to ash and calorific value. The briquettes will be free-burning and will not produce excessive clinker as the fusibility of ash temperature as determined from the raw lignite is 2,300° F.

DISCUSSION OF RESULTS

The analysis of the lignite sample from northern Ontario, as shown in Table I, indicates a very high moisture content. The sample contained 40 per cent of water and as it must be considered an outcrop sample, it is highly probable that much higher average moisture will exist in the seam. In this connexion it might be noted that the Abitibi lignite is a lower grade fuel than the Saskatchewan lignites, and more nearly approaches the Australian lignites as mined at Morwell. In appearance, however, as received and after continued exposure, the sample resembles rather closely the brown lignites of Saskatchewan.

The following table shows a comparison of the analyses of various Canadian lignites, together with peat and Australian brown coal:

Coal	Moisture content		Ash	B.T.U. per lb.	
	As re- ceived	Air- dried	Dry basis	Dry	Dry and ash-free
	%	%	%		
Black lignite, Drumheller area.....	20	15	9	11,700	12,850
Brown lignite, Saskatchewan.....	35	17	11	11,200	12,550
Brown lignite, northern Ontario.....	40	17	12	10,300	11,700
Brown lignite, Australia.....	50	.....	4	9,700	10,100
Peat, from bog at Alfred, Ont.....	90	25	6	9,750	10,350

A summary of the results of the carbonization tests is shown in Table II. It will be noted that the char contains 7.4 per cent volatile matter and 16.5 per cent ash. The ash is somewhat high, but when the char is briquetted the ash is reduced to reasonable limits as shown above. The calorific value shows an increase of 108 per cent as compared to an 85 per cent increase for Saskatchewan lignite and 35 per cent for Alberta black lignite. The yield, however, is low, being only 37 per cent, so that it will require at least $2\frac{1}{2}$ tons of the raw coal to produce a ton of briquetted fuel.

The yield of by-products as shown in the table does not offer very great possibilities for profit commercially. The gas and tar yields are, however, practically identical with the yields obtained from Saskatchewan lignite. The low yields are not an obstacle to the treatment of the fuel, as the quantity of gas obtained is ample for carbonization purposes, and while the tar does not appear to be a suitable source of binder, it has a fuel value and may be utilized in the process for that purpose.

CONCLUSION

The tests carried out on the sample of lignite from northern Ontario indicated that the fuel may be considered as slightly inferior to the lignite mined in Saskatchewan which is being treated commercially for the production of a domestic briquette. Carbonization tests show that the lignite when treated at low temperatures produces a char which is sufficiently hard to briquette satisfactorily. The yields of by-products are low, but sufficient gas is obtained to effect carbonization. The briquettes produced in a laboratory plunger press with approximately 9 per cent of asphalt binder may be considered as of satisfactory quality commercially. From the yield of char, it may be estimated that $2\frac{1}{2}$ tons of the lignite will be required for one ton of briquettes.

TABLE I

Analysis of the Lignite as Carbonized

	As received	Dry basis
Moisture.....per cent	39.9	.....
Ash....."	7.3	12.1
Volatile matter....."	26.8	44.6
Fixed carbon....."	26.0	43.3
	100.0	100.0
Sulphur....."	3.0	5.0
B.T.U. per pound.....	6,170	10,265

TABLE II
Summary of Carbonization Tests
(Yields per 2,000 pounds of coal as received)

	Lead bath apparatus	Tube test
Temperature of carbonization.....	600° C.	600° C.
Carbonized residue or char:		
Per cent of coal carbonized.....	37.0	37.0
Pounds per ton.....	740	740
Proximate analysis:		
Ash..... per cent	16.5	.....
Volatile matter..... "	7.4	.....
Fixed carbon..... "	76.1	.....
Sulphur..... "	4.2	.....
B. T. U. per pound.....	12,860	.....
Gas (at 60° F. and 30 inches mercury):		
Cubic feet per ton.....	3,430	3,300
B. T. U. per cubic foot.....	444	442
Density (Air=1).....	0.91	0.91
Tar (dry):		
Imperial gallons per ton.....	5.5	6.1
Specific gravity at 15.5° C.....	1.065	.....
Liquor (aqueous):		
Imperial gallons per ton.....	200.7	191.1
Ammonium sulphate, pounds per ton.....	1.3	4.0

TABLE III
Weight Balance
(Parts by weight for 100 pounds of coal charged)

	Lead bath apparatus	Tube test
Char.....	37.0	37.0
Tar.....	2.9	3.2
Liquor.....	49.9	49.5
Light oils.....	0.2	0.3
Gas.....	10.4	10.0
Loss or gain.....	+0.4	.....

TABLE IV
Analyses of Tar Oils

Tar (dry): specific gravity at 15.5..... 1.060

	Per cent by volume	Specific gravity, 15.5° C.
Distillation:		
0-225° C.....	40.5	1.015
225-255° C.....	28.4	1.033
Pitch (by weight).....	27.7	.....
Fraction I: (0-225° C.)		
Phenols.....	74.0	.....
Bases.....	1.3	.....
Neutral oil.....	24.7	0.920
Unsaturation.....	44.0	.....
Fraction II: (225-255° C.)		
Phenols.....	63.0	.....
Bases.....	0.0	.....
Neutral oil.....	37.0	0.945
Unsaturation (insoluble in H ₂ SO ₄).....	33.0	.....

TABLE V
Analyses of Gases

	Lead bath apparatus	Tube test
Density (air=1).....	0.91	0.91
Carbon dioxide (CO ₂)..... per cent	35.3	35.2
Illuminants..... "	0.5	0.8
Carbon monoxide (CO)..... "	11.6	13.5
Methane (CH ₄)..... "	32.0	30.9
Hydrogen (H ₂)..... "	14.4	13.6
Nitrogen (N ₂)..... "	6.2	6.0
B.T.U. per cubic foot:		
Gross.....	444	442
Net.....	399	397

II

OIL SHALE FROM PICTOU COUNTY, NOVA SCOTIA

A. A. Swinnerton

INTRODUCTION

Information available regarding the oil shale deposits of Pictou county is of a vague and somewhat contradictory nature. In order to obtain some first-hand information regarding them, the writer spent two weeks in August, 1928, sampling the more accessible outcrops in the vicinity of New Glasgow, Nova Scotia. The results here reported should not be considered final but rather as a preliminary guide to a subsequent and more detailed examination.

The writer wishes to acknowledge the courtesy and co-operation of Col. Mackenzie and Mr. Graham of the Acadia Coal Company, Stellarton, in furnishing him with skilled labour, which greatly facilitated the work.

PREVIOUS WORK

The oil-shales of Pictou county were discovered in 1859 and, although worked for a few years, very little real attention was given them until about 1909, when the introduction of oil fuel into the British Navy again revived interest in them. Dr. Ells reported the immense deposits of oil-bearing shales of eastern Canada to be richer in hydrocarbons than the average Scotch shales. However, little was done, as of the eight samples collected by him in 1909 from points along McLellan brook and adjacent outcrops, only one gave a yield of more than 40 gallons per ton, the others yielding only 3 to 14 gallons per ton.

In 1919 the post-war search for oil again directed attention to these deposits, and W. J. Wright, of the Geological Survey, spent some time in this area in that year. In his report¹ he states that "these shales may be divided into three varieties, which grade into each other," viz.—

1. A soft, massive, greasy-black shale which occurs in distinct beds 1 to 4 feet thick and comprises a relatively small amount of the whole and estimated to yield 35 to 40 gallons per ton.
2. A thinly bedded, pliable, brownish shale, occurring in beds up to 20 feet thick and estimated to yield 20 to 25 gallons per ton.
3. A thinly bedded, brittle, slightly bituminous shale which does not contain sufficient oil to warrant development.

In addition to these three varieties is a very highly bituminous variety of cannel coal called "Stellarite", published analyses of which show yields of from 50 to 126 gallons per ton.

Samples were taken by him and tested in the Fuel Testing Laboratories, but the results were disappointing. One sample yielded 15 gallons per ton, but the others gave yields of only between 2 and 6 gallons per ton.

¹ Geol. Surv., Canada, Mem. 129, "Geology of the Moncton Map-area," p. 53.

In 1923 important boring operations were undertaken by the Nova Scotia Coal Company in search of coal. Those parts of the drill cores that gave promise of yielding oil on distillation were sent to these Laboratories by W. A. Bell, of the Geological Survey, but in this case also the yields were very low, no sample yielding more than 10 gallons per ton.¹

In 1926 Prof. A. E. Flynn, of the Nova Scotia Technical College, issued a report² dealing with his investigations of these shales. A full account was given of the characteristics of the shales from three localities and this was the most promising report that had hitherto appeared on these shales.

Of the samples that have been sent to the Fuel Testing Laboratories by private individuals, there is generally no information regarding the thickness and relation of the beds. Moreover, it is probable that many of them have been more in the nature of grab samples from thin, rich beds rather than samples systematically taken from bands of potentially workable thickness, so that the analyses are of very little value.

FIELD WORK

The oil shales of Pictou county occur in the productive coal measures which underlie an area of approximately 20 square miles in the vicinity of New Glasgow. They are exposed in a number of places, the best showings being along the McLellan brook, so that it was decided to start by sampling these outcrops, the locations of which are shown on the accompanying sketch map, Figure 1. They are indicated as A, AB, B, BC, C, and D; the first three occur in the Stellarton formation, and the remaining three in the Thorburn. In the case of beds B and C, where the outcrops were exposed on both sides of the brook, the subscripts "n" and "s" have been added to indicate the northern and southern outcrops, e.g., Bn, Bs, Cn, Cs. Sampling was done by breaking down the shale until an unweathered face was reached and then taking a wide channel sample down the face. The samples from the different sections of the face were kept separate, the natural partings being used as points of separation. A fairly large channel sample was taken (15 to 20 pounds) from which, by crushing and quartering, a good average sample was obtained for analysis. Eighteen representative samples were obtained. In addition, large samples totaling 2,800 pounds were taken from beds A and D for large-scale testing.

Description of Beds Sampled

A short description of the beds and sections that were sampled follows:

Bed A

This bed outcrops in a cliff on the north side of a small brook running into McLellan brook at Stephen Brook's brickyard, about 1½ miles south of New Glasgow.

Section of Seam—

- A1—Upper band, cannel shale, 1 foot.
- A2—Middle band, flaggy shale, 2½ feet.
- A3—Lower band, cannel shale, 1 foot.

¹ Geol. Surv., Canada, Sum. Rept, 1923, pt. C-2, p. 33.

² National Research Council Rept. 18—Investigations on the Treatment of Nova Scotia Oil Shales.

Bed AB

This bed outcrops in the bed of McLellan brook about 300 yards above the junction of Steep brook and McLellan brook. As it was impossible to get a channel sample of this bed, a large sample (about 200 pounds) was taken, which represented a thickness of about 5 feet of blocky shale. This was crushed and quartered to obtain a representative sample for analysis.

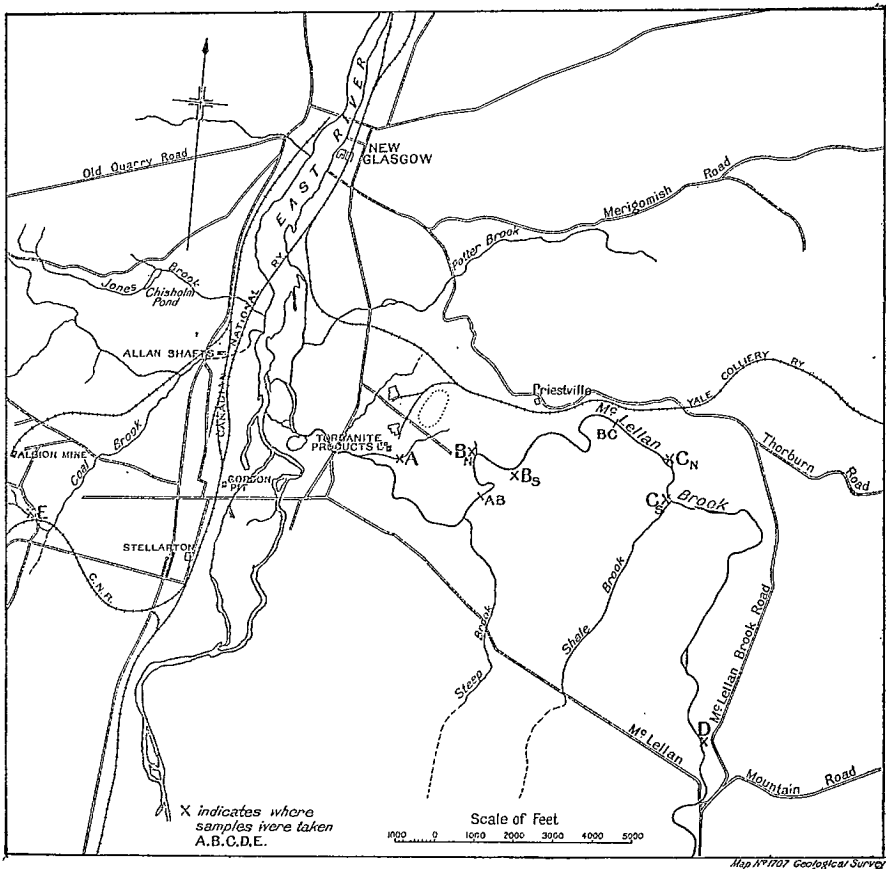


Figure 1. Sketch map showing location of oil shale outcrops on McLellan brook, near New Glasgow, N.S.

Bed B

This bed outcrops on both sides of McLellan brook about a quarter of a mile upstream from bed AB.

Section of Seam, northern exposure—

Bn1—Upper band, thinly bedded brittle shale, 2½ feet.

Bn2—Lower band, thinly bedded brittle shale, 2½ feet.

Southern exposure—

Bs1—Upper band, thinly bedded brittle shale, 3 feet.

Bs2—Lower band, thinly bedded brittle shale, 3 feet.

Bed BC

This bed outcrops in McLellan brook about half a mile below Shale brook. It is associated with a thin seam of coal (4 to 6 inches thick) and is composed of heavy, black shale with bright coal-like inclusions. The sample taken represents a thickness of about 2 feet.

Bed C

This bed also outcrops on both sides of McLellan brook, the exposures being just below the junction of Shale brook and McLellan brook.

Section of Seam, northern exposure—

Cn1—Upper band, thinly bedded brittle shale, 3 feet.
Cn2—Lower band, thinly bedded brittle shale, 3 feet.

Southern exposure—

Cs1—Upper band, thinly bedded brittle shale, 2 feet.
Cs2—Middle band, thinly bedded brittle shale, 2½ feet.
Cs3—Lower band, thinly bedded brittle shale, 3 feet.

Bed D

This bed outcrops on the east bank of McLellan brook a quarter of a mile north of the bridge on the McLellan Mountain road. An entry was opened up about 25 feet south of the old Patrick slope (which has been flooded for some years). The samples were taken from this entry, which cut into an old heading driven some sixty years ago.

Section of Seam—

D1—Roof, thinly bedded slaty shale, 1 foot.
D2—Upper band, flaggy greyish shale (torbanite), 1 foot.
D3—Lower band, flaggy heavy shale, 2½ feet.
D4—Stellarite bed, 4 to 6 inches.

TABLE VI
Summary of Results

Bed No.	Thickness	Oil yield, Imp. gals. per ton (2,000 lb.)	Average oil content of bed, gallons per ton	Average nitrogen content of bed, per cent
	Ft. ins.			
A1.....	1 0	30.5	17.5	1.1
A2.....	2 6	12.0		
A3.....	1 0	18.1		
AB.....	5 0	26.4	26.4	1.1
Bn1.....	3 0	7.9	8.5	0.7
Bn2.....	3 0	11.1		
Bs1.....	2 6	7.4		
Bs2.....	2 6	7.8		
Cn1.....	3 0	2.8	6.0	0.5
Cn2.....	3 0	7.5		
Cs1.....	2 0	2.3		
Cs2.....	2 6	9.8		
Cs3.....	3 0	7.4		
D1.....	1 0	19.3	28.5	0.7
D2.....	1 0	33.2		
D3.....	2 6	26.8		
D4.....	0 6	48.1		

SUMMARY AND CONCLUSIONS

From the results summarized in the preceding table, it will be seen that bed "A", which may be considered composed of varieties 1 and 2 of Wright's classification, is worth further study. The Torbanite Products Company have opened up a tunnel in this bed, from which they expect to obtain the shale for their retorting plant; bed "AB" would also seem to have some promise. In this latter case it would be necessary to sink one or two test pits on the bank of the river in order to get representative samples.

Beds "B", "BC", and "C" obviously belong to variety No. 3 and are of too low a grade to be worth further examination. It will be noticed that there is quite a variation in different parts of the beds, especially in bed "C", where the variation is from 2.3 to 9.8 gallons per ton.

The results indicate that bed "D" is the most promising, and much information could be obtained by clearing out and sampling the old workings at this place. It will be noticed that the highest oil yield was obtained from the seam of stellarite, which at this place is not more than 6 inches thick, but old reports state that it occurs in beds from one inch to 8 feet in thickness. This statement is corroborated by I. A. McKinnon of the National Museum staff, who was in this area collecting mineral specimens after the writer had left. He opened up a test pit near Stellarton, in which he found two varieties of stellarite, one a laminated variety about 18 inches thick, and a curly variety several feet thick; the bottom of the test pit was still in the stellarite seam. This locality would, therefore, repay further detailed examination and sampling.

The results indicate that there are at least four localities that warrant further examination, viz. A, AB, D, and E (near Stellarton).

APPENDIX

This appendix includes a description of the apparatus and method used for the examination of samples of oil shale, as well as the proximate analyses and distillation data of the samples from each bed. Analyses of the oils obtained and a diagram showing their distillation curves, are also included.

DESCRIPTION OF APPARATUS AND METHODS

The samples on arrival at the laboratory are crushed and quartered. A sample is taken for retorting and another quartered sample is taken and ground in the ball mill for proximate analysis according to the standard method for coal. The method of examining the samples and the apparatus is as follows: The oil shale distillation apparatus developed in the Fuel Testing Laboratories is a modification of that used by the U. S. Bureau of Mines, the arrangement of the retort and accessory apparatus being shown in Figure 2. The retort is described in the catalogue as a "mercury retort, pint size" with removable lid, fastened by a screw clamp, and fitted with a $\frac{3}{4}$ -inch pyrometer well and $\frac{1}{4}$ -inch delivery tube.

To make a distillation, the retort is charged with about 400 grammes of shale, the asbestos gasket inserted, and after the lid is placed in position and screwed down tightly, the apparatus is connected up as shown in the diagram. The heating is started slowly at first and so regulated that no fog appears in the condenser. The oil vapours start to come over in about half an hour, and, after passing through the condenser, collect in the graduated cylinder. The uncondensed vapours pass up the reflux arm of the condenser, which condenses the last trace of oil, and thence to the gas collecting bottle, which is filled with acidified water, the outlet tap of the siphon being so adjusted as to maintain a slight suction ($\frac{1}{2}$ -inch of water) in the gas collector. The temperature of the retort is gradually raised to 550°C ., at which temperature no more oil and very little gas is evolved, the time required for the distillation being about 4 hours.

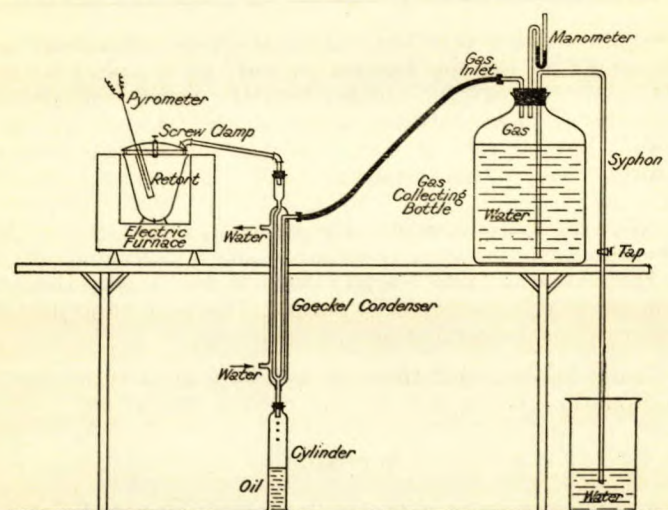


Figure 2. Oil shale distillation apparatus.

EXAMINATION OF CRUDE OIL, GAS, AND SPENT SHALE

The graduated cylinder is weighed before and after the distillation, so as to obtain the weight of the distillate, which is allowed to stand overnight in a warm place, when a complete separation of the water and oil takes place. The water is carefully sucked off and measured into a small graduated cylinder. The weight of the dry oil is obtained by subtracting the weight of this water from that of the total distillate.

The specific gravity of the oil is obtained by means of the Westphal balance, and from the weight of oil obtained, and its specific gravity, the yield in gallons per ton is calculated. The distillation range of the dry oil is determined in a standard gasoline testing apparatus, using a standard gas burner for heating. A 100 c.c. sample is distilled in a weighed Engler flask of standardized dimensions at a rate of approximately 5 c.c. per minute, temperature readings being taken at every 5-c.c. mark on the

100-c.c. graduated cylinder. The distillation is continued, as nearly as possible, at the above rate, up to the cracking point, which is indicated by a fall in the thermometer reading. From the distillation range curve, obtained by plotting the percentage recovered against temperature reading, the fractions obtained at any temperature can be read off. The total distillate recovered is measured, and its gravity is also taken, and the flask is weighed after the distillation in order to obtain the weight of the coke residue.

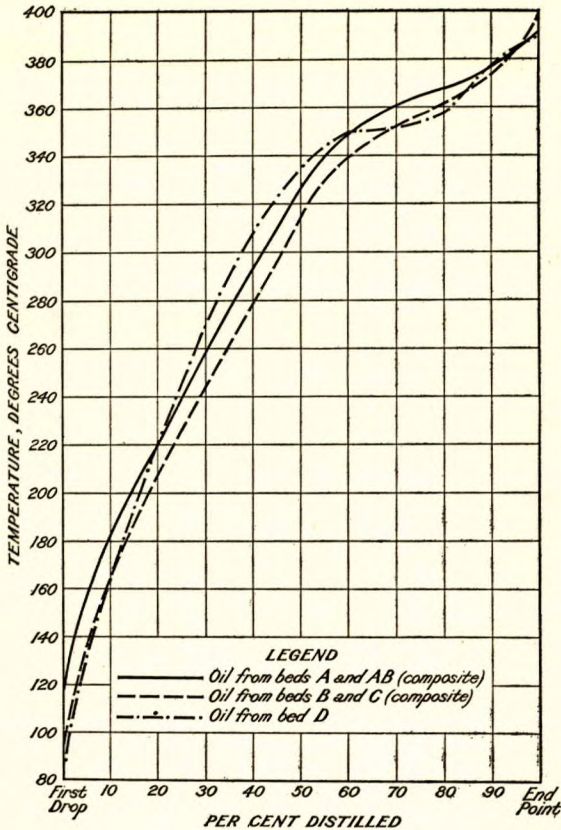


Figure 3. Distillation curves, crude shale oil from Pictou oil shales. (See Tables VII to X.)

The volume of the gas evolved is obtained from the weight of the displaced water, and from this volume (after being corrected to 60° F. and 30 inches of mercury) the yield in cubic feet per ton is calculated. The density and calorific value of the gas are obtained by calculation from the gas analysis, which is performed in a Burrell or modified Hempel apparatus. The weight of the gas is then obtained and the result used in making up the weight balance for each distillation.

The spent shale is examined according to the standard procedure for the proximate analysis of coal, where moisture, ash, and volatile matter determinations are made.

TABLE VII
Distillation Data—Beds A and AB
(Maximum temperature, 550° C.)

Section No.....	A1	A2	A3	AB
Thickness.....	1 foot	2½ feet	1 foot	5 feet
Shale charged, grms.....	350	350	350	350
<i>Proximate Analysis—</i>				
Moisture..... per cent	1.1	1.9	1.7	1.1
Ash..... "	53.1	75.4	61.6	51.0
Volatile matter..... "	27.7	16.5	22.1	28.4
Fixed carbon..... "	18.0	6.2	14.6	19.5
Nitrogen (composite sample)..... "		1.1		1.1
<i>Products, Weight balance—</i>				
Spent shale..... per cent	75.6	84.7	83.8	79.2
Oil (water-free)..... "	13.8	5.1	8.3	11.9
Aqueous distillate..... "	4.3	7.8	4.1	2.8
Gas (calculated)..... "	6.5	2.4	4.4	5.2
Loss (by difference)..... "	0.2	0.0	0.6	0.9
<i>Shale Oil—</i>				
Imperial gals. per ton (2,000 lb.).....	30.5	12.0	18.1	26.4
Specific gravity at 60° F.....	0.904	0.883	0.915	0.903
Degrees Baumé.....	25.0	28.7	23.1	25.2
<i>Gas—</i>				
Cubic feet per ton (2,000 lb.).....	2,700	1,060	1,590	1,880
Calorific value (B.T.U. per cu. ft.).....	580	515	635	670
Density (air=1).....	0.60	0.65	0.77	0.72
<i>Spent Shale—</i>				
Pounds per ton (2,000 lb.).....	1,512	1,694	1,676	1,584
Moisture..... per cent	1.0	0.6	0.8	1.2
Ash..... "	70.9	87.9	77.6	61.7
Volatile matter..... "	4.0	4.2	4.3	9.4
Fixed carbon..... "	24.1	7.3	17.3	27.7

TABLE VIII
 Distillation Data—Beds B and BC
 (Maximum temperature, 550° C.)

Section No.....	Bn1	Bn2	Bs1	Bs2	BC
Thickness.....	3 feet	3 feet	2½ feet	2½ feet	1½ feet
Shale charged, grms.....	450	450	450	500	450
<i>Proximate Analysis—</i>					
Moisture..... per cent	2.3	3.0	2.6	3.7	0.8
Ash..... "	79.2	76.9	80.6	80.4	79.4
Volatile matter..... "	17.7	17.5	13.2	13.9	15.4
Fixed carbon..... "	0.7	2.6	3.6	2.0	4.4
Nitrogen (composite sample).. "			0.7		
<i>Products, Weight balance—</i>					
Spent shale..... per cent	86.3	87.3	89.1	88.3	89.8
Oil (water-free)..... "	3.5	4.9	3.3	3.4	3.8
Aqueous distillate..... "	5.9	4.7	5.1	5.7	3.1
Gas (calculated)..... "	3.5	3.1	2.1	2.2	3.4
Loss (by difference)..... "	0.8	0.0	0.4	0.4	0.1
<i>Shale Oil—</i>					
Imperial gallons per ton (2,000 lb.).....	7.9	11.1	7.4	7.8	8.3
Specific gravity at 60° F.....	0.893	0.890	0.887	0.880	0.920
Degrees Baumé.....	27.0	27.5	28.0	29.3	22.3
<i>Gas—</i>					
Cubic feet per ton (2,000 lb.).....	1,200	960	750	740	1,060
Calorific value (B.T.U. per cu. ft.).....	300	300	470	455	410
Density (air=1).....	0.93	0.92	0.80	0.80	0.84
<i>Spent Shale—</i>					
Pounds per ton (2,000 lb.).....	1,726	1,746	1,782	1,766	1,796
Moisture..... per cent	0.4	0.5	0.6	0.3	0.3
Ash..... "	88.7	87.6	88.7	90.4	87.5
Volatile matter..... "	9.9	8.5	5.7	6.6	6.2
Fixed carbon..... "	1.0	3.4	5.0	2.7	6.0

TABLE IX
Distillation Data—Bed C
(Maximum temperature, 550° C.)

Section No.....	Cn1	Cn2	Ca1	Ca2	Ca3
Thickness.....	3 feet	3 feet	2 feet	2½ feet	3 feet
Shale charged, grms.....	450	450	450	450	450
<i>Proximate Analysis—</i>					
Moisture..... per cent	2.2	1.4	2.3	1.8	1.4
Ash..... “	36.2	32.8	37.7	32.9	32.8
Volatile matter..... “	10.7	14.1	11.1	14.2	13.7
Fixed carbon..... “	0.9	1.7	.....	1.1	2.1
Nitrogen (composite sample).... “	.....	.....	0.5	.....	.....
<i>Products, Weight balance—</i>					
Spent shale..... per cent	92.6	89.9	92.0	88.2	90.7
Oil (water-free)..... “	1.2	3.3	1.0	4.3	3.2
Aqueous distillate..... “	4.3	4.2	5.1	5.2	3.9
Gas (calculated)..... “	1.8	2.4	2.6	2.4	2.7
Loss (by difference)..... “	0.1	0.2	0.7	0.1	0.5
<i>Shale Oil—</i>					
Imperial gallons per ton (2,000 lb.).....	2.8	7.5	2.3	9.8	7.4
Specific gravity at 60° F.....	0.877	0.877	0.875	0.875	0.878
Degrees Baumé.....	29.8	29.8	30.2	30.2	29.6
<i>Gas—</i>					
Cubic feet per ton (2,000 lb.).....	540	730	820	990	860
Calorific value (B.T.U. per cu. ft.).....	360	360	295	365	335
Density (air=1).....	0.87	0.87	0.86	0.76	0.82
<i>Spent Shale—</i>					
Pounds per ton (2,000 lbs.).....	1,852	1,708	1,840	1,764	1,814
Moisture..... per cent	0.2	0.2	0.3	0.2	0.1
Ash..... “	91.3	91.2	94.0	92.2	90.6
Volatile matter..... “	7.0	6.1	5.5	5.0	7.1
Fixed carbon..... “	1.5	2.5	0.2	2.6	2.2

TABLE X
 Distillation Data—Bed D
 (Maximum temperature, 550° C.)

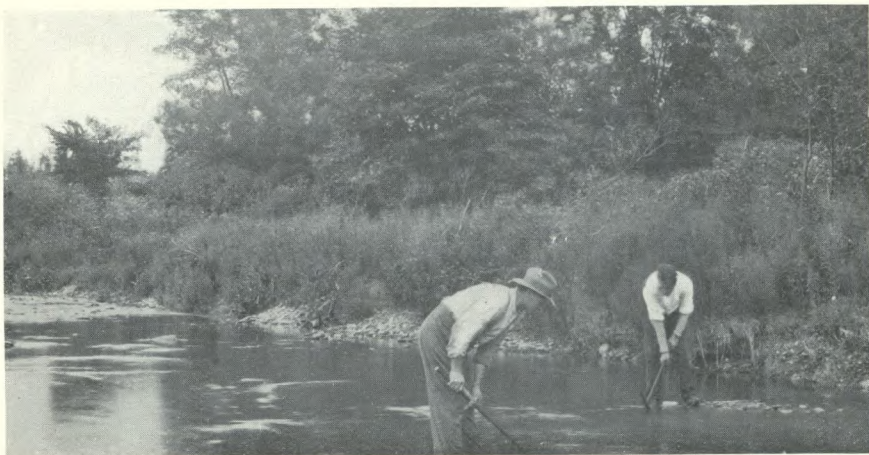
Section No.....	D1	D2	D3	D4
Thickness.....	1 foot	1 foot	2½ feet	½foot
Shale charged, grms.....	400	350	350	350
<i>Proximate Analysis—</i>				
Moisture..... per cent	2.1	2.4	3.1	1.6
Ash..... “	75.7	71.2	72.9	62.6
Volatile matter..... “	22.5	25.5	26.5	32.1
Fixed carbon..... “		0.9		3.7
Nitrogen (composite sample)..... “			0.7	
<i>Products, Weight balance—</i>				
Spent shale..... per cent	32.8	78.2	80.4	72.6
Oil (water-free)..... “	8.5	14.2	11.4	20.7
Aqueous distillate..... “	5.7	4.2	5.2	3.3
Gas (calculated)..... “	3.0	3.2	3.2	3.6
Loss (by difference)..... “	0.0	0.2	0.2	0.2
<i>Shale Oil—</i>				
Imperial gallons per ton (2,000 lb.).....	19.3	33.2	26.8	48.1
Specific gravity at 60° F.....	0.881	0.856	0.861	0.863
Degrees Baumé.....	29.1	33.8	32.8	32.4
<i>Gas—</i>				
Cubic feet per ton (2,000 lb.).....	1,010	1,030	1,120	1,220
Calorific value (B.T.U. per cu. ft.).....	415	570	575	650
Density (air=1).....	0.75	0.81	0.75	0.78
<i>Spent Shale—</i>				
Pounds per ton (2,000 lb.).....	1,656	1,564	1,608	1,452
Moisture..... per cent	0.4	0.6	0.5	0.8
Ash..... “	94.2	93.1	91.9	83.8
Volatile matter..... “	5.3	3.4	3.5	8.8
Fixed carbon..... “	0.1	2.9	4.1	6.6

TABLE XI

Analyses of the Oils obtained by Distillation

Oil from bed.....	A and AB* (composite)	B and C* (composite)	D
Specific gravity at 60° F.....	0.906	0.883	0.863
Degrees A.P.I.....	24.7	28.7	32.5
Distillation range, °C—			
1st drop.....	114	94	83
5 c.c.....	167	133	128
10 c.c.....	171	161	164
20 c.c.....	218	199	219
30 c.c.....	256	243	269
40 c.c.....	294	278	307
50 c.c.....	328	313	336
60 c.c.....	349	342	350
70 c.c.....	362	352	351
80 c.c.....	367	360	357
90 c.c.....	375	372	368
95 c.c.....		383	386
End point.....	393	398	389
Recovery, c.c.....	93.0	96.5	95.5
Specific gravity of distillate.....	0.878	0.865	0.844
Degrees A.P.I.....	29.7	32.1	36.2
Oil recovered (per cent by weight).....	89.8	93.4	93.0
Coke residue (per cent by weight).....	6.0	4.6	4.2
Total recovered (per cent by weight).....	95.8	98.0	97.2
Loss (by difference) (per cent by weight).....	4.2	2.0	2.8

* Composite samples were made of the oils from these beds owing to the small quantities available.



A.—Bed AB.



B.—Bed B, southern exposure.



A.—Bed C, northern exposure.



B.—Bed C, southern exposure.



C.—Bed D, tunnel mouth.

III

LABORATORY NOTES

J. H. H. Nicolls and E. Swartzman

(1) UNDER-WATER STORAGE OF SASKATCHEWAN LIGNITE

The lignite mined in southern Saskatchewan is not a good open-storage coal, as it disintegrates when stored in piles. When subjected to weathering the lumps gradually break up into fines and dust. In order to determine whether storage under water would prevent the disintegration, a series of tests was made between May 21 and September 15 during a wet season.

For purposes of comparison a sample of stove-size lumps of lignite, which had been mined for only six days, was procured from Bienfait, Saskatchewan, and examined in comparison with a sample of Pennsylvania anthracite, of mixed nut and pea sizes, obtained from an Ottawa dealer. The lignite was shipped in a metal container, and was therefore "fresh" when delivered. Throughout the series described below, parallel tests were run with the lignite and anthracite. Tests were carried out, with weighings every week or ten days, under the following three conditions:

- (a) Storage indoors for 14½ weeks in large, flat enamelled trays; about 3,000 grammes of coal per sample.
- (b) Storage out-of-doors, with full exposure to rain, in wooden boxes with iron screens for bottoms. The boxes were raised on strips of wood so as to allow water to run through and drain away freely; 14½ weeks, followed by 1 week's indoor drying in enamelled trays; about 3,000 grammes of coal per sample.
- (c) Storage under water in wide-mouthed, uncorked glass jars: (i) Three weeks under water, followed by 11½ weeks' indoor drying in porcelain basins; about 1,000 grammes of coal per sample. (ii) 14½ weeks under water, followed by 1 week's drying in enamelled trays; about 1,500 grammes of coal per sample.

The lumps of lignite spread out in the trays indoors began to check after less than one week's exposure, and cracks were opening up in all directions after two or three weeks, with the production of a small amount of fine coal by the end of the tests. As a contrast to this, the lignite stored out-of-doors, owing partly to heavy rain during the first three days, was reduced almost to a pulp after a week's exposure, and only a few lumps were to be found in the centre of a mass of crumbly material.

The lignite stored under water remained intact, and apparently quite unchanged, as long as it was covered by water. The water was changed weekly and was found to become turbid, in contrast to that covering the anthracite, which remained practically clear. The first portion of lignite removed from under water began to check after about four days' exposure to the atmosphere, or slightly more quickly than the corresponding coal which had not been under water. However, at the end of the tests the coal from under water was apparently little more cracked up than the other sample. The coal which was kept under water for 14½ weeks began to check quite soon after exposure to the atmosphere, but it was ground too soon for any lengthy observation.

Except for some very slight checking in the sample exposed out-of-doors, all the anthracite samples were apparently unaffected physically by any of the forms of exposure employed in the tests. From earlier tests

(as described in the 1924 report) it is known that the friability of anthracite increases as a result of outdoor exposure. However, no attempt was made during the tests here described to determine whether, or to what extent, under-water storage of the anthracite (or of the lignite) would alter its friability.

The analyses of the coals, before and after the tests, are shown in the table below. The first and sixth columns contain the analyses of average samples taken from the two coals as received at the Laboratories, while the remaining columns contain the analyses of the individual samples following the storage tests. It is apparent that the respective individual samples, which were taken at random from the two main samples, cannot have had originally quite the same analyses as the average samples. On this account the analyses are disappointing, though they do clearly demonstrate that three or four months' exposure under any of the conditions tried does not materially lower the fuel ratio (i.e. the ratio of fixed carbon to volatile matter) of either the lignite or the anthracite. Furthermore, the exposure has only a slightly detrimental effect upon the calorific value of the lignite, as judged from the ash- and moisture-free, or "pure coal," basis, and apparently none at all upon the anthracite. It appears also as if the storage under water removed a little of the mineral matter from each of the coals, and in particular from the lignite. The A sample of lignite was air-dried in the standard apparatus, while the A sample of anthracite was analysed as received. All the other samples were considered as "air-dried" following the various periods of indoor exposure.

	No. 4168, Saskatchewan lignite					No. 4169, Pennsylvania anthracite				
	A	B	C	D	E	A	B	C	D	E
Moisture (total)..... per cent	33.8	32.5	34.8	35.0	29.5	4.0	4.3	5.9	6.6	4.8

Analyses of air-dried coals

Moisture..... per cent	20.1	17.4	18.8	21.2	18.3	4.0	3.6	3.6	4.0	3.9
Ash..... "	8.4	13.4	11.8	7.4	11.7	11.5	13.7	13.2	12.1	15.3
Calories per grm., gross.....	4,920	4,590	4,650	4,940	4,690	6,940	6,820	6,870	6,970	6,680

Analyses of coals; dry basis

Ash..... per cent	10.5	16.2	14.5	9.4	14.3	11.9	14.2	13.7	12.6	15.9
Volatile matter..... "	40.8	37.4	38.9	41.2	40.7	7.6	7.0	6.7	6.5	6.8
Fuel ratio.....	1.19	1.24	1.20	1.20	1.10	10.65	11.30	11.75	12.45	11.45
Sulphur..... per cent	0.7	0.6	0.6	0.7	0.9	0.8	0.7	1.3	1.0	0.8
Calories per grm., gross.....	6,150	5,560	5,720	6,260	5,740	7,230	7,080	7,130	7,260	6,950

Calorific value of coals; ash- and moisture-free basis

Calories per grm., gross.....	6,870	6,640	6,690	6,920	6,700	8,200	8,250	8,250	8,300	8,260
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- A. Original coals as received in May; general average samples.
 B. Coals after 14½ weeks' indoor exposure.
 C. Coals 3 weeks in water and 11½ weeks in air indoors.
 D. Coals 14½ weeks in water and 1 week in air indoors.
 E. Coals 14½ weeks out-of-doors and 1 week in air indoors.

(2) EFFECTS OF PROLONGED WEATHERING ON THE FRIABILITIES OF CERTAIN COALS

The five samples referred to in the following notes are among those described in the 1924 paper on friability and subsequently referred to in the 1925 paper. They have since been subjected to two more years' open-shed exposure, with screening and tumbling tests at one-year intervals, so that their total time of exposure amounts to three years.

A brief description of the samples is as follows:

- No. 8 Scotch semi-anthracite coal.
- No. 21 Foothills, Coalspur area, Alberta, domestic coal.
- No. 22 Saunders Creek, Saunders area, Alberta, domestic coal.
- No. 32 Galt, Lethbridge area, Alberta, domestic coal.
- No. 25 Newcastle, Drumheller area, Alberta, domestic coal.

The tables show the amounts of disintegration and also the changes in friability of each of the fuels, of 1-inch to 1½-inch size, during the three years' exposure.

Disintegration. None of the five samples underwent any very great disintegration even after three years' open-shed exposure, though the Drumheller and Saunders coals broke up more than the other three coals. The Saunders coal disintegrated to a much greater extent, and also became much more friable, than that from the Coalspur area, though these may not be representative of the areas in which they occur. There was usually a tendency to greater disintegration during the first year than in any subsequent year. There also seemed to be generally more disintegration during the third than during the second year. As was pointed out in the 1925 report, screening errors of as much as 2 or 3 per cent may occur in determining the disintegration. However, even such extreme figures would not upset the order in which the coals occur, and there is no reason why such figures should hold.

Changes in Friability. There was very little change in the Scotch semi-anthracite during the three years, so that it is clearly a good storage coal. Of the first three Alberta coals, those from the Coalspur and Saunders areas are generally considered similar, while that from the Lethbridge area is more like the lignites. It would, therefore, be expected that the Saunders coal would be less friable, and increase in friability less, than the Lethbridge coal, and that it would have about the same physical properties as the Coalspur area coal. However, the sample tested resembled the Lethbridge coal much more closely than that from Coalspur, so that it is probably not representative of the Saunders area. This conclusion is supported by the tests on Harlech coal (sample No. 23), as shown in the 1924 report. The changes in friability of all these coals are marked by a greatly increased production of "smalls" and comparatively little change in "fines" and "dust". As noted in earlier reports, one effect of storage upon lignite and other low-rank coals seems to be to decrease the amount of "dust" produced. The friability of the Drumheller coal increased less than was expected after the first year's storage.

Exposure, years	Weight of fuel exposed, pounds	Disintegration		Moisture content of coal per cent	Tumbling Tests—Friability			
		During period of 12 months per cent	Total disintegration per cent		"Lumps," on 0.742-inch screen per cent	"Smalls," through 0.742-inch on 0.0164-inch (35-mesh) screen per cent	"Fines," through 0.0164-inch on 0.0029-inch (200-mesh) screen per cent	"Dust," through 0.0029-inch screen per cent
<i>Scotch semi-anthracite coal</i>								
-				2.3	69.2	7.0	10.3	13.5
1	64	5.9	5.9	2.9	74.1	5.3	7.2	13.4
2	50	5.6	11.2	2.7	72.4	7.9	7.0	12.7
3	34	3.7	14.5		68.9	8.7	9.0	13.4
<i>Alberta, Coalspur, domestic coal</i>								
-				8.9	67.1	10.9	12.2	9.8
1	40	3.1	3.1	8.1	61.2	13.5	13.0	12.3
2	27	3.7	6.7	7.3	60.7	14.2	13.8	11.3
3	14	3.4	9.9	7.6	62.9	14.2	11.7	11.2
<i>Alberta, Saunders, domestic coal</i>								
-				9.5	62.9	13.3	12.2	11.6
1	55	11.3	11.3	8.0	52.7	21.8	13.1	12.4
2	37	5.4	16.1	7.9	50.4	24.9	13.0	11.7
3	23	8.8	23.5	8.0	40.0	35.2	13.4	11.4
<i>Alberta, Lethbridge, domestic coal</i>								
-				10.3	78.4	6.0	6.3	9.3
1	44	8.0	8.0	9.7	64.1	19.2	6.3	10.4
2	29	4.4	12.1	10.0	52.4	28.0	8.6	11.0
3	15	6.8	18.0	9.4	39.4	43.5	7.3	9.8
<i>Alberta, Drumheller, domestic coal</i>								
-				18.5	73.5	13.5	4.8	8.2
1	44	10.3	10.3	15.5	61.4	20.4	9.9	8.3
2	27	7.5	17.0	15.5	60.8	23.2	7.9	8.1
3	12	10.2	25.5	15.2	56.6	26.5	9.3	7.6

(3) OBSERVATIONS CONCERNING ORGANIC AND OTHER FORMS OF SULPHUR IN COALS CONTAINING LARGE AMOUNTS OF SULPHUR

Sulphur in coal is divisible into four principal forms, namely, sulphate, pyritic, resinic and humus, the last two being usually grouped together as organic sulphur. Powell's methods¹ for determining quantitatively these forms of sulphur were employed, with slight modifications, by the senior author in the examination of many Canadian coals, as described in the

¹ Univ. of Illinois Bull. No. 111, vol. 16, No. 34, 1919.

Investigations of Fuels and Fuel Testing, 1923¹ and 1926². The inorganic forms were dealt with in the earlier papers, but the organic forms were not considered to any extent. The organic sulphur forms may be of considerable importance in the manufacture of coke and gas, so that more attention than heretofore has been directed towards them during the observations described in this paper.

The methods usually employed in these Laboratories agree very closely with those used by Powell. Sulphate sulphur is determined by treating 5 grammes of coal with 3 per cent hydrochloric acid for 40 hours at 60°C. Pyritic sulphur is determined by digesting 1 gramme of coal with nitric acid, of a specific gravity of 1.12, for 96 hours at room temperature, and subtracting from the percentage thus obtained the amount of sulphate sulphur. Organic sulphur is not determined, but it has been assumed that it corresponds to the difference between the total sulphur as determined by the Eschka (or sodium peroxide) method and the sum of the sulphate and pyritic sulphur.

Resinic sulphur was determined by Powell by digesting 0.5 gramme of coal with phenol for 20 hours at 140°C., filtering off the residue, and determining the sulphur in this by fusion with sodium peroxide. The difference between this sulphur and the total organic sulphur was considered as the resinic sulphur. Humus sulphur was determined by digestion of 1 gramme of coal with concentrated nitric acid for about half an hour at room temperature, treating the coal residue, after washing, with strong ammonia water for several hours at room temperature, filtering off this second coal residue, evaporating the filtrate to dryness, and determining the sulphur present in the residue from the evaporation by fusion with sodium peroxide.

EXPERIMENTAL WORK

The experimental work herein described may be divided into two principal sections: (1) oxidation and other reactions taking place when coal is treated either with 3 per cent hydrochloric acid or water, and (2) changes in organic sulphur brought about by digestion of coal with nitric acid. Table XII contains the analyses, according to the usual methods of these Laboratories, of six coals used for a considerable proportion of the tests.

The first part of the work was carried out upon a water bath at 60°C. (except in one special case) as is usually done for the determination of sulphate sulphur. Either 3 per cent hydrochloric acid or water was used, and in most cases the coals were repeatedly extracted. It is believed that all the sulphate sulphur in coal (exclusive of calcium sulphate which is usually present in such small amounts as to be of little account) consists of the ferrous and ferric salts produced by the oxidation of iron pyrites either in the mine or during storage after mining. The oxidation of pyrites, and the possibility of spontaneous combustion as a result thereof, has been thoroughly dealt with by Simpkin and his collaborators.³ In most

¹ Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923.

² Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1926.

³ Lancashire and Cheshire Coal Research Assoc. Bull. No. 12 (1922).

Safety in Mines Research Board (England) Paper No. 26 (1926).

Safety in Mines Research Board (England) Paper No. 47 (1928).

of the tests herein described the so-called "pyritic" sulphur was determined in the residues from the extractions with water or hydrochloric acid, which, it should be noted, is not the usual procedure in these Laboratories. Finally, the total sulphur in the residues from the extractions with nitric acid (or the organic sulphur) was determined by Eschka's method.

Table XIII shows the results of twelve similar aqueous extractions of samples Nos. 5299 and 5590. It is evident that the total amount of sulphate sulphur produced from each coal by oxidation in water is greatly in excess of that normally determined as sulphate sulphur, and that in the second and following extractions the amount of sulphate is nearly constant for each coal. All extractions of sample No. 5299, and the first, ninth, and subsequent extractions of No. 5590, were slightly acid and contained iron in solution, thus confirming the oxidation of pyritic, or similar, sulphur to the form of iron sulphate. The intermediate extractions of No. 5590 contained a sulphate which was different from the usual form and was probably derived from the organic sulphur. Prolonged aqueous extractions of these coals during 200 hours brought into solution only about 70 per cent of the total amounts contained in the first five 40-hour extractions of each coal.

The following additional information was obtained from the aqueous and hydrochloric acid extractions of certain coals, as shown in part in Table XIII A.

- (a) Aqueous extraction of coal invariably promotes more oxidation of sulphur to the sulphate form than takes place in dilute hydrochloric acid solution, though some oxidation takes place in the presence of the acid.
- (b) Aqueous and acid extractions of a coal promote definite and respective amounts of oxidation in each medium during every 40-hour period, and these amounts do not vary whether one medium is used entirely, or the water and acid are used alternately.
- (c) Substitution of carbon dioxide for air over the aqueous or acid extraction of coal somewhat retards the oxidation of sulphur; conversely, the passage of air during the extraction very slightly increases the amount of oxidation.
- (d) Increase of the temperature of extraction from 60° to 90°C. somewhat retards the oxidation.
- (e) Oxidation in water at 40°C. takes place to practically the same extent when pyrites is mixed with a coal as when the pyrites is treated alone; in other words, coal is not a sufficiently strongly reducing agent to interfere with the oxidation of pyrites.

Table XIII A also shows the amounts of sulphur dissolved by nitric acid (specific gravity 1.12) out of the residues from the extractions of sulphate sulphur, and of the amounts of sulphur determined by Eschka's method in the residues from the second extractions. The second amounts specified ought to represent the total organic sulphur. The percentages of the various sulphur forms have been added together, and the totals shown in the table. In addition there are shown the respective differences

between these totals and the percentages of sulphur in the untreated coals as determined by Eschka's method. In most cases there is a loss of sulphur during the successive analyses, and in some cases the loss is of large dimensions.

The percentages of sulphur extracted by nitric acid, following extraction with hydrochloric acid and water, from coals Nos. 4852 and 5637 agree closely with the "pyritic" sulphur as shown in Table XII, whereas there is a loss of about 1 per cent from Nos. 5589 and 5590. Hydrogen sulphide was identified, by means of paper soaked in lead acetate solution, as coming from these coals following the addition of dilute hydrochloric acid. The amount of this gas was subsequently determined by passing the gases evolved from No. 5590, when treated with hydrochloric acid, through cadmium chloride solution, and titrating with standard iodine solution. The sulphide sulphur so determined amounted to 0.85 per cent, a figure in fairly close agreement with the calculated loss from the "pyritic" sulphur. The results obtained when coal No. 5590 was treated with nitric acid without previous extraction with hydrochloric acid (in other words, the usual procedure in these Laboratories) gave no indication of loss of inorganic sulphur. However, a series of calculations based on the various extractions of No. 5590 indicates that about 0.6 per cent of the coal, belonging to its organic sulphur and corresponding to the sulphur removed during the first eight aqueous extractions, was dissolved in nitric acid of the strength normally employed. Therefore, it is possible that, in some of the earlier analyses, the so-called "pyritic" sulphur may have included some organic sulphur. There is certainly reason to believe that some of the so-called "pyritic" sulphur, particularly in samples Nos. 5589 and 5590, is sometimes partly composed of inorganic sulphides other than iron pyrites. It is, therefore, proposed to substitute for "pyritic" the term "sulphide" sulphur.

The second part of the present work deals with digestion of coal with dilute nitric acid and its effect on the total organic sulphur as determined by Eschka's method following the acid digestion. The analyses which led up to the consideration of this effect are those of coals containing percentages of sulphur considerably higher than average. Three modified methods were employed for comparison with the usual, or standard, procedure of these Laboratories: (1) Prolonged aqueous extraction, followed by digestion with dilute nitric acid, and determination of sulphur in the residue by Eschka's method; (2) Usual hydrochloric acid extraction, followed by nitric acid and Eschka, as before; and (3) Digestion with nitric acid, followed by Eschka.

Table XIV shows that nearly all the loss from No. 5590 corresponds to the hydrogen sulphide previously referred to. The losses from Nos. 5299 and 5331 consist entirely of organic sulphur, and these are shown by the results of method (3) to occur during digestion with the dilute nitric acid.

In order to further study the effect of nitric acid upon organic sulphur, 17 out of 22 consecutive vertical sections (omitting 5 containing comparatively little sulphur) of a 7-foot coal seam, or Nos. 7795 to 5816, were chosen, together with three of the coals used in the preliminary experi-

ments. These were digested with dilute nitric acid (specific gravity 1.12) at room temperature for 96 hours, and the percentages of sulphur in the extracts determined according to the usual procedure. The sulphur contents of the residues were determined by Eschka's method.

Table XV shows the results obtained with the 20 samples which are tabulated in order of their contents of total sulphur. In addition to the total sulphur in each case, there are shown (III) the total "inorganic" sulphur, (IV) the organic sulphur as calculated by the difference between the total sulphur and the "inorganic" sulphur, (V) the organic sulphur as determined in the residue from digestion with nitric acid, and (VI) the difference between the determined and calculated organic sulphur. Ten of the samples show determined percentages of organic sulphur which do not vary by more than 0.10 per cent from the values obtained by difference. The range of variation between the determined and the calculated values for the 12 coals with sulphur contents below 7 per cent is from 0.01 to 0.25 per cent with an average of 0.09 per cent. Six of these twelve coals show determined values greater than those calculated, and six show smaller values.

The variations between the determined and calculated values for organic sulphur in the 8 coals with over 7 per cent total sulphur deserve special comment. In all cases the determined values are decidedly less than the calculated values, the differences ranging from 0.47 to 1.14 per cent, with an average of 0.79 per cent. Since the average of the total sulphur values for these 8 coals is 9.6 per cent, it follows that the average loss of organic sulphur during digestion with nitric acid is slightly over 8 per cent of the total sulphur. The maximum loss represents nearly 12 per cent of the total sulphur. The average loss of organic sulphur from the 5 coals having sulphur contents of less than 5 per cent, with an average sulphur content of 4.3 per cent, amounts to 0.15 per cent, or 3.5 per cent of the total sulphur.

Sample No. 5811, containing the large amount of 10.99 per cent of sulphur, was selected in order to investigate the possibility of the occurrence, during the roasting of the coal and Eschka's mixture, of loss of sulphur which had become loosely combined during the digestion with nitric acid. Portions of the coal were digested with the dilute nitric acid according to the usual procedure, and the sulphur contents of the residues determined by means of: (1) Eschka's method, and (2) fusion with sodium peroxide. The percentages of organic sulphur determined in these special tests were (1) 2.02, and (2) 2.14, as against a value of 3.15 per cent obtained by difference. There is, therefore, no reason to suppose that there is a loss of sulphur during the Eschka determination following digestion with dilute nitric acid.

There is, however, every reason to expect a loss, or volatilization of organic sulphur during the digestion with nitric acid of coals which contain 3 per cent or more of sulphur, quite apart from its possible solution in the acid. Therefore, the values obtained for organic sulphur, as determined by any of the usual methods for total sulphur, following digestion with nitric acid, are not so satisfying as those obtained by subtracting from the total percentage of sulphur the percentage of "inorganic" sulphur. In other words, the procedure heretofore employed in these Laboratories

is the most satisfactory. Furthermore, the method described earlier in this paper for the determination of humus sulphur is probably unreliable, since strong nitric acid is employed to digest coal prior to extraction of the humus sulphur with ammonia water.

SUMMARY

Investigation of the reactions taking place when coals are extracted with 3 per cent hydrochloric acid, either by the usual method for the determination of sulphate sulphur or by slight modifications of it, or when the coals are extracted with water under similar conditions, shows that:—

Oxidation of pyritic sulphur to form the sulphates of iron takes place in regular increments in successive treatments of coal, with either water or dilute hydrochloric acid, but more particularly with the former medium.

Inorganic sulphide sulphur is evolved from certain coal samples following the addition of dilute hydrochloric acid. Furthermore, dilute nitric acid may dissolve a little of the organic sulphur. Therefore, the sulphur heretofore described as "pyritic" is not necessarily of such a nature and is better described as "sulphide" sulphur.

Coal is not of such a nature as to promote reduction, and so materially inhibit the oxidation of pyrites in water or dilute hydrochloric acid.

Such other variations of the usual method for the determination of sulphate as were investigated brought about distinct changes, though none of them were of particular magnitude.

Investigation of the reactions taking place when coals are digested with nitric acid of 1.12 specific gravity shows that:—

Organic sulphur is often lost during the digestion, so that the most suitable method for its estimation is by subtracting the percentage of "inorganic" sulphur from the total percentage of sulphur.

Because of the liability of loss of organic sulphur, the method originally proposed for the determination of humus sulphur is probably unreliable.

TABLE XII

No.	—	Total sulphur, Eschka	Sulphate sulphur	Pyritic sulphur	Organic sulphur
		%	%	%	%
5299	.....	8.55	0.50	5.60	2.45
5589	.....	5.98	0.19	3.37	2.42
5590	.....	6.63	0.10	4.72	1.81
5637	.....	6.34	0.19	4.40	1.75
5331	.....	4.11	0.74	2.58	0.79
4852	.....	0.85	0.02	0.15	0.68

TABLE XIII

Sample No.....	Sulphur (per cent of original coal)	
	5299	5590
1st water extraction.....	0.55	0.19
2nd " ".....	0.15	0.07
3rd " ".....	0.15	0.06
4th " ".....	0.14	0.06
5th " ".....	0.14	0.06
6th " ".....	0.17	0.08
7th " ".....	0.14	0.06
8th " ".....	0.15	0.07
9th " ".....	0.13	0.07
10th " ".....	0.11	0.07
11th " ".....	0.11	0.08
12th " ".....	0.11	0.08
Total of water extractions.....	2.05	0.95

TABLE XIII A

Sample No.....	Sulphur (per cent of original coal)							
	4852		5589		5590		5637	
By water extraction.....	0.03	0.03	0.30	0.10	0.18	0.10	0.46	0.13
By hydrochloric extraction....	0.03	0.02	0.05	0.19	0.04	0.10	0.08	0.19
By water extraction.....		0.03		0.10		0.09		0.13
By nitric acid extraction.....	0.11	0.12	2.54	2.49	3.70	3.84	4.26	4.53
By Eschka on residue.....	0.63	0.63	2.25	2.35	1.90	1.89	1.68	1.67
Total of forms of sulphur.....	0.80	0.80	5.14	5.13	5.82	5.92	6.48	6.52
Loss of sulphur during extrac- tions.....	0.05	0.05	0.84	0.85	0.81	0.71	gain	gain

TABLE XIV

Sample No.....	Sulphur, Eschka method	Forms of sulphur (per cent of original coal)			Total of sulphur forms	Loss of sulphur,
		Sulphate	Sulphide	Organic		
<i>Sample No. 5590—</i>	%				%	%
Standard method.....	6.63	0.10	4.72	1.81	6.63	.....
Modified " (1).....	6.63	0.95	2.82	1.63	5.40	1.23
" " (2).....	6.63	0.10	3.74	1.90	5.74	0.89
" " (3).....	6.63	4.88		1.89	6.77	Gain
<i>Sample No. 5299—</i>						
Standard method.....	8.55	0.50	5.60	2.45	8.55	.....
Modified " (1).....	8.55	2.05	4.08	1.37	7.45	1.10
" " (2).....	8.55	0.50	5.48	1.57	7.55	1.00
" " (3).....	8.55	6.10		1.43	7.53	1.02
<i>Sample No. 5331—</i>						
Standard method.....	4.11	0.74	2.58	0.79	4.11	.....
Modified " (2).....	4.11	0.74	2.72	0.52	3.98	0.13
" " (3).....	4.11	3.32		0.54	3.86	0.25

Standard Method: Hydrochloric acid extraction for sulphate; nitric acid digestion for sum of sulphide and sulphate; calculation of the difference as representing organic sulphur.

Modified Method: (1) Prolonged aqueous extraction; nitric acid digestion; determination of sulphur in residue by Eschka's method.

(2) Hydrochloric acid extraction followed by same procedure as in (1).

(3) Nitric acid digestion, followed by Eschka's method.

TABLE XV

I Sample No.	II Total sulphur by Eschka method	III Sum of sulphate and sulphide sulphur, by nitric acid digestion	IV Organic sulphur, difference between II and III	V Organic sulphur, in residue from nitric acid digestion, by Eschka method	VI Difference between determined and calculated organic sulphur
	%	%	%	%	
5805.....	3.54	1.55	1.99	1.91	-0.08
5804.....	4.10	2.19	1.91	1.76	-0.15
5831.....	4.11	3.32	0.79	0.54	-0.25
5803.....	4.81	3.08	1.73	1.69	-0.04
5806.....	4.83	2.46	2.37	2.21	-0.16
5799.....	5.48	4.17	1.31	1.36	+0.05
5798.....	6.10	4.43	1.67	1.68	+0.01
5808.....	6.18	4.32	1.86	1.90	+0.04
5797.....	6.43	4.55	1.88	1.71	-0.17
5802.....	6.48	4.49	1.99	2.05	+0.06
5590.....	6.63	4.82	1.81	1.89	+0.08
5801.....	6.68	4.81	1.87	1.89	+0.02
5800.....	7.07	4.93	2.14	1.67	-0.47
5795.....	7.79	5.54	2.25	1.55	-0.70
5299.....	8.55	6.10	2.45	1.43	-1.02
5796.....	8.56	6.16	2.40	1.81	-0.59
5814.....	9.34	6.46	2.88	2.43	-0.45
5816.....	10.78	7.87	2.91	1.77	-1.14
5811.....	10.99	7.84	3.15	2.09	-1.06
5815.....	13.61	10.56	3.05	2.14	-0.91

IV

ANALYSES OF COALS AND OTHER SOLID FUELS

Compiled by J. H. H. Nicolls and C. B. Mohr

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.¹
- (3) Miscellaneous solid fuels.

The first group of fuels (Table XVI) 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 few "commercial" samples occur in the first group; each of these is considered to be representative of the corresponding product as shipped from the mine.

The second group of fuels (Table XVII) consists entirely of bituminous coals purchased by the Department of Pensions and National Health 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.P. & N.H., only 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 XVIII) consists of imported coals, such as are sold by local dealers either for heating private residences or public buildings, or for various industrial purposes. In addition, it includes a few samples of coke, most of which were obtained from various Ottawa dealers. The most of these were made in Canada, but all from coals from the United States. They are all "commercial" samples. The third group also contains some processed fuels, samples of wood charcoal, such as may be used for kindling, and a sample of partially dried beechwood, which may be considered as typical of hardwood used for domestic heating.

Table XIX contains the screen analyses of a few 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

¹ Now the Department of Pensions and National Health.

as used in the headings of the table 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. A study of the screen analyses of the cokes (in the Departmental reports of the two previous years as well as the present one) shows that there is a lack of uniformity in size designation between the products of the various manufacturing plants.

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 apparatus¹. 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 1-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.

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

TABLE XVI

Analyses of Solid Fuels Occurring in Canada

Dominion Coal Company, Limited (Besco), Glace Bay, Nova Scotia.—Coal delivered to Canadian National Railways and sampled from their storage pile at Windmill Point, Montreal																			
Sample No.....	5194	5195	5196	5197	5198	5199	5200	5201	5202	5203	5739	5740	5741	5742	5777	5778	5779	5780	
Moisture (as received) per cent	2.4	2.2	2.3	2.2	2.2	2.2	2.3	2.6	2.4	2.4	5.6	2.6	3.0	2.8	3.1	3.3	3.8	4.0	
<i>Dry Basis—</i>																			
Ash.....per cent	7.4	9.0	8.1	7.7	9.2	8.4	7.9	8.5	8.1	8.8	8.2	8.1	8.0	8.5	8.7	8.6	9.1	7.6	
Volatile matter. “	34.6	34.0	33.8	34.6	34.3	34.2	34.6	34.2	33.5	34.1	34.5	34.5	34.5	35.1	34.7	34.6	33.4	34.6	
Fixed carbon... “	58.0	57.0	58.1	57.7	56.5	57.4	57.5	57.3	58.4	57.1	57.3	57.4	57.5	56.4	56.6	56.8	57.5	57.8	
Sulphur..... “	3.3	3.3	3.0	3.3	3.3	3.6	3.0	3.1	3.5	3.4	2.9	2.9	2.5	2.9	2.9	3.1	3.0	2.8	
<i>Calorific Value—</i>																			
Calories per gramme, gross.....			7,760						7,740		7,780				7,690				
B.T.U. per pound, gross			13,960						13,940		14,000				13,840				
Fuel ratio.....	1.70	1.70	1.70	1.65	1.65	1.70	1.65	1.70	1.75	1.65	1.65	1.65	1.65	1.60	1.65	1.65	1.70	1.65	
Coking properties.....	Good	Fair	Good	Good	Good	Good	Good	Good	Good	Good	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good	
Designation of coal.....	Screened run-of-mine.....																		
Taken by.....	R. E. Gilmore and R. A. Strong, Fuel Inspectors of Canadian National Railways.....																		
Date of sampling.....	July 24, 1928.....						August 15, 1928.....				January 16 to 21, 1929....				February 20 to 28, 1929....				

TABLE XVI—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

Sample No.....	Government peat bog, Alfred, Prescott county, Ontario														
	5303		5304		5305		5324		5325		5326		5327		
Moisture condition.....	AD	D	AD	D	AD	D	AD	D	AD	D	AD	D	AD	D	
<i>Proximate Analysis—</i>															
Moisture..... per cent	24.9	....	17.3	...	17.2	...	20.9	...	24.7	...	23.1	...	25.0	....
Ash..... "	4.1	5.5	3.8	4.6	3.5	4.2	3.6	4.6	3.4	4.5	3.4	4.4	3.2	4.3	
Volatile matter..... "	49.2	65.5	54.3	65.6	55.0	66.4	52.0	65.7	49.2	65.3	50.8	66.1	49.7	66.2	
Fixed carbon..... "	21.8	29.0	24.6	29.8	24.3	29.4	23.5	29.7	22.7	30.2	22.7	29.5	22.1	29.5	
<i>Ultimate Analysis—</i>															
Sulphur..... per cent	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	
Fuel ratio.....	0.44		0.45		0.44		0.45		0.46		0.44		0.44		
Kind of sample.....	All mine.....														
Location in deposit.....	First 30 rows		31st to 60th row		61st to 90th row		91st to 120th row		121st to 150th row		151st to 180th row		181st to 215th row		
Taken by.....	All by, or under the direction of, H. A. Leverin, Mines Branch.														
Date of sampling.....	About October 1, 1928.....							October 10, 1928.....							

TABLE XVI—Continued
Analyses of Solid Fuels Occurring in Canada—Continued

	Brown coal from near Blacksmith falls, on Abitibi river, northern Ontario						Coal from Ravenscrag formation in Cypress hills, Saskatchewan					
	5331			5333			4780			4779		
Sample No.....	R	AD	D	R	AD	D	R	AD	D	R	AD	D
Moisture condition.....												
<i>Proximate Analysis—</i>												
Moisture..... per cent	39.9	16.7	.....	30.7	17.2	.....	37.5	18.4	.....	36.0	18.9	.....
Ash..... “	7.3	10.1	12.2	10.5	14.5	17.5	9.3	12.1	14.8	17.7	22.4	27.6
Volatile matter..... “	26.8	37.2	44.6	25.3	34.7	41.9	27.0	35.2	43.2	25.6	32.5	40.0
Fixed carbon..... “	26.0	36.0	43.2	24.5	33.6	40.6	26.2	34.3	42.0	20.7	26.2	32.4
<i>Ultimate Analysis—</i>												
Sulphur..... per cent	3.0	4.1	4.9	1.0	1.4	1.7	0.4	0.5	0.6	0.4	0.6	0.7
<i>Calorific Value—</i>												
Calories per gramme, gross.....	3,430	4,760	5,710	3,300	4,530	5,480	3,220	4,200	5,140	2,540	3,210	3,960
B.T.U. per pound, gross.....	6,170	8,560	10,280	5,940	8,160	9,860	5,790	7,560	9,260	4,570	5,780	7,130
Fuel ratio.....	0.97			0.97			0.97			0.81		
Coking properties.....	Non-coking			Non-coking			Non-coking			Non-coking		
Softening temperature of ash.....	2,300° F. (1,260° C.)			—			—			—		
Designation of fuel.....	Lumps.....			Smalls and fines obtained in procuring lumps.								
Kind of sample.....	All prospect.....											
Location in deposit.....							From lower 3-foot 5-inch bench of main seam, in small gully.			From main 4-foot 7-inch seam, including 5-inch and 7-inch shale partings.		
Taken by.....	W. S. Dyer, Ontario Department of Mines.....						F. H. McLearn, Geological Survey.....					
Date of sampling.....	Early fall of 1928.....						August 26, 1927.....			August 16, 1927.....		

TABLE XVI—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	Superba Coal Co., Ltd., Mile 58, Alberta Coal Branch, Lovett, Al- berta; sec. 2, tp. 47, R. 19, W. 5 mer.			Sterling Collieries Co., Ltd., No. 769, Sterco, Al- berta; sec. 35, tp. 47, R. 20, W. 5 mer.			Saunders Ridge Coal Co., No. 846, Mercoal, Alberta; sec. 25, tp. 48, R. 22, W. 5 mer.						Coalspur Collieries, Ltd., No. 648, Mile 40, Al- berta Coal Branch, Coalspur, Alberta; sec. 23, tp. 48, R. 25, W. 5 mer.					
Sample No.....	5505			5506			5509			5510			5508			5507		
Moisture condition.....	R	AD	D	AD	D	R	AD	D	R	AD	D	R	AD	D	R	AD	D	
<i>Proximate Analysis—</i>																		
Moisture.....per cent	8.7	7.0	...	7.1	....	8.9	7.0	...	8.9	7.8	....	8.5	7.0	....	8.1	6.9	....
Ash.....“	10.3	10.6	11.4	12.1	13.0	8.6	8.3	9.4	7.6	7.7	8.4	9.5	9.7	10.4	7.5	7.7	8.2	
Volatile matter. “	33.9	34.5	37.1	33.8	36.4	35.5	36.2	39.0	35.9	36.4	39.4	37.1	37.7	40.6	35.9	36.3	39.0	
Fixed carbon.... “	47.1	47.9	51.5	47.0	50.6	47.0	48.0	51.6	47.6	48.1	52.2	44.9	45.6	49.0	48.5	49.1	52.8	
<i>Ultimate Analysis—</i>																		
Sulphur.....per cent	0.1	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	
<i>Calorific Value—</i>																		
Calories per gramme, gross.....	6,130	6,240	6,710	6,110	6,580	6,210	6,330	6,810	6,260	6,330	6,870	6,200	6,310	6,780	6,340	6,420	6,900	
B.T.U. per pound, gross.	11,030	11,230	12,080	11,000	11,840	11,180	11,400	12,260	11,260	11,390	12,360	11,160	11,350	12,200	11,410	11,560	12,420	
Fuel ratio.....	1.40			1.40			1.30			1.30			1.20			1.35		
Coking properties.....	Non-coking			Non-coking			Agglomerates			Agglomerates			Agglomerates			Agglomerates		
Kind of sample.....	Mine.....			Tipple; from con- veyer belt at in- tervals during week's run.			Mine.....			Mine.....			Mine.....			Mine.....		
Location in mine.....	Val d'Or series; 13-foot seam, No. 2 bench.			Mynheer seam.			Val d'Or series; top 8-foot bench of No. 2 seam, at No. 2 entry east.			Val d'Or series, bottom 4-foot bench of same seam, at same location.			Val d'Or seam; from No. 1 entry face.			Val d'Or seam; from No. 2 entry face.		
Taken by.....	All by B. R. MacKay, Geological Survey.....																	
Date of sampling.....	October, 1928.....																	

TABLE XVI—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	West Canadian Collieries, Ltd., No. 396, Greenhill mine, Blair- more, Alberta; sec. 2, tp. 8, R. 4, W. 5 mer.		Canmore Coal Co., Ltd., No. 2, Canmore, Alberta; sec. 29 tp. 24, R. 10, W. 5 mer.		Mountain Park Collieries, Ltd. No. 282, Moun- tain Park, Al- berta; sec. 32, tp. 45, R. 23 W. 5 mer.		Gibo Collieries, Ltd., located on Gregg river, about 2½ miles west of Luscar, Alberta; from faces of tunnels driven in seams in south Gibo prospect			Blue Diamond Coal Co., Ltd. No. 428, Brûlé Mines, Alberta sec. 16, tp. 52, R. 27, W. 5 mer.						
Sample No.....	4775		4774		4926		5502		5503			5504			4789	
	R	D	R	D	R	D	R	D	R	AD	D	R	AD	D	R	D
<i>Proximate Analysis—</i>																
Moisture.....per cent	1.0	...	1.1	....	1.3	...	1.8	...	13.5	9.0	....	20.3	15.8	....	0.6	....
Ash.....“	8.9	9.0	10.2	10.3	9.5	9.6	9.2	9.4	8.5	8.9	9.8	12.8	13.5	16.1	15.8	15.8
Volatile matter.....“	25.9	26.1	25.0	25.2	19.1	19.4	30.4	30.9	22.3	23.5	25.8	20.4	21.6	25.6	19.9	20.1
Fixed carbon.....“	64.2	64.9	63.7	64.5	70.1	71.0	58.6	59.7	55.7	58.6	64.4	46.5	49.1	58.3	63.7	64.1
<i>Ultimate Analysis—</i>																
Sulphur.....per cent	0.6	0.6	0.5	0.6	1.1	1.2	0.6	0.6	0.2	0.2	0.3	0.2	0.2	0.3	....	....
<i>Calorific Value—</i>																
Calories per gramme, gross.....	7,790	7,870	7,670	7,750	7,810	7,910	7,680	7,820	5,970	6,270	6,890	4,750	5,010	5,950	....	....
B.T.U. per pound, gross.....	14,020	14,160	13,800	13,950	14,050	14,240	13,820	14,080	10,750	11,290	12,400	8,540	9,020	10,710	....	....
Fuel ratio.....	2.50		2.55		3.65		1.95		2.50			2.25			3.20	
Coking properties.....	Good		Good		Non-coking		Good		Non-coking			Non-coking			Good	
Designation of coal.....	“Washed nut, 1½-inch lump”		Briquettes.....		.....		.....		.....			.....			.....
Kind of sample.....	Commercial— 46 tons.		Commercial— 20 tons.		Commercial.		Mine.....		Prospect.....			Prospect.....			Commercial....	
Location in mine.....	.....		.....		.....		Michelean seam; at face of work- ings.		Jewel seam; 1,700 feet west of Stupor pros- pect.			Boa seam; 2,300 feet northwest of Louis Stupor prospect.			.....
Taken by.....	Staff of Military District No. 12, Regina.		.....		From stock of Ottawa dealer.		B. R. MacKay,		Geological Survey.....			.....			Board of Rail- way Commis- sioners.	
Date of sampling.....	Dec. 29, 1927.		Feb. 25, 1928.		July, 1928.		Sept. 15, 1928.		Autumn of 1928.....			.....			March, 1928.	

TABLE XVI—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	Coal samples from near the north branch of Hay river, from the northern portion of Brûlé area, Alberta, in tp. 52, Rs. 4 and 5, W. 6 mer.														
	From south limb of Hay River anticline						From prospect on Redmond creek, 1,300 feet from junction with Hay river								
Sample No.....	5486		5487		5499		5491		5492		5493				
Moisture condition.....	R	D	R	D	R	D	R	D	R	D	R	D			
<i>Proximate Analysis—</i>															
Moisture.....per cent	11.8	.....	14.9	.....	23.6	.....	5.9	.....	11.7	.....	3.4	.....		
Ash.....“	8.8	10.0	8.9	10.4	9.3	12.2	11.5	12.2	17.5	19.8	15.6	16.2			
Volatile matter.....“	26.5	30.0	25.5	30.0	24.9	32.5	26.4	28.1	24.3	27.5	25.9	26.8			
Fixed carbon.....“	52.9	60.0	50.7	59.6	42.2	55.3	56.2	59.7	46.5	52.7	55.1	57.0			
<i>Ultimate Analysis—</i>															
Sulphur.....per cent	0.2	0.3	0.2	0.3	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3			
<i>Calorific Value—</i>															
Calories per gramme, gross.....	5,560	6,300	5,320	6,250	4,540	5,950	6,740	7,160	5,460	6,190	6,240	6,470			
B.T.U. per pound, gross.....	10,010	11,340	9,580	11,250	8,170	10,710	12,130	12,890	9,830	11,140	11,240	11,640			
Fuel ratio.....	2.00		2.00		1.70		2.10		1.90		2.15				
Coking properties.....	Non-coking		Non-coking		Non-coking		Poor		Agglomerates		Poor				
Kind of sample.....	All prospect.....														
Location in deposit.....	No. 2 seam, 21 feet 6 inches; 10,800 feet southwest of junction of Thoreau creek and Hay river; omitting clay partings.			No. 2 seam, 30 feet; 18,600 feet west of junction of Thoreau creek and Hay river; omitting clay partings.			No. 2 seam, 21 feet 7 inches; 24,800 feet west of junction of Thoreau creek and Hay river; omitting clay partings.			No. 2 seam, 35 feet. No. 2 seam; composite of 5 subsections.			No. 2 seam; uppermost 10 feet.		
Taken by.....	B. R. MacKay, Geological Survey.....														
Date of sampling.....	August, 1928.....														

TABLE XVI—Continued
Analyses of Solid Fuels Occurring in Canada—Continued

	Coal samples from near the north branch of Hay river, from the northern portion of Brûlé area, Alberta, in tp. 52, R. 4, W. 5 mer.																	
	From prospect on Redmond creek, 1,300 feet from junction with Hay river					From prospect on west side of Thoreau creek, 5,300 feet from junction with Hay river, and 700 feet below camp												
Sample No.....	5494		5495		5496		5497		5498		5476		5477					
Moisture condition.....	R	D	R	D	R	D	R	D	R	D	R	D	R	D				
<i>Proximate Analysis—</i>																		
Moisture.....per cent	6.8	.....	6.5	....	4.9	.....	12.8	.....	1.3	....	10.8	.....	4.3	.....			
Ash.....“	11.8	12.7	8.6	9.2	10.9	11.5	12.6	14.5	11.8	11.9	13.6	15.2	7.7	8.0				
Volatile matter...“	25.3	27.1	25.7	27.5	23.9	25.1	24.3	27.9	26.0	26.4	24.9	27.9	28.5	29.8				
Fixed carbon.....“	56.1	60.2	59.2	63.3	60.3	63.4	50.3	57.6	60.9	61.7	50.7	56.9	59.5	62.2				
<i>Ultimate Analysis—</i>																		
Sulphur.....per cent	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	3.1	3.1	0.3	0.3	0.3	0.3				
<i>Calorific Value—</i>																		
Calories per gramme, gross	6,280	6,740	6,550	7,000	6,500	6,830	5,760	6,600	7,360	7,460	5,720	6,420	6,660	6,960				
B.T.U. per pound, gross...	11,310	12,130	11,790	12,600	11,700	12,300	10,370	11,880	13,250	13,430	10,300	11,560	11,990	12,530				
Fuel ratio.....	2.20		2.30		2.50		2.05		2.35		2.05		2.10					
Coking properties.....	Non-coking		Non-coking		Non-coking		Non-coking		Poor		Non-coking		Agglomerates					
Kind of sample.....	All prospect.....																	
Location in deposit.....	No. 2 seam, 35 feet; second bench, 8 feet 4 inches.			No. 2 seam; third bench, 5 feet 8 inches.			No. 2 seam; fourth bench, 4 feet.			No. 2 seam; lowermost 4 feet.			No. 3 seam, 8 feet; 370 feet below No. 2 seam; from bore-hole.		No. 2 seam, 32 feet 5 inches; composite, omitting clay bands.		No. 2 seam; uppermost 3 feet.	
Taken by.....	B. R. MacKay, Geological Survey.....																	
Date of sampling.....	August, 1928.....																	

TABLE XVI—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	Coal samples from near the north branch of Hay river, from northern portion of Brûlé area, Alberta, in tp. 52, R. 4, W. 6 mer.								From prospect on Thoreau creek, half a mile west of camp on north side of trail	
	From prospect on west side of Thoreau creek, 5,300 feet from junction with Hay river and 700 feet below camp									
Sample No.....	5478		5480		5481		5482		5500	
Moisture condition.....	R	D	R	D	R	D	R	D	R	D
<i>Proximate Analysis—</i>										
Moisture..... per cent	2.4	....	3.0	....	5.1	....	4.1	....	13.7	....
Ash..... "	13.4	13.7	6.9	7.1	8.9	9.3	15.8	16.5	12.4	14.4
Volatile matter..... "	26.5	27.2	29.2	30.1	26.7	28.2	24.8	25.8	26.7	30.9
Fixed carbon..... "	57.7	59.1	60.9	62.8	59.3	62.5	55.3	57.7	47.2	54.7
<i>Ultimate Analysis—</i>										
Sulphur..... per cent	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
<i>Calorific Value—</i>										
Calories per gramme, gross.....	6,380	6,530	6,820	7,030	6,510	6,860	6,070	6,320	5,120	5,930
B.T.U. per pound, gross.....	11,480	11,750	12,270	12,650	12,720	12,350	10,920	11,380	9,220	10,670
Fuel ratio.....	2.20		2.10		2.20		2.25		1.75	
Coking properties.....	Poor		Poor		Agglomerates		Agglomerates		Non-coking	
Kind of sample.....	All prospect									
Location in deposit.....	No. 2 seam, 32 feet 5 inches; second bench, 1 foot 1 inch of splinty coal.		No. 2 seam; fourth bench, 4 feet 8 inches.		No. 2 seam; fifth bench, 5 feet 5 inches, omitting 3-inch clay parting		No. 2 seam; lowermost 9 feet 10 inches.		No. 1 seam, 7 feet; omitting sandstone partings.	
Taken by.....	B. R. MacKay, Geological Survey									
Date of sampling.....	August, 1928.									

TABLE XVI—Concluded

Analyses of Solid Fuels Occurring in Canada—Concluded

	Coal samples from near the north branch of Hay river, from the northern part of Brûlé area, or the southern portion of Smoky River area, Alberta, from tps. 52 or 53, R. 4, W. 6 mer.												Tulameen Valley Coal Co., Princeton, British Columbia.
	From hill slope, 4,000 feet northeast of camp.		From saddle of ridge dividing Thoreau and Berland creeks				From 1,200 ft. north of trail crossing; north limb of syncline.						
			From trail crossing; south limb of anticline.										
Sample No.....	5501		5483		5484		5485		4783				
Moisture condition.....	R	D	R	D	R	D	R	D	R	AD	D		
<i>Proximate Analysis—</i>													
Moisture..... per cent	12.5	.....	11.6	.....	14.0	.....	16.4	.....	19.1	18.2	.....	
Ash..... "	8.9	10.1	13.8	15.5	13.7	16.0	10.5	12.6	7.0	7.0	8.6		
Volatile matter..... "	26.0	29.8	23.8	26.9	22.9	26.6	22.4	26.8	31.5	31.9	39.0		
Fixed carbon..... "	52.6	60.1	50.8	57.6	49.4	57.4	50.7	60.6	42.4	42.9	52.4		
<i>Ultimate Analysis—</i>													
Sulphur..... per cent	0.4	0.4	0.2	0.3	0.1	0.2	0.3	0.3	0.3	0.3	0.4		
<i>Calorific Value—</i>													
Calories per gramme, gross.....	5,400	6,180	5,430	6,150	5,210	6,060	5,220	6,250	5,460	5,520	6,750		
B.T.U. per pound, gross.....	9,730	11,120	9,770	11,070	9,330	10,910	9,400	11,250	9,330	9,940	12,150		
Fuel ratio.....	2.00		2.05		2.15		2.25		1.35				
Coking properties.....	Non-coking		Non-coking		Non-coking		Non-coking		Non-coking				
Kind of sample.....	All prospect.....												
Location in deposit.....	28-foot 11-inch seam.		No. 2 seam, 25 feet; upper 8 feet; omitting clay bands.		No. 2 seam, 25 feet; bottom 16 feet.		No. 2 seam, 22 feet; omitting clay partings.						
Taken by.....	B. R. MacKay, Geological Survey.....												
Date of sampling.....	August, 1928.....												
	Mine operators. March, 1928.												

TABLE XVIII

Analyses of Miscellaneous Solid Fuels

Sample No.	Pennsylvania anthracite coal										"Pocohontas" semi-bituminous or "smokeless" coal from West Virginia								
	5335		5336		5337		5570		5747		5207		5210		5211		5214		
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	
<i>Proximate Analysis—</i>																			
Moisture..... per cent	3.9	...	4.7	...	4.7	...	4.8	...	1.7	...	1.3	...	1.5	...	1.4	...	1.8	....
Ash..... "	9.0	9.4	10.7	11.2	13.8	14.4	11.5	12.0	9.7	9.9	9.7	9.8	7.7	7.8	7.7	7.8	12.7	13.0	
Volatile matter..... "	5.2	5.4	5.7	6.0	5.4	5.7	6.6	7.0	8.0	8.2	18.7	19.0	19.1	19.4	18.8	19.1	18.7	19.0	
Fixed carbon..... "	81.9	85.2	78.9	82.8	76.1	79.9	77.1	81.0	80.6	81.9	70.3	71.2	71.7	72.8	72.1	73.1	66.8	68.0	
<i>Ultimate Analysis—</i>																			
Sulphur..... per cent	0.7	0.8	0.9	0.9	0.6	0.7	...	...	...	...	0.8	0.9	0.7	0.7	0.7	0.7	3.1	3.2
<i>Calorific Value—</i>																			
Calories per gramme, gross.....	7,300	7,600	7,000	7,350	6,760	7,090	.....	.....	.....	.....	7,790	7,890	7,940	8,060	8,010	8,120	7,360	7,490
B.T.U. per pound, gross.....	13,140	13,680	12,600	13,230	12,170	12,770	.....	.....	.....	.....	14,020	14,200	14,290	14,510	14,420	14,620	13,240	13,480
Fuel ratio.....	15.70		13.75		14.05		11.60		10.00		3.75		3.75		3.85		3.55		
Coking properties.....	Non-coking		Non-coking		Non-coking		Non-coking		Non-coking		Good		Good		Good		Good		
Designation of coal.....	Egg.....		Stove.....		Nut.....		"Temple" buckwheat.		"Red Ash".....		.....							
Kind of sample.....	3 samples from holdings of Connell Anthracite Mining Company.										Delivered in Ottawa.				Delivered to Ottawa public schools.....				
Date.....	October, 1928.....						November, 1928.		February, 1929.		August, 1928.....								

TABLE XVIII—Continued
Analyses of Miscellaneous Solid Fuels—Continued

	Semi-bituminous coals from the United States				Bituminous coals from the United States									
	"Red Star," Pennsylvania.		"Keystone" or "Lilly" coal from lower Kittanning seam, Cambria co., Pennsylvania		"Gilbert-Davis No. 1" mine, Sewickley seam, Morgantown, Monongalia county, West Virginia.		"Brock" mine, Sewickley seam, Cassville, Monongalia co., West Virginia.		"Sumner No. 2" mine, Pittsburgh seam, Fayette City (or Brazz-nell), Fayette co., Pennsylvania.		"Horner" mine, Pittsburgh seam, Washington co., Pennsylvania.			
Sample No.	4923		5593		4796		4797		5222		5594		5219	
Moisture condition:	R	D	R	D	R	D	R	D	R	D	R	D	R	D
<i>Proximate Analysis—</i>														
Moisture..... per cent	1.2	...	1.8	...	1.9	...	1.9	...	2.3	...	1.4	...	1.8	...
Ash..... "	5.6	5.7	8.1	8.2	11.4	11.6	11.6	11.8	10.4	10.6	9.7	9.9	7.8	8.0
Volatile matter..... "	18.1	18.3	22.4	22.8	33.6	34.3	33.9	34.6	35.5	36.4	33.5	33.9	36.3	36.9
Fixed carbon..... "	75.1	76.0	67.7	69.0	53.1	54.1	52.6	53.6	51.8	53.0	55.4	56.2	54.1	55.1
<i>Ultimate Analysis—</i>														
Sulphur..... per cent	0.9	0.9	0.8	0.8	1.6	1.6	1.4	1.4	2.1	2.1	1.5	1.5	2.1	2.1
<i>Calorific Value—</i>														
Calories per gramme, gross.....	.....	.....	7,950	8,100	7,310	7,450	7,350	7,490	.....	.....	7,570	7,680	.....	.....
B.T.U. per pound, gross.....	.....	.....	14,310	14,580	13,160	13,410	13,230	13,480	.....	.....	13,630	13,820	.....	.....
Fuel ratio.....	4.15		3.05		1.60		1.55		1.45		1.65		1.50	
Coking properties.....	Good		Good		Good		Good		Good		Good		Fair	
Designation of coal.....	Smithing.....		Smithing.....		"1½-inch lump".....				.....				"Youghiougheny gas coal".....	
Kind of sample.....	From stocks of Ottawa dealers.....		.....		Delivered to Camp Borden, and stored in pile. Season 1927-1928.....				Delivered in Ottawa.....				From Ottawa dealer's stock. September, 1928.	
Date.....	July, 1928.		December, 1928.		.....				September, 1928.		Autumn of 1928.		.....

TABLE XVIII—Continued

Analyses of Miscellaneous Solid Fuels—Continued

	Bituminous coals from the United States										Scotch semi-anthracite coal.	Russian anthracite coal								
	"Edna No. 2" mine, Pittsburgh seam, Wendel, Westmoreland co., Pennsylvania.		"Yatesboro" mine, upper Freeport seam, Yatesboro, Armstrong co., Pennsylvania.				"Grant" mine, lower Kittanning seam, Claytonia, Butler county, Pennsylvania.													
Sample No.....	5595		5683		5684		5685		4788		5328		5723		5781		5782			
Moisture condition.....	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D		
<i>Proximate Analysis—</i>																				
Moisture.....per cent	1.7	....	3.3	...	3.1	...	3.1	...	2.4	....	3.5	...	4.2	...	3.9	...	4.7	...
Ash..... " "	8.2	8.3	8.7	9.0	8.4	8.7	9.3	9.6	7.6	7.8	6.6	6.8	3.4	3.5	2.7	2.8	3.5	3.7		
Volatile matter. " "	33.1	33.7	26.1	27.0	29.3	30.2	31.4	32.4	35.4	36.2	9.0	9.3	4.3	4.5	4.1	4.3	3.8	4.0		
Fixed carbon.... " "	57.0	58.0	61.9	64.0	59.2	61.1	56.2	58.0	54.6	56.0	80.9	83.9	88.1	92.0	89.3	92.9	88.0	92.3		
<i>Ultimate Analysis—</i>																				
Sulphur.....per cent	1.3	1.4	.....	.....	.....	.....	2.1	2.2	1.6	1.7	0.7	0.8	1.4	1.4	1.3	1.4	1.4	1.5
<i>Calorific Value—</i>																				
Calories per gramme, gross.....	7,660	7,790	.....	.....	.....	.....	7,590	7,830	7,530	7,720	7,600	7,870	7,660	8,000	7,750	8,070	7,580	7,960
B.T.U. per pound, gross	13,790	14,030	.....	.....	.....	.....	13,660	14,100	13,550	13,890	13,680	14,170	13,790	14,400	13,950	14,530	13,640	14,320
Fuel ratio.....	1.70		2.35		2.05		1.80		1.55		9.00		20.65		21.55		23.40			
Coking properties.....	Good		Good		Good		Good		Good		Non-coking		Non-coking		Non-coking		Non-coking			
Softening temperature of ash.....	.....																		
Designation of coal.....			Slack.....												Large-egg to furnace size.		Medium—stove to nut size.			
Kind of sample.....	Delivered in Ottawa.		Supplied to Fuel Research Laboratories.										Delivered in Arnprior, Ontario.		Delivered in Ottawa.		From Ottawa dealers.....			
Date.....	Autumn of 1928.		January, 1929.....										March, 1928.		Autumn of 1928.		February and March, 1929.....			

TABLE XVIII—Continued
Analyses of Miscellaneous Solid Fuels—Continued

By-product coke made in Koppers ovens by Montreal Coke and Manufacturing Company, Ville LaSalle, Quebec														
Sample No.....	4927		5598		5599		5600		5601		5611		5612	
Moisture condition.....	R	D	R	D	R	D	R	D	R	D	R	D	R	D
<i>Proximate Analysis—</i>														
Moisture.....per cent	1.6	...	0.1	...	0.1	...	0.1	...	0.2	...	10.7	...	11.1	...
Ash.....“	9.3	9.5	9.8	9.8	9.7	9.7	10.0	10.0	9.7	9.8	8.6	9.7	8.3	9.3
Volatile matter.....“	1.7	1.7	1.2	1.2	1.3	1.3	0.9	0.9	3.2	3.2	0.9	1.0	0.9	1.0
Fixed carbon.....“	87.4	88.8	88.9	89.0	88.9	89.0	89.0	89.1	86.9	87.0	79.8	89.3	79.7	89.7
<i>Ultimate Analysis—</i>														
Sulphur.....per cent	0.8	0.8	0.8	0.8	0.7	0.7	0.8	0.9	0.7	0.7	0.7	0.8	0.7	0.8
<i>Calorific Value—</i>														
Calories per gramme, gross.....	6,960	7,070	7,100	7,110	7,170	7,180	7,080	7,090	7,150	7,160	6,370	7,130	6,390	7,190
B.T.U. per pound, gross.....	12,530	12,720	12,780	12,800	12,910	12,920	12,740	12,760	12,870	12,890	11,460	12,840	11,500	12,940
Softening temperature of ash.....			2,640° F. (1,450° C.)		2,635° F. (1,445° C.)		2,680° F. (1,470° C.)		2,650° F. (1,455° C.)		—		—	
Specific gravity (apparent).....											0.940		0.975	
Designation of coke.....	Stove.....		Foundry.....		Egg.....		Stove.....		Nut.....		Stove.....		Stove.....	
Kind of sample.....	From dealer's stock		.....		.....		.....		.....		From dealers' stocks		.....
Date.....	July, 1928.		December, 1928.		.....		.....		.....		.....		.....

TABLE XVIII—Concluded

Analyses of Miscellaneous Solid Fuels—Concluded

Sample No.....	By-product coke made in Ford plant, near Detroit, Michigan						Briquettes made with carbonized Bienfait, Saskatchewan, Saskatchewan, lignite by Tapping Cohesives, of Birmingham England.		"Coalite" made by Low Temperature Carbonization, Ltd. of London, England.		Charcoal made from hardwood at Nominingue, Quebec.		Charcoal made from poplar (soft) wood at Nominingue, Quebec.		Beechwood borings, from a block which had been barked and stood indoors for several weeks.		
	5608		5609		5610		4898		4806		4869		4870		5725		
Moisture condition.....	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	AD	D
<i>Proximate Analysis—</i>																	
Moisture..... per cent	12.7	...	12.7	...	12.7	....	7.2	....	2.8	...	5.2	...	4.9	...	29.3	10.8	....
Ash..... " "	8.8	10.0	8.4	9.6	9.0	10.3	13.5	14.5	5.2	5.3	1.4	1.5	4.1	4.3	0.8	0.9	1.0
Volatile matter.... " "	1.1	1.3	1.2	1.4	1.7	1.9	18.7	20.2	7.6	7.8	33.7	35.6	24.2	25.5	58.9	74.4	83.4
Fixed carbon..... " "	77.4	88.7	77.7	89.0	76.6	87.8	60.6	65.3	84.4	86.9	59.7	62.9	66.8	70.2	11.0	13.9	15.6
<i>Ultimate Analysis—</i>																	
Sulphur..... per cent	0.4	0.5	0.4	0.5	0.4	0.5	1.2	1.3	1.0	1.0	0.1	0.1	0.1	0.1	Trace		
<i>Calorific Value—</i>																	
Calories per gramme, gross	6,220	7,130	6,230	7,140	6,190	7,090	6,380	6,880	7,540	7,760	6,810	7,180	6,930	7,290	3,330	4,200	4,710
B.T.U. per pound, gross...	11,990	12,830	11,220	12,850	11,140	12,770	11,490	12,380	13,570	13,960	12,260	12,930	12,470	13,120	5,990	7,560	8,470
Fuel ratio.....	0.880		0.885		0.935		3.25		11.05								
Specific gravity (apparent)...	0.880		0.885		0.935		3.25		11.05								
Designation of fuel.....	Egg.....		Nut.....		Hickory.....												
Kind of sample.....	From Ottawa dealer's stock.....										Secured through an official of the Canadian Pacific Railway.				Delivered for fuel, to Fuel Research Laboratories. Autumn of 1928.....		
Date.....	December, 1928.....						July 16, 1928.		April 24, 1928.		June 25, 1928.....						

TABLE XIX
 Screen Analyses
 (Wire Screens with Square Openings)

Fuel.....	Russian anthracite		Montreal (LaSalle) coke		Detroit (Ford) coke		
	Large-egg to furnace	Medium-stove to nut	Stove	Stove	Egg	Nut	Hickory
Designation.....							
Sample No.....	5781	5782	5611	5612	5608	5609	5610
Remaining on 3-inch screen (Lump)..... per cent	11.2	0.0	0.0	0.0	0.0	0.0	0.0
Passing 3 inch, remaining on 2 inch (Egg)..... "	65.9	0.0	12.5	12.1	11.8	0.0	0.0
" 2 " " 1½ " (Stove)..... "	19.4	36.2	73.1	74.9	55.6	26.2	0.0
" 1½ " " ¾ " (Nut)..... "	2.6	59.0	13.7	11.0	31.9	70.9	19.4
" ¾ " " ¼ " (Pea)..... "	0.2	3.7	0.5	1.1	0.7	2.5	63.1
" ¼ " screen (Screenings)..... "	0.7	1.1	0.2	0.9	0.0	0.4	17.5

V

GASOLINE SURVEY FOR 1928

P. V. Rosewarne and R. J. Offord

The 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 five years¹. This report covers a similar survey for 1928. During the latter part of August, 77 samples were collected² 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, specific gravity, and iodine value. The distillation range was determined according to the method recommended by the United States Bureau of Mines³. From the results so obtained, a weighted index number was calculated after the method advocated by Gruse⁴, with the difference that the index numbers were calculated from the 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 to 60° F., according to the National Standard Petroleum Oil Tables⁵. The degrees A.P.I. were obtained by conversion of the specific gravity according to the above tables. The iodine values were determined by the Hanus method⁶.

In addition to the above, each sample was analysed to determine the relative amounts of unsaturates, aromatic, naphthenes, and paraffins present. The method chosen was that outlined by Egloff and Morrell⁷. The results obtained by the method were good, reproducible values being given consistently on repetition of the work on any sample.

¹ Investigations of Fuels and Fuel Testing, Mines Branch, 1923 to 1927 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 323-B.

⁴ Chemical and Metallurgical Engineering, vol. 29, No. 22, page 970. Investigations of Fuels and Fuel Testing 1923, page 53.

⁵ U. S. Bureau of Standards Circular No. 154.

⁶ Ellis and Meigs: "Gasoline and Other Motor Fuels."

⁷ Industrial and Engineering Chemistry, vol. 18, No. 4, page 354.

TABLE XX
Results of Analyses

Sample No.	Brand	Distillation Range								Index number °F.	Specific gravity	Degrees A.P.I.	Iodine value	Hydrocarbons			
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.	Recovery					Unsaturates %	Aromatics %	Naphthenes %	Paraffins %
HALIFAX, N.S.																	
1	Ethyl.....(a)	122	178	200	261	302	360	420	97.5	1721	0.754	56.2	15	2.7	14.2	22.4	60.7
2	Premier.....(a)	115	166	194	260	306	360	408	97.5	1694	0.754	55.2	19	8.3	15.3	26.5	49.9
3	Primrose.....(b)	96	131	150	226	284	356	404	96.5	1551	0.719	65.3	18	4.7	4.0	26.4	64.9
	Average.....	111	158	181	249	297	359	411	97.2	1655	0.742	59.2	17	5.2	11.2	25.1	58.5
SAINT JOHN, N.B.																	
4	Premier.....(a)	100	138	162	239	288	355	409	96.8	1591	0.724	63.9	25	4.2	5.2	21.7	68.9
5	White Rose.....(c)	104	152	178	258	304	369	425	97.0	1686	0.732	61.8	15	3.6	4.0	21.8	70.6
6	Fundy.....(d)	98	140	162	238	288	357	406	96.5	1591	0.723	64.2	28	5.0	4.3	26.3	64.4
	Average.....	101	143	167	245	293	360	413	96.8	1623	0.726	63.4	23	4.3	4.5	23.3	67.9
QUEBEC																	
7	Red Seal.....(c)	108	174	202	268	310	362	407	97.5	1723	0.745	58.4	27	6.6	7.4	23.7	62.3
8	Peerless.....(e)	104	150	172	234	270	329	377	98.0	1532	0.723	64.2	13	3.3	1.1	27.6	65.0
9	Premier.....(a)	112	170	203	270	314	368	412	98.0	1737	0.747	57.9	29	5.9	8.7	24.5	60.9
10	Ethyl.....(a)	119	178	201	260	300	358	408	98.0	1705	0.753	56.4	26	6.6	13.7	28.9	50.8
11	Aviation.....(f)	104	150	173	230	269	329	382	97.0	1533	0.720	65.0	9	4.3	0.4	28.2	67.1
	Average.....	109	164	190	252	293	349	397	97.7	1646	0.738	60.2	21	5.3	6.3	26.6	61.8

MONTREAL, QUE.

12	Premier.....(a)	112	172	198	264	312	370	418	97-5	1734	0-746	58-2	26	5-2	8-9	13-7	72-2
13	Marathon.....(g)	108	169	197	262	309	372	425	97-8	1734	0-740	59-7	13	4-0	4-8	23-1	68-1
14	Cyclo.....(g)	102	158	186	276	333	392	420	97-0	1765	0-753	56-4	78	20-8	15-5	8-8	54-9
15	Blue Sunoco.....(h)	104	165	198	278	330	388	428	97-0	1787	0-758	55-2	41	7-9	10-9	34-6	46-6
16	Peerless.....(e)	105	153	176	236	277	340	387	97-3	1569	0-727	63-1	17	3-4	2-9	28-0	65-7
17	Super-Power.....(e)	108	167	197	270	312	368	413	97-5	1727	0-745	58-4	30	5-1	8-0	13-9	73-0
18	Ethyl.....(a)	120	170	192	270	318	372	422	98-0	1744	0-756	55-7	15	3-6	18-0	14-1	64-3
19	Aviation.....(f)	106	150	174	234	270	328	384	98-0	1840	0-722	64-5	14	2-6	1-6	17-3	78-5
	Average.....	108	163	190	261	308	366	412	97-5	1700	0-743	58-9	29	6-6	8-8	19-2	65-4

OTTAWA, ONT.

20	Sunoco (H.T.).....(h)	110	161	185	240	281	350	426	97-0	1643	0-726	63-4	10	3-3	3-3	17-6	75-8
21	Premier.....(a)	110	159	184	268	303	368	416	97-5	1698	0-746	58-2	28	4-2	9-7	4-4	81-7
22	Cities-Service (H.T.).....(i)	104	142	169	243	285	346	396	97-0	1581	0-728	62-9	92	17-0	13-9	20-5	48-6
23	Ethyl.....(a)	114	168	192	262	310	365	416	97-5	1713	0-756	55-7	16	3-2	16-3	28-9	51-6
24	Red Seal.....(c)	110	163	194	267	313	369	421	97-0	1727	0-741	59-4	22	3-1	7-4	25-3	64-2
25	Supertest.....(k)	114	165	191	265	310	369	413	98-0	1713	0-745	58-4	28	4-3	9-7	22-6	63-4
26	Marathon.....(g)	103	143	166	241	292	370	416	96-0	1623	0-724	63-9	28	6-7	5-5	6-1	81-7
27	Super-Service.....(l)	114	167	195	266	310	372	420	98-0	1730	0-747	57-9	31	4-9	10-4	22-7	62-0
28	Peerless.....(e)	105	150	174	237	278	341	385	96-7	1565	0-722	64-5	9	3-4	1-6	16-5	78-5
29	Sunoco (L.T.).....(h)	113	161	184	247	288	353	403	97-3	1636	0-732	61-8	7	2-6	1-7	25-9	69-8
30	Supertest (H.C.).....(k)	100	145	174	250	294	364	412	96-3	1639	0-731	62-1	18	3-5	6-1	26-0	64-4
31	Cities-Service (L.T.).....(i)	111	169	200	268	313	370	416	97-0	1736	0-744	58-7	35	4-8	8-9	23-1	63-2
32	Aviation.....(f)	106	147	168	225	264	324	372	97-0	1500	0-720	65-0	12	3-0	0-6	27-5	58-9
33	Shell.....(f)	105	143	166	224	267	325	370	96-8	1495	0-721	64-7	16	3-0	1-4	28-6	67-0
34	White Rose.....(c)	97	144	174	252	300	371	428	96-0	1689	0-728	62-9	14	2-7	4-1	23-5	69-7
35	Super-Power.....(e)	110	168	200	269	312	370	417	97-5	1736	0-745	58-4	32	4-0	9-0	25-7	61-3
36	Beach (S.Q.).....(m)	104	141	160	221	260	324	393	97-4	1499	0-719	65-3	11	3-4	0-8	31-3	64-5
	Average.....	108	155	181	250	293	356	407	97-1	1642	0-734	61-3	24	4-5	6-5	22-1	66-9

- (a) Imperial Oil, Limited.
 (b) E. B. Boyd, Limited.
 (c) Canadian Oil Companies, Limited.
 (d) Canadian Independent Oil, Limited.
 (e) British American Oil Company, Limited.
 (f) Shell Oil Company, Limited.
 (g) McColl-Frontenac Oil Company, Limited.
 (h) Sun Oil Company, Limited.
 (i) Cities-Service Oil Company, Limited.
 (k) Supertest Petroleum Corporation.
 (l) Hull Iron and Steel.
 (m) Beach Motors.
 (n) Transport Oil, Limited.
 (o) Dominion Oil Company.

- (p) Perfection Petroleum Company, Limited.
 (q) J. T. Hayes.
 (r) Western Motor Corporation.
 (s) Prairie City Oil Company.
 (t) Western Oil Company.
 (u) North Star Oil and Refining Company, Limited.
 (v) Maple Leaf Oil and Refining Company, Limited.
 (w) Regal Oil and Refinery Company, Limited.
 (z) Alberta Refining Company, Limited.
 (y) General Petroleum Corporation.
 (z) Home Oil Distributors, Limited.
 (aa) Union Oil Company of Canada, Limited.
 (bb) Victoria Petroleum Company, Limited.

TABLE XX—Concluded
Results of Analyses—Concluded

Sample No.	Brand	Distillation Range							Index number °F.	Specific gravity	Degrees A.P.I.	Iodine value	Hydrocarbons				
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.					Recovery	Unsaturates %	Aromatics %	Naphthenes %	Paraffins %
TORONTO, ONT.																	
37	Trail.....(n)	103	150	173	240	284	352	401	97.0	1600	0.721	64.7	38	9.1	3.5	19.5	67.9
38	Premier.....(a)	116	172	200	268	315	370	417	97.0	1742	0.745	58.4	34	7.0	10.2	14.4	68.4
39	Cities-Service.....(i)	94	136	158	240	300	380	422	96.0	1636	0.723	64.2	18	3.6	4.0	21.7	70.7
40	Shell.....(f)	101	149	178	240	276	331	375	96.5	1549	0.720	65.0	7	4.0	0.0	25.5	70.5
41	Blue Sunoco.....(h)	98	148	178	270	326	386	420	97.0	1728	0.746	58.2	75	10.1	15.8	27.6	46.5
42	Dominion.....(c)	105	162	188	248	288	350	408	97.0	1644	0.721	64.7	7	3.4	1.8	14.6	80.2
43	White Rose.....(c)	107	163	193	261	307	370	429	97.0	1723	0.736	60.7	32	2.8	7.0	20.9	69.3
44	Perfection.....(p)	96	148	170	230	260	324	374	97.3	1506	0.722	64.5	106	14.1	13.4	15.4	57.1
	Average.....	102	153	180	250	294	358	406	96.8	1641	0.729	62.6	40	6.8	7.0	19.9	66.3
LONDON, ONT.																	
45	Premier.....(a)	100	166	196	270	310	366	410	97.5	1718	0.739	60.0	39	5.3	8.3	20.6	65.8
46	Shell.....(f)	108	154	165	246	288	360	452	97.0	1665	0.727	63.1	7	3.1	0.4	25.9	70.6
47	Standard.....(g)	96	180	212	278	320	366	412	98.0	1768	0.744	58.7	45	5.8	9.5	20.2	64.5
48	Supertest.....(k)	112	178	212	278	320	368	409	97.5	1765	0.745	58.4	42	5.8	10.0	19.0	65.2
49	Super-Power.....(e)	109	166	197	271	312	367	414	97.0	1727	0.738	60.2	39	4.0	8.5	21.1	66.4
50	Marathon.....(g)	94	139	164	240	288	360	410	97.0	1601	0.722	64.5	24	5.2	4.9	22.4	67.5
51	White Rose.....(c)	108	170	198	262	304	366	423	97.0	1723	0.738	60.2	37	4.4	7.3	23.4	64.9
52	Starline.....(r)	100	148	170	230	262	310	384	98.0	1504	0.720	65.0	6	2.7	0.4	28.1	68.8
	Average.....	103	163	189	259	300	358	414	97.4	1684	0.734	61.3	30	4.5	6.2	22.6	66.7
WINNIPEG, MAN.																	
53	Buffalo.....(s)	106	168	198	268	308	362	406	98.0	1710	0.739	60.0	44	3.7	9.4	21.1	65.8
54	British Motor.....(e)	112	178	208	274	315	367	411	98.0	1753	0.741	59.4	45	7.3	10.4	20.9	61.4
55	Sunbeam.....(f)	100	154	180	248	294	358	406	97.5	1640	0.731	62.1	32	4.2	6.1	25.9	63.8
56	Ethyl.....(a)	123	185	210	261	300	348	392	98.0	1696	0.741	59.4	27	4.1	8.5	23.0	64.4
57	North Star.....(u)	104	160	182	246	290	354	412	97.0	1644	0.732	61.8	23	3.1	4.9	27.0	65.0
	Average.....	109	169	196	259	301	358	405	97.7	1689	0.737	60.5	34	4.5	7.8	23.6	64.1

REGINA, SASK.

58	Imperial.....(a)	110	172	204	268	312	366	418	97.7	1740	0.742	59.2	32	4.3	10.3	17.4	68.0
59	British Motor.....(e)	110	178	206	270	310	368	412	98.0	1744	0.744	58.7	33	3.9	10.5	21.0	64.6
60	White Rose.....(c)	95	142	175	252	300	370	436	97.0	1670	0.730	62.3	25	4.8	4.4	25.8	65.0
61	North Star.....(u)	112	139	150	186	216	278	364	98.0	1333	0.704	69.5	6	2.6	0.0	29.3	68.1
	Average.....	107	158	182	244	284	345	407	97.7	1622	0.730	62.3	24	3.9	6.3	23.4	66.4

CALGARY, ALTA.

62	Premier.....(a)	106	165	195	261	308	367	418	97.0	1714	0.746	58.2	12	3.1	6.5	35.9	54.5
63	Maple Leaf.....(v)	128	198	226	294	340	394	432	98.0	1884	0.745	58.4	5	3.3	0.0	15.7	81.0
64	Regal.....(w)	110	168	190	252	296	356	406	98.0	1668	0.740	59.7	23	3.0	9.8	20.4	66.8
65	Sunshine.....(x)	135	194	223	290	332	381	416	98.0	1836	0.750	57.2	6	2.7	2.9	15.2	79.2
	Average.....	120	181	208	274	319	374	418	97.7	1775	0.745	58.4	11	3.0	4.8	21.8	70.4

EDMONTON, ALTA.

66	Premier.....(a)	108	160	186	258	300	364	414	98.0	1682	0.747	57.9	12	2.2	7.0	31.2	59.6
67	White Rose.....(c)	104	162	190	260	302	362	413	97.5	1689	0.739	60.0	42	6.5	10.9	19.7	62.9
68	North Star.....(u)	106	166	194	262	304	360	409	97.5	1695	0.742	59.2	29	3.8	9.7	24.2	62.3
69	British Motor.....(e)	108	169	199	260	304	360	414	97.5	1706	0.740	59.7	25	4.4	8.5	22.9	64.2
	Average.....	106	164	192	260	302	361	412	97.6	1693	0.742	59.2	27	4.2	9.0	24.5	62.3

VANCOUVER, B.C.

70	General.....(y)	99	159	196	274	326	388	426	97.0	1769	0.756	55.7	7	3.8	8.2	34.9	53.1
71	Northern Light.....(z)	100	148	180	254	306	376	424	97.0	1688	0.744	58.7	6	2.7	2.3	32.2	62.8
72	Shell.....(f)	110	168	197	261	305	362	404	98.0	1697	0.747	57.9	14	2.2	4.9	33.9	59.0
73	Three Star.....(a)	96	146	180	250	292	357	412	97.0	1637	0.744	58.7	6	6.1	4.0	39.5	50.4
	Average.....	101	155	188	260	307	371	416	97.2	1698	0.748	57.7	8	3.7	4.9	35.1	56.3

VICTORIA, B.C.

74	Union.....(aa)	96	148	180	250	294	356	409	97.0	1637	0.744	58.7	6	1.7	4.2	41.8	52.3
75	Three Star.....(a)	104	154	184	250	292	348	409	97.5	1637	0.745	58.4	6	1.8	3.8	45.1	51.3
76	Shell.....(f)	108	166	196	263	305	364	401	97.5	1695	0.747	57.9	14	1.7	5.8	37.0	55.5
77	Home.....(bb)	100	152	183	250	293	354	414	97.0	1646	0.746	58.2	5	1.3	3.8	42.9	52.0
	Average.....	102	155	186	253	296	355	408	97.2	1654	0.745	58.4	8	1.6	4.4	41.2	52.8
	Average of all samples.	107	160	186	255	298	359	409	97.3	1667	0.737	60.5	25	4.7	6.8	24.0	64.5

TABLE XXI
Average Result of Analyses, by Cities

District	Distillation Range								Index number °F.	Specific gravity	Degrees A.P.I.
	1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.	Recovery			
Halifax, N.S.....	111	158	181	249	297	359	411	97.2	1655	0.742	59.2
Saint John, N.B.....	101	143	167	245	293	360	413	96.8	1623	0.726	63.4
Quebec, Que.....	109	164	190	252	293	349	397	97.7	1646	0.738	60.2
Montreal, Que.....	108	163	190	261	308	366	412	97.5	1700	0.743	58.9
Ottawa, Ont.....	108	155	181	250	293	356	407	97.1	1642	0.734	61.3
Toronto, Ont.....	102	153	180	250	294	358	406	96.8	1641	0.729	62.6
London, Ont.....	103	163	189	259	300	358	414	97.4	1684	0.734	61.3
Winnipeg, Man.....	109	169	196	259	301	358	405	97.7	1689	0.737	60.5
Regina, Sask.....	107	158	182	244	284	345	407	97.7	1622	0.730	62.3
Calgary, Alta.....	120	181	208	274	319	374	418	97.7	1775	0.745	58.4
Edmonton, Alta.....	106	164	192	260	302	361	412	97.6	1693	0.742	59.2
Vancouver, B.C.....	101	155	183	260	307	371	416	97.2	1698	0.748	57.7
Victoria, B.C.....	102	155	186	253	296	355	408	97.2	1654	0.745	58.4
Average*.....	107	160	186	255	298	359	409	97.3	1667	0.737	60.5

* This is the average value for all the samples tested.

TABLE XXII
Average Results for Comparison

	Distillation Range								Index number °F.	Specific gravity	Degrees A.P.I.	Iodine value
	1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.	Recovery				
Canada, 1916.....	125	170	192	237	270	330	380	.....	1579	0.732	61.8	17
Canada, 1923.....	120	170	193	255	296	358	423	97.1	1695	0.737	60.5	19
Canada, 1924.....	113	173	195	249	288	347	410	97.4	1662	0.736	60.8	18
Canada, 1925.....	116	174	199	258	299	359	412	97.0	1701	0.739	60.0	18
Canada, 1926.....	110	164	191	256	300	360	410	97.4	1681	0.739	60.0	21
Canada, 1927.....	107	161	189	259	304	366	416	97.0	1693	0.741	59.5	.....
Canada, 1928.....	107	160	186	255	298	359	409	97.3	1667	0.737	60.5	25
United States, July, 1928.....	100	.....	190	265	.....	380	413	96.1	.....	0.748	57.8	.....
United States Federal Specification.....	131	.....	221	284	.....	392	437	.....	.....	.....	.....	.....

TABLE XXIII
Ten per cent of Samples having Maximum End Point

Sample No.	Brand	Distillation Range								Index number °F.	Specific gravity
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.	Recovery		
46	Shell.....	108	154	165	246	288	360	452	97.0	1665	0.727
60	White Rose.....	95	142	170	252	300	370	436	97.0	1670	0.730
63	Maple Leaf.....	123	198	226	294	340	394	432	98.0	1884	0.745
43	White Rose.....	107	163	193	261	307	370	429	97.0	1723	0.736
15	Blue Sunoco.....	104	165	198	278	330	388	428	97.0	1787	0.758
34	White Rose.....	97	144	174	252	300	371	428	96.0	1669	0.728
20	Sunoco (H.T.).....	110	161	185	240	281	350	426	97.0	1643	0.726
70	General.....	99	159	196	274	326	388	426	97.0	1769	0.756
	Average.....	106	161	188	262	309	374	432	97.0	1726	0.738

TABLE XXIV

Ten per cent of Samples having Minimum End Point

Sample No.	Brand	Distillation Range							Index number °F.	Specific gravity	
		1st drop °F.	10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	End point °F.			Recovery
61	North Star.....	112	139	150	186	216	278	364	98.0	1333	0.704
33	Shell.....	105	143	166	224	267	325	370	96.8	1495	0.721
32	Aviation.....	106	147	168	225	264	324	372	97.0	1500	0.720
44	Perfection.....	96	148	170	230	260	324	374	97.3	1506	0.722
40	Shell.....	101	149	178	240	276	331	375	96.5	1549	0.720
8	Peerless.....	104	150	172	234	270	329	377	98.0	1532	0.723
11	Aviation.....	104	150	173	230	269	329	382	97.0	1533	0.720
52	Staroline.....	100	148	170	230	262	310	384	98.0	1504	0.720
	Average.....	103	147	168	225	260	319	375	97.3	1494	0.719

COMPARISON OF RESULTS

It is quite interesting to compare the above figures with others obtained in somewhat the same way. Table XXII gives the average results of 88 samples collected in Canada, presumably in 1916, and reported by the laboratories of the Department of Inland Revenue¹; the average of 48 samples collected in Canada during 1923²; the average of 59 samples collected in Canada during 1924³; the average of 73 samples collected during 1925⁴; the average of 76 samples collected during 1926⁵; the average of 83 samples collected during 1927⁶; the average of 77 samples collected during 1928; the average of 162 samples collected in United States during July, 1928, and reported by the U. S. Bureau of Mines⁷, and the essential features of the specification for motor gasoline adopted by the Specification Board of the United States⁸, for the use of the various departments and independent establishments of the United States Government. When judged by the distillation range, which is the ordinarily accepted standard, it will be observed that the gasoline sold in Canada during the present year shows an average of good quality, being superior to that sold during the three previous years, and very nearly equal to the average quality during 1924.

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 77 samples) having the highest end point, and the average of the 8 samples having the lowest end point was obtained as in preceding years. The results are shown in Table XXIII and Table XXIV.

TABLE XXV

Difference between Maximum and Minimum End Points

	1916	August 1923	August 1924	August 1925	August 1926	August 1927	August 1928
Maximum 10 per cent.....	432	446	459	458	437	438	432
Minimum 10 per cent.....	322	331	358	366	379	380	375
Difference.....	110	65	101	92	58	58	57

Table XXV 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 1916⁹, 1923, 1924, 1925, 1926, 1927, and in 1928. The differ-

¹ Department of Inland Revenue, Canada, Bulletin No. 363 ("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 Mines Branch, Dept. of Mines, Canada: Invest. of Fuels and Fuel Testing, 1927.

⁷ U. S. Bureau of Mines, Report of Investigations, Serial No. 2887.

⁸ U. S. Bureau of Mines, Technical Paper, 323B.

⁹ Mines Branch, Dept. of Mines, Canada: Invest. of Fuels and Fuel Testing, 1923.

ence 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 1928 the variation in quality, when determined by the above method, was practically the same as, although slightly less than, that obtained in the survey of 1926 and 1927.

An attempt was made last year to obtain a figure which would indicate more exactly the variations in quality. For that purpose the index number was chosen because it represented 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. The results obtained for the current year's survey are shown in Tables XXVI and XXVII.

TABLE XXVI
Ten per cent of Samples having Maximum Index Numbers

Sample No.	Brand	Index No. °F.	Specific gravity	Distillation Range					End point °F.
				10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	
63	Maple Leaf.....	1884	0.745	198	226	294	340	394	432
65	Sunshine.....	1836	0.750	194	223	290	332	381	416
15	Blue Sunoco.....	1787	0.758	165	198	278	330	388	428
70	General.....	1769	0.756	159	196	274	326	388	426
47	Standard.....	1768	0.744	180	212	278	320	366	412
14	Cyclo.....	1765	0.753	158	186	276	333	392	420
48	Supertest.....	1765	0.745	178	212	278	320	368	409
54	British Motor.....	1753	0.741	178	208	274	315	367	411
	Average.....	1791	0.749	176	208	280	327	380	419

TABLE XXVII
Ten per cent of Samples having Minimum Index Numbers

Sample No.	Brand	Index No. °F.	Specific gravity	Distillation Range					End point °F.
				10% °F.	20% °F.	50% °F.	70% °F.	90% °F.	
61	North Star.....	1333	0.704	139	150	186	216	278	364
33	Shell.....	1495	0.721	143	166	224	267	325	370
36	Beach (S.Q.).....	1499	0.719	141	160	221	260	324	393
32	Aviation.....	1500	0.720	147	168	225	264	324	372
52	Staroline.....	1504	0.720	148	170	230	262	310	384
44	Perfection.....	1506	0.722	148	170	230	260	324	374
8	Peerless.....	1532	0.723	150	172	234	270	329	377
11	Aviation.....	1533	0.720	150	173	230	269	329	382
	Average.....	1488	0.719	146	166	222	258	318	377

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

TABLE XXVIII

Difference between Maximum and Minimum Index Numbers

	1923	1924	1925	1926	1927	1928
Maximum 10 per cent.....	1791	1806	1821	1815	1823	1791
Minimum 10 per cent.....	1500	1428	1497	1524	1518	1488
Difference.....	291	378	324	291	305	303

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, since the variation in quality was very slightly less during 1928 than during 1927.

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 1928 was lower than an average index number calculated in like manner from the samples examined in the four previous years and was the same as that obtained for the year 1923. This indicates that the average volatility of that group of samples was greater in 1928 than in 1927, 1926, 1925, and 1924, and similarly equal to that of 1923. It is to be noted that the average index number of ten per cent of the samples having the lowest index numbers of those examined in 1928 was lower than an average index number calculated in like manner from the samples examined in the three previous years. This indicates that the average volatility of this group was greater in 1928 than in 1927, 1926, and 1925. Accordingly, it may be said that the lowest grades of the samples examined in 1928 were more volatile than similar grades of the samples examined in the four previous years, and that the highest grades of the samples examined in 1928 were more volatile than similar grades of the samples examined in the three previous years.

SUMMARY

Seventy-seven samples of gasoline were collected in August, 1928, 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 examinations show that the average gasoline sold during 1928 was of good quality, being superior to that sold during the three previous years, and very nearly equal to the average quality during 1924.

The variation in quality during 1928 was very slightly less than that during 1927.

The lowest and the highest grades of the samples examined in 1928 were more volatile than similar grades of the samples examined in 1927, 1926, and 1925.

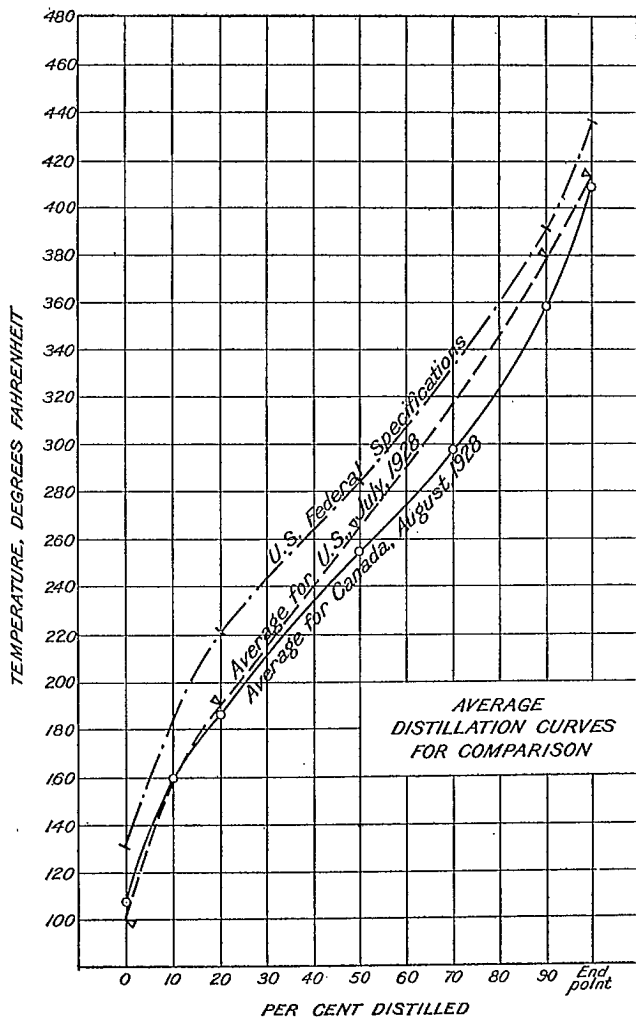


Figure 4.

According to the distillation curves and other data, the gasoline marketed in Canada during August, 1928, was superior to that sold in United States during July, 1928, and to the United States Federal Specifications for the United States Government motor gasoline.

INDEX

	PAGE		PAGE
Acadia Coal Co.....	13	Dognail coal m. <i>See</i> Burnrite coal m.	
Alberta		Dominion Coal Co., coal, analysis.....	38
Coal, analyses.....	43-48, 49, 50	Drumheller, coals, effect of weathering..	27, 28
effect of weathering on.....	27	Dyer, W. S.....	42
Gasoline, analyses.....	61, 62	Eastend, Sask., coal, analysis.....	42
Alfred, Ont., peat, analyses.....	9, 41	Edmonton, gasoline sold in, analysis....	61, 62
Anthracite coal, analyses		Edna No. 2 coal m., Pa., coal analysis....	53
Pennsylvania.....	51	Ells, Dr. R. W.....	13
Russia.....	53	Emmerson Coal Co., coal, analysis.....	39
screen analyses.....	56	Flynn, Prof. A. E.....	4
Scotland.....	53	Ford coke. <i>See</i> Detroit coke.	
Australia, lignite, analysis.....	9	Forty Brine coal seam, coal, analysis....	40
Baltzer, C. E.		Freeport, (upper) coal seam, Pa., coal, analysis.....	53
Experiments on danger of refuse from oil-burning locomotives.....	1	Friability test on coals.....	27, 28
Visit to industrial pulverized coal plants	1, 2	Foothills coal, effect of weathering.....	27, 28
Bayview coal m., coal, analysis.....	39	Fundy seam, coal, analysis.....	39
Blacksmith falls, Ont., lignite, analysis of	42	Fundy No. 6 coal m., coal, analysis.....	39
Blairmore, Alberta, coal, analysis.....	44	Galt, coals, effect of weathering.....	27, 28
Blue Diamond Coal Co., Ltd., coal, analysis.....	44	Gas. <i>See</i> Natural gas.	
Boa coal seam, coal, analysis.....	44	Gasoline, analyses of, sold in Canada....	57-68
Briquettes, lignite, analysis.....	55	Gibo Collieries, Ltd., coal, analysis.....	44
Briquetting experiments on Ontario lignite	8, 9	Gilbert-Davis No. 1 coal m., Pa., coal, analysis.....	52
British Columbia		Gilmore, R. E., general review of investi- gations, 1928 (with B. F. Haanel).....	1-6
Coal, analysis.....	48	Glace Bay, N. S., coal, analysis.....	38, 49
Gasoline, analysis.....	61, 62	Graham, Mr.....	13
Brook coal m., W. Va., coal, analysis....	52	Grant coal m., Pa., coal, analysis.....	53
Brook, Stephen.....	14	Greenhill coal m., coal, analysis.....	44
Brûlé coal area, coal, analysis.....	44-48	Gregg r., coal, analysis.....	44
Brûlé Mines, Alberta, coal, analysis.....	44	Haanel, B. F., general review of investi- gations, 1928 (with R. E. Gilmore)....	1-6
Burnrite coal m., coal, analysis.....	40	Halifax, gasoline sold in, analysis of....	58, 62
Burn Rite Coal Co., Ltd., coal, analysis.	40	Harbourside coal m., coal, analysis.....	39
Burrough, E. J.....	2	Hardscrabble coal seam. <i>See</i> Fundy seam.	
Calgary, gasoline, analysis of, sold in....	61	Hay r., Alberta, coals, analyses.....	45, 48
Camp Hill Hospital, coal sold to, analysis of.....	49	Hayes, A. O.....	39
Canmore, Alberta, coal, analysis.....	44	Horner coal m., Pa., coal, analysis.....	52
Canmore Coal Co., Ltd., coal, analysis..	44	Humus sulphur. <i>See</i> Sulphur.	
Carbonization tests on Ontario lignite....	7-12	Indian Cove coal seam, coal, analysis....	49
Charcoal, analysis.....	55	International Coal and Coke Co., coal, analysis.....	49, 50
Chilton seam, W. Va., coal, analysis.....	50	Jamieson Nos. 8 and 9 coal m., W. Va., coals, analyses.....	50
Christie Street Hospital, coal sold to, analysis of.....	50	Jewel coal seam, coal, analysis.....	44
"Coalite," analysis.....	55	Joggins, coal, analysis.....	39
Coals		Joggins coal seam, coal, analysis.....	39, 40
Analyses of.....	36-56	Jones, I. W.....	39, 40
Effect of weathering on friability of....	27	Kimberley coal seam, coal, analysis....	40
Sulphur in, forms of.....	28-35	Kittanning (lower) coal seam, Pa., coal, analysis.....	52, 53
43		Knollys, coal, analysis.....	42
Coalspur, Alberta, coal, analysis.....	43	Lancaster Hospital, coal sold to, analysis	49
Coalspur area, coals, effect of weathering.	27, 28	La Salle coke, <i>See</i> Montreal Coke and Manufacturing Co.	
Coalspur Collieries, Ltd., coal, analysis..	43	Lethbridge coals, effect of weathering..	27, 28
Coke, by-product, analysis.....	54, 55	Leverin, H. A.....	41
screen analysis.....	56	Lovett, Alberta, coal, analysis.....	43
Coleman, Alberta, coal, analysis.....	49, 50	London, gasoline sold in, analysis of....	60, 62
Connell Anthracite Mining Co., coal, analysis.....	51	Low Temperature Carbonization, Ltd., coalite, analysis.....	55
Cumberland county, N. S., coals, analyses	39, 40		
Cypress hills, coal, analysis.....	42		
Deer Lodge Hospital, coal sold to, analysis of.....	49, 50		
Detroit (Ford) coke, analysis.....	55		
screen analysis.....	56		

	PAGE		PAGE
Lignite		Ontario	
Analysis.....	9	Gasoline, analysis.....	59, 60, 62
Alberta		Lignite, analysis.....	42
Australia.....	9	carbonization tests.....	7-12
Ontario.....	9, 42	Peat, analysis.....	9, 41
Saskatchewan.....	9	Ottawa, gasoline, sold in, analysis.....	59, 62
Carbonization tests on, Ontario.....	7-12	Paragon coal m., W. Va., coal, analysis..	50
Effect of under-water storage.....	25	Peat, Ontario, analysis.....	9, 41
Little Bras d'Or, N.S., coal, analysis... 49		Pennsylvania	
Lundale coal m., W. Va., coal, analysis.. 50		Anthracite, analysis.....	51
Luscar, Alberta, coal, analysis.....	44	Bituminous, analysis.....	52
McGregor coal m., coal, analysis.....	50	Semi-bituminous, analysis.....	52
MacKay, B. R.....	39, 43, 48	Pictou county, N.S., oil shales of.....	13-24
MacKenzie, Col.....	13	Pittsburgh coal seam, Pa., coal, analysis	
McLearn, F. H.....	42	.....	50, 52, 53
McLellan brook, oil shale on.....	13-17	Prescott county, Ont., peat, analysis....	41
Photos.....	Facing 24	Princeton, B.C., coal, analysis.....	43
Malloch, E. S., experiments on danger of		Pulverized fuel, at industrial plants.....	1-2
refuse from oil-burning locomotives....	1	Pyritic sulphur. <i>See</i> Sulphur.	
Manitoba, gasoline, analysis.....	60, 62	Quebec, gasoline sold in, analysis....	58, 59, 62
Maple Leaf (No. 4) coal m., coal, analysis	39	Queen coal seam, coal, analysis.....	39
Maritime Coal Railway and Power Co.,		Ravenscrag formation, coal, analysis....	42
coal, analysis.....	39	Redmond etc., coal, analysis.....	45, 46
Marsh coal m., coal, analysis.....	40	Regina, gasoline sold in, analysis.....	61, 62
Mercoal, Alberta, coal, analysis.....	43	Resiniferous sulphur. <i>See</i> Sulphur.	
Michelean coal seam, coal, analysis.....	44	Richmond county, N.S., coal, analysis... 39	
Milner Coal Co., coal, analysis.....	40	River Hebert, N.S., coal, analysis.....	39, 40
Milner coal m., coal, analysis.....	40	Rosewarne, P. V. <i>See</i> Rosewarne and	
Minto Coal Co., Ltd., coal, analysis....	49	Offord.	
Minto, N.B., coal, analysis.....	49	Rosewarne and Offord, rept. by, on gaso-	
Miramichi Lumber Co., coal, analysis... 49		line survey for 1928.....	57-68
Mohr. <i>See</i> Nicolls (and Mohr.)		Russia, anthracite, analysis.....	53
Montreal Coke and Manufacturing Co.		screen analysis.....	56
Coke, analysis.....	54	St. Anne de Bellevue Hospital, coal sold	
screen analysis.....	56	to, analysis.....	49
Montreal, gasoline sold in, analysis....	59, 62	Saint John, gasoline sold in, analysis....	58, 62
Mountain Park, Alberta, coal, analysis.. 44		Saskatchewan	
Mountain Park Collieries, Ltd., coal,		Briquettes, analysis.....	55
analysis.....	44	Coal, analysis.....	42
Mullin coal seam, coal, analysis.....	39	storage.....	27, 28
Mynheer coal seam, coal, analysis.....	43	Gasoline, analysis.....	61, 62
Natural gas, investigation of Turner		Saunders area, coals, effect of weathering	27
valley.....	3	Saunders Creek, coals, effect of weather-	27
New Brunswick		ing.....	27
Coal, analysis.....	49	Saunders Ridge Coal Co., coal, analysis.	43
Gasoline, analysis.....	58, 62	Scotland, semi-anthracite, analysis....	53
Newcastle, coals, effect of weathering... 27, 28		Semi-bituminous coal, analysis.....	51
Nicolls, J. H. H.		Sewickley seam, coal, analysis.....	52
Rept. by (and C. B. Mohr) on analyses		Shale brook.....	16
of coals and other solid fuels.....	36-56	Smoky River coal area, coal, analysis... 48	
Rept. by (and E. Swartzman), on effects		Steep brook.....	15
of prolonged weathering on friabilities		Stellarite.....	13
of certain coals.....	27-28	Stellarton formation.....	14
Rept. by (and E. Swartzman) on organic		Sterco, Alberta, coal, analysis.....	43
and other forms of sulphur in coals	28-35	Sterling Collieries Co., Ltd., coal, analysis	43
Rept. by (and E. Swartzman) on under-		Strong, R. A.....	2
water storage of Saskatchewan lignite	25-26	Rept. by, on carbonization of Ontario	
North Sydney, N.S., coal, analysis.....	39	lignite.....	7-12
Nova Scotia		Sulphate sulphur. <i>See</i> Sulphur.	
Coal, analysis.....	38-40, 49	Sulphur, forms of, in coals.....	28-35
Gasoline, analysis.....	58, 62	Sumner No. 2 coal m., coal, analysis....	52
Oil shales.....	13-24	Superba Coal Co., Ltd., coal, analysis... 43	
Nova Scotia Coal Co.....	14	Swartzman, E. <i>See</i> Nicolls and Swartz-	
Offord, R. J. <i>See</i> Rosewarne and Offord.		man.	
Oil shale, apparatus for distillation.....	17	Swinerton, A. A., rept. by, on oil shales	
Oil crude, collecting and analysing of		from Pictou county, N.S.....	13-24
samples.....	2	Tapping Cohesives, lignite briquettes,	
		analysis.....	55

	PAGE		PAGE
Thorburn formation.....	14	Weathering of various coals, tests on.....	27, 28
Thoreau ck., coal, analysis.....	46, 47	West Canadian Collieries, Ltd., coal,	
Torbanite Products, Ltd.....	17	analysis.....	44
Toronto, gasoline sold in, analysis.....	60, 62	Westminster Hospital, coal sold to,	
Tracy coal seam. <i>See</i> Mullin.		analysis.....	50
Tulameen Valley Coal Co., coal, analysis	48	West Virginia, U.S.	
Val d'Or coal seam, coal, analysis.....	43	Coal, analysis.....	50
Vancouver, gasoline sold in, analysis.....	61, 62	Semi-bituminous, analysis.....	51
Vet Craft shops, coal sold to, analysis....	50	Winnipeg, gasoline sold in, analysis.....	60, 62
Victoria, B.C., gasoline sold in, analysis.61,	62	Wood (beech), analysis.....	55
Victoria Coal Co., Ltd., coal, analysis... 40	40	Wright, W. J.....	13
Victoria coal m., coal, analysis.....	40	Yatesboro coal m., Pa., coal, analysis....	53

