CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

INVESTIGATIONS
OF
FUELS AND FUEL TESTING

(Testing and Research Laboratories)

1926

PART I

PART II

No. 689

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

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

INVESTIGATIONS
OF
FUELS AND FUEL TESTING

(Testing and Research Laboratories)

1926

PART I

PART II

No. 689

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

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.

CONTENTS

ILLUSTRATIONS

Photographs

Drawings

TABLES

MINES BRANCH INVESTIGATIONS OF

FUELS AND FUEL TESTING, 1926

GENERAL REVIEW OF INVESTIGATIONS

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

The investigations conducted by the staff of the Division of Fuels and Fuel Testing during 1926 are for convenience reported in two parts. Part I consists of five papers on solid fuels, and Part II contains the same number of papers on liquid fuels. In addition to the analyses of the coals and coke examined during the year, together with a short paper on instructions for burning different household fuels, Part I contains reports of investigations on the low-temperature carbonization of bituminous coals; the nature of sulphur in coal and coke; and on drying and moisture reabsorption of lignite. All the coals and cokes examined were Canadian products. Part II contains, in addition to the annual gasoline survey, papers on the treatment of crude shale oil from New Brunswick oil shale, and on bitumen emulsion obtained from Alberta bituminous sands for the production of gasoline and fuel oil. Samples of crude shale oil and bitumen, after preliminary treatment in the Fuel Testing Laboratories, were forwarded for pressure-cracking tests according to the Dubbs and Cross processes; for the conducting of these tests and the reports on the same, grateful appreciation of the services rendered by the Universal Oil Products Company of Chicago and the Kansas City Testing Laboratories, respectively, is acknowledged. A general review of the contents of the papers and the results obtained is as follows:—

PART I

Instructions for Burning Coal, Coke, and Peat: by E. S. Malloch and C. E. Baltzer. This paper, a revision of a former publication by the Dominion Fuel Board of Canada, consists of brief and pertinent suggestions for burning various fuels in standard types of furnaces. These suggestions are based on the experience of the authors obtained during comprehensive tests of various household and substitute fuels in domestic furnaces.

Low-Temperature Carbonization—Continuation of Tests on Canadian Bituminous Coals: by R. A. Strong. This paper comprises tests on bituminous coals according to the standard low-temperature carbonization method described in Investigations of Fuels and Fuel Testing for 1925, and is a continuation of a systematic low-temperature carbonization survey of Canadian solid fuels. Ten different coals, two from Nova Scotia, four from Alberta, and four from British Columbia were examined and their amenability to low-temperature carbonization reported.

In respect to yield and quality of the cokes obtained, all the ten coals tested showed favourable results; but, with possibly one exception, none may be considered as specially suitable for low-temperature carbonization on account of the comparatively low tar-oil and gas yields. The same uniformity of the neutral oil content of the different tar oils from the different coals, in respect to specific gravity, distillation range, etc., was noted as in previous tests. This uniformity is an important factor in favour of the use of these neutral oils as crude oils, as a source of motor fuel and other petroleum oil products.

A Study of the Nature of Sulphur in Canadian Coals and Coke: by J. H. H. Nicolls. This investigation—a continuation of a similar study, the results of which were published in Investigations of Fuels and Fuel Testing for 1923—comprises a study of the forms of sulphur in fifty-six samples of different coals from different coal-mining areas in Canada, and also on six samples of coke from Canadian coals. The subject matter is treated under three sections, viz., (1) nature of sulphur in forty-six coals from western Canada, (2) the nature of sulphur in six cokes, and (3) the distribution and nature of sulphur in ten bituminous coals from the Maritime Provinces.

The results show all the western coals examined to be low sulphur coals. With two or three exceptions, they contain very little or no pyritic sulphur, most of the sulphur being present in the organic form. In the cokes tested, the sulphide sulphur varied from 10 to 59 per cent of the total present, with 33 to 49 per cent present in what is termed solid solution sulphur. The other forms reported were free and sulphate sulphur. Solutions of zinc chloride of different gravities, in comparision with certain organic solutions, were used in sink and float tests and the results discussed. The proportions of sulphate, pyritic, and organic sulphur in the ten high sulphur Nova Scotia and New Brunswick coals tested averaged 13, 55, and 32 per cent, respectively. The data presented is of value in the study of the weathering properties of the coals examined, and also in a study of the amenability of such high sulphur coals to beneficiation and carbonizing treatments.

Air-drying of Canadian Lignite, and the Re-absorption of Moisture by the Same: by J. H. H. Nicolls. This paper is a continuation of the air-drying observations reported in previous Investigations of Fuels and Fuel Testing, and refers to moisture re-absorption by dried lignite coals when exposed in small quantities and in a comparatively finely divided state. Alterations in the standard air-drying apparatus used in the laboratory for the drying of coals to constant weight prior to chemical analysis; and the effect of drying certain lignite coals in atmospheres of varying humidities are reported. Data showing the alterations in moisture contents of samples of powdered lignite in bottles over a period of twenty months are also given.

Analyses of Solid Fuels: Compiled by J. H. H. Nicolls. This compilation comprises the analyses of the coals, cokes, and other solid fuels examined in the Fuel Testing Laboratories during 1926. The analyses are given in three sections, viz.:—

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

Nova Scotia and New Brunswick	20 samples of coal.
Quebec	10 samples of peat.
Ontario	26 samples: 12 of peat, 7 of lignite from the northern part of the province, and 7 samples of anthraxolite, etc., from the Sudbury district.
Saskatchewan	1 sample of coal.
Alberta	17 samples of coal.
British Columbia	16 samples of coal.

2. *Analyses of coals submitted by the Department of Soldiers' Civil Re-establishment.* This section is of a similar nature to that published in the Investigations of 1925 and contains the analyses of 68 samples of coal submitted during 1926 by that Department. These results show the quality as judged by chemical analyses of typical coals delivered in different parts of Canada for steam-raising purposes. They are of importance on account of the fact that the price paid was adjusted for bonuses and penalties based on the variation of the moisture, ash, and calorific values for "contract" grade.

3. *Analyses of miscellaneous solid fuels* comprising the following:—

Cokes	20	samples
Pennsylvania and Welsh anthracites	6	"
Low-volatile bituminous, and bituminous coals	7	"
Charcoal, and peat briquettes, etc	6	"

All but one of the twenty samples of coke reported represent an analyses survey of the by-product and gas cokes sold in Ottawa during the winter of 1926-27, as a follow-up on the "Examination of Typical Cokes Sold in Canada," reported in the Investigations of 1925. In addition to the usual chemical analyses the screen analyses of the cokes are given.

PART II

Gasoline Survey for 1926: by P. V. Rosewarne and A. F. Gill. This is the fourth annual analyses survey of the gasoline sold in Canada, conducted by the Fuel Testing Laboratories. The 1926 survey comprised a total of seventy-six samples collected during the month of August from wholesalers in thirteen cities in different parts of the country, by officers of the Department of Health, the hearty co-operation of all concerned being herewith gratefully acknowledged. As in the three previous years, the quality of the gasoline sold during 1926 was good, the average of which was found to be superior to the average gasoline sold in the United States during July of the same year. The variation in quality was less during 1926 than during the two previous years.

Report of Experiments on the Dehydration of Bitumen Emulsion from Alberta Bituminous Sands: by P. V. Rosewarne and G. P. Connell. This paper comprises experiments made on a barrel sample of "separated" bitumen supplied by Dr. K. A. Clark of the Research Council of Alberta, and describes both small and large laboratory-scale methods which have been found satisfactory for dehydrating, by means of heat, the crude bitumen which was in the form of a "very stubborn" emulsion. The apparatus and method are reported in full in the hope that it will be found suitable for dehydrating similar troublesome water-oil emulsions.

Oil Shale from Rosevale, New Brunswick: by A. A. Swinnerton. This is a short paper describing the method of obtaining a large supply of oil shale for experimental purposes in the Fuel Testing Laboratories. The location of the seam, the mining of the shale and the shipping of a carload are described, and the uniformity of the shale obtained in respect to oil content as judged by distillations according to a standard laboratory method is given. The sample obtained was of a uniform quality, the average laboratory oil yield being nearly 35 Imperial gallons per short ton.

Report on the Pritchard Process for the Distillation of Oil Shale: by R. E. *Gilmore and A. A. Swinnerton.* This paper comprises tests on Canadian oil shale in the technical-scale retort of the Pritchard Process Company of Toronto, Ont. The shale used was part of the sample obtained from Rosevale, New Brunswick. The main feature of the Pritchard process, also known as the Whitaker-Pritchard process, originally designed for the distillation of wood, is the recirculation of the uncondensed gases through the charge during distillation. A description of the retorting apparatus, the operation of the same, and the results of three tests are given. The oil yields in the three tests, using 1,500 pounds of shale in two of the tests and 1,600 pounds in the other, were 20, 22, and 29 Imperial gallons per ton, respectively, the highest of which represents less than 85 per cent of the maximum yield obtained by assay in the laboratory. In all three runs there was distinct evidence of serious decomposition of the oil vapours present in the gas as they were recirculated through the hot preheater tubes and against the hot retort walls. Although increased condensing and scrubbing efficiencies would improve matters, the extra cost of such scrubbing equipment would be an important item, which, coupled with the high fuel requirements to preheat the gas circulated and to effect complete distillation, do not make the process in question specially attractive for the distillation of Canadian oil shale.

Canadian Shale Oil, and Bitumen from Bituminous Sands, as Sources of Gasoline and Fuel Oil by Pressure Cracking: by R. E. Gilmore, P. V. Rosewarne, and A. A. Swinnerton.

I. Tests on shale oil by the Dubbs cracking process.

II. Tests on bitumen from bituminous sand and on shale oil by the Cross cracking process.

The bitumen from the bituminous sands of Alberta has, in the past, been considered by certain investigators as unsuitable for the production of gasoline and other petroleum oil products. The yield of gasoline, amounting to 25 per cent or so of the crude shale oil by ordinary refining at atmospheric pressure, was considered good. Gasoline yields, as high as 65 per cent from the shale oil and 40 per cent from the bitumen by pressure-cracking refining, as reported here, are therefore remarkable. The quality of the gasoline from the shale oil was considered good and that from the bitumen exceptionally good.

These results are of value in comparing crude shale oil and bitumen with imported crude petroleums, and with gas and fuel oils now used as sources of gasoline by cracking processes. Although the use of either the shale oil or bitumen may not be economical for some time, a knowledge of the yields and quality of gasoline and other products from them should be of value to those interested in the extraction of these crude oils from their raw materials and their utilization for the production of motor fuel.

PART I

I

INSTRUCTIONS FOR BURNING COAL, COKE, AND PEAT.

E. S. Malloch and C. E. Baltzer

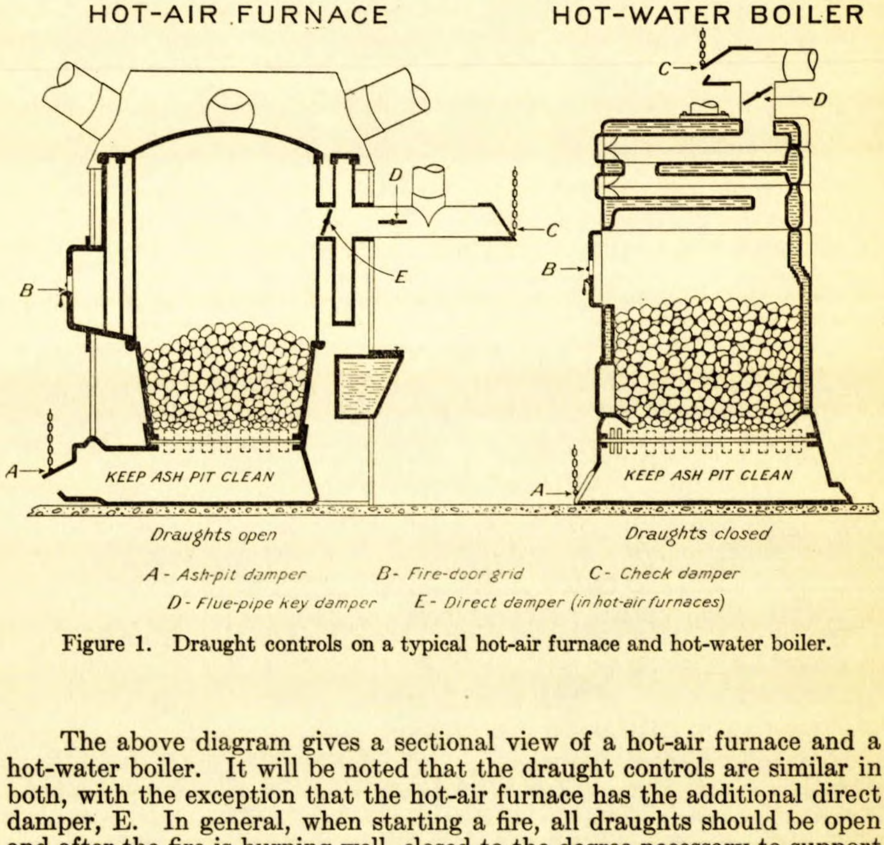


Figure 1. Draught controls on a typical hot-air furnace and hot-water boiler.

The above diagram gives a sectional view of a hot-air furnace and a hot-water boiler. It will be noted that the draught controls are similar in both, with the exception that the hot-air furnace has the additional direct damper, E. In general, when starting a fire, all draughts should be open and after the fire is burning well, closed to the degree necessary to support combustion at the rate desired.

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

It must be borne in mind that each furnace has its own peculiarities, and only practice will determine the best method of operating the furnace. The instructions given below for each fuel have been found to give satisfactory results and can, therefore, be used as a general guide.

AMERICAN ANTHRACITE

DIRECTIONS

Building the Fire. Spread a layer of ashes 2 to 3 inches thick over the grate and then build a good wood fire in the usual manner. When the wood is well ignited and burning briskly, spread a layer of fuel about 3 or 4 inches thick over the fire, leaving the draughts and fire-door grid wide open. When the gases given off by the fuel are burning—this may be noted by the appearance of blue flame over the fuel bed—add more fuel; and again, when the gases appear to be burning well add enough fuel to bring the fuel bed level with the bottom of the fire-door, and close the draughts, leaving the fire-door grid half open. When red spots appear in the fuel bed open the check damper. The fire is then in a condition to last from 8 to 12 hours without further attention. When the fire begins to burn low shake the grates until light is reflected on the bottom of the ash-pit, charge more fuel, and regulate the draughts and check damper in the manner stated above.

Remarks and Cautions. Do not poke the fire needlessly. It is necessary to do so only when there is evidence of clinkers having been formed. This may be noted by the sluggish condition of the fire or by dull spots in the fuel bed when the rest is bright. Remove the clinkers by slicing and hooking them out through the fire-door. The regulation of the draughts must be determined by experiment; each furnace requires different draught settings and no hard and fast rules can be laid down for their operation. When burning the smaller sizes of American anthracite more draught will be necessary than when burning the larger sizes, and the draught settings must be regulated accordingly.

WELSH AND SCOTCH ANTHRACITES

DIRECTIONS

The instructions for burning these two fuels are the same as those applying to American anthracite, with the exception that greater care must be exercised in the manipulation of the dampers, as the ash of these fuels has a tendency to clinker if the draughts are left open too long and the fire is allowed to burn fiercely. A very brisk fire should not be necessary at any time, and if such a fire occurs it shows poor judgment on the part of the furnace attendant. The clinkers when formed are very hard and are much more difficult to remove than the clinker found when burning American anthracite.

Remarks and Cautions. In general, the same remarks and cautions as were applied to American anthracite apply to these fuels also, and as Welsh and Scotch anthracites are more friable, are not so uniformly sized as American anthracite and have an exceptionally low ash content, greater care must be used in shaking the grates; and, furthermore, as they have a higher volatile matter content, the fire-door grid must always be left open from one-half to full. The fines which are always present with either of these two fuels may be best utilized by covering the fuel bed with them after firing the usual charge of fuel.

GAS AND BY-PRODUCT COKES

These directions apply to all cokes whether derived from Western Canada, Nova Scotia, or American coking coals.

DIRECTIONS

In general, all cokes, though having slightly different weights per cubic foot, behave in exactly the same manner when burned in the ordinary domestic furnace, with the exception that gas coke will ignite a little more readily and will burn more freely than by-product coke.

Building the Fire. Spread a layer of ashes 3 or 4 inches thick over the grate, and on top of the ash build a wood fire in the usual manner. When the wood is burning well charge 3 or 4 shovelfuls of coke on top of the burning wood, leaving the draughts and fire-door grid wide open until blue flames appear over the top of the fuel bed. Then completely fill the fire-pot with coke and wait until blue flames appear again. Immediately on the first showing of red through the fuel bed, close all draughts, open the check damper and leave the fire-door grid slightly open. This fire should burn from 6 to 8 hours without attention. When the fire needs replenishing shake the grates until a red glow shows in the ash-pit and again fill the fire-pot with coke. If there is very little live fuel left on the grate it will be necessary to open the draughts fully, but do not leave them open after the first sign of red shows through the fuel bed.

Remarks and Cautions. Coke fuel is bulky, and, therefore, in order to fire the requisite weight of fuel which will burn for eight hours, it is necessary to fire a large quantity, and if it is required to run the furnace for twelve hours, or for the night, without attention, it is often necessary to charge as much fuel as the furnace will hold. Difficulty may at first be experienced in controlling the fire: either it will burn through too quickly or else it will go out because of too little draught. The proper setting of the draughts can be determined only by trial. Within limits, the smaller the size of the coke the more easily the fire can be controlled.

LOW-VOLATILE SEMI-BITUMINOUS COAL

This fuel is also called smokeless steam coal.

DIRECTIONS

Building the Fire. Spread a layer of ashes 2 or 3 inches thick on the grate; then build a small wood fire and charge a little of this fuel on top, leaving the draughts wide open and the grid in the fire-door open to its fullest extent. Charge more fuel from time to time as each previous fuel charge becomes red. This should be done until the fuel bed is built up to the bottom of the fire-door. The fire may then be left for from 6 to 8 hours. To replenish the fire shake the grates gently and slice the fuel bed with a poker to break up the fuel that has coked into a hard mass. Throw a good charge of fuel on to one side of the fuel bed only, leaving a large bright spot which will act in such a manner as to ignite the volatile gases as they are given off from the freshly charged fuel. After this fire has been left for from 6 to 8 hours, it may be found advantageous to slice the fuel bed, and then the fire may be left for from 2 to 3 hours longer without further addition of fuel.

Remarks and Cautions. Always leave the grid in the fire-door wide open, otherwise the soots and tars given off will not burn and will foul the furnace, flue-pipe, and chimney; and further, great care should be exercised in order to leave part of the glowing fuel bed uncovered when replenishing the fire.

BITUMINOUS COAL

The following directions apply to all bituminious coals from Nova Scotia, New Brunswick, Alberta, British Columbia, and United States.

DIRECTIONS

This fuel is handled in much the same manner as low-volatile semi-bituminous coal, except that greater care must be taken with the fuel bed in order that the volatile gases may be burned before reaching the top of the furnace. Even with great care a good deal of soot will be formed and will lodge in the furnace, flue-pipe, and chimney. The furnace should, therefore, be cleaned every day and the flue-pipe from time to time. Always leave a bright spot in the fuel bed either at one side or the other. This may be done by charging the fuel on one side for the first firing, and then when the fire is replenished charge on the opposite side.

Remarks and Cautions. If the fire smokes excessively, keep the draughts closed and open the fire-door a little, by this means admitting more air across the fuel bed to burn the volatile gases. Never open the draught in the ash-pit more than is absolutely necessary when lighting the fire, because when the draughts are open, smoke will pour out through the grid in the fire-door, unless the chimney draught is very strong.

ALBERTA DOMESTIC COALS

DIRECTIONS

Building the Fire. Spread a layer of ashes 3 or 4 inches thick on the grates, on which a good wood fire should be built. When the wood is burning briskly cover the fire completely with a thin charge of lump coal. This coal will ignite very readily and when burning freely more lump fuel may be fired. When this fuel has become red more fuel should be charged on one side of the fire-pot only. This can probably be best accomplished by placing the larger lumps across the centre of the fire-pot from front to rear so as to form a sort of bridge wall, to one side of which the smaller lump fuel may be fired and sloped up towards the side of the fire-pot. The whole pile may then be covered with the fines or small pieces of coal which will be found in the bottom of the fuel bin, taking care, however, not to cover the glowing part of the fuel bed on the opposite side of the bridge wall. Alberta domestic coals require very little draught for satisfactory combustion, and it is always necessary to leave the grid in the fire-door wide open, and in the majority of cases, the dampers in the ash-pit tightly closed. The glowing embers of wood and coal covering the other half of the grate will ignite the gases as they are distilled from the freshly charged fuel and as they are met by the incoming air from the fire-door grid. A fire built in this manner will give off heat for a considerable time, dependent upon the amount of draught which is given the fire. When this pile of fuel has burned down to glowing embers, slice the fuel bed if necessary, and remove clinkers by hooking them out through the fire-door; the light ash remaining usually falls through the grate bars into the ash-pit. When replenishing the fire a similar pile of fuel should be charged to the other side of the fire-pot, building a bridge wall of lump coal in the same manner as before.

Remarks and Cautions. Always leave a glowing spot on one side of the fuel bed, as almost one-third of the heat value of the fuel is given off in the form of gas, and this gas must be ignited and burned, otherwise its heat content will be lost. For the same reason the fire-door grid must always be left open to the fullest extent to provide air for the complete combustion of the gases. These coals are free-burning and therefore require practically no draught through the fuel bed. Never poke or stir the glowing fuel except to remove the clinker which may have formed, nor shake the grates needlessly, as the ash in most cases is light and fluffy and will readily fall through the grate bars into the ash-pit.

PEAT

DIRECTIONS

Building the Fire. Make up a small wood fire on the bare grates, then charge enough peat to almost cover the wood. Lump peat may be added from time to time until a good body of glowing coals is obtained. Always leave the grid in the fire-door wide open and never charge enough fuel at one time to smother the flame completely. The secret of obtaining satisfaction when burning peat is to fire a little at a time at frequent intervals. At the end of the day there will be a good body of red hot embers in the fire-pot. These embers, although they will remain glowing all night, give out very little heat, but will be hot enough in the morning to kindle a fresh charge of peat. Very little draught is required when burning peat but the fire-door grid should always be open to the fullest extent.

Remarks and Cautions. Never shake the grates or poke the fire except in the morning and then only just enough to uncover the embers left from the previous day's fire. Peat burns with a long flame which must not be smothered with fresh fuel or else tar, which will be very difficult to remove, will be deposited at the top of the furnace and in the flue-pipe.

Peat makes an ideal fuel for use in the open grate and may also be conveniently and satisfactorily used in cook stoves.

MIXTURE OF BITUMINOUS COAL AND COKE

DIRECTIONS

Building the Fire. Spread a layer of ashes 3 or 4 inches thick on the grate, over which build a good coke fire and then charge a mixture of coke and coal, so that the fuel-bed level will be at the bottom of the fire-door or a little higher. The draughts should be open a little and the fire-door grid always left wide open. The coal will cake but not to the extent it does when burned alone. Therefore, the fuel bed does not require to be broken up so frequently.

Remarks and Cautions. By burning coke with bituminous coal many of the disadvantages of the latter fuel are lessened; it is not necessary to poke the fire so often, the deposit of soot in the furnace is not so heavy, and the fuel will give up its heat at a more uniform rate than when burning bituminous coal alone. The fire-door grid must never be closed. The furnace should be cleaned every day.

II

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

R. A. Strong

During 1926 the low-temperature carbonization program of the writer consisted of the testing of 10 bituminous coals—2 from the Maritime Provinces, 4 from Alberta, and 4 from British Columbia. The samples were selected as being representative coals mined in the respective bituminous coal areas of these provinces. As the title suggests, these tests were a continuation of the carbonization experiments[1] conducted during the previous year when two representative coals from the Maritime Provinces—one from Nova Scotia and one from New Brunswick—were examined in comparison with a standard imported "gas" coal. The experiments in 1925 were quite extensive, consisting of the carbonization of the 3 coals at various temperatures, according to the regular low-temperature carbonization method, carbonization in the presence of steam, and carbonization with the recirculation of the uncondensed gases. The tests on the 10 coals reported here were at one temperature only, and were conducted in temperature control (lead bath) apparatus at a maximum temperature of 600° C. (1110° F.) according to the standard low-temperature carbonization method adopted in the Fuel Testing Laboratories.

A list of the 10 coals tested is as follows:—

Laboratory Number	Known in this report as	Origin
4028	Springhill coal...........	Cumberland Railway and Coke Co., Springhill, N.S.
4029	Stellarton coal...........	Acadia Coal Co.—Albion collieries, Foord seam, Stellarton, N.S.
4032	Blue Diamond coal......	Blue Diamond Coal Co., Brulé, Alta.
4034	Cadomin coal............	Cadomin Coal Co., Cadomin, Alta.
4036	Greenhill coal............	West Canadian Collieries, Blairmore, Alta.
4038	International coal........	International Coal and Coke Co., Ltd., Coleman, Alta.
4039	Michel coal..............	Crow's Nest Pass Coal Co., Ltd., Fernie, B.C.
4040	Coal Creek coal..........	Crow's Nest Pass Coal Co., Ltd., Fernie, B.C.
4041	Cassidy coal.............	Granby Consolidated Mining, Smelting and Power Co., Cassidy, B.C.
4042	Comox coal..............	Canadian Collieries (Dunsmuir) Ltd., Union Bay, B.C.

The samples tested were freshly mined coal obtained direct from the mines. On arrival at the Fuel Testing Laboratories the coal was crushed to pea size and placed in air-tight containers until required.

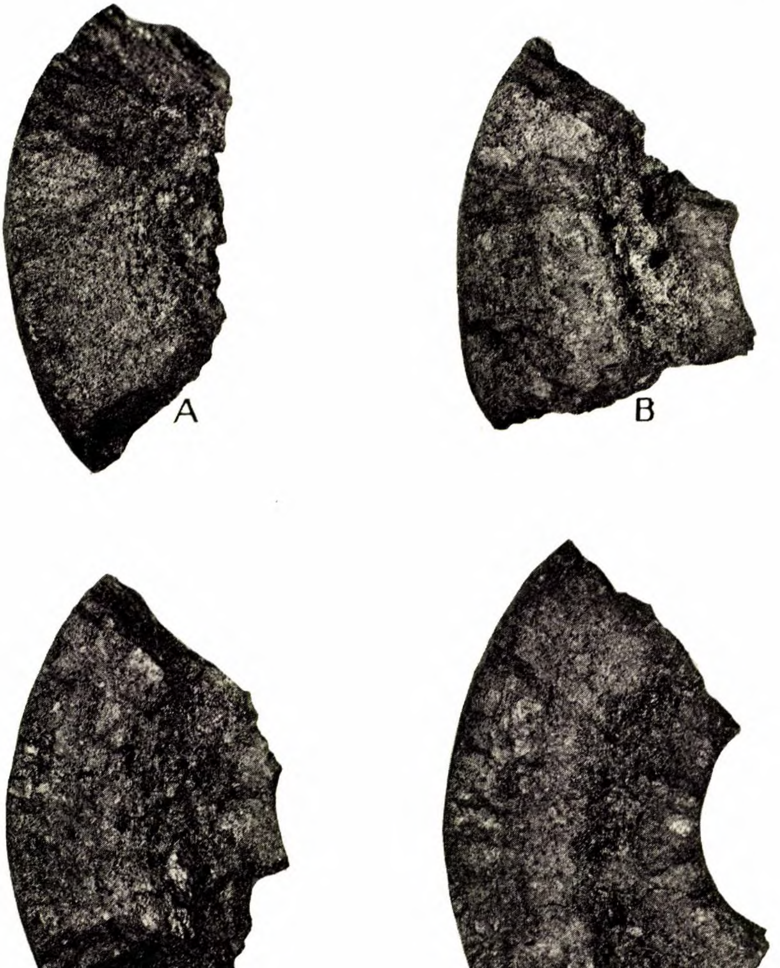
APPARATUS AND METHOD EMPLOYED

The apparatus used consisted of an electrically heated, lead bath, a circular iron retort connected to a condensing train, gas meter and holder; the apparatus being the same as that used in carbonization tests during 1925, and described in the report of investigations for that year. A slight change was made in the condensing train, a sulphuric acid scrubber and an activated carbon tube being added. Figure 2 shows diagrammatically the layout as used in these experiments. The carbonization method employed was identical with that described in the report just referred to, the lead being previously heated to the desired temperature, after which the retort was immersed in the bath and the temperature raised to the desired point and held there until completion of the run.

---

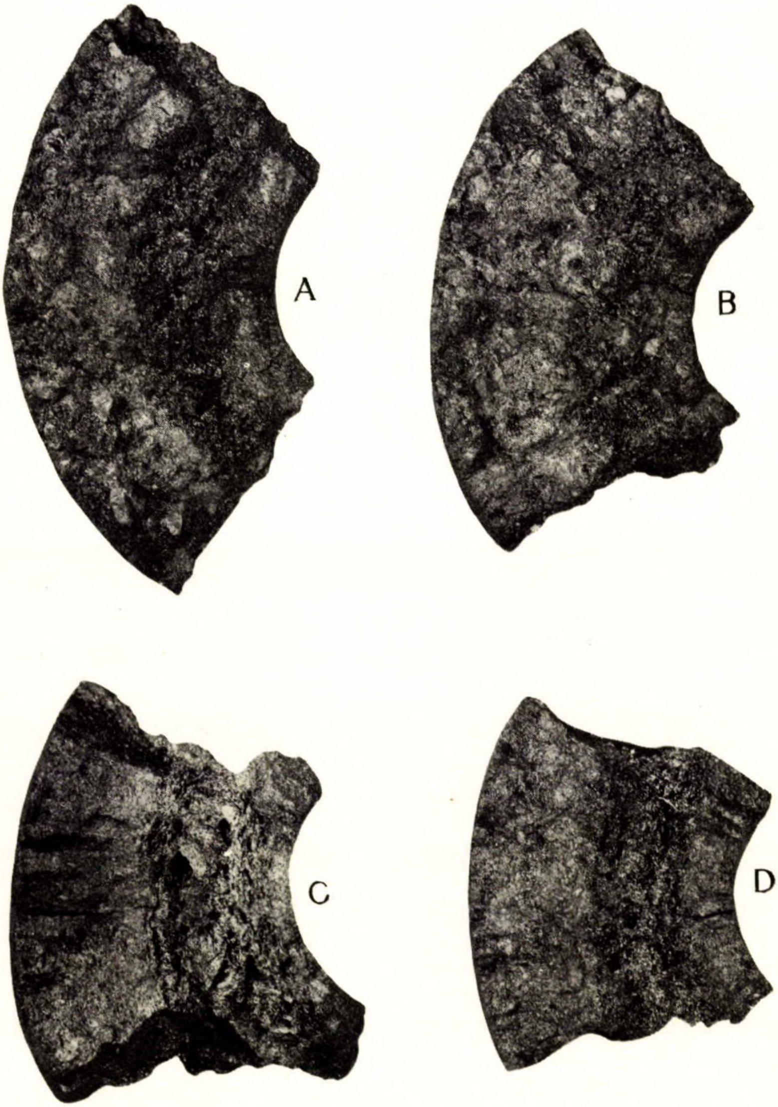
[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1925, pp. 64–105.

PLATE I



A. Coke from Springhill coal.
B. Coke from Stellarton coal.
C. Coke from Blue Diamond coal.
D. Coke from Cadomin coal.

Plate II



A. Coke from Greenhill coal.
B. Coke from International coal.
C. Coke from Michel coal.
D. Coke from Coal Creek coal.

PLATE III

A. Coke from Cassidy coal.

B. Coke from Comox coal.

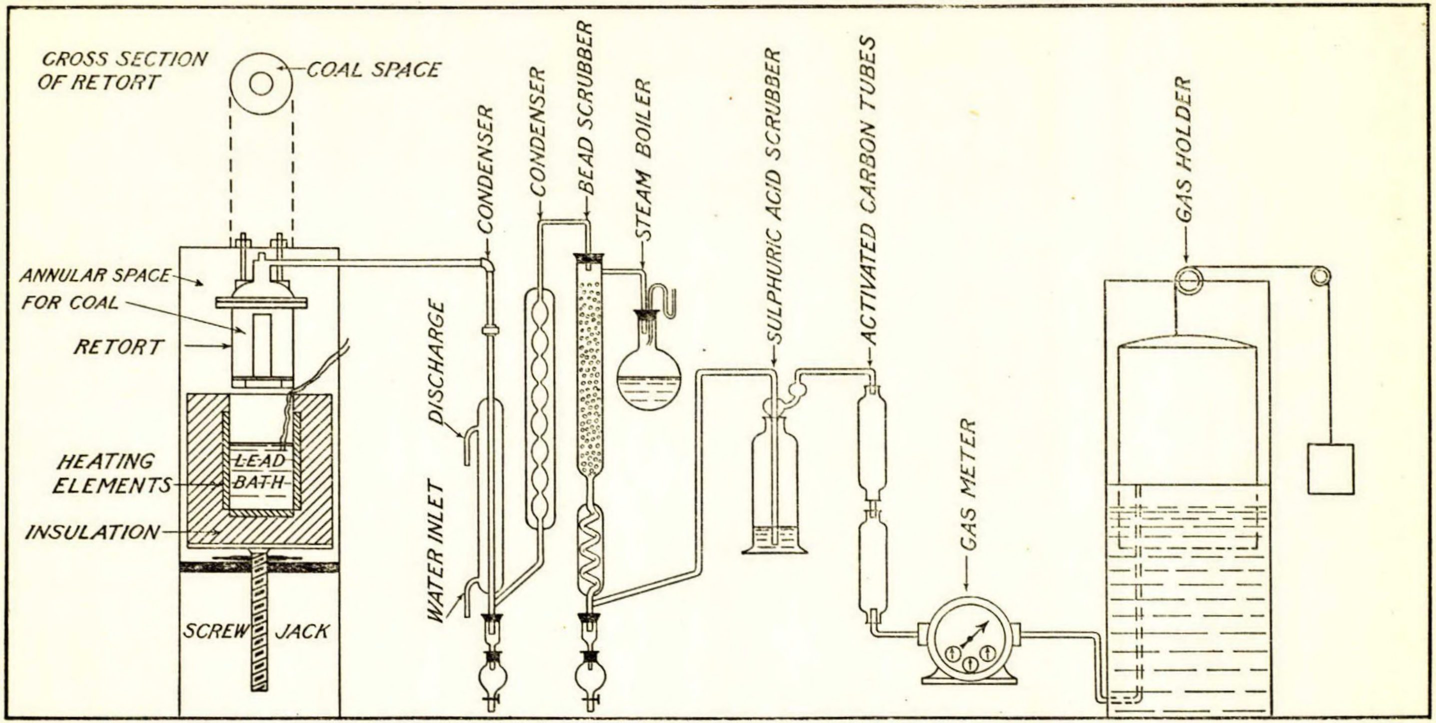


Figure 2. Diagrammatic sketch of lead bath apparatus for low-temperature carbonization.

The charge consisted of 2,000 grammes of crushed coal and duplicate runs were made on each coal, the products being weighed after every experiment. Readings were taken at 30-minute intervals of the temperature and the gas yield, as well as the meter temperature. The products of the two runs were joined and the tar and liquor separated, the final traces of water being removed from the tar by distillation. Acid was added to the liquor and the total ammonia determined and reported in the form of ammonium sulphate. The activated carbon was distilled with glycerine to recover the light oils, and the quantity and density reported.

The following data sheet is from a typical run and shows the readings taken:—

Date	January 31, 1927.
Coal	Springhill.
Condition	Straight distillation.
Weight of charge	2,000 grammes.
Barometer	30·0 inches.

Time	Temperature of lead	Meter reading	Meter temperature	Gas flow
	° F.			cu. ft.
9.30	1060	8375	55	....
10.00	1045	9025	55	0·650
10.30	1060	9830	56	0·805
11.00	1105	11440	57	1·610
11.30	1135	13600	59	2·160
12.00	1125	15170	59	1·570
12.30	1120	15875	60	0·705
1.00	1135	16290	61	0·415
1.30	1130	16510	62	0·220
2.00	1120	16712	63	0·202
2.30	1120	16830	64	0·118
3.00	1120	16943	64	0·113
3.30	1135	17053	65	0·110
4.00	1120	17130	65	0·077
4.30	1125	17138	65	0·008

The procedure for the examination of the products was the same as outlined in the previous report, and as shown in Figure 2, the results being given in the series of tables appended to this report. Table I shows the analyses of the coals as received, and Table II is a summary of the yields and analyses of the coal as charged and of the coke residue obtained. Tables III and IV are weight and thermal balances respectively, and in Table V the results of distilling the tar as obtained by both atmospheric and vacuum distillation, together with the gravities of the various fractions, are shown. In Table VI the analyses of the gases are given and Table VII shows the acid, base, and neutral oil content of the tar-oil fractions. Tables VIII and IX are the results of distilling the neutral oils and the tar acids respectively. Table X shows the yields of various neutral oil fractions and their gravities, together with the results of their treatment with concentrated sulphuric acid, and Table XI gives the various yields in terms of total tar, both in per cent and Imperial gallons per ton.

DISCUSSION OF RESULTS

The various coals behaved somewhat differently during carbonization as evidenced by the appearance of the charge on opening the retort. In the case of Michel and Coal Creek the residue was very much swollen, the charge having partly plugged the offtake of the retort. The other two coals from this district, namely, Greenhill and International, were just the reverse. No evidence of swelling was indicated and with both coals the charge showed definite signs of shrinkage. The remainder of the coals showed signs of expansion, followed by contraction. The cokes obtained from the volatile matter determinations at 950° C. confirm these observations, with the exception of Springhill which resulted in a swollen coke.

Examination of the Low-temperature Cokes Obtained

Owing to the influence of various factors such as temperature and pressure on the quality of coke from any given coal, it is difficult to interpret the results in respect to quality of the coke of small-scale tests, such as these experiments represent. It is sufficient to say that all the coals examined showed good coking properties, with the exception of Cassidy. The coals from the Crowsnest pass in Alberta did not show the swollen structure to the same degree as those from the same district in British Columbia. The difference in the ash content may account for this variation, as the former were much higher in ash than the latter. All the cokes were quite grey in colour and bore a considerable resemblance to the high temperature product. The handling properties could not be considered as good, although in most cases the structure was such that they could be considered as a domestic fuel.

Plates I to III show the structure of a representative piece of coke from the various coals examined. In all cases the section selected for photographing was taken from the lower part of the retort.

A section of the coke from top to bottom of the retort was selected for apparent specific gravity determinations and the results obtained, along with the comparative yields of coke, were as follows:—

Yields and Apparent Specific Gravities of the Cokes

Coal	Cokes obtained	
	Lb./ton	Apparent specific gravity
Springhill	1480	0·63
Stellarton	1540	0·74
Blue Diamond	1700	0·79
Cadomin	1570	0·70
Greenhill	1628	0·71
International	1730	0·80
Michel	1550	0·61
Coal Creek	1650	0·67
Cassidy	1410	0·66
Comox	1500	0·73

The analyses of the various cokes are given in Table II. The average volatile matter remaining in the coke after carbonization at 600° C. was 6·8 for the 10 coals examined. The variation was from 6·1 to 10·3 per cent, Blue Diamond being the lowest and Cassidy the highest. A comparison of volatile matter contents of the coal and coke and the fuel ratio of each are as follows:—

Coal	Volatile matter		Fuel ratio	
	Coal	Coke	Coal	Coke
Springhill	30·9	7·1	1·9	11·6
Stellarton	27·3	6·5	2·1	11·8
Blue Diamond	19·5	6·1	3·3	12·4
Cadomin	27·9	7·4	2·3	11·3
Greenhill	25·2	7·1	2·5	11·2
International	23·8	6·3	2·6	12·4
Michel	27·3	7·6	2·5	11·5
Coal Creek	22·7	7·4	3·2	11·8
Cassidy	37·4	10·3	1·3	6·8
Comox	30·9	8·9	1·8	8·5

The calorific value in every case shows a decrease from that of the coal. The following data give the average calorific value of the coal as charged with that of the coke:—

Coal	Calorific value B.T.U. per lb.		Difference	Decrease
	Coal	Coke		
				p.c.
Springhill	13,676	13,215	−461	3·4
Stellarton	13,190	12,299	−891	6·8
Blue Diamond	12,980	12,244	−736	5·7
Cadomin	14,260	13,812	−448	3·1
Greenhill	13,575	12,933	−642	4·7
International	13,065	12,629	−436	3·3
Michel	14,835	14,373	−462	3·0
Coal Creek	14,973	14,483	−490	3·3
Cassidy	12,365	11,871	−494	4·0
Comox	13,070	12,445	−625	4·9

EXAMINATION OF THE TAR OILS

The separation of the tar and liquor was effected as outlined in the previous report, namely, by the addition of a hot solution of sodium sulphate, which allowed most of the liquor to be drained off. The tar was then distilled in order to remove the last trace of liquor, after which the gravity was determined in a Westphal balance, and a calorific value determination made.

The yields of tar varied considerably for the different coals, the following being a summary of the various yields obtained, in parts by weight for 100 parts of coal, and in Imperial gallons per ton.

Coal	Yield of tar oils obtained	
	Per cent	Gals./ton
Springhill	9·5	18·3
Stellarton	9·0	17·8
Blue Diamond	4·0	7·5
Cadomin	8·7	17·0
Greenhill	6·3	12·1
International	5·9	11·5
Michel	7·6	14·5
Coal Creek	5·8	11·0
Cassidy	11·3	22·4
Comox	9·6	19·0

As will be noted, with the exception of Cassidy coal, the tar yield on all of the coals examined was disappointingly low. Washing to effect ash reduction could no doubt in some cases be used to increase this yield, but even then the yield would not be sufficiently high to warrant the adoption of low-temperature methods in place of high temperature, in view of the poorer quality of coke obtained.

All the tars were brownish black in colour and fluid at room temperature. The densities varied considerably but all were above 1·000.

Coal	Gravity of tar oils at 15·5° C.
Springhill	1·041
Stellarton	1·014
Blue Diamond	1·065
Cadomin	1·026
Greenhill	1·039
International	1·024
Michel	1·051
Coal Creek	1·059
Cassidy	1·008
Comox	1·008

The light oils were absorbed by passing the gas through activated carbon, as shown in Figure 2, the oils being recovered by distillation with glycerine. The following shows the light oil content and its specific gravity.

Coal	Light oil obtained		
	Per cent of coal by weight	Gals./ton	Specific gravity at 15·5° C.
Springhill	0·6	1·6	0·720
Stellarton	0·9	2·7	0·968
Blue Diamond	0·4	1·1	0·758
Cadomin	0·6	1·8	0·702
Greenhill	0·6	1·7	0·713
International	0·6	1·6	0·752
Michel	0·7	2·1	0·702
Coal Creek	0·7	2·0	0·708
Cassidy	0·9	2·5	0·681
Comox	0·6	1·8	0·702

The total light oils from all the coals examined were joined and the distillation range determined as shown in the following table:—

Examination of Light Oils

Specific gravity at 60° F.	0·715 (65·8° Bé.)
Distillation range—	
1st drop at	31° C. (88° F.)
10 per cent vol. at	40° C.
20 “ “	48°C.
30 “ “	57° C.
40 “ “	63° C.
50 “ “	74° C. (133° F.)
60 “ “	83° C.
70 “ “	96° C.
80 “ “	109° C.
90 “ “	134° C.
End point	170° C. (216° F.)
Recovery	96 per cent

EXAMINATION OF THE GAS

The gases liberated during the carbonization tests were stored in a gas holder over water as shown in Figure 2. A sample was drawn off for analysis after the gases had been allowed to stand for several hours in order to ensure complete mixing, the sample representing the total gas made from duplicate runs. The yields of gas varied from 3,200 to 4,000 cubic feet per ton, the lowest yield being obtained from Coal Creek coal and the highest from Cassidy coal. The density of the gases varied from 0·52 to 0·56, with the exception of that from Blue Diamond coal, which was 0·47, and that from Stellarton coal which was 0·61. The methane content of the gas varied from 50 to 60 per cent and the hydrogen from 17 to 30 per cent, this low hydrogen content being a characteristic of gas from low-temperature processes.

The following table compares the results of the 10 coals as to yields of gas and the hydrogen and methane contents of the same. The volatile matter contents of the different coals tested is also added as a matter of general interest.

Coal	Volatile matter	Gas obtained		
		Cu. ft./ton	H	CH_4
	p.c.		p.c.	p.c.
Springhill	30·8	3,887	21·8	50·2
Stellarton	27·2	3,879	22·2	56·0
Blue Diamond	19·2	3,359	32·5	51·1
Cadomin	27·5	3,735	19·5	55·9
Greenhill	25·2	3,543	20·5	56·3
International	23·8	3,339	24·7	52·0
Michel	26·4	3,807	19·6	56·9
Coal Creek	22·3	3,192	22·9	60·3
Cassidy	37·3	4,012	23·3	58·8
Comox	30·5	3,676	17·2	56·2

The yield of gas was recorded every half hour during each run, as noted above in the data sheet. It was found in every case that at the end of the fourth hour, approximately 90 per cent of the gas yield was obtained. The yields per hour for the different coals were fairly constant and in view of this the results were averaged and plotted, the result being shown in Figure 3.

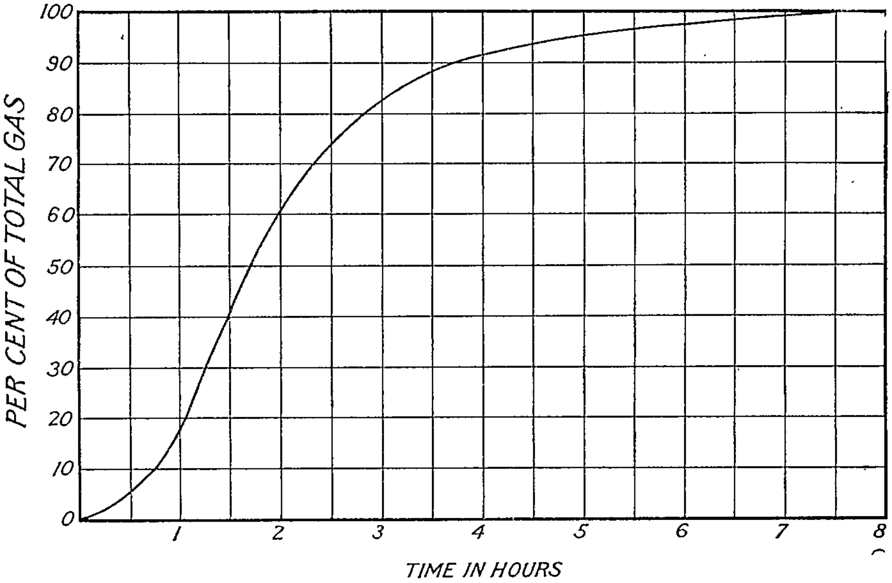


Figure 3. Curve showing average flow of gas from the ten coals when heated in lead bath retorting apparatus to a maximum temperature of 600° C.

AQUEOUS DISTILLATE

The aqueous distillate and the acid from the ammonia scrubber were joined and after being made up to a definite amount a sample was taken for analysis. The results in the form of ammonium sulphate were low, as was expected, averaging around 7 pounds per ton. Stellarton and Cassidy coals were an exception to this, the former yielding 17·2 pounds and the latter 11·5 pounds per ton. The results are shown in Table II which gives the amount of liquor per ton in gallons and the ammonium sulphate in pounds.

ANALYSES OF THE LOW-TEMPERATURE TAR OILS

The examination of the tar oils was carried out as outlined in the 1925 report, namely distillation in a Hempel flask at atmospheric pressure to 275° C., making a cut at 225° C., followed by distillation at reduced pressure (40 mm.) to 300° C. The three fractions were treated with caustic soda and dilute sulphuric acid, and the neutral oils joined. These were distilled in an Engler flask, three fractions being made, i.e. 0° to 200° C., 200° to 275° C., and 275° C. to end point.

The results of the distillation of the tars are shown in Table V, while Table VIII shows the boiling range of the neutral oils. The following table compares the distillation results of the ten coals showing the yield and gravity of the different fractions.

Coal	Tar					
	0-225° C.	Specific gravity at 15·5°C.	225-275°C.	Specific gravity at 15·5°C.	0-300° C. (Vac.)	Specific gravity at 15·5°C.
	p.c.		p.c.		p.c.	
Springhill	30·7	0·907	14·3	0·990	30·3	1·060
Stellarton	31·2	0·855	14·1	0·945	30·3	1·024
Blue Diamond	20·0	0·897	13·6	0·960	31·4	1·080
Cadomin	25·0	0·866	13·0	0·958	30·7	1·034
Greenhill	25·8	0·876	16·3	0·975	31·7	1·080
International	27·3	0·862	15·9	0·961	29·8	1·072
Michel	25·4	0·891	13·8	0·983	29·4	1·068
Coal Creek	25·3	0·867	14·2	0·967	28·0	1·064
Cassidy	30·7	0·891	16·9	0·972	30·0	1·040
Comox	27·8	0·875	14·7	0·953	31·3	0·030

Tar Acids

These were recovered from the caustic soda solution by acidifying with dilute sulphuric acid and distilling. The results of this distillation are given in Table IX. The following results show the yield of tar acids from the various coals examined:—

Coal	Tar acids	
	Yield	Specific gravity at 15·5° C.
	p.c.	
Springhill	22·7	1·080
Stellarton	14·3	1·092
Blue Diamond	13·2	1·085
Cadomin	13·7	1·082
Greenhill	13·0	1·092
International	13·2	1·090
Michel	17·1	1·078
Coal Creek	10·0	1·076
Cassidy	24·0	1·074
Comox	18·7	1·081

Pyridine Bases

The quantity of bases present was insufficient to warrant their recovery and special examination. The quantity was estimated by the contraction after treatment of the acid-free oil with a 20 per cent solution of sulphuric acid. The results are shown in Table VII.

Neutral Oils

The three fractions obtained from the distillation of the tar in a Hempel flask were neutralized by treatment with caustic soda, followed by dilute sulphuric acid. The resultant neutral oils were joined and distilled in an Engler flask, cuts being made at 200° C. and 275° C.

Table X shows the quantity in per cent of the various fractions and their specific gravity. As will be noted, the average light oil content (0°-200° C.) is 28 per cent with an average gravity of 0·825. This fraction, together with the light oils recovered from the gas, can be considered as a gasoline substitute. The boiling ranges of the neutral oils from the various tars are shown in Table VIII. The uniformity of the boiling range of the neutral oils from the various coals is worthy of note. This is in conformity with the results obtained and published in Investigations of Fuels and Fuel Testing, 1925, using two coals from the Maritime Provinces and an American coal.

The neutral oil, according to Egloff and Morrell,[1] is an excellent cracking stock from which over 50 per cent motor fuel can be produced. Moreover, the motor fuel produced by this method contains over 50 per cent of aromatic hydrocarbon equivalent, which renders it an excellent anti-knock motor fuel. The average distillation range of the neutral oils and the tar acids is shown in the following table. The results are also shown as curves in Figure 4.

——	Tar acids	Neutral oils
	° C.	° C.
1st drop at	....	87
10 per cent vol. at	203	141
20 " "	211	171
30 " "	217	205
40 " "	227	240
50 " "	239	267
60 " "	273	292
70 " "	318	322
80 " "	351	353
90 " "	370	383
End point	378	407

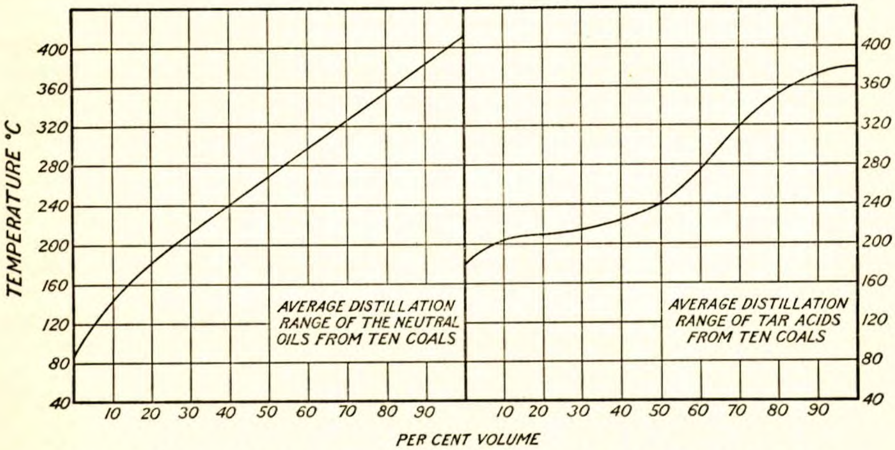


Figure 4. Curves showing average distillation range of neutral oils and tar acids from Canadian bituminous coals.

---

[1] "The Cracking of Low-Temperature Coal Tar by the Dubbs Process," by Gustav Egloff and Jacque Morrell, page 9.

Unsaturated Compounds in Neutral Oils. The neutral oils were treated with concentrated sulphuric acid to determine the percentage of unsaturated compounds, the results being shown in Table X. The average percentage of the light oils soluble in concentrated sulphuric acid was 43, middle oil 44, and heavy oil 64. This test has no commercial significance, other than an indication of refining loss with sulphuric acid treatment, and that there would be a smaller loss in the refining of the light and middle oils than of the heavy oils.

SUMMARY

1. The tests reported here on 10 bituminous coals—2 from Nova Scotia, 4 from Alberta, and 4 from British Columbia—are a continuation of a survey as to the amenability of Canadian coals for low-temperature carbonization. These tests were conducted in the temperature control (lead bath) retorting apparatus at a maximum temperature of 600° C. (1110° F.) according to the standard method adopted in the Fuel Testing Laboratories. The context of this report, besides containing a brief description of the apparatus and method used, consists of a summary of the results and a discussion of the same. The detailed results are given in a series of eleven tables following.

2. The coals tested, while they were all coking coals, varied considerably in volatile matter and ash contents. The volatile matter contents varied from 19 to 37 per cent with an average of 27 per cent. The yields of the coke and gas, therefore, varied appreciably. The coke yields varied from approximately 1,500 to over 1,700 pounds per ton, the gas yields from roughly 3,300 to 4,000 cubic feet per ton, and the tar-oil yields from 7½ to 22½ Imperial gallons per 2,000 pounds of coal carbonized.

3. The cokes obtained from all coals with one exception were more or less of a uniformly fair grade of low-temperature coke. They were of a dark greyish colour, the structure of which is shown in the plates illustrating the same. As judged by hand-inspection the friability of all the cokes, except one, was seemingly good enough to be considered as fair to good coke for domestic purposes. The apparent specific gravities of the 10 cokes varied roughly from 0·61 to 0·80, with an average of 0·70, in which respect they were appreciably lighter than average by-product or gas coke on the market.

4. The average tar-oil yield for the 10 coals was 6·8 per cent by weight of the coal charged, equal to less than 13½ Imperial gallons per ton. Only one of the ten coals showed a tar-oil yield between 20 and 25 gallons per ton, which is comparable with the high tar-oil yields from the three coals, two Canadian and one imported, previously reported. With this exception, therefore, the tar-oil yields from the 10 coals tested were low, being not appreciably higher than that obtainable from typical bituminous coals in high-temperature by-product ovens or in gas retorts.

5. The yields of light oils obtained from the gas by absorption in activated carbon varied from 1·1 to 2·7 Imperial gallons per ton of coal carbonized with an average of 1·9 gallons. A composite sample of these light oils had a specific gravity of 0·715 (65·8° Bé.) and a distillation range of 88° to 216° F. with a "recovery" of 96 per cent.

6. The average specific gravities for the crude tar oils obtained, the tar acids, and the neutral oils were 1·053, 1·082, and 0·940 respectively. Considerable variation was noticed in the crude tar oils obtained in respect to comparative yields of light, medium, and heavy oil contents and in respect to the proportions of tar acids and neutral oils present. The tar-acid contents of the 10 tars examined were from 10 to 24 per cent of the volume of the crude tar oil, the remaining proportion of which consisted almost entirely of neutral oils. The neutral oils, in respect to specific gravity and distillation range, showed a remarkable similarity, one to another, as was also the case with the tar acids; which was in agreement with the results previously obtained and reported. The uniformity of the neutral oils from the different coals, in respect to specific gravity and distillation range, is a factor in favour of their use as crude petroleum substitutes where a uniform product is desirable.

CONCLUSIONS

In respect to yield and quality of the low-temperature coke obtainable, all the 10 coals showed favourable results. With one exception, however, the coals tested were not specially suitable for low-temperature carbonization on account of the comparatively low tar-oil and gas yields.

TABLE III

Weight Balance—Low-Temperature Carbonization Tests

(Parts by weight per 100 parts of coal charged)

Name of coal	Spring-hill	Stellar-ton	Blue Diamond	Cadomin	Green-hill	Inter-national	Michel	Coal Creek	Cassidy	Comox
Laboratory No.	4028	4029	4032	4034	4036	4038	4039	4040	4041	4042
Coke ... per cent	74·1	76·9	85·3	78·7	81·4	81·5	77·6	82·4	70·4	74·9
Tar ... "	9·5	9·0	4·0	8·7	6·3	5·9	7·6	5·8	11·3	9·6
Light oil ... "	0·6	0·9	0·4	0·6	0·6	0·6	0·7	0·7	0·9	0·6
Liquor ... "	6·6	5·2	3·5	4·2	4·3	5·4	5·8	3·3	8·5	6·6
Gas ... "	9·0	8·1	6·1	8·2	7·2	6·9	8·2	8·4	8·5	7·9
Loss ... "	0·2	+0·1	0·7	+0·4	0·2	+0·3	0·1	+0·6	0·5	0·4

TABLE IV

Thermal Balance—Low-Temperature Carbonization Tests

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

Name of coal	Spring-hill	Stellar-ton	Blue Diamond	Cadomin	Green-hill	Inter-national	Michel	Coal Creek	Cassidy	Comox
Laboratory No.	4028	4029	4032	4034	4036	4038	4039	4040	4041	4042
Coke ... per cent	71·6	71·7	81·8	76·2	77·6	79·8	75·2	79·8	67·6	71·3
Tar ... "	12·2	12·8	5·7	11·0	8·6	8·5	9·3	7·4	16·6	13·7
Gas ... "	8·8	10·0	8·4	8·6	8·8	8·1	8·5	7·6	11·7	9·3
Loss ... "	7·4	5·5	4·1	4·2	5·0	3·6	7·0	5·2	4·1	5·7

TABLE V

Analyses of Tars—Low-Temperature Carbonization Tests

Name of coal	Springhill			Stellarton			Blue Diamond			Cadomin			Greenhill		
Laboratory No.	4028			4029			4032			4034			4036		
Tar (water-free)—															
Specific gravity at 15·5° C.	1·041			1·014			1·065			1·026			1·039		
B.T.U. per pound	16,560			17,091			16,852			16,907			16,902		
—	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.
Atmospheric distillation	First drop 58° C.	......	....	First drop 49° C.	......	....	First drop 46° C.	......	....	First drop 56° C.	......	....	First drop 50° C.	......	....
75° C.	1·3	1·3	....	2·3	2·3	....	0·7	0·7	....	1·7	1·7	....	2·5	2·5	....
100° C.	1·2	2·5	....	1·0	3·3	....	1·1	1·8	....	1·3	3·0	....	4·1	6·6	....
125° C.	1·2	3·7	....	4·2	7·5	....	1·4	3·2	....	2·3	4·6	....	0·5	7·1	....
150° C.	4·5	8·2	....	5·3	12·8	....	3·9	7·1	....	3·0	7·6	....	2·9	10·0	....
175° C.	5·1	13·3	....	5·5	18·3	....	5·0	12·1	....	5·0	12·6	....	5·0	15·0	....
200° C.	8·0	21·3	....	6·1	24·4	....	3·6	15·7	....	5·4	18·0	....	5·8	20·8	....
225° C.	9·4	30·7	0·907	6·8	31·2	0·855	4·3	20·0	0·897	7·0	25·0	0·866	5·0	25·8	0·876
250° C.	7·3	38·0	....	6·4	37·7	....	5·7	25·7	....	5·4	30·4	....	7·5	33·3	....
275° C.	7·0	45·0	0·990	7·6	45·3	0·945	7·9	33·6	0·960	4·6	38·0	0·958	8·8	42·1	0·975
Vacuum distillation (40 mm. pressure)—															
175° C.	0·3	0·3	....	0·0	0·0	....	0·0	0·0	....	0·0	0·0	....	0·0	0·0	....
200° C.	5·7	6·0	....	4·7	4·7	....	5·0	5·0	....	5·0	5·0	....	3·3	3·3	....
225° C.	4·0	10·0	....	4·3	9·0	....	4·3	9·3	....	5·3	10·3	....	9·2	12·5	....
250° C.	6·7	16·7	....	6·3	15·3	....	7·8	17·1	....	3·7	14·0	....	6·7	19·2	....
275° C.	6·0	22·7	....	6·7	22·0	....	6·4	23·5	....	6·7	20·7	....	4·6	23·8	....
300° C.	7·6	30·3	1·060	8·3	30·3	1·024	7·9	31·4	1·080	10·0	30·7	1·034	7·9	31·7	1·080
Pitch (by weight), grammes	71·0			74·0			100·5			95·0			83·0		

TABLE V—continued

Analyses of Tars—Low-Temperature Carbonization Tests

Name of coal	International			Michel			Coal Creek			Cassidy			Comox		
Laboratory No.	4038			4039			4040			4041			4042		
Tar (water-free)— Specific gravity at 15·5° C. B.T.U. per pound	1·024 17,057			1·051 16,641			1·059 16,960			1·008 16,862			1·008 17,114		
—	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.	p.c. vol.	Cum. p.c. vol.	Sp. Gr. at 15·5° C.
Atmospheric distillation	First drop 52° C.	......	....	First drop 50° C.	......	....	First drop 48° C.	......	....	First drop 46° C.	......	....	First drop 44° C.	......	....
75° C.	2·3	2·3	....	1·5	1·5	....	2·3	2·3	....	3·3	3·3	....	2·8	2·8	....
100° C.	0·7	3·0	....	0·6	2·1	....	2·2	4·5	....	1·2	4·5	....	0·8	3·6	....
125° C.	2·5	5·5	....	1·2	3·3	....	0·6	5·1	....	0·8	5·3	....	1·4	5·0	....
150° C.	5·4	10·9	....	5·8	9·1	....	4·4	9·5	....	3·4	8·7	....	4·0	9·0	....
175° C.	5·5	16·4	....	4·4	13·5	....	5·5	15·0	....	4·3	13·0	....	4·2	13·2	....
200° C.	5·4	21·8	....	4·3	17·8	....	5·0	20·0	....	6·7	19·7	....	6·3	19·5	....
225° C.	5·5	27·3	0·862	7·6	25·4	0·891	5·3	25·3	0·867	11·0	30·7	0·891	8·3	27·8	0·875
250° C.	7·7	35·0	....	5·1	30·5	....	5·5	30·8	....	7·6	38·3	....	7·2	35·0	....
275° C.	8·2	43·2	0·961	8·7	39·2	0·983	6·7	39·5	0·967	9·3	47·6	0·972	7·5	42·5	0·953
Vacuum distillation (40 mm. pressure)—															
175° C.	0·0	0·0	....	0·0	0·0	....	1·7	1·7	....	0·0	0·0	....	0·7	0·7	....
200° C.	4·1	4·1	....	4·7	4·7	....	0·8	2·5	....	2·0	2·0	....	1·6	2·3	....
225° C.	11·4	15·5	....	7·3	12·0	....	3·5	6·0	....	6·7	8·7	....	5·7	8·0	....
250° C.	1·8	17·3	....	3·3	15·3	....	5·0	11·0	....	5·3	14·0	....	6·7	14·7	....
275° C.	4·5	21·8	....	5·8	21·1	....	6·5	17·5	....	4·7	18·7	....	8·6	23·3	....
300° C.	8·0	29·8	1·072	8·3	29·4	1·068	10·5	28·0	1·064	11·3	30·0	1·040	8·0	31·3	1·030
Pitch (by weight), grammes	85·0			99·0			103·0			71·0			80·0		

TABLE VI

Analyses of Gases—Low-Temperature Carbonization Tests

Name of coal	Springhill	Stellarton	Blue Diamond	Cadomin	Greenhill	International	Michel	Coal Creek	Cassidy	Comox
Laboratory No.	4028	4029	4032	4034	4036	4038	4039	4040	4041	4042
Density (air=1)	0·61	0·55	0·48	0·58	0·54	0·55	0·57	0·53	0·55	0·57
Carbon dioxide per cent	5·8	3·3	3·1	2·5	3·7	3·5	2·4	2·7	4·9	3·6
Illuminants "	2·1	2·2	1·0	1·3	1·0	1·1	1·3	1·4	2·6	1·6
Oxygen "	4·6	1·6	3·6	2·9	2·0	1·9	2·2	1·6	1·4	3·4
Carbon monoxide "	3·6	4·3	4·6	4·6	4·0	5·1	3·9	3·1	6·0	6·6
Methane "	50·2	56·0	51·1	55·9	56·3	52·0	56·9	60·3	58·8	56·2
Hydrogen "	21·8	22·2	32·5	19·5	24·7	24·7	19·6	22·9	23·3	17·2
Nitrogen "	11·9	10·4	4·1	13·3	8·3	11·7	13·7	8·0	3·0	11·4
B.T.U. per cubic foot—										
Net	553	610	577	589	600	567	597	635	650	596
Gross	618	680	646	658	671	633	665	709	724	664

TABLE VII

Crude Tar Acids, Bases, and Neutral Oil Contents of Tars from Low-Temperature Carbonization Tests

Laboratory No.	Coal	Fraction I: 0° to 225° C. (atmospheric pressure)			Fraction II: 225° to 275° C. (atmospheric pressure)			Fraction III: 0° to 300° C. (40 mm. pressure)		
		Tar acids by alkali treatment	Pyridine bases by acid treatment	Washed neutral oil	Tar acids by alkali treatment	Pyridine bases by acid treatment	Washed neutral oil	Tar acids by alkali treatment	Pyridine bases by acid treatment	Washed neutral oil
		p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
4028	Springhill	34·8	3·2	62·0	34·9	4·7	60·4	23·1	3·3	73·6
4029	Stellarton	19·2	3·2	77·6	19·1	11·8	69·1	18·7	14·3	67·0
4032	Blue Diamond	19·6	3·6	76·8	15·8	5·3	78·9	18·2	6·8	75·0
4034	Cadomin	24·0	0·7	75·3	28·2	1·3	70·5	13·0	7·6	79·3
4036	Greenhill	24·2	3·2	72·6	20·5	5·1	74·4	21·1	5·2	73·7
4038	International	20·0	1·7	78·3	20·0	2·8	77·2	15·4	7·7	76·9
4039	Michel	27·2	2·8	70·0	26·7	5·3	68·0	22·2	4·9	72·9
4040	Coal Creek	19·8	3·0	77·2	21·0	5·3	73·7	7·1	10·7	82·2
4041	Cassidy	32·6	2·2	65·2	31·4	5·9	62·7	28·9	10·0	61·1
4042	Comox	29·8	2·4	67·8	27·3	2·3	70·4	20·2	7·5	72·3

TABLE VIII

Distillation Range of Neutral Oils from Low-Temperature Carbonization Tests

Name of coal	Springhill	Stellarton	Cadomin	Greenhill	International	Michel	Coal Creek	Cassidy	Comox
Laboratory No.	4028	4029	4034	4036	4038	4039	4040	4041	4042
Specific gravity at 15·5° C.	0·945	0·890	0·931	0·962	0·940	0·967	0·954	0·908	0·968
Distillation range—	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
1st drop	95	90	90	96	73	82	98	75	78
10 per cent vol.	145	125	145	150	132	142	145	145	140
20 "	171	150	170	183	163	165	175	178	180
30 "	204	178	215	221	197	200	203	211	215
40 "	245	212	245	256	227	242	242	244	247
50 "	273	250	268	282	257	267	270	270	273
60 "	300	278	291	310	280	293	297	293	289
70 "	327	310	317	342	313	320	330	319	324
80 "	359	350	348	370	350	349	356	347	352
90 "	387	395	370	389	380	380	387	374	385
End point	415	410	405	420	410	405	410	392	395

TABLE IX

Distillation Range of Tar Acids from Low-Temperature Carbonization Tests

Name of coal	Springhill	Stellarton	Cadomin	Michel	Cassidy	Comox
Laboratory No.	4028	4029	4034	4039	4041	4042
Specific gravity at 15·5° C.	1·080	1·092	1·082	1·078	1·074	1·081
Distillation range—	° C.	° C.	° C.	° C.	° C.	° C.
10 per cent vol.	210	206	210	196	206	192
20 "	214	215	217	208	214	200
30 "	219	221	223	213	222	206
40 "	228	229	237	220	235	213
50 "	235	240	252	235	248	222
60 "	270	290	300	255	275	250
70 "	315	339	332	307	308	305
80 "	358	373	365	345	338	328
90 "	385	380	381	363	370	340
End point	390	385	385	365	380	365
Specific gravity of distilled tar acids at 15·5° C.	1·065	1·072	1·076	1·071	1·068	1·074

TABLE X

Yields, Specific Gravities, etc., of Neutral Oil Fractions

Name of coal	Springhill	Stellarton	Blue Diamond	Cadomin	Greenhill	International	Michel	Coal Creek	Cassidy	Comox
Laboratory No.	4028	4029	4032	4034	4036	4038	4039	4040	4041	4042
Light oil (0° to 200° C.)	28·0	36·5	25·6	27·5	25·5	31·0	30·0	29·0	26·5	25·0
Specific gravity at 15·5° C.	0·830	0·805	0·871	0·811	0·821	0·823	0·833	0·831	0·806	0·818
Insolubility in conc. H_2SO_4 per cent.	59	64	60	61	76	66	80	78	58	64
Middle oil (200° to 275° C.)	23·0	23·5	24·5	25·0	21	26·0	23·5	22·5	26·0	25·5
Specific gravity at 15·5° C.	0·916	0·885	0·954	0·911	0·921	0·930	0·936	0·923	0·888	0·914
Insolubility in conc. H_2SO_4 per cent.	60	66	66	67	72	67	76	75	54	59
Heavy oil (275° C. to end point)	48·0	38·5	46·7	45·0	51·5	41·0	45·5	47·5	46·0	46·5
Specific gravity at 15·5° C.	1·018	0·973	1·061	1·000	1·037	1·033	1·026	1·032	0·964	0·991
Insolubility in conc. H_2SO_4 per cent.	24	38	34	35	40	30	38	47	34	41

TABLE XI

Yields of Crude Tar Oils and Fractions

Name of coal	Springhill		Stellarton		Blue Diamond		Cadomin		Greenhill		International		Michel		Coal Creek		Cassidy		Comox	
Laboratory No.	4028		4029		4032		4034		4036		4038		4039		4040		4041		4042	
	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton	Per cent of tar (vol.)	Imp. gals. per ton
Crude water-free tar oil	......	18·3	......	17·8	......	7·5	......	17·0	......	12·1	......	11·5	......	14·5	......	11·0	......	22·4	......	19·0
Fraction (0° to 225° C.)	30·7	5·6	31·2	5·6	20·0	1·5	25·0	4·3	25·8	3·1	27·3	3·1	25·4	3·7	25·3	2·8	30·7	6·9	27·8	5·3
Fraction (225° to 275° C.)	14·3	2·6	14·1	2·5	13·6	1·0	13·0	2·2	16·3	2·0	15·9	1·8	13·8	2·0	14·2	1·6	16·9	3·8	14·7	2·8
Fraction (0° to 300° C. vacuum)	30·3	5·5	30·3	5·4	31·4	2·4	30·7	5·2	31·7	3·8	29·8	3·4	29·4	4·3	28·0	3·1	30·0	6·7	31·3	5·9
Neutral Oil—																				
Fraction (0° to 225° C.)	19·0	3·5	24·3	4·3	15·4	1·2	18·8	3·2	18·7	2·3	21·4	2·5	17·8	2·6	19·5	2·1	20·0	4·5	19·0	3·6
Fraction (225° to 275° C.)	8·7	1·6	9·7	1·7	10·7	0·8	9·2	1·6	12·1	1·5	12·3	1·4	9·3	1·3	10·5	1·2	10·7	2·4	10·3	2·0
Fraction (0° to 300° C. vacuum)	22·3	4·1	20·3	3·6	23·6	1·8	24·3	4·1	23·3	2·8	22·7	2·6	23·3	3·4	23·0	2·5	18·3	4·1	22·7	4·3
Tar acids from all three fractions	22·7	4·2	14·3	2·5	13·2	1·0	13·7	2·3	13·0	1·6	13·2	1·5	17·1	2·5	10·0	1·1	24·0	5·4	18·7	3·6
Tar acids (recovered)	22·0	4·0	14·3	2·5	10·7	0·8	13·3	2·3	11·7	1·4	12·3	1·4	16·9	2·5	10·0	1·1	22·3	5·0	18·7	3·6
Tar bases from all three fractions	2·7	0·5	7·0	1·2	3·6	0·3	2·7	0·5	3·3	0·4	3·2	0·4	2·9	0·4	4·5	0·5	4·7	1·1	3·3	0·6
Light neutral oil (0° to 200° C.)	14·0	2·6	19·8	3·5	12·7	1·0	14·4	2·4	13·8	1·7	17·5	2·0	15·1	2·2	15·4	1·7	13·0	2·9	13·0	2·
Middle neutral oil (200° to 275° C.)	11·5	2·1	12·8	2·3	12·2	0·9	13·1	2·2	11·4	1·4	14·7	1·7	11·8	1·7	11·9	1·3	12·7	2·8	13·3	2·5
Heavy neutral oil (275° C. to end point)	24·0	4·4	20·9	3·7	23·2	1·7	23·5	4·0	27·9	3·4	23·1	2·7	22·9	3·3	25·2	2·8	22·6	5·1	24·2	4·6

III

A STUDY OF THE NATURE OF SULPHUR IN CANADIAN COAL AND COKE

J. H. H. Nicolls

In an earlier paper[1] the writer discussed in considerable detail the forms of sulphur occurring in coals from the Maritime Provinces, which generally contain a higher percentage of sulphur than any other Canadian coals. The present work is supplementary and more general, and has been divided into three sections: (1) the nature of the sulphur in western Canadian coals; (2) the nature of the sulphur in cokes made from Canadian coals; (3) the nature of the pyritic sulphur in coals of high sulphur content from the Maritime Provinces.

NATURE OF THE SULPHUR IN WESTERN CANADIAN COALS

Since it is particularly undesirable that coals which are to be used for the manufacture of coke should contain high percentages of sulphur, the coals first selected for this investigation were those which coked, or at least gave indications that they could be blended and used in coke manufacture. The pyritic sulphur content of these was noted particularly, as this was considered to be the form of sulphur most readily removed by washing. In addition to these coals a few others representative of the non-coking coals occurring in western Canada were investigated.

In selecting the representative samples coals from large areas, or areas of large production, were considered of primary importance. To these were added certain coals from smaller or less productive areas on account of their distinctive properties. For the same reason, a few coals from undeveloped, or scarcely developed, areas were also included.

The methods of analysis were identical with those described in the previous paper, except that the period for extraction of pyritic sulphur was increased to four days. This change was made following a series of analyses of coals of higher than normal sulphur content. It was found that one day's treatment with the dilute nitric acid would dissolve all the inorganic sulphur from coals containing up to 4 per cent of total sulphur, but that it might not dissolve the entire amount from coals of higher sulphur content. However, the figures obtained with such coals were irregular; in some cases exposure of a high sulphur coal to the nitric acid for one day caused the solution of more sulphur than the exposure of a second sample of the same coal for a longer period. It was found that when treating Minto coals having 7 to 8 per cent sulphur content, about 80 per cent of which was inorganic, variations as great as 14 per cent of the total sulphur content were obtained as a result of treating different samples of the same coal under what seemed to be practically identical conditions. In this

---

[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923, p. 28.

connexion it was thought likely that slight alterations in strength of the different lots of nitric acid made up, or variations in the temperature of the acid as added to the coal, might have a considerable effect upon the amount of sulphur dissolved, and these conditions were much more closely watched than in the earlier investigation.

Table XII gives the different forms of sulphur in the coals analysed, as percentages, both of the coal as used for the tests and of the total content of sulphur. It shows that the amounts of pyritic sulphur in the coking coals from the Mountain Park area, and in those from both the Crowsnest Pass areas, are almost negligible, and that the probable effect of washing these coals would be to remove principally ash, leaving slightly increased sulphur contents in the washed coals. It also shows that, although the partially coking coals from the Nanaimo area contain comparatively little pyritic sulphur except in one or two cases, the coking coals from the adjoining Comox area contain somewhat larger percentages, which ought to be readily reduced by washing. In this connexion it should be noted that the washed Comox coal was of pea size, and that the raw coal from which it was prepared would probably have contained more ash and sulphur than the crushed lump described in the table.

Except for a few coals from the south of the province, none of the other Alberta coals, whether of higher or lower grade than the coking variety, contain much sulphur and this when present is principally organic. The only exceptions to this are the coals from the Taber, Magrath, and Lundbreck areas, which contain a notable percentage of pyritic sulphur.

The two Saskatchewan lignites were chosen from the little-developed centre of the coal areas of that province because of their high sulphur content. This sulphur is largely inorganic, and a considerable part of it is in the form of sulphate. This may be expected since occurrence of the sulphates of sodium and magnesium in the prairies is quite common. Calcium sulphate must also be present since the ash of coal No. 2770 contains 8 per cent of calcium oxide, a higher percentage than that found in the ashes of any other Canadian coal so far analysed in these laboratories, except that from the Phalen seam at Glace Bay.

NATURE OF THE SULPHUR IN COKES MADE FROM CANADIAN COALS

With the exception of the Comox coke, which was made in a "Beehive" oven from coal corresponding to sample No. N10 of washed pea coal, all the cokes listed in Table XIII were made in Semet-Solvay coke ovens at Hamilton during special tests carried out by the Department in 1924, and may be regarded as typical of cokes made from the Maritime coals. In several cases the Nova Scotia and New Brunswick coals were blended with Pocohontas and Elkhorn (United States) coals in order to reduce the sulphur contents of the cokes.

Unfortunately the table contains no analyses of cokes made from the coals from either of the Crowsnest Pass areas, or from the Mountain Park area, nor does it contain an analysis of a coke corresponding to that made by the Granby Company at Anyox from Cassidy coal blended with Alberta coal. Presumably none of such cokes would retain sufficient sulphur to impair their usefulness for any purpose whatever, but they would all probably contain considerably more ash than the Nova Scotia cokes.

The methods of analysis were the same as those employed in the earlier investigation, though in the cases where the sulphur was evolved as hydrogen sulphide it was found advisable to increase the rate of heating the evolution flask, and to pass hydrogen rapidly through the apparatus until the liquid in the flask began to boil.

The coke made from the Springhill coal is the only one with a sufficiently low sulphur content to be classed as metallurgical, though the sulphur in the Sydney-Pocohontas, Comox, and Sydney cokes is not much too high. (It should be noted that this coke was made from unwashed Sydney coal). On the other hand, the coke from Minto coal has an abnormally high sulphur content, which would render it useless for most purposes. However, as the ash of this coal is also very high, washing would be a necessary preliminary to any coking operations, and, as will be shown in the third section of the present paper, such washing would greatly reduce the sulphur and ash contents and thus improve the coke from all standpoints. According to the table in Haanel's and Gilmore's report[1] of the tests at Hamilton, the cokes made from Minto coal had a good appearance. Therefore, although the washing of Minto coal for coke manufacture is unlikely at present on account of the cost, it is possible that this may be undertaken some day.

The writer's previous paper referred to the work on sulphur forms in coal and coke carried out by Powell, who has since published more papers on the subject. Some of these deal with the desulphurization of coke by hydrogen, steam, carbon monoxide, and other gases, and one of them, in collaboration with Thompson,[2] discusses the commercial possibilities of such processes. These investigators believe that the processes may become economically feasible when, on account of depletion of resources, it becomes necessary to use coals with high sulphur contents for coke manufacture. These processes attack and remove all forms of coke sulphur, except that in solid solution, and more particularly the free sulphur. Since the removable sulphur in the cokes made from Minto coals amounts to some 65 per cent of the total sulphur, it can be readily seen that the commercial development of a desulphurization process would increase the value of such coals as sources of by-product coke, not only for general purposes but also for some metallurgical uses.

NATURE OF THE PYRITIC SULPHUR IN COALS OF HIGH SULPHUR CONTENT FROM THE MARITIME PROVINCES

The writer's earlier paper[3] indicates that, in his opinion, while oxidation of the carbonaceous material in coal is the principal cause of spontaneous combustion, the oxidation of finely disseminated pyrites is also a contributing factor. Therefore, the main purpose of the third section of the present investigation was to determine how much of the pyritic sulphur of each of these coals was in a finely disseminated condition. It was proposed to do this by separating each of the coals into two parts by means of a solution heavier than water, which would float the finely divided pyritic sulphur. It was thought that the results thus obtained might also indicate how the ash and sulphur constituents would separate out in coal-washing practice.

---

[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1924, p. 6.
[2] Carnegie Inst. Tech., Coal Mining Investigations, Bull. No. 7 (1923).
[3] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923, p. 29.

The apparatus employed was similar to one used by Yancey[1] and his co-workers at the University of Illinois. A sketch of the principal parts of it is shown in Figure 5, and the following is Yancey's and Fraser's description of it:—

> The apparatus was made in the laboratory shop of a 3-inch round-way stop-cock valve, a piece of a 4-inch galvanized pipe and a tilting frame. . . . . The bore of the valve plug was cut out to 4-inch size at one end and almost through to the other side of the plug. A cylindrical wooden core was then inserted, and babbit was poured in around this to fill up the corners in the interior of the plug and stop up the small end of the bore so that the valve plug, instead of a 3-inch round hole through it, has a 4-inch cylindrical well in it. . . . . In the valve body one opening was cut out to 4-inch diameter and a galvanized pipe 10 inches long and 4 inches in inside diameter was soldered on; the opposite opening was closed with babbit. The 4-inch galvanized pipe and the 4-inch well in the valve plug form the container for the sink and float bath. For convenience in manipulation this barrel was pivoted on a tilting frame fitted with a spring at the bottom for holding the barrel rigid when in the vertical position, and a stop for the valve handle to facilitate lining up the well in the valve plug with the bore of the galvanized pipe.

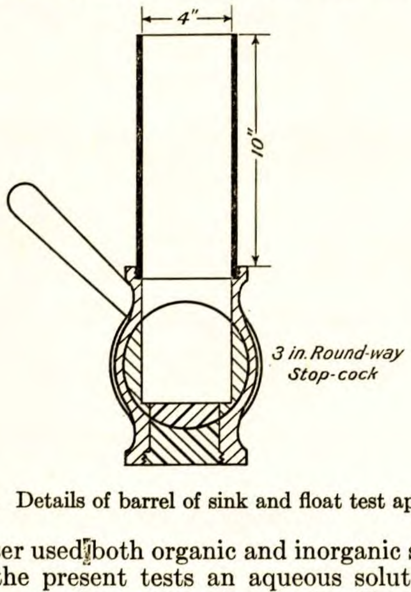


Figure 5. Details of barrel of sink and float test apparatus.

Yancy and Fraser used both organic and inorganic separation solutions, but for nearly all the present tests an aqueous solution of zinc chloride was used. In order to make a separation the handle of the apparatus was turned so that the well and the galvanized pipe were connected and in alignment. Two hundred grammes of coal were then poured in, and covered with 1,600 c.c. of solution of the desired specific gravity. The contents of the apparatus were then stirred for several minutes, or until the coal was thoroughly wetted, and allowed to stand for five minutes. It was found that in this way a very thorough separation of the "float" and "sink" coal was effected. The handle of the apparatus was then turned round so that the well, containing the "sink," was completely cut off from the galvanized pipe containing the "float." By means of the tilting frame the contents of the pipe were poured on to a filter paper in a Buchner funnel, filtered under suction and washed with water. The float coal was

---

[1] University of Illinois Bull. No. 125 (1921).
Ind. and Eng. Chem., vol. 16-5-501 (1924).

then removed from the filter, air-dried and ground for analysis. In a similar way the sink coal was recovered from the well of the apparatus, after turning the handle back to its original position.

Coal passing through a ¼-inch round hole screen was used in Yancey's tests. In his earlier series of tests a solution of specific gravity of 0·05 higher than that of the coal substance was employed to float the finely disseminated pyritic sulphur; in the later series it was considered that a solution that would float 80 per cent of any coal would also float the finely disseminated pyritic sulphur of that coal and allow the more massive form to sink. After a study of Yancey's reports, the writer became of the opinion that, since no more specific size of coal than that passing a designated screen was recommended, the size of the coal employed was not of great moment, provided that it was not too large to permit a separation of the impurities from the coal; also that there was such a difference in size between the finely divided and heavier pyritic sulphur that the specific gravity of the separating solution could be considerably varied and still divide the pyritic sulphur in the same proportions.

Tables XIV and XV respectively, contain the average apparent specific gravities and chemical analyses, and the screen analyses of the ten coals used in the tests following. The coals were broken either in a Sturtevant rotary crusher, a coffee mill such as is used by grocers, or steel rolls, and it will be seen that there is fair agreement in size between the different samples having the same size designation. The sizes of square screen openings, in inches, at the tops of the columns in Table XV, refer in all cases to the smaller screens.

Tests were first carried out in order to ascertain what changes, if any, particularly in the proportions of pyritic sulphur in float coal (in other words in the determined amounts of finely disseminated pyritic sulphur), were brought about by the use of finer sizes than the Sturtevant size of coal as generally employed. Table XVI shows the figures obtained with two coals, one of them in three different sizes (*see* also Table XV), and indicates that there is little difference produced in the proportions separated into float and sink by a change from Sturtevant to coffee mill size, but that a considerable alteration is produced by a further change to rolls size. This is particularly noticeable in the pyritic sulphur separation, for the amount in the float, or the finely disseminated variety, is much greater in the rolls size than in the other two. This indicates that crushing to finer than coffee mill size produces fine pyritic sulphur from the larger nodules, and that therefore it is not advisable to use smaller coal than coffee mill size for the tests.

Table XVI also shows the amounts of the sulphate, pyritic and organic sulphur lost during the separations, as percentages both of the individual forms and of the total sulphur content. The sulphate sulphur is very largely removed by solution, particularly from coal No. 2290, in fact subsequent data on the coals tested showed that it is exceptional for as much as fifty per cent of the original sulphate sulphur to remain in the floats and sinks. The table also shows that there is sometimes an apparent gain in the total amount of pyritic sulphur, often accompanied by a corresponding loss of organic sulphur. In such cases the organic sulphur appears to have been altered to a condition in which it is attacked by the dilute nitric acid used for the determination of pyritic sulphur.

In order to test the theory already propounded, that for any coal the specific gravity of the separating solution could be varied and still divide the pyritic sulphur in about the same proportions, series of separations were carried out with sample No. 2341 from Sydney Mines, and No. 2290 from Minto. The figures obtained from these separations are given in Table XVII. These in turn are shown graphically in Figure 6 in which the ordinates represent the yields of float coal, and the abscissæ the pyritic sulphur in the floats, each as percentages of the coal as used for the separations. In addition to those from zinc chloride solution separations, Table XVII contains the results of two separations with organic liquids, but these are not shown in the diagram.

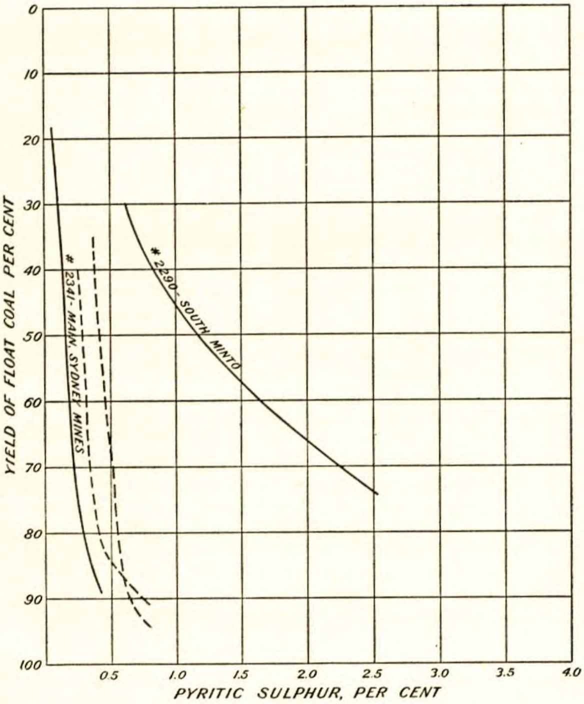


Figure 6. Curves showing relation of pyritic sulphur content to yield of float coal in South Minto and main Sydney Mines coals.

The curves obtained from Sydney Mines (Main seam) and Minto coals have been plotted alongside the dotted curves obtained by Yancey and Parr from Illinois and Pennsylvania coals. The dotted curves are only approximately correct, the points having been taken from small printed diagrams, but show the general trend of the curves obtained at Illinois. It will be seen that the slopes of these curves are not far from perpendicular, indicating reasonably constant percentages of pyritic sulphur, until yields of 80 to 90 per cent of float coal are obtained, after which the percentages of pyritic sulphur in the floats rapidly increase. On this account it was considered that the solution floating 80 per cent of a coal would also float the major portion of the finely disseminated pyritic sulphur and allow the heavier forms to sink.

It will be observed that the curve obtained from the Sydney Mines (Main seam) coal is of the same general nature as the dotted curves, though it has not been extended far enough to show a sharp bend to the right. This is in agreement with the theory that there is such a difference in size between the finely divided and heavier pyritic sulphur that the specific gravity of the separating solution may be considerably varied, and still divide the pyritic sulphur in about the same proportions. On the other hand the curve for the Minto coal, with high sulphur and ash contents, slopes across the diagram in such a way as to show that gradual increases of specific gravity of the separating liquid result in gradual increases in the amounts of pyritic sulphur in the float coal. This indicates that there may be no distinct break between the finely disseminated and coarser pyritic sulphur, and makes the differentiation between the two forms more difficult.

The last two lines in Table XVII show the results of separations with organic liquids, the first with a mixture of carbon tetrachloride and ethyl alcohol, the second with carbon tetrachloride alone. The general procedure was the same as that adopted with the zinc chloride separations, except that the coal was washed with the particular liquid used for the separation instead of water. It will be noted that the total sulphur losses during the separations with organic liquids were very much less than the corresponding losses with solutions of zinc chloride. The losses of organic sulphur were considerably greater, but these were compensated for by the apparent gains in inorganic sulphur, even the sulphate form showing slight increases. Apparently, therefore, some of the organic sulphur is altered in such a way that it is readily attacked by nitric acid of 1·12 specific gravity, and some of it even by the dilute hydrochloric acid used to dissolve the sulphate sulphur.

As had been planned at the outset of the present work, separations were made with the whole ten coals, described in Table XIV, with *(a)* such solutions as floated about 80 per cent of the coal, and *(b)* solutions having respective specific gravities 0·05 higher than those of the individual coals. The results of these are shown in Tables XVIII and XIX, and it will be noticed, in the first table, that there was very seldom 80 per cent of float coal. The value aimed at was 75 to 80 per cent, but this was not attained owing to the fact that the float coal as originally weighed contained more moisture than anticipated, thereby misleading the chemist looking after the separations. However, since the average mechanical loss per separation amounted to something over three per cent of the weight of the coal used, it was considered that the results in Table XVIII were close enough to 80 per cent.

It was found that in five cases solutions of specific gravities 0·05 higher than those of the coals also floated about 80 per cent of each of the coals. In other words, the pyritic sulphur in each of these five coals was divided in the same proportions either by a solution floating 80 per cent of the coal or by one with a specific gravity 0·05 higher than that of the coal. This, according to the writer's first theory, should have been the case with all ten samples, and was actually the case with most of the coals except those from Minto. Apparently the Minto coals and the coal from River Hebert either contain pyritic sulphur of all sizes so that there is no distinct break between the finely disseminated and coarser varieties, or have such a high ash content as necessitates heavy separating solutions which float some of the coarser pyrites. For this reason the conclusions following have been based principally upon the results obtained with solutions of specific gravities 0·05 greater than those of the coals.

Tables XVIII and XIX contain full information regarding the two series of separations, the most important data from the standpoint of this paper being the relative values, the percentages of the total recovered pyritic sulphur contained in the floats, and the absolute values, the contents of pyritic sulphur in the floats expressed as percentages of the coals before the separations. Consideration of the combined sixth, seventh, and eighth columns in the tables shows that, as might be expected, the greater proportion of the organic sulphur goes into the float coal, while as a general rule the recovered sulphate sulphur is comparatively evenly divided between the floats and sinks. Owing to the different sizes of pyrites, there are considerable variations between the percentages of pyritic sulphur in the floats obtained from the different coals, and these percentages appear to be as great for some of the Sydney coals as for some of the Minto coals. However, the corresponding values in the thirteenth columns show that the total percentages of finely disseminated pyritic sulphur are much less in most of the Sydney coals than in the Minto coals containing large percentages of total sulphur. Unless, therefore, the ratio between the finely disseminated and coarser pyritic sulphur (and possibly the other forms of sulphur) bears any relation to liability to spontaneous combustion, the conclusion may be arrived at that spontaneous heating due to finely disseminated pyritic sulphur would more readily occur in the Minto than in the Sydney coals. The sample from the Toronto seam is an exception to this, and will be dealt with subsequently.

The figures in either of the two tables show clearly that the Minto coals in the raw or untreated condition contain more finely disseminated pyritic sulphur than the other coals tested, while the Glace Bay coals, together with Sydney Mines coal from the Main seam, contain less of this form. It seems, therefore, that from its nature the pyritic sulphur in the Minto coals might perhaps cause or promote spontaneous combustion. The sample from the Toronto seam at Sydney Mines contained a comparatively large percentage of finely divided pyrites, some of which (as will be shown) had already undergone oxidation to sulphate, so that coal from this seam might be more liable to spontaneous ignition than the other coals from the Sydney area. Joggins Area coals (Nos. 2311 and 2315) contain relatively high percentages of finely disseminated pyritic sulphur, while the Inverness coal, with a large total sulphur content, has less than would have been expected. However, the Inverness coal, having a high moisture and oxygen content, would from its chemical nature be more liable to spontaneous heating than the other coals. For the same reason coals from the Joggins area and the Toronto seam would probably show a somewhat greater tendency to heat in storage than the average run of bituminous coal.

All but one of the laboratory samples under discussion were second samples from the 125-pound bag lots collected by the writer in 1923, and were given the same numbers as the earlier laboratory samples. It may be reasonably supposed that the analyses of two distinct samples of any one of these coals, taken at the same time, would as a general rule agree closely, and that therefore any considerable differences between the present and the earlier series of samples may be considered as the results of oxidation. The following figures show the percentages of sulphur present as sulphate, in 1923 and 1926 respectively, in six of the coals which were analysed for forms of sulphur three years ago.

Sample No.	1923*	1926	Increase
	p.c.	p.c.	p.c.
2289 S. Minto	0·27	0·66	0·39
2315 Joggins	1·18	1·28	0·10
2337 Inverness	1·62	1·41	−0·21
2338 Sydney Mines	0·69	1·19	0·50
2341 Sydney Mines	0·21	0·25	0·04
2359 Glace Bay	0·22	0·37	0·15

(*The 1923 figures have been altered in order to conform to the ash and moisture contents of the 1926 samples.)

In every case but one (in which there was probably an abnormal sampling error) these coals contained more sulphate sulphur in 1926 than they did three years previously, and this must have been produced by the oxidation of pyrites. The oxidations taking place in the Minto and Sydney Mines, Toronto (No. 2338), coals were much greater than those in the other coals, which fact is in agreement with the theory that the large amounts of finely disseminated pyritic sulphur in the coals specified would promote rapid oxidation, and generate heat in the coals when in storage.

Consideration of the Tables XVIII and XIX show that there was a great deal of variation in the proportions of the forms of sulphur, and of the ash, lost during the separations of the several coal samples. Apparently the various forms of sulphur were affected by contact with the zinc chloride solution in such a way that they were more or less readily attacked by the acids which would not dissolve them previous to the separations. While it was generally the case that there was a loss of organic sulphur, that is that it was affected in such a way as to cause it to be readily attacked by dilute nitric acid and therefore included with the pyritic form, with the Joggins area (Nos. 2311 and 2315) coals and the Inverness coal there was little loss of, or apparent change in, the organic sulphur content. In the case of coal No. 2311 there was actually an apparent gain in organic sulphur, accompanied by a considerable apparent loss of pyritic sulphur. There was nearly always a certain amount of ash lost during the separations, and this was particularly marked where a high loss or solution of sulphate sulphur occurred.

The separations with zinc chloride solutions, as just described, in most cases effect a much greater removal of ash and sulphur than would be brought about in any commercial coal-cleaning operation. However, there have been assembled in Table XX the percentages of total sulphur, ash, and of the coal itself removed in the "sinks," which correspond to the refuse material in coal-cleaning. These show that any very great reduction in sulphur and ash would be accompanied by a considerable loss of coal, and that on this account only the heavier solutions produce such separations as would resemble those obtained in commercial practice. The table as a whole serves as an indication of what might be expected under various coal-cleaning conditions.

The writer wishes to acknowledge his indebtedness to J. D. Johnston and J. L. Bowlby, who made a large number of the analyses and carried out all the "float" and "sink" separations. In addition they were responsible for many helpful suggestions.

Other analyses were carried out by G. E. LeWorthy and K. W. Bowles.

SUMMARY

Typical western Canadian coals were analysed for sulphate, pyritic and organic sulphur, and the following conclusions drawn:—

None of the coking coals from the Mountain Park or the two Crowsnest Pass areas contain any appreciable amount of pyritic sulphur, nor do the partly coking coals from the Nanaimo area contain much of this form of sulphur. The sample of coking coal from the Comox area contained considerable pyritic sulphur, but this would be reduced by washing.

Alberta coals, other than those which coke, do not contain much inorganic sulphur, with the exception of those occurring in the Taber, Magrath, and Lundbreck areas, and even in those areas the content is not large.

The two Saskatchewan coals analysed came from a little-developed area; they were found to contain a considerable percentage of both pyritic and sulphate sulphur.

Cokes made from Maritime Provinces' coals, either alone or blended with United States coals, and one coke made from Comox, B.C., coal, were analysed for sulphide, sulphate, free and solid solution sulphur. It was found that:—

The coke made from Springhill coal was the only one with a low enough sulphur content to be classed as a good metallurgical coke.

The cokes made from the Sydney (unwashed) and Comox (washed) coals contained a little too much sulphur to be classed as satisfactory metallurgical cokes.

The cokes made from Minto coal contained such a large percentage of sulphur as to render them unsatisfactory for almost any purpose whatever. However, coal-washing, which would be necessary on account of the high percentage of ash, would greatly reduce the sulphur content.

If, owing to depletion of low sulphur coals, it should become necessary to manufacture coke from coals of high sulphur content, and to subsequently reduce the amount of this sulphur with steam or some gas, it would be found that coke made from Minto coal yielded readily to such treatment, having a large percentage of its total sulphur content removable.

"Float" and "sink" separation tests were made with Maritime Provinces' coals of high sulphur content primarily in order to estimate the amount of finely disseminated pyritic sulphur, this being a possible source, though not generally the principal cause, of spontaneous combustion. It was found that:—

Coal passing through a ¼-inch screen is suitable for the separations, provided that it is not so small as rolls size, or crushed so finely that it passes through a square opening of 0·09 inches.

Considerable variations in the specific gravities of the separating solutions did not to any extent affect the division of pyritic sulphur in coals with low ash contents, but such variations might affect such a division in coals containing large percentages of ash. For instance, the results of two series of tests, employing respectively *(a)* solutions with specific gravities 0·05 higher than those of the coals, and *(b)* such solutions as would float 80 per cent of each of the coals, were similar for the Sydney coals of low or medium ash contents, but different for the Minto coal with abnormally high ash and sulphur content. It was considered that the first type of solution was preferable to the second type for separating finely disseminated from coarser pyritic sulphur.

The results of the tests showed that:—

The Minto coals, and the sample from the Toronto seam at Sydney Mines, contain a comparatively large amount of finely disseminated pyritic sulphur, which may render them somewhat liable to spontaneous combustion. During three years' storage of small samples of these coals a considerable quantity of pyritic sulphur was oxidized to sulphate sulphur. Such oxidation would cause heating in coal piles, and would therefore be likely to bring about, or promote, spontaneous combustion.

The Joggins coals also contain a considerable amount of finely disseminated pyritic sulphur, though not so much as the Minto coals, while the Inverness coal contains somewhat less fine pyritic sulphur than would be expected in a coal of so high a sulphur content. All these coals would, from the chemical nature of their carbonaceous material, be probably more liable to spontaneous heating than the average run of bituminous coal.

The coals from the Glace Bay (Dominion) mines, and those from the principal, or Main, seam at Sydney Mines contain a comparatively small amount of finely disseminated pyritic sulphur. This, however, represents a large percentage of the total pyritic sulphur in these coals.

A table is given showing the percentages of sulphur, ash, and coal proper contained in the "sink" from each separation in the two principal series of tests. This "sink" corresponds to the refuse obtained in coal-cleaning operations.

TABLE XII

Forms of Sulphur in Western Canadian Coals

Sample No.	Description of coal		Sulphur determined				Percentages of total sulphur		
	Location	Area	Total	Sulphate	Pyritic	Organic	Sulphate	Pyritic	Organic
	Saskatchewan								
2773	Lapointe mine, near Willowbunch	Willowbunch	0·65	0·06	0·32	0·27	9·2	49·3	41·5
2770	Woodend mine, near Mitchellton	"	1·95	0·66	0·70	0·59	33·8	35·9	30·3
	Alberta								
2930	From near Wainwright	Wainwright	0·93	0·02	0·12	0·79	2·2	12·9	84·9
2747	Majestic mine, Taber	Taber	1·18	0·07	0·32	0·79	5·9	27·1	67·0
N12	Kleenbirn, Eyremore	Brooks	0·84	0·02	0·19	0·63	2·4	22·6	75·0
2746	Rose Deer, Wayne	Drumheller	0·49	trace	0·05	0·44	trace	10·2	89·8
N5	North Star, Alix	Ardley	0·47	trace	0·05	0·42	trace	10·6	89·4
2745	Canadian Coal, Cardiff	Edmonton	0·28	0·01	nil	0·27	3·6	nil	96·4
N42	"Wall" mine, Magrath	Magrath	1·63	0·03	0·88	0·72	1·8	54·0	44·2
3028	Galt, Lethbridge	Lethbridge	0·65	trace	0·06	0·59	trace	9·2	90·8
N2	Garrett, Lundbreck	Pincher	0·98	0·01	0·34	0·63	1·0	34·7	64·3
3019	Bighorn and Saunders creeks	Saunders	0·34	trace	0·02	0·32	trace	5·9	94·1
2621	McLeod river, near Coalspur	Coalspur	0·27	trace	0·04	0·23	trace	14·8	85·2
N1	Hillcrest	Crowsnest Pass	0·68	0·01	0·29	0·38	1·5	42·6	55·9
N22	Bellevue	" "	0·48	0·01	0·09	0·38	2·1	18·7	79·2
N23	Greenhill	" "	0·44	nil	0·02	0·42	nil	4·5	95·5
N46	" crude	" "	0·36	trace	0·02	0·34	trace	5·6	94·4
N47	" washed	" "	0·42	trace	0·04	0·38	trace	9·5	90·5
N17	International, Coleman	" "	0·50	0·02	0·05	0·43	4·0	10·0	86·0
N21	McGillivray creek, Coleman	" "	0·63	0·02	0·16	0·45	3·2	25·4	71·4
2896	Kananaskis river	Highwood or Cascade	1·18	0·03	0·17	0·98	2·5	14·4	83·1
3031	Canmore	Cascade	0·74	trace	0·08	0·66	trace	10·8	89·2
2918	Mountain Park	Mountain Park	0·45	nil	0·01	0·44	nil	2·2	97·8
2892	Smoky river	Smoky River	0·35	trace	trace	0·35	trace	trace	<100·0

TABLE XII—Concluded

Forms of Sulphur in Western Canadian Coals—Concluded

Sample No.	Description of coal		Sulphur determined				Percentages of total sulphur		
	Location	Area	Total	Sulphate	Pyritic	Organic	Sulphate	Pyritic	Organic
	British Columbia								
N44	Corbin, crude	Crowsnest Pass	0·21	nil	nil	0·21	nil	nil	100·0
N43	" washed	" "	0·26	nil	nil	0·26	nil	nil	100·0
N31	Michel No. 3	" "	0·37	nil	nil	0·37	nil	nil	100·0
N32	"	" "	0·49	trace	0·02	0·47	trace	4·1	95·9
N27	Coal Creek No. 1	" "	0·32	trace	0·01	0·31	trace	3·2	96·8
N28	" No. 2	" "	0·39	trace	0·01	0·38	trace	2·5	97·5
N29	" No. 3	" "	0·67	trace	0·01	0·66	trace	1·5	98·5
N30	" No. 8	" "	0·51	trace	0·01	0·50	trace	2·0	98·0
2220	Peace River block	Peace River	0·71	0·01	0·01	0·69	1·4	1·4	97·2
2489	Princeton Coal & Land Company	Princeton	0·62	trace	0·04	0·58	trace	6·5	93·5
N7	Middlesboro No. 1	Nicola	0·81	nil	0·03	0·78	nil	3·7	96·3
N8	Middlesboro No. 4	"	0·59	nil	0·03	0·56	nil	5·1	94·9
N15	Granby, Cassidy, crude	Nanaimo	0·52	trace	0·13	0·39	trace	25·0	75·0
N16	" " washed pea and slack	"	0·55	trace	0·06	0·49	trace	10·9	89·1
N18	Nanaimo, Newcastle	"	1·63	0·07	0·61	0·95	4·3	37·4	58·3
N19	" Douglas	"	0·56	trace	0·03	0·53	trace	5·4	94·6
2800	" Reserve, Douglas	"	1·59	0·08	0·35	1·16	5·0	22·0	73·0
N20	" Wellington	"	0·46	trace	0·04	0·42	trace	8·7	91·3
N13	Ladysmith, Douglas	"	0·50	0·03	0·09	0·38	6·0	18·0	76·0
N14	" Wellington	"	0·53	0·01	0·06	0·46	1·9	11·3	86·8
N9	Comox, Union Bay, crushed lump	Comox	1·03	0·06	0·36	0·61	5·8	35·0	59·2
N10	Comox, Union Bay, washed pea	"	1·09	0·05	0·33	0·71	4·6	30·3	65·1

TABLE XIII

Forms of Sulphur in Canadian Cokes

Sample No.	Description of coke	Sulphur, total	Sulphide	Sulphate	Free sulphur	Solid solution sulphur	Ash
		p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
2676	Sydney	2·00	0·95 47·5*	0·05 2·5*	0·13 6·5*	0·87 43·5*	11·6
2677	Sydney-Pocohontas	1·71	0·88 51·4*	0·05 2·9*	0·16 9·4*	0·62 36·3*	12·0
2669	Springhill	1·18	0·12 10·2*	0·09 7·6*	0·30 25·4*	0·67 56·8*	13·2
2665	Minto-Elkhorn-Pocohontas	5·08	3·00 59·0*	0·02 0·4*	0·34 6·7*	1·72 33·9*	25·0
2664	" "	4·68	2·32 49·5*	0·06 1·3*	0·44 9·4*	1·86 39·8*	22·3
N11	Comox	1·90	0·65 34·2*	0·10 5·3*	0·21 11·1*	0·94 49·4*	18·1

*These are the percentages of the various forms of sulphur in the total sulphur.

TABLE XIV

Analyses of Coal Samples Used for Tests

Sample No.	Description of coal	Specific gravity	Moisture, per cent	Ash, per cent	Sulphur, per cent			
					Total	Sulphate	Pyritic	Organic
2289	South Minto	1·36	2·2	14·2	6·48	0·66	3·56	2·26
2290	South Minto	1·43	3·5	17·6	8·01	1·01	4·65	2·35
2292	North Minto	1·30	2·5	17·0	6·77	0·67	3·93	2·17
2311	River Hebert	1·34	5·2	16·7	5·58	0·61	3·47	1·50
2315	Joggins	1·50	5·5	17·6	6·73	1·28	3·23	2·22
2337	Inverness	1·42	9·2	12·0	7·04	1·41	3·31	2·32
2338	Toronto, Sydney Mines	1·37	4·9	12·5	6·31	1·19	3·23	1·89
2341	Main, Sydney Mines	1·26	3·5	8·7	2·16	0·25	1·20	0·71
2359	Phalen, Glace Bay	1·22	2·9	7·7	2·48	0·37	1·37	0·74
2644	Dominion Coal	1·24	3·2	7·5	2·41	0·14	1·38	0·89

TABLE XV

Screen Analyses

Sample No.	Description of coal	On 4 (0·185") mesh	4 to 8 (0·093") mesh	8 to 10 (0·065") mesh	10 to 35 (0·0164") mesh	35 to 65 (0·0082") mesh	Through 65 (0·0082") mesh	Total through 10 (0·065") mesh
2359	Phalen, Glace Bay, Sturtevant size	5·3	27·1	15·8	32·1	7·5	12·2	51·8
2290	S. Minto, Sturtevant size	10·4	32·2	14·6	26·2	6·5	10·1	42·8
	" Coffee Mill size	....	21·2	24·5	37·9	6·8	9·6	54·3
	" Rolls size	....	2·0	13·4	53·4	12·6	18·6	84·6
2289	" Sturtevant size	11·2	31·9	14·6	26·2	6·3	9·8	42·3
2311	River Hebert, Sturtevant size	16·4	30·3	12·8	25·1	6·4	9·0	40·5
2292	N. Minto, Sturtevant size	11·8	33·9	14·1	24·3	6·6	9·3	40·2
2338	Toronto, Sydney Mines, Sturtevant size	10·3	37·8	16·6	24·3	5·2	5·8	35·3
2337	Inverness, Sturtevant size	14·3	35·9	14·8	23·9	4·8	6·3	35·0
2315	Joggins, Sturtevant size	23·9	37·3	12·0	18·4	3·4	5·0	26·8
2341	Main, Sydney Mines, Sturtevant size	22·2	42·9	11·8	16·1	2·8	4·2	23·1
	Main, Sydney Mines, Coffee Mill size	....	37·7	21·9	30·5	4·9	5·0	40·4
2644	Dominion coal, Sturtevant size	33·8	34·9	10·1	15·5	2·6	3·1	21·2

TABLE XVI

Separations With Different Sizes of the Same Coal

No. 2290 with solution of 1·35 specific gravity
No. 2341 " 1·27 "

Sample No.	Size	Yields on basis of coal as separated		Recovered sulphur percentages in floats and sinks						Percentages of forms of sulphur lost in separations			Forms of sulphur lost as percentages of total sulphur		
				Sulphate		Pyritic		Organic							
		Float	Sink	Float	Sink	Float	Sink	Float	Sink	Sulphate	Pyritic	Organic	Sulphate	Pyritic	Organic
		p.c.	p.c.												
2290	Sturtevant.	39·2	56·3	29	71	17	83	33	67	71	−5·3	13·3	8·9	−3·1	3·9
	Coffee Mill......	42·2	54·1	32	68	18	82	34	66	66	−14·1	16·5	8·3	−8·2	4·8
	Rolls......	57·0	35·7	48	52	39	61	51	49	71	−0·5	4·7	9·0	−0·3	1·4
2341	Sturtevant.	66·3	33·0	28	72	17	83	59	41	45	19·0	15·0	5·1	10·6	5·1
	Coffee Mill......	59·8	37·4	34	66	16	84	54	46	39	19·0	16·0	4·5	10·6	5·3

TABLE XVII

Separations of Individual Coals with Solutions of Different Specific Gravities

(Sturtevant size coals)

Specific gravity of solution	Yields, basis of coal as separated		Percentage in floats of total recovered amount of each form of sulphur			Pyritic sulphur in float as percentage of coal as separated	Ash in float, per cent	Forms of sulphur lost as percentages of total sulphur		
	Float, p.c.	Sink, p.c.	Sulphate	Pyritic	Organic			Sulphate	Pyritic	Organic
					(Sample No. 2341)					
1·25	18·1	80·8	11	5	17	0·06	1·9	7·1	5·3	6·3
1·27	66·3	33·0	28	17	59	0·21	1·8	5·1	10·6	5·1
1·30	81·0	18·1	47	23	80	0·29	2·0	7·2	5·5	5·3
1·37	89·3	10·3	65	36	82	0·43	2·4	6·9	5·7	7·7
					(Sample No. 2290)					
1·30	29·9	64·9	17	13	24	0·61	6·2	8·2	3·8	3·0
1·35	39·2	56·3	29	17	33	0·80	7·5	8·9	−3·1	3·9
1·40	45·9	48·7	28	25	36	1·14	7·8	8·7	5·3	0·1
1·45	57·1	39·1	49	32	53	1·46	8·8	7·9	−4·7	4·5
1·50	62·6	31·4	51	41	58	1·89	9·7	7·9	5·3	−0·5
1·59	74·3	20·5	66	55	78	2·54	12·2	8·6	1·6	5·0
1·49	70·9	27·9	65	50	67	2·32	11·6	−0·8	−0·6	5·8
1·62	74·7	24·1	56	51	75	2·37	11·9	−3·7	−4·3	7·3

TABLE XVIII

Separations of Coals with Solutions Yielding about 80 per cent of Float Coal

(Sturtevant size coals)

Sample No.	Designation	Specific gravity		Float yield, basis of coal as separated	Percentage in float of total recovered amount of each form of sulphur			Forms of sulphur lost as percentages of total sulphur			Sulphur		Ash	
		Coal	Solution		Sulphate	Pyritic	Organic	Sulphate	Pyritic	Organic	Total in coal as separated	Pyritic in float as per cent of coal as separated	Total in coal as separated	Per cent of total lost in separation
											p.c.		p.c.	
2280	S. Minto	1·36	1·50	76·8	63	51	78	4·6	0·5	6·8	6·5	1·84	14·2	−1·4
2290	S. Minto	1·43	1·59	74·3	66	55	78	8·6	1·6	5·0	8·0	2·54	17·7	3·8
2292	N. Minto	1·30	1·49	71·2	58	42	81	5·1	0·0	5·2	6·8	1·64	17·1	−1·7
2311	R. Hebert	1·34	1·46	73·9	66	50	85	4·8	10·6	−1·0	5·6	1·73	16·7	9·9
2315	Joggins	1·50	1·55	73·3	54	43	77	12·1	0·4	1·6	6·7	1·37	17·5	12·9
2337	Inverness	1·42	1·47	73·9	58	34	72	11·4	−1·1	1·2	7·0	1·10	12·0	18·5
2338	Sydney Mines	1·37	1·42	71·5	48	46	66	11·5	−0·9	5·6	6·3	1·47	12·4	17·2
2341	Sydney Mines	1·26	1·30	81·0	47	23	80	7·2	5·5	5·3	2·2	0·28	8·7	9·1
2359	Glace Bay	1·22	1·273	74·9	50	40	74	7·6	13·7	1·1	2·5	0·55	7·7	5·7
2644	Dominion	1·24	1·29	78·5	44	38	76	2·1	0·8	4·6	2·4	0·52	7·5	5·6

TABLE XIX

Separations of Coals with Solutions Having Specific Gravities 0·05 Higher than those of Coals

(Sturtevant size coals)

Sample No.	Designation	Specific gravity		Float yield, basis of coal as separated	Percentage in float of total recovered amount of each form of sulphur			Forms of sulphur lost as percentages of total sulphur			Sulphur		Ash	
		Coal	Solution		Sulphate	Pyritic	Organic	Sulphate	Pyritic	Organic	Total in coal as separated	Pyritic in float as per cent of coal as separated	Total in coal as separated	Per cent of total lost in separation
											p.c.		p.c.	
2289	S. Minto	1·36	1·41	64·4	49	37	64	6·6	−5·0	4·3	6·5	1·29	14·2	−2·3
2290	S. Minto	1·43	1·50	62·6	51	41	58	7·9	5·3	−0·5	8·0	1·89	17·7	7·2
2292	N. Minto	1·30	1·35	56·7	34	26	55	7·0	−4·2	2·7	6·8	1·03	17·1	0·2
2311	River Hebert	1·34	1·39	63·5	56	35	75	5·7	5·6	−0·8	5·6	1·20	16·7	8·1
2315	Joggins	1·50	1·55	73·3	54	43	77	12·1	0·4	1·6	6·7	1·37	17·5	12·9
2337	Inverness	1·42	1·47	73·9	58	34	72	11·4	−1·1	1·2	7·0	1·10	12·0	18·5
2338	Sydney Mines	1·37	1·42	71·5	48	46	66	11·5	−0·9	5·6	6·3	1·47	12·4	17·2
2341	Sydney Mines	1·26	1·30	81·0	47	23	80	7·2	5·5	5·3	2·2	0·28	8·7	9·1
2359	Glace Bay	1·22	1·27	74·3	54	48	75	9·4	9·5	0·9	2·5	0·66	7·7	14·4
2644	Dominion	1·24	1·29	78·5	44	38	76	2·1	0·8	4·6	2·4	0·52	7·5	5·6

TABLE XX

Sulphur and Ash Removed from Coal by Separations with Zinc Chloride Solutions

Sample No.	Designation	Percentage of total sulphur removed	Percentage of ash removed	Percentage of coal substance removed	Sulphur reduced		Ash reduced	
					From	To	From	To
					p.c.	p.c.	p.c.	p.c.
	Separations with solutions having specific gravities 0·05 higher than those of coals							
2289	S. Minto.............	57	67	22	6·5	4·4	14·2	7·4
2290	S. Minto.............	59	66	20	8·0	5·4	17·7	9·7
2292	N. Minto.............	67	78	24	6·8	4·0	17·1	6·6
2311	River Hebert.........	57	74	19	5·6	3·8	16·7	7·0
2315	Joggins...............	52	64	10	6·7	4·5	17·5	8·8
2337	Inverness.............	56	68	12	7·0	4·1	12·0	5·2
2338	Sydney Mines......	57	68	15	6·3	3·9	12·4	5·7
2341		64	81	10	2·2	1·0	8·7	2·0
2359	Glace Bay...........	54	61	19	2·5	1·6	7·7	4·0
2644	Dominion............	53	65	15	2·4	1·4	7·5	3·3
	Separations with solutions yielding about 80 per cent of float coal							
2289	S. Minto.............	46	50	13	6·5	4·5	14·2	9·3
2290	S. Minto.............	48	50	12	8·0	5·8	17·7	12·2
2292	N. Minto.............	51	63	14	6·8	4·7	17·1	8·9
2311	River Hebert.........	46	64	11	5·6	4·1	16·7	8·2
2315	Joggins...............	52	64	10	6·7	4·5	17·5	8·8
2337	Inverness.............	56	68	12	7·0	4·1	12·0	5·2
2338	Sydney Mines......	57	68	15	6·3	3·9	12·4	5·7
2341		64	81	10	2·2	1·0	8·7	2·0
2359	Glace Bay...........	58	56	19	2·5	1·4	7·7	4·5
2644	Dominion............	53	65	15	2·4	1·4	7·5	3·3

IV

AIR-DRYING OF CANADIAN LIGNITE, AND THE RE-ABSORPTION OF MOISTURE BY THE SAME

J. H. H. Nicolls

A previous report by the writer[1] describes two series of experiments to show the effects of exposing Alberta lignites, either crushed to about ¼-inch size or smaller, or finely ground, to the atmosphere. The first series was carried out at high, summer, humidity and the second at comparatively low, winter (indoor), humidity. The experiments were made not only with raw coals, but also with coals previously dried to a very low moisture content in an electric oven.

The experiments showed distinctly that a coal dried in the electric oven, when exposed to an atmosphere of a certain humidity, would never re-absorb as much moisture as would be contained in another sample of the same coal air-dried in the same atmosphere. In other words, there was in every case a gap between the moisture curve resulting from air-drying and the curve resulting from the re-absorption of moisture. Such a gap was lessened by lowering the humidity of the atmosphere to which the coal was exposed; again, there would be a larger gap in the case of a lignite of high moisture content than in the case of one containing less moisture. The experiments also showed that the respective crushed and ground samples of the same coal lost or re-absorbed moisture until nearly identical moisture contents were obtained in each case, but that the finely ground always either lost a little more moisture than the crushed coal in air-drying or failed to re-absorb quite as much moisture as the crushed coal.

However, for all practical purposes these differences may be disregarded, and so the present experiments were carried out with only finely ground coals. These coals were ground so as to pass through a 35-mesh (0·0164″) sieve, which is somewhat coarser than the ordinary samples as used for analysis. The following are the screen analyses of the Cardiff and Taber coals:—

Mesh	Cardiff	Taber
On 65 (0·0082″)	67·1	55·6
On 100 (0·0058″)	10·9	12·3
On 200 (0·0029″)	11·2	11·8
Through 200 (0·0029″)	10·8	20·3

---

[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1924, p. 36.

It was thought that the failure of the coal dried in the electric oven to re-absorb moisture until the moisture content of the air-dried coal was reached was due to oxidation in the drying oven, for, although a current of carbon dioxide was passed through the oven, the fact that spontaneous combustion occurred showed that a considerable oxidation must have taken place. The first of the present series of experiments was undertaken with the purpose of preventing oxidation, or of allowing very little of it to occur, during drying. For this purpose the scale of the experiments had to be changed from samples weighing from 300 to 900 grammes to those weighing only 4 grammes. However, it is believed that the results of the series are comparable, the only probable differences being that in the smaller scale experiments the percentage loss, or gain, in moisture during the first one or two days may be greater than in corresponding larger scale experiments. After two days' exposure it is believed that the results of the different scale experiments will be quite comparable.

For the first of the present series of experiments samples of the ground Cardiff and Taber coals were spread on 3-inch watch glasses and dried in an evacuated desiccator over concentrated sulphuric acid for three days, or until practically all the moisture was removed. At the same time as the drying was begun, another similar sample of each of the coals was placed in a desiccator (not evacuated) over a calcium chloride solution of 1·30 specific gravity, by means of which a relative humidity of 60 per cent was maintained in the desiccator. After drying, the first two samples were put into the desiccator over calcium chloride, and the four samples allowed to remain there until it was evident, from frequent weighings, that absorption or loss of moisture was practically complete. In order that an atmosphere of 60 per cent humidity might be maintained, the coal samples were occasionally changed from the first desiccator to a second one containing fresh calcium chloride solution, and subsequently back to the first desiccator which had been re-filled with the chloride solution. This was the regular procedure in all the present small-scale experiments.

Figures 7 and 8 show the moisture content curves for the Cardiff and Taber coals, the curves for the present series being given as dotted lines. For the sake of comparison the curves for the series of two years ago, in which the finely ground coals were dried in an electric oven, are shown as solid lines. The curves have been plotted so that any two points in the curves vertically in line represent the same day, and, therefore, the same humidity condition for each of the corresponding drying or absorption curves. There is little difference between the two drying curves for each coal, but a great deal of difference between the re-absorption curves. The coals dried over sulphuric acid re-absorb moisture with much greater rapidity than those dried in the oven, the maximum moisture contents being practically attained at the first weighing, or two days after exposure to an atmosphere of 60 per cent humidity. It is very probable that the maximum moisture contents were attained in one day, or even less, whereas from six to eleven days were required by the coals dried in the oven. Allowances must be made for the differences in volume between the samples, but it is not considered that this would nearly account for the differences in the time of moisture absorption.

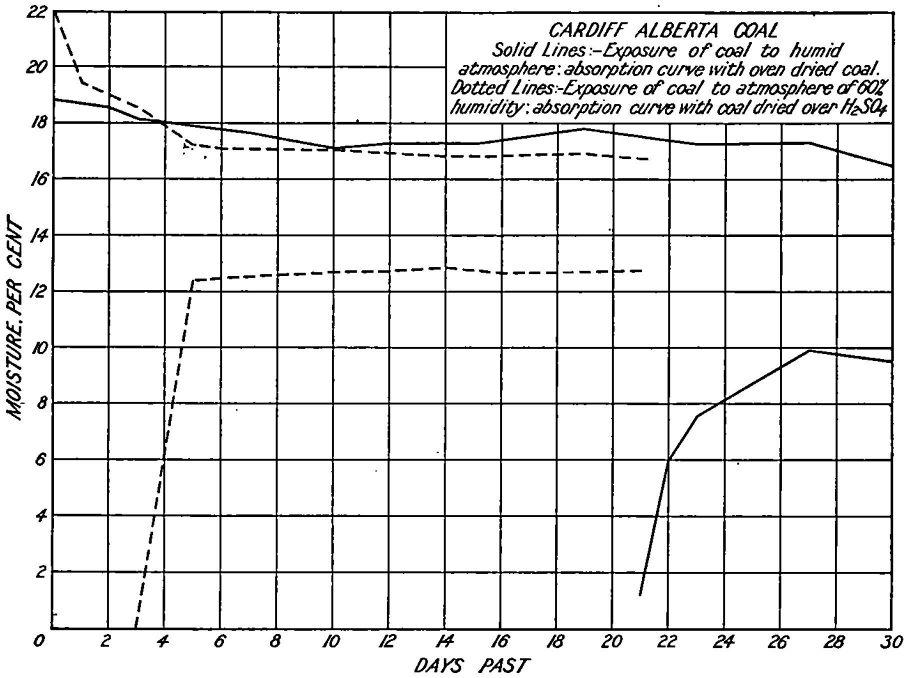


Figure 7. Cardiff, Alberta, coal: effect of exposure to humid atmosphere.

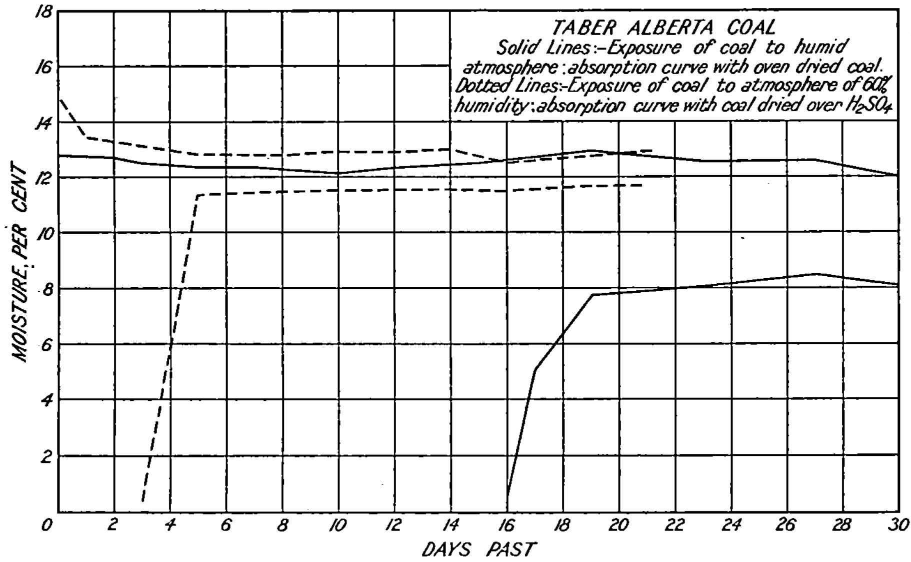


Figure 8. Taber, Alberta, coal: effect of exposure to humid atmosphere.

Furthermore, coal dried over sulphuric acid re-absorbs considerably more moisture than the same coal dried in the oven, so that oxidation, or whatever prevents the re-absorption of moisture, has taken place to a lesser degree. However, even the coal dried under moderate conditions over sulphuric acid will not re-absorb as much moisture as is contained in the corresponding air-dried coal. The gap referred to in an earlier paragraph as occurring between the drying and absorption curves seems bound to be present, by no matter what means the coal is dried before exposure to the humid atmosphere. The points shown on the dotted curves are values calculated from the initial moisture contents and the subsequent changes in weight of the coals, as the final moisture contents determined by drying the coals (following exposure to 60 per cent humidity) over sulphuric acid were not considered to be satisfactory owing to loss of coal from one or more of the samples.

Since it had been shown that a gap always occurs between the curve for air-drying of a raw coal and the moisture re-absorption curve for the same coal after drying, it was next decided to ascertain what changes would occur in these curves if the coal samples were wetted with water previous to exposure. First, two samples of raw Cardiff coal, one of which had previously been soaked in distilled water for four weeks, were dried in a desiccator in an atmosphere of 60 per cent relative humidity. It was found that, after four days' exposure, the moisture contents of the two samples were nearly the same, and that, after fourteen days' exposure, the difference between them amounted to less than the average experimental error. Similar tests with crushed lignite from Estevan area, Saskatchewan, on a larger scale in the standard air-drying apparatus, revealed the fact that, after three days' drying, there was no more moisture in the portion of the coal that had been wetted than in the portion that had been put to air-dry in its natural raw condition.

For the next experiment two samples of Cardiff coal were dried in the toluol oven for twenty-four hours in all. One of these was then wetted with water, and both of them put into a desiccator over calcium chloride solution, together with two samples of the raw coal, one of which had been wetted with water. During seventeen days' exposure over calcium chloride solution the samples were weighed frequently, and at the end of that time their moisture contents were determined in the toluol oven. The following were the percentages of moisture, calculated from the initial moisture content, in each of the four samples: *(a)* in the raw coal, 17·6 per cent; *(b)* in the raw coal with water added, 17·5 per cent; *(c)* in the dried coal, 13·7 per cent; *(d)* in the dried coal with water added, 14·7 per cent. The moisture contents determined in the toluol oven at the end of the experiment were as follows: *(a)* 16·3 per cent; *(b)* 16·0 per cent; *(c)* 12·5 per cent; *(d)* 14·3 per cent. There must, therefore, have been gains in weight of something other than moisture, probably of oxygen and carbon dioxide, by the coal samples, quite independently of whether they were drying or absorbing moisture.

It is clear that wetting the dried coal will not cause it to retain as much moisture as is retained by the corresponding air-dried coal, and that there will still be a gap between the two curves. To test this still further, Cardiff coal was dried in the toluol oven for sixteen to eighteen hours, and then soaked in distilled water for one week. Even after this treatment the coal would only retain 12·9 per cent of moisture (determined in the toluol oven) as against 16·3 per cent in the raw coal exposed at the same time over the calcium chloride solution.

The foregoing experiments indicated that the more prolonged or severe the drying conditions to which a coal was exposed, the less moisture it would re-absorb. To further test this the following series of experiments was carried out. Small samples of Cardiff coal were dried in the toluol oven to different moisture percentages varying from 16·7 to 1·5 per cent (for periods of drying of from ten to thirty minutes), and then exposed to the 60 per cent humidity atmosphere over calcium chloride solution. The curves for re-absorption of moisture are shown in Figure 9, for which the moisture values have been calculated from the initial moisture content of the coal rather than from the moisture determined following the re-absorption, which was again found to give somewhat lower values. The points where the curves cut the vertical axis represent in all cases the percentages of moisture to which the respective samples were dried. The four lower curves in the diagram represent one exposure over calcium chloride and the two upper curves represent another, which accounts for slight discrepancies in their respective directions. It is clear that the more a coal is dried, under the same conditions, the less moisture it will re-absorb. No weighings were made until two days after the samples were exposed to 60 per cent humidity, so that the portions of the curves at the extreme left do not necessarily show how rapidly the samples re-absorbed moisture during the first few hours. However, it seems clear that, when dealing with samples of a coal dried by the same method and for a comparatively short time, the drier samples will re-absorb the more moisture during the first two days' exposure to a humid atmosphere. On the other

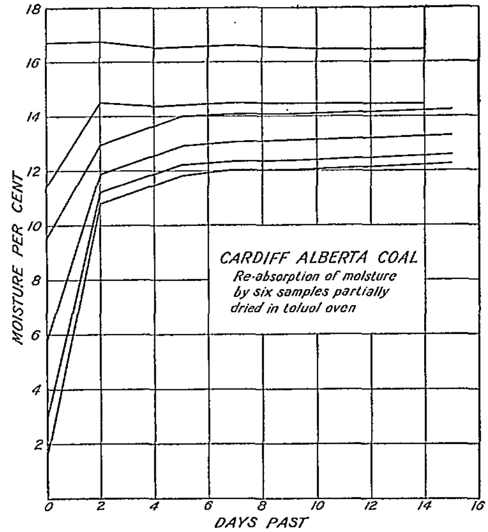


Figure 9. Cardiff, Alberta, coal: re-absorption of moisture by six samples partly dried in toluol oven.

hand, a sample of a coal dried by severe and prolonged heating in an electric oven appeared to re-absorb moisture less rapidly than a sample of the same coal dried at room temperatures over sulphuric acid.

Since the writer's previous paper was written, a good deal of experimental work has been carried out with the standard air-drying apparatus,[1] and a few alterations or modifications made in the original form. The main parts of the apparatus as now used are constructed entirely of sheet iron, which obviates the leaks which occurred as a result of the drying of the wooden parts. It was found that the first motor used gradually became corroded in the fan chamber, so it was replaced by a fresh motor which was mounted on a bracket just outside the elbow of the air circulating pipe, and connected by means of a shaft with the fan, which remained in the chamber. This is running satisfactorily at present, but it is planned to ease the strain on the motor (and also lessen the noise) by shortening the shaft and moving the fan from the chamber into the circulating pipe. It has been found advisable to have a calcium chloride system operating in each of the two pipes, and the wicks in each case suspend a large lead ring (instead of the small weights) which holds them in such a position that the air cannot move them aside in passing and must always come in contact with the calcium chloride solution.

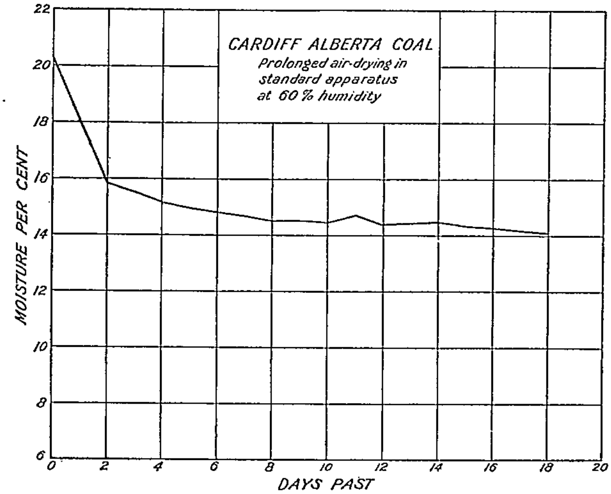


Figure 10. Cardiff, Alberta, coal: prolonged air-drying in standard apparatus at 60 per cent humidity.

Figure 10 shows the average of the curves obtained by prolonged drying of two samples of crushed Cardiff coal, at a time when the apparatus was functioning well and the relative humidity in the drying chamber remained close to 60 per cent. While it seems likely that the loss in weight of the coal would continue indefinitely, but very slowly, it is also clear that it is not great after eight days' drying, in fact for practical purposes air-drying may be stopped at the end of four days. However, in these laboratories seven to eight days' drying is considered advisable with coals containing 15 per cent or more of moisture, as received.

---

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

The samples of Cardiff coal just referred to weighed 400 to 500 grammes, which is about the average weight employed in air-drying. In order to test the effect of changing the weight of the coal used, three samples of high moisture coal from Estevan area were dried for seven days at 60 per cent humidity. The raw coal contained 35·7 per cent of moisture, which was reduced as follows by the seven days' drying: when 1,600 grammes were used the loss was 17·6 per cent, leaving 22·0 per cent moisture in the coal; when 990 grammes were used the loss was 20·5 per cent, leaving 19·1 per cent moisture; when 430 grammes were used the loss was 23·6 per cent, leaving 15·8 per cent of moisture in the coal. The Estevan Area coal contained very high moisture, and is, therefore, an extreme case, but at the same time the tests show the advisability of keeping the weight of coal used in air-drying fairly close to a standard amount.

The following figures show the results of drying different grades of lignite and sub-bituminous coal in the air-drying apparatus, at various relative humidities produced by the use of calcium chloride solutions of different specific gravities. A great many of these figures represent the average of several determinations, and are relative only. They were obtained at a time when the apparatus was running much less evenly than at present, but nevertheless show fairly closely what changes are likely to be brought about by alterations of humidity in the air-drying apparatus.

Coal or area	Original moisture	Relative humidity		
		73 to 74	59 to 62	50 to 53
	p.c.	p.c.	p.c.	p.c.
Estevan	36·2	21·5	16·9	....
Cardiff	22·8	19·7	16·3	17·1
Pond Inlet	18·0	17·5	14·2	....
Drumheller	17·9	16·3	14·5	13·9
Pembina	16·6	15·6	13·6	13·3
Taber	14·2	13·0	11·7	11·6
Saunders	9·5	8·6	7·1	....
Coalspur	8·2	7·9	6·6	6·2

A relative humidity of 60 per cent was selected as the original standard for air-drying, as representing average atmospheric humidity. In Ottawa the average outdoor humidity for two subsequent years was some 84 per cent, whereas the average indoor humidity in these laboratories is about 43 per cent. A value of 60 per cent is not very close to either of these, and, partly for this reason, and in order to draw comparisons, the figures above tabled were obtained. Although the 73 per cent humidity is the closest to the average outdoor humidity, and though the drying of Alberta coals at this humidity gives an indication of the losses to be expected during the commercial shipment of such coals to Winnipeg or eastern Canada, it is not satisfactory on account of the probable losses of moisture during the pulverization of the air-dried coals in the pebble mills prior to further analysis. For the same reason, and also because coals dried at such a humidity would be liable to lose moisture while standing in the laboratory, a relative humidity of 60 per cent was considered to be a little too high for a good standard. Accordingly a humidity of some 52 per cent was maintained in the air-drying apparatus. This lowered the moisture in the air-dried coal very little below that obtained in 60 per cent humidity. Furthermore, the necessarily concentrated solution of calcium chloride was more difficult to handle and maintain constant. It was accordingly decided that a relative humidity of 60 per cent was the most suitable for the air-drying apparatus.

Reference has just been made to the probable loss of moisture by ground coals when standing in the laboratory. In order to ascertain how great a change of moisture content might occur under such conditions, samples of seven lignites and sub-bituminous coals were ground, and allowed to stand in the laboratory for about twenty months. The ground coals were kept in glass-stoppered bottles, of about 125 c.c. capacity, such as are generally used in these laboratories for coal samples, and the moisture contents determined for the first time immediately following grinding. The moistures were determined in a toluol oven, and before weighing each coal sample the contents of the bottle were thoroughly mixed by shaking and stirring.

Table XXI shows the alterations in moisture content of the seven coals over a period beginning in April, 1925, and ending in December, 1926. Moisture determinations were made at regular intervals throughout this period, but a large number of these have been omitted from the table. In a great many instances the moisture contents of the individual coals were not all determined on the same day, which accounts for the occurrence of two dates together in the table. In each case the average relative humidity for the preceding ten days or two weeks has been given. The moisture contents have been tabulated more frequently during the first few months on account of their liability to change during that period, and it will be observed that, with several of the coals, there is a tendency for the determined moisture to increase during the first few weeks.

Before consideration of the latter part of the table it should be realized that the supplies of coal in the 125 c.c. bottles became gradually exhausted by the moisture determinations, and that by December, 1926, there was very little coal left in any of the bottles. The Drumheller coal was absolutely used up for the last moisture determinations. This would, in the writer's opinion, accelerate any drying effect because of the increased air space over the coal, so that the figures in the table probably exaggerate any changes that would occur with full bottles of coal. It seems quite likely that, with full bottles, the lowerings of moisture content would have been much smaller, and that the moistures attained during the second summer would have been almost as high as those of the first summer.

However, the figures show clearly how the moisture contents of the coals altered with changes of atmospheric humidity. In the summer months, when the humidity was high, the moisture contents became greater than they had been during the previous months; whereas in the winter, when the indoor humidity was exceptionally low, all the moistures decreased. The effects of changes of humidity were gradual rather than instantaneous. For instance, the highest moisture contents were found in September, after some three or four months of high humidity, in spite of the fact that the highest humidities occurred in July and August. The results of these tests point to the inadvisability of allowing delay in the analysis of a high-moisture coal, more especially during the winter months.

The writer wishes to acknowledge the valuable assistance of J. D. Johnston, who carried out numerous moisture determinations.

SUMMARY

Series of experiments were carried out principally to investigate the behaviour of dried lignites when exposed to the same atmosphere as lignites in the process of air-drying. As the result of the experiments, the following conclusions have been drawn:—

Dried lignite will not in any case re-absorb as much moisture as is contained in the corresponding air-dried coal.

The less severe the method of drying employed, the more moisture the lignite will re-absorb; conversely the more severe the drying, the less moisture the lignite will re-absorb.

The less severe the method of drying, the more rapidly the lignite will at first re-absorb moisture; however, it seems to be the case that, of two samples dried rapidly under similar conditions, the one with the lower moisture content will re-absorb moisture the more rapidly at first.

The addition of water to lignite, either raw or dried, previous to exposure to the air-drying atmosphere, does not alter the relation between the air-drying and moisture re-absorption curves.

Various alterations in the standard air-drying apparatus are described, and a curve is given for the prolonged air-drying of crushed lignite under reasonably steady humidity conditions. Consideration of this curve points to the advisability of air-drying coals of high-moisture content for seven or eight days. It is also considered advisable to use not more than 600, nor less than 400, grammes of high-moisture coals for air-drying.

Figures are given, showing the moisture remaining in coals of high-moisture content after air-drying at humidities of about 73, 60, and 52 per cent, respectively. Examination of these figures, together with consideration of the manipulation conditions in each case, shows that 60 per cent relative humidity is the most satisfactory for air-drying.

A table is given, showing the alterations of moisture content in ground coal samples standing in the laboratory during twenty months under varying conditions of humidity. The figures in the table show that the coals lose moisture as the room humidity falls, and re-absorb it with increasing humidity. The figures point to the inadvisability of delaying the analyses of ground coals, particularly in the winter.

TABLE XXI

Moisture Changes in Ground Coals, in Glass-stoppered Bottles in Laboratory

Date	Relative humidity	Source of coal—area or district						
		Estevan	Cardiff	Pond Inlet	Drumheller	Pembina	Saunders	Coalspur
	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
				1925				
April 3-7	32	....	....	....	....	....	6·9	6·8
April 27	33	....	....	....	....	13·8	....	....
May 4-11	40	16·9	....	....	14·1	14·4	6·8	7·0
May 15-18	40	17·2	....	....	14·3	....	6·8	7·0
May 26–June 1	45	17·4	....	....	14·3	14·6	6·8	7·3
June 8-15	57	17·1	14·8	14·4	14·2	14·6	6·8	7·2
June 22-29	57	17·1	15·0	14·7	14·3	14·6	6·8	7·0
July 20-27	69	17·2	15·1	14·4	14·2	14·6	6·9	7·1
August 17-24	57	17·1	15·0	14·3	13·8	14·5	6·8	....
September 14-21	64	17·1	15·1	14·6	14·2	14·6	7·0	7·4
October 12-19	43	16·9	15·0	14·2	13·7	14·4	6·8	7·1
November 10-16	41	16·6	14·4	13·5	13·2	14·1	6·6	6·8
December 7-14	34	16·2	13·7	12·9	12·4	13·3	6·2	6·3
				1926				
January 4-11	27	15·6	13·3	12·2	11·8	12·7	5·8	6·1
February 1-12	26	15·1	12·5	11·3	11·0	12·4	5·4	5·6
March 1-8	24	14·4	12·3	11·0	10·6	11·5	5·1	5·4
April 1-6	26	14·3	12·0	10·2	10·0	11·4	5·0	5·4
April 26-May 3	34	13·8	11·5	10·0	9·4	10·7	4·8	5·2
June 10	53	13·5	11·2	10·2	9·3	10·7	4·9	5·2
July 15	60	13·8	11·5	11·3	9·8	10·9	5·4	5·8
August 11	61	13·2	11·8	12·2	9·4	11·2	5·9	6·1
September 21	59	13·6	11·9	....	10·5	11·3	6·2	6·4
November 4	36	13·3	11·5	....	9·7	10·8	5·8	6·0
December 7	22	13·1	10·9	....	8·6	10·1	5·0	5·5

V

ANALYSES OF SOLID FUELS

Compiled by J. H. H. Nicolls

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

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

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

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

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

The third group of fuels (Table XXIV) consists largely of imported coals, such as are sold by local dealers either for private residences or public buildings. It also includes a number of cokes recently obtained from various Ottawa dealers. These are all "commercial" samples. In addition, the third group contains some processed fuels and some samples of foreign peat.

Table XXV contains the screen analyses of a large number of the coke samples belonging to the third group of fuels. A certain ambiguity exists as to the exact definition of the sizes named, but it is believed that the screen sizes as used in the first column of the table are approximately correct. Wherever possible the sizes to which the various coke samples are supposed to correspond are given, and it will be seen that the nomenclature is somewhat erratic. Not only do the designated samples fail to correspond entirely with the screen sizes accepted here as standard, but also they do not agree among themselves.

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

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

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

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

(c) The "coking properties" described were obtained by heating 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. On the whole, however, they may be considered as useful guides in coking practice.

The analyses reported below were carried out under the direct supervision of the author, according to the general directions of the Superintendent of the Fuel Testing Laboratories and his senior officers. The samples were prepared for analysis by a laboratory attendant, who also carried out the screen analyses, under supervision. Proximate analyses for moisture, ash, and volatile matter were made by G. E. LeWorthy and K. W. Bowles; sulphur determinations by J. L. Bowlby and G. E. LeWorthy; and calorific value and nitrogen determinations by J. D. Johnston and J. L. Bowlby. Carbon and hydrogen, and apparent density determinations were made by C. B. Mohr, who also assisted in checking the results of the analyses and in the reporting of the same.

---

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

TABLE XXII

Analyses of Solid Fuels Occurring in Canada

Dominion Coal Co., Ltd. (Besco), Glace Bay, Nova Scotia

—	Supplied to Ottawa Public School Board				Supplied to Fuel Testing Station, through Department of Public Works					
Sample No.	3796 and 3871		4105 and 4106		4070		4092		4135	
Moisture condition	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—										
Moisture . . . per cent	2·9	....	2·8	....	4·7	....	4·1	....	6·4	....
Ash . . . "	8·4	8·7	8·1	8·3	9·4	9·9	8·6	9·0	8·6	9·2
Volatile matter . . . "	33·3	34·3	33·5	34·5	32·6	34·2	33·0	34·4	29·7	31·7
Fixed carbon . . . "	55·4	57·0	55·6	57·2	53·3	55·9	54·3	56·6	55·3	59·1
Ultimate Analysis—										
Sulphur . . . per cent	3·5	3·6	..	...	3·2	3·3	3·5	3·7	2·8	3·0
Calorific Value—										
Calories per gramme, gross	7,480	7,690	....	....	7,220	7,580	7,350	7,660	7,110	7,590
B.T.U. per pound, gross	13,460	13,850	....	....	13,000	13,640	13,230	13,790	12,800	13,670
Fuel ratio	1·65		1·65		1·65		1·65		1·85	
Coking properties	Good		Good		Good		Good		Good	
Designation of coal	"¾ lump"				Run-of-mine					
Kind of sample	Commercial				Commercial—10 or 12 tons monthly					
Taken by	Public School Board officials				Staff of Fuel Testing Laboratories					
Date of sampling	Aug. 15 and Sept. 8, 1926		February, 1927		Throughout January, 1927		Throughout February, 1927		Throughout March, 1927	

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Dominion Coal Co., Ltd. (Besco), Glace Bay, Nova Scotia.													
	Supplied to Ottawa Civic Hospital													
Sample No.	3836		3910		3962		3978		4043		4072		4131	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture, per cent	3·0	....	4·0	....	4·1	....	6·1	....	5·9	....	5·1	....	1·9	....
Ash, "	10·0	10·3	9·2	9·6	9·0	9·4	9·2	9·8	13·2	14·1	10·4	10·9	7·7	7·9
Volatile matter, "	33·4	34·4	32·2	33·5	32·0	33·4	31·4	33·4	30·4	32·3	32·7	34·5	35·1	35·7
Fixed carbon, "	53·6	55·3	54·6	56·9	54·9	57·2	53·3	56·8	50·5	53·6	51·8	54·6	55·3	56·4
Ultimate Analysis—														
Sulphur, per cent	3·3	3·4	2·9	3·1	2·6	2·8	2·7	2·9	2·5	2·6	2·5	2·6	3·2	3·3
Calorific Value—														
Calories per gramme, gross	7,320	7,540	7,290	7,600	7,270	7,580	7,080	7,540	6,640	7,060	7,040	7,420	7,580	7,730
B.T.U. per pound, gross	13,180	13,580	13,130	13,670	13,080	13,640	12,750	13,570	11,960	12,710	12,670	13,350	13,650	13,910
Fuel ratio	1·60		1·70		1·70		1·70		1·65		1·60		1·60	
Coking properties	Good		Fair		Fair to good		Good		Poor to fair		Good		Good	
Designation of coal	Slack													
Kind of sample	Commercial													
Taken by	Hospital engineers													
Date of sampling	August, 1926		September, 1926		October, 1926		November, 1926		December, 1926		January, 1927		February, 1927	
Number of tons represented	223		285		389		467		555		600		505	

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Acadia Coal Co., Ltd. (Besco), Albion colliery, Stellarton, N.S.				Cumberland Railway and Coal Co., Ltd. (Besco), No. 2 mine, Springhill, N.S.		From an area 7 or 8 miles north of Springhill, N.S.		From Chipman, N.B., through Dept. of Public Works.		Evans (Rothwell) Coal Co., Ltd., Minto, N.B.	
Sample No.	4029		4029A		4028		3965		3730		4030	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture per cent	1·6	....	1·8	....	2·2	....	4·0	....	1·2	....	1·0	....
Ash "	13·7	13·9	12·7	12·9	7·5	7·6	17·9	18·7	10·6	10·7	14·5	14·7
Volatile matter "	27·2	27·7	27·2	27·7	30·8	31·5	36·6	38·1	35·4	35·8	31·8	32·1
Fixed carbon "	57·5	58·4	58·3	59·4	59·5	60·9	41·5	43·2	52·8	53·5	52·7	53·2
Ultimate Analysis—												
Sulphur per cent	0·7	0·7	1·7	1·8	1·4	1·4	11·0	11·5	5·3	5·3	6·2	6·2
Nitrogen "	2·0	2·0	1·8	1·8	1·9	1·9	....	....	....	....	....	....
Calorific Value—												
Calories per gramme, gross	7,260	7,370	7,170	7,300	7,620	7,790	5,950	6,200	7,560	7,650	7,160	7,230
B.T.U. per pound, gross	13,070	13,270	12,900	13,130	13,710	14,020	10,710	11,160	13,600	13,770	12,890	13,020
Fuel ratio	2·10		2·15		1·95		1·15		1·50		1·65	
Coking properties	Good		Fair		Good		Poor to fair		Poor to fair		Fair to good	
Location in mine	Foord seam		MacGregor seam								B1 shaft	
Taken by	Mine operators						Private individual				Mine operators	
Date of sampling	December, 1926						October, 1926		May, 1926		November, 1926	

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Peat fuel, from Chicoutimi bog, Chicoutimi county, Que., on the line of Canadian National railway										Peat fuel, from Henryville bog, Iberville and Missisquoi counties, Que., near Quebec, Montreal and Southern railway									
Sample No..........	3949		3950		3951		3952		3953		3954		3955		3956		3957		3958	
Moisture condition...	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																				
Moisture....... p.c.	11·0	....	12·1	....	11·3	....	11·2	....	11·1	....	11·4	....	10·7	....	11·0	....	11·1	....	11·4	....
Ash........... "	7·9	8·9	8·1	9·2	11·1	12·6	9·2	10·4	3·6	4·1	6·7	7·5	6·2	7·0	6·5	7·3	6·6	7·4	5·2	5·9
Volatile matter "	56·8	63·8	55·9	63·6	54·1	61·0	54·8	61·7	59·9	67·4	54·7	61·8	55·4	62·0	54·8	61·6	54·0	60·8	55·0	62·1
Fixed carbon... "	24·3	27·3	23·9	27·2	23·5	26·4	24·8	27·9	25·4	28·5	27·2	30·7	27·7	31·0	27·7	31·1	28·3	31·8	28·4	32·0
Ultimate Analysis—																				
Sulphur........ p.c.	0·4*	0·4	0·4*	0·4	0·4*	0·4	0·4*	0·4	0·4*	0·4	0·5*	0·6	0·5*	0·6	0·5*	0·6	0·5*	0·6	0·5*	0·6
Nitrogen....... "	1·5	1·7	1·5	1·7	1·3	1·5	1·2	1·4	1·4	1·6	1·3	1·4	1·3	1·4	1·3	1·5	1·4	1·5	1·4	1·5
Calorific Value—																				
Calories per grm., gross............	4,800	5,390	4,600	5,240	4,580	5,160	4,640	5,220	5,070	5,700	4,710	5,320	4,790	5,360	4,750	5,350	4,740	5,330	4,820	5,440
B.T.U. per pound, gross............	8,650	9,710	8,290	9,430	8,240	9,280	8,350	9,400	9,120	10,260	8,480	9,570	8,630	9,650	8,560	9,630	8,530	9,600	8,680	9,800
Fuel ratio...........	0·43		0·43		0·43		0·45		0·42		0·50		0·50		0·50		0·52		0·52	
Kind of sample......	All prospect................																			
Taken by...........	A. Anrep, Geological Survey................																			
Date of sampling.....	Summer of 1926................																			

* Average for bog.

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Peat from Lakeside, Ont.		Samples from Sudbury district, Ontario,											
			"Anthraxolite" or "Sudbury Coal"										"Coynite"† from Azilda	
Sample No.	3809		2070		2077		2088		2089		3619		3738, 3741	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture per cent	17·9	....	10·9	....	4·3	....	4·6	....	3·4	....	1·9	....	0·5	....
Ash "	6·6	8·0	1·0	1·1	21·7	22·6	62·7	65·7	27·5	28·5	33·7	34·3	94·8	95·2
Volatile matter "	52·8	64·4	5·4	6·0	3·8	4·0	....	....	....	....	3·4	3·5	4·5	4·6
Fixed carbon "	22·7	27·6	82·7	92·9	70·2	73·4	....	....	....	....	61·0	62·2	0·2	0·2
Ultimate Analysis—														
Sulphur per cent	0·2	0·2	....	....	....	....	....	....	....	....	0·9	0·9	0·1	0·1
Calorific Value—														
Calories per gramme, gross	4,160	5,070	6,890*	7,730	5,560*	5,810	....	....	....	....	4,830	4,920	None	None
B.T.U. per pound, gross	7,490	9,130	12,400	13,920	10,010	10,460	....	....	....	....	8,690	8,850	None	None
Fuel ratio	0·43		15·45		18·30		....		....		17·65		0·05	
Taken by	Private individual		Private individual		R. M. Coleman, Assayer, Sudbury.		Private individual				Private individual		A. F. A. Coyne.	
Date of sampling	Summer of 1926		Summer of 1922		1922		1922				Fall of 1925		1926.	

*Corrected for representative sulphur value.

†This material was found to contain a trace of carbon and about 0·7 per cent of hydrogen.

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Lignite from west bank of Abitibi river, northern Ontario, at Blacksmith falls			Lignite from 3-foot seam on east bank of Mattagami river, N. Ontario; about 6⅓ miles below Long Portage		From east bank of Mattagami river; about 6⅓ miles below Long Portage				Lignite from No. 2 shaft, McCarthy camp, Mattagami river	
						Matrix of lignite "seam"		Lignitized wood from "seam"			
Sample No.		2239		4021		4014		4018		4010	
Moisture condition	R	AD	D	R	D	R	D	R	D	R	D
Proximate Analysis—											
Moisture ... per cent	35·1	21·1	....	6·9	....	5·0	....	6·8	....	7·2	....
Ash ... "	21·0	25·5	32·3	20·4	21·9	54·2	57·1	6·7	7·2	3·5	3·8
Volatile matter ... "	26·6	32·4	41·1	35·9	38·6	25·5	26·8	43·8	47·0	44·2	47·6
Fixed carbon ... "	17·3	21·0	26·6	36·8	39·5	15·3	16·1	42·7	45·8	45·1	48·6
Ultimate Analysis—											
Sulphur ... per cent	....	....	....	0·3	0·4	0·5	0·5	0·7	0·8	0·7	0·8
Calorific Value—											
Calories per gramme, gross	....	....	....	4,670	5,010	2,020	2,130	5,780	6,200	5,960	6,430
B.T.U. per pound, gross	....	....	....	8,400	9,020	3,640	3,830	10,400	11,160	10,730	11,570
Fuel ratio		0·65		1·00		0·60		0·97		1·00	
Kind of sample				Prospect							
Taken by	Private individual			F. H. McLearn, Geological Survey							
Date of sampling	1923			August, 1926							

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Lignite from lower reaches of Mattsgami river, northern Ontario		Lignite from float along banks of Coal brook, about ¼ mile above junction with Missinaibi river, northern Ontario		Peat from outcrop in east bank of Opazatika river, about 5 miles, in a straight line, above its junction with Missinaibi river					
Sample No.	3699		4013		4020		4016		4019	
Moisture condition	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—										
Moisture per cent	12·2	....	9·8	....	5·5	....	9·0	....	5·8	....
Ash "	3·0	3·4	19·1	21·2	55·7	59·0	18·5	20·3	49·6	52·7
Volatile matter "	44·0	50·1	38·2	42·3	27·7	29·3	49·4	54·3	29·8	31·6
Fixed carbon "	40·8	46·5	32·9	36·5	11·1	11·7	23·1	25·4	14·8	15·7
Ultimate Analysis—										
Sulphur per cent	0·3	0·4	0·7	0·7	0·2	0·2	0·3	0·3	....	....
Nitrogen "	....	....	....	....	0·7	0·8	....	....	....	....
Calorific Value—										
Calories per gramme, gross	5,790	6,590	4,220	4,680	2,130	2,250	4,210	4,630	....	....
B.T.U. per pound, gross	10,420	11,860	7,590	8,420	3,830	4,060	7,580	8,330	....	....
Fuel ratio	0·93		0·86		0·40		0·47		0·50	
Kind of sample	Prospect									
Location in deposit	....		....		1-foot 7-inch layer at upstream end of outcrop.		Upper, 10-inch layer at downstream end of outcrop.		Lower, 6-inch layer at downstream end of outcrop.	
Taken by	Submitted by Supt. of Development, C.N.R.		F. H. McLearn, Geological Survey							
Date of sampling	Probably 1925		August, 1926							

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Peat from outcrop in east bank of Missinaibi river, about ¾ mile below mouth of Soweska river.								Peat from outcrop in east bank of Soweska river, about 3½ miles, in a straight line, above its junction with Missinaibi river.						Peat layer on east bank of Missinaibi river, 6 miles above mouth of Soweska river.	
Sample No.	4011		4006		4007		4008		4015		4009		4012		4017	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																
Moisture per cent	6·2	....	4·8	....	5·2	....	6·3	....	8·9	....	6·4	....	7·9	....	7·3	....
Ash "	52·9	56·4	63·2	66·4	64·2	67·8	56·7	60·5	24·5	26·9	53·6	57·3	32·3	35·1	48·3	52·1
Volatile matter "	31·7	33·8	23·8	25·0	22·2	23·4	27·2	29·1	43·7	48·0	27·0	28·8	41·1	44·6	31·8	34·3
Fixed carbon "	9·2	9·8	8·2	8·6	8·4	8·8	9·8	10·4	22·9	25·1	13·0	13·9	18·7	20·3	12·6	13·6
Ultimate Analysis—																
Sulphur per cent	....	....	....	....	....	....	....	....	....	....	....	....	0·2	0·3	0·3	0·3
Nitrogen "	....	....	....	....	....	....	....	....	....	....	....	....	1·1	1·2	....	....
Calorific Value—																
Calories per gramme, gross	....	....	....	....	....	....	....	....	....	....	....	....	3,280	3,560	....	....
B.T.U. per pound, gross	....	....	....	....	....	....	....	....	....	....	....	....	5,900	6,400	....	....
Fuel ratio	0·29		0·34		0·38		0·36		0·52		0·48		0·45		0·40	
Kind of sample	Prospect															
Location in deposit	Top peat layer, upstream end of outcrop.		Peaty silt layer, downstream end of outcrop.		Impure peat, downstream end of outcrop.		Lower peat layer, downstream end of outcrop.		Upper peat bed, downstream end of outcrop.		Middle (impure) peat layer, downstream end of outcrop.		Lower peat layer; downstream end of outcrop.		....	
Taken by	F. H. McLearn, Geological Survey															
Date of sampling	August, 1926															

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Western Dominion Collieries Co., Ltd., Taylorton, Saskatchewan, secs. 3 and 26, tp. 2, R. 6, W. 2 mer.			Leland Coal Co., Ltd., No. 105, "Majestic" mine, Taber, Alberta, sec. 6, tp. 10, R. 16, W. 4 mer.						From outcrop on Brazeau river, near Cardinal River Forks cabin, Alberta.			From creek 3½ miles N.W. of Cardinal River Forks cabin.		
										Samples from tp. 45, R. 18, W. 5 mer.					
Sample No.		4054			4096			4097			3929			3930	
Moisture condition	R	AD	D	R	AD	D	R	AD	D	R	AD	D	R	AD	D
Proximate Analysis—															
Moisture per cent	32·5	26·7	....	13·8	11·3	....	14·5	11·9	....	6·0	5·7	....	7·9	6·2	....
Ash "	7·6	8·2	11·2	12·1	12·5	14·0	10·9	11·2	12·7	5·3	5·3	5·6	8·0	8·2	8·7
Volatile matter "	26·2	28·5	38·8	32·5	33·4	37·7	32·4	33·4	37·9	34·2	34·3	36·4	34·2	34·8	37·1
Fixed carbon "	33·7	36·6	50·0	41·6	42·8	48·3	42·2	43·5	49·4	54·5	54·7	58·0	49·9	50·8	54·2
Ultimate Analysis—															
Sulphur per cent	0·4	0·5	0·7	1·6	1·7	1·9	1·5	1·5	1·7	0·2	0·2	0·2	0·4	0·4	0·4
Nitrogen "	0·7	0·8	1·1	....	....	....	....	....	....	....	....	....	....	....	....
Calorific Value—															
Calories per gramme, gross	4,180	4,540	6,190	5,490	5,650	6,370	5,530	5,700	6,470	6,940	6,960	7,380	6,580	6,700	7,140
B.T.U. per pound, gross	7,520	8,170	11,150	9,890	10,170	11,470	9,950	10,270	11,650	12,490	12,530	13,290	11,850	12,060	12,860
Fuel ratio		1·30			1·30			1·30			1·60			1·45	
Coking properties		Non-coking			Non-coking			Non-coking			Agglomerates			Agglomerates	
Kind of sample	....			Mine			Mine			Prospect—choice sample.			Prospect		
Location in mine	....			No. 1 room left, No. 3 east of main north entry.			No. 3 room left, No. 3 west of main north entry.			Supposed to be Silkstone seam.			Supposed to be Val d'Or seam.		
Taken by	Official of Lignite Utilization Board.			F. M. Steel, Inspector, Northwest Territories and Yukon Branch.						B. R. MacKay, Geological Survey.					
Date of sampling	Nov. 14, 1926			Feb. 28, 1927			Feb. 26, 1927			August 2, 1926			....		

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

—	Alberta Canadian Collieries, Ltd., near Lovett, Alberta, tp. 47, R. 19, W. 5 mer.			Northern Alberta Coal Mines, No. 833, "Brookdale" mine, near Lovett, Alberta, sec. 16, tp. 47, R. 19, W. 5 mer.			Balkan Coal Co., Ltd., No. 775, "Minehead" mine, Robb, Alberta, sec. 11, tp. 49, R. 21, W. 5 mer.			Bryan Coal Co., Ltd., No. 1157, Robb, Alberta, sec. 15, tp. 49, R. 21, W. 5 mer.			West Canadian Collieries Ltd., No. 396, "Greenhill" mine, Blairmore, Alberta, sec. 2, tp. 8, R. 4, W. 5 mer.		International Coal and Coke Co., Ltd., No. 88, "Denison" mine, Coleman, Alberta, sec. 16, tp. 8, R. 4, W. 5 mer.	
Sample No.	3928			3931			3933			3932			4036		4038	
Moisture condition	R	AD	D	R	AD	D	R	AD	D	R	AD	D	R	D	R	D
Proximate Analysis—																
Moisture per cent	8·7	7·5	...	10·5	8·3	....	10·7	8·6	....	11·3	8·3	....	0·6	...	1·2	. .
Ash "	7·0	7·1	7·7	13·7	14·1	15·3	10·6	10·8	11·8	14·3	14·8	16·1	10·8	10·8	12·8	13·0
Volatile matter "	35·5	36·0	38·9	32·1	32·9	35·9	33·9	34·7	38·0	32·3	33·4	36·4	25·2	25·4	23·8	24·1
Fixed carbon "	48·8	49·4	53·4	43·7	44·7	48·8	44·8	45·9	50·2	42·1	43·5	47·5	63·4	63·8	62·2	62·9
Ultimate Analysis—																
Sulphur per cent	0·2	0·2	0·2	0·2	0·2	0·2	0·1	0·1	0·2	0·1	0·1	0·2	0·7	0·7	0·5	0·6
Nitrogen "	....	....	....	....	....	....	....	....	....	....	....	....	1·0	1·0	1·5	1·6
Calorific Value—																
Calories per gramme, gross	6,330	6,410	6,930	5,700	5,840	6,370	5,800	5,940	6,500	5,410	5,590	6,100	7,550	7,600	7,270	7,360
B.T.U. per pound, gross	11,390	11,540	12,480	10,270	10,510	11,470	10,450	10,700	11,700	9,740	10,070	10,980	13,590	13,680	13,080	13,240
Fuel ratio	1·35			1·35			1·30			1·30			2·50		2·60	
Coking properties	Slight tendency to agglomerate			Non-coking			Non-coking			Non-coking			Fair coke		Poor coke	
Designation of coal										Run-of-mine						
Kind of sample	Mine; average of seam.			Mine; average of seam.			Mine; average of seam.			Commercial-tipple						
Location in mine	24-foot seam of Val d'Or series.			Mynheer seam			Val d'Or seam			Val d'Or seam						
Taken by	B. R. MacKay, Geological Survey												Mine operators		Mine operators	
Date of sampling	Summer of 1926												March 3, 1927		Dec. 21, 1926	

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	Mine No. 1061, operated by Ernest Skeen, of Nanton, on headwaters of Johnson creek, Oldman area, Alberta, sec. 35, tp. 14, R. 4, W. 5 mer.			Canmore Coal Co., Ltd., No. 2, Canmore, Alberta, sec. 29, tp. 24, R. 10, W. 5 mer.		Brazeau Collieries Ltd., No. 256, Nordegg, Alberta, sec. 22, tp. 40, R. 15, W. 5 mer.		Mountain Park Collieries, Ltd., No. 282, Mountain Park, Alberta, sec. 33, tp. 45, R. 23, W. 5 mer.		Cadomin Coal Co., Ltd., No. 693, Cadomin, Alberta, sec. 31, tp. 46, R. 23, W. 5 mer.		Luscar Collieries, Ltd., No. 905, Luscar, Alberta, sec. 23, tp. 47, R. 24, W. 5 mer.		Blue Diamond Coal Co., Ltd No. 429, Brûlé Mines, Alberta sec. 16, tp. 52, R. 27, W. 5 mer.		Corbin Coals Ltd., Corbin, B.C.	
Sample No.	3808			3963		4031		4035		4034		4033		4032		3999	
Moisture condition	R	AD	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																	
Moisture p.c.	3·9	1·1	....	1·4	....	1·1	....	1·7	....	1·2	....	0·7	....	0·8	....	1·1	....
Ash "	10·9	11·3	11·4	8·9	9·0	13·8	13·9	12·1	12·3	6·7	6·8	13·3	13·4	15·3	15·4	13·7	13·8
Volatile matter "	22·8	23·4	23·7	19·9	20·2	16·7	16·9	29·4	29·9	27·5	27·8	20·5	20·6	19·2	19·4	23·3	23·6
Fixed carbon "	62·4	64·2	64·9	69·8	70·8	68·4	69·2	56·8	57·8	64·6	65·4	65·5	66·0	64·7	65·2	61·9	62·6
Ultimate Analysis—																	
Sulphur p.c.	0·7	0·7	0·8	1·3	1·3	0·4	0·5	0·7	0·7	0·3	0·3	0·3	0·3	0·5	0·5	0·4	0·4
Nitrogen "	....	....	....	....	....	1·1	1·1	1·2	1·2	1·1	1·2	1·1	1·1	1·1	1·1	....	....
Calorific Value—																	
Calories per gramme, gross	7,280	7,490	7,570	7,870	7,980	7,370	7,460	7,370	7,500	7,940	8,040	7,380	7,430	7,210	7,270	7,210	7,290
B.T.U. per pound, gross	13,100	13,480	13,630	14,170	14,370	13,270	13,420	13,260	13,490	14,300	14,470	13,290	13,380	12,970	13,080	12,980	13,130
Fuel ratio	2·75			3·50		4·10		1·95		2·35		3·20		3·35		2·65	
Coking properties	Poor to fair			Agglomerates		Poor		Fair to good		Fair to good		Fair		Good		Poor	
Designation of coal	....			Briquettes made with asphaltum binder.		....								....		....	
Kind of sample	Mine..................			Commercial....		....								....		....	
Taken by	Provincial inspector of mines.			All by mine operators...										....		Mine operators, at request of B. R. MacKay, Geological Survey.	
Date of sampling	August 20, 1926..........			Sept., 1926......		All during November, 1926....................................								....		....	

TABLE XXII—Continued

Analyses of Solid Fuels Occurring in Canada—Continued

	Crow's Nest Pass Coal Co., Ltd., Fernie, B.C.								South Okanagan Collieries, Ltd., White lake, near Penticton, B.C.				Tulameen Valley Coal Mine, Princeton, B.C.			Coalmont Collieries Ltd., Coalmont, B.C.		
	Michel colliery		Coal Creek colliery															
Sample No.	4039A		3944		3945		4040		3934		3935		3939			3938		
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	AD	D	R	AD	D
Proximate Analysis—																		
Moisture p.c.	1·8	....	1·1	....	0·9	....	0·8	....	0·9	....	0·9	....	20·5	17·2	....	6·5	5·3	....
Ash "	3·5	3·5	2·2	2·2	2·9	2·9	4·2	4·2	15·4	15·5	16·1	16·2	4·9	5·1	6·2	9·8	9·9	10·5
Volatile matter "	26·4	26·9	26·4	26·7	23·9	24·1	22·3	22·5	19·5	19·7	21·3	21·5	32·9	34·3	41·4	35·7	36·2	38·2
Fixed carbon "	68·3	69·6	70·3	71·1	72·3	73·0	72·7	73·3	64·2	64·8	61·7	62·3	41·7	43·4	52·4	48·0	48·6	51·3
Ultimate Analysis—																		
Sulphur p.c.	0·6	0·6	0·5	0·5	0·6	0·6	0·5	0·5	5·4	5·4	1·4	1·4	0·3	0·3	0·4	0·3	0·3	0·3
Nitrogen "	1·6	1·6	....	....	....	....	1·3	1·3	....	....	....	....	....	....	....	....	....	....
Calorific Value—																		
Calories per gramme, gross	8,280	8,430	8,530	8,620	8,460	8,540	8,340	8,410	7,190	7,250	7,240	7,310	5,450	5,670	6,850	6,440	6,520	6,880
B.T.U. per pound, gross	14,900	15,180	15,350	15,520	15,230	15,370	15,020	15,140	12,940	13,050	13,040	13,160	9,810	10,210	12,230	11,590	11,730	12,390
Fuel ratio	2·60		2·65		3·05		3·25		3·30		2·90		1·25			1·35		
Coking properties	Good		Good		Good		Good		Good		Good		Non-coking			Agglomerates		
Designation of coal	....		....		....		....		....		....		Run-of-mine			Run-of-mine		
Kind of sample	....		Mine: top coal		Mine: top coal		....		Mine		Mine		Commercial, tipple			Commercial, tipple		
Location in mine	No. 8 mine		No. 1 east mine, No. 1 seam; from west side return.		No. 3 mine, No. 2 seam; No. 3 slope.		No. 3 mine		No. 3 seam		No. 5 seam		....			....		
Taken by	Mine operators		B. R. MacKay, Geological Survey.				Mine operators		B. R. MacKay									
Date of sampling	Dec. 10, 1926		Sept. 28, 1926				Dec. 10, 1926		Season of 1926				Sept. 21, 1926			Sept. 20, 1926		

TABLE XXII—Concluded

Analyses of Solid Fuels Occurring in Canada—Concluded

—	Coal from outcrop at Normandale, near Nicola, B.C.			Middlesboro Collieries, Ltd., Middlesboro, Merritt, B.C.											Granby Consolidated Mining, Smelting and Power Co., Ltd., Cassidy, B.C.		Canadian Collieries (Dunsmuir), Ltd., Cumberland, B.C., Comox mines, Union Bay.	
Sample No.	3937			3936			4059			3763		3906			4041		4042	
Moisture condition	R	AD	D	R	AD	D	R	AD	D	R	D	R	AD	D	R	D	R	D
Proximate Analysis—																		
Moisture per cent	13·2	12·4	....	8·4	7·4	....	8·8	6·7	....	6·2	....	7·1	6·8	....	2·2	....	1·7	....
Ash "	6·9	7·0	8·0	13·6	13·7	14·8	6·2	6·3	6·7	11·1	11·8	14·5	14·6	15·6	14·0	14·3	10·1	10·3
Volatile matter "	31·8	32·1	36·6	35·3	35·7	38·6	36·2	37·0	39·7	34·4	36·7	34·4	34·5	37·1	37·3	38·1	30·5	31·0
Fixed carbon "	48·1	48·5	55·4	42·7	43·2	46·6	48·8	50·0	53·6	48·3	51·5	44·0	44·1	47·3	46·5	47·6	57·7	58·7
Ultimate Analysis—																		
Carbon per cent	....	....	....	....	....	....	....	....	....	65·9	70·3	....	....	....	....	....	....	....
Hydrogen "	....	....	....	....	....	....	....	....	....	5·0	4·5	....	....	....	....	....	....	....
Ash "	6·9	7·0	8·0	13·6	13·7	14·8	6·2	6·3	6·7	11·1	11·8	....	....	....	14·0	14·3	10·1	10·3
Sulphur "	0·5	0·5	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·4	0·4	....	....	....	0·6	0·6	0·9	1·0
Nitrogen "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1·0	1·1
Calorific Value—																		
Calories per gramme, gross	5,210	5,250	6,000	6,170	6,230	6,730	6,830	7,000	7,500	6,480	6,900	....	....	....	6,830	6,980	7,330	7,460
B.T.U. per pound, gross	9,370	9,460	10,800	11,100	11,220	12,120	12,300	12,600	13,500	11,660	12,420	....	....	....	12,300	12,570	13,200	13,430
Fuel ratio	1·50			1·20			1·35			1·40		1·30			1·25		1·90	
Carbon-Hydrogen ratio	....	....	....	....	....	....	....	....	....	13·3	15·5	....	....	....	....	....	....	....
Coking properties	Non-coking			Agglomerates			Poor coke			Agglomerates		Barely cokes			Fair		Good	
Designation of coal				Run-of-mine													60 per cent No. 4 lump; 40 per cent washed nut and pea.	
Kind of sample	Prospect			Commercial: tipple.			Commercial: tipple.			Commercial		Commercial						
Location in mine				No. 2 seam			No. 2 seam					No. 2 seam			No. 1 mine		No. 4 mine	
Taken by	B. R. MacKay, Geological Survey.						Provincial inspector of mines.			Fire ranger, Board of Railway Commissioners.					Mine operators.		Mine operators.	
Date of sampling	Sept. 20, 1926			Sept. 18, 1926			Jan. 12, 1927			July, 1926		Sept. 20, 1926			Nov., 1926		Oct. 27, 1926	

TABLE XXIII

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

—	Delivered to Ste. Anne de Bellevue hospital: described as "Dominion" or Glace Bay, Nova Scotia, slack coal											
Sample No.	3793	3794	3805	3900	3901	3904	3911	3914	3925	3942	3960	3966
Moisture (as received)....per cent	5·2	3·9	6·0	3·7	3·8	5·3	4·6	4·5	3·9	4·5	4·2	5·3
Dry Basis—												
Ash....per cent	13·2	12·7	14·7	7·1	8·2	11·3	8·9	9·7	9·8	10·0	9·8	10·7
Volatile matter.... "	31·1	31·3	32·3	34·3	33·9	34·3	35·6	33·6	34·5	34·4	34·2	32·7
Fixed carbon .... "	55·7	56·0	53·0	58·6	57·9	54·4	55·5	56·7	55·7	55·6	56·0	56·6
Sulphur.... "	2·9	3·0	2·2	2·9	2·9	2·3	2·6	2·9	2·7	2·6	2·6	2·9
Calories per gramme, gross....	7,250	7,270	6,960	7.830	7,710	7,360	7,600	7,590	7,540	7,530	7,580	7,500
B.T.U. per pound, gross....	13,060	13,080	12,530	14,100	13,870	13,240	13,690	13,670	13,570	13,560	13,640	13,500
Number of tons represented by sample..	296	226	271	270	240	194	167	203	199	309	308	197
Date of delivery....	July 8 to 21, 1926	Aug. 3	Aug. 14	Aug. 27	Sept. 14	Sept. 21	Sept. 26	Oct. 8	Oct. 15	Oct. 21	Oct. 28	Nov. 3

—	Delivered to Ste. Anne de Bellevue hospital						Delivered to Camp Hill hospital, Halifax				
Sample No.	3967	3971	3977	3998	4066	3767	3969	4047	4088	4108	4138
Moisture (as received)....per cent	3·4	4·9	5·2	5·0	4·4	12·5	6·2	2·8	4·3	4·9	5·5
Dry Basis—											
Ash....per cent	9·9	10·0	9·6	10·4	9·3	10·2	7·9	7·0	8·0	8·3	8·4
Volatile matter.... "	33·1	35·8	33·8	33·2	33·9	31·8	34·7	33·7	34·1	33·6	33·2
Fixed carbon.... "	57·0	54·2	56·6	56·4	56·8	58·0	57·4	59·3	57·9	58·1	58·4
Sulphur.... "	2·6	3·4	2·7	2·8	2·7	2·5	2·4	2·8	3·1	3·2	3·4
Calories per gramme, gross....	7,580	7,450	7,660	7,490	7,610	7,400	7,710	7,900	7,730	7,680	7,720
B.T.U. per pound, gross....	13,650	13,420	13,790	13,490	13,700	13,310	13,880	14,220	13,910	13,820	13,890
Number of tons represented by sample....	193	188	200	249	100	477	134	199	177	51	165
Date of delivery....	Nov. 4 to 9, 1926	Nov. 16	Nov. 24	Dec. 2	Dec. 11	Throughout June, 1926	Oct. 15 to 30	Throughout Dec., 1926	Jan. 5 to 31,1927	Feb. 7 to 23	Mar. 10 to 29

TABLE XXIII—Continued

Analyses of Coal Samples Submitted by Department of Soldiers' Civil Re-establishment—Continued

—	Delivered to Lancaster hospital, St. John, N.B., described as "Rothwell," Minto, N.B., run-of-mine coal.		Delivered to Deer Lodge hospital, Winnipeg							
			Described as "Greenhill," Blairmore, Alberta, run-of-mine coal						Described as "McGillivray," Coleman, Alberta, run-of-mine coal.	
Sample No.	3970	4107	3948	3976	4052	4074	4101	4136	3722	3723
Moisture (as received) . . . per cent	1·3	1·5	3·1	3·6	3·7	2·0	2·2	1·7	7·0	5·6
Dry Basis—										
Ash . . . per cent	15·2	16·8	16·4	16·0	12·0	13·4	15·3	13·8	19·6	12·9
Volatile matter "	32·3	31·6	22·3	22·1	22·3	22·8	24·8	24·9	26·9	23·9
Fixed carbon "	52·5	51·6	61·3	61·9	65·7	63·8	59·9	61·3	53·5	63·2
Sulphur "	8·1	6·3	0·5	0·4	0·7	0·4	0·6	0·6	0·6	0·8
Calories per gramme, gross	7,100	6,980	7,080	7,150	7,530	7,370	7,110	7,260	6,690	7,410
B.T.U. per pound, gross	12,780	12,560	12,750	12,870	13,560	13,270	12,800	13,080	12,050	13,330
Number of tons represented by sample	80	72	25	46	45	53	36	33	45	32
Date of delivery	Oct. 20 and Nov. 2, 1926	Feb. 2 and Mar. 2, 1927	Sept. 30 to Oct. 14, 1926	Nov. 6 to 24, 1926	Dec. 17 to 31, 1926	Jan. 10 to 31, 1927	Throughout Feb., 1927	Mar. 17 to 26, 1927	During Mar., 1926	During April, 1926

	Delivered to Westminster hospital, London.*	Delivered to Christie St. hospital, Toronto; described as coming from the Pittsburgh seam in Monongalia or Marion co., West Virginia, U.S.; from Byrne No. 1 mine at Scottdale near Louisville.										
Sample No.	3698	3806	3872	3905	3915	3964	3975	4001	4027	4051	4053	4055
Moisture (as received) . . . per cent	4·4	3·4	4·6	4·1	3·7	3·9	4·8	3·0	8·5	3·0	3·7	4·2
Dry Basis—												
Ash . . . per cent	6·3	9·5	9·3	9·5	9·0	9·1	11·9	10·2	17·6	9·2	10·1	10·3
Volatile matter "	34·6	35·7	35·3	35·2	34·2	34·4	34·4	35·7	32·8	35·8	34·9	35·2
Fixed carbon "	59·1	54·8	55·4	55·3	56·8	56·5	53·7	54·1	49·6	55·0	55·0	54·5
Sulphur "	0·8	3·1	2·7	2·6	2·3	2·5	3·3	3·0	2·4	3·1	3·1	2·7
Calories per gramme, gross	7,970	7,610	7,650	7,620	7,680	7,690	7,410	7,650	6,790	7,680	7,600	7,580
B.T.U. per pound, gross	14,340	13,690	13,770	13,720	13,820	13,850	13,330	13,770	12,220	13,820	13,690	13,650
Number of tons represented by sample	363	150	160	170	170	233	250	170	300	250	450	400
Date of delivery	Mar. 19 to April 6, 1926	Aug. 8 to 23, 1926	Sept. 7	Sept. 23	Oct. 4	Oct. 27	Nov. 15 to 19	Dec. 3 to 7	Dec. 20 to 25	Dec. 29, 1926, to Jan. 3, 1927	Jan. 10	Jan. 17

---

*Described as from Logan co., West Virginia, U.S.; from following mines: "Monitor" on Draper seam at Monitor Mines, or "Rossmore" on Silent Creek seam at Rossman.

TABLE XXIII—Concluded

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

—	Delivered to Christie Street hospital, Toronto; described as coming from the Pittsburgh seam in Monongalia or Marion co., West Virginia, U.S.; from Byrne No. 1 mine at Scottdale near Louisville.						Delivered to Westminster hospital, London; described as coming from the lower Kittanning seam in Butler co., Pennsylvania, U.S.; from "Grant" mine at Claytonia.				
Sample No	4065	4073	4087	4089	4095	4111	3795	3801	3890	3891	3903
Moisture (as-received)...per cent	3·6	4·1	3·1	3·7	3·7	2·9	4·6	5·1	4·9	5·3	6·1
Dry Basis—											
Ash...per cent	11·2	9·5	10·3	9·2	9·8	10·1	9·1	10·4	9·4	11·9	11·6
Volatile matter... "	35·0	36·1	35·5	36·1	35·3	35·3	34·3	33·2	33·2	32·3	32·4
Fixed carbon... "	53·8	54·4	54·2	54·7	54·9	54·6	56·6	56·4	57·4	55·8	56·0
Sulphur... "	3·1	2·9	3·4	2·9	3·0	3·5	1·7	1·6	1·5	1·7	1·7
Calories per gramme, gross	7,470	7,650	7,560	7,640	7.590	7,540	7,560	7,460	7,540	7,300	7,330
B.T.U. per pound, gross	13,440	13,770	13,610	13,760	13,660	13,580	13,610	13,420	13,580	13,150	13,190
Number of tons represented by sample	140	195	200	350	330	320	179	265	235	274	284
Date of delivery	Jan. 20, 1927	Jan. 29	Feb. 12	Feb. 21	Feb. 28	Mar. 21	July 27 to Aug. 6, 1926	Aug. 18	Aug. 27	Sept. 8	Sept. 22

—	Delivered to Westminster hospital, London; described as coming from the lower Kittanning seam in Butler co., Pennsylvania, U.S.; from "Grant" mine at Claytonia.								Delivered to Christie Street hospital, Toronto; described as coming from the Pittsburgh, or No. 8, seam in Belmont co., Ohio, U.S.; from the following mines: "Oco" at Lafferty, "Columbia" at Fairpoint or "Lucy" at Stewartsville.			
Sample No	3912	3926	3961	3968	3997	4005	4046	4071	3715	3725	3728	3744
Moisture (as-received)...per cent	5·7	4·7	5·6	4·6	6·0	5·9	5·4	3·1	4·7	3·6	4·2	4·8
Dry Basis—												
Ash...per cent	10·9	10·5	10·7	11·3	10·9	11·7	11·1	10·7	9·2	9·1	10·1	13·6
Volatile matter... "	32·5	33·3	33·3	32·7	32·1	32·3	32·1	33·4	32·8	33·5	34·3	32·9
Fixed carbon... "	56·6	56·2	56·0	56·0	57·0	56·0	56·8	55·9	58·0	57·4	55·6	53·5
Sulphur... "	1·4	1·6	1·7	1·7	1·7	1·6	1·6	1·6	1·7	1·6	1·7	1·6
Calories per gramme, gross	7,490	7,470	7,470	7,370	7,430	7,410	7,450	7,360	7,840	7,760	7,610	7,260
B.T.U. per pound, gross	13,480	13,440	13,440	13,270	13,380	13,340	13,410	13,250	14,110	13,960	13,690	13,070
Number of tons represented by sample	219	363	353	338	311	285	147	147	300	280	300	203
Date of delivery	Sept. 25 to Oct. 4, 1926	Oct. 13	Oct. 27	Nov. 15	Dec. 1	Dec. 13	Dec. 16	Jan. 4, 1927	April 16 to 22, 1926	May 5	May 17	June 21, 1926

TABLE XXIV

Analyses of Miscellaneous Solid Fuels

—	By-product coke made in Koppers ovens by Dominion Iron & Steel Co. (Besco), Sydney, N.S., from washed "Dominion" coal from Glace Bay.		Cokes manufactured by Ottawa Gas Company, Ottawa, Ont.								By-product coke made in Wilputte ovens by Steel Company of Canada, Hamilton, Ont.			
			Gas coke made in Glover-West retorts						New, intermittent process coke.					
Sample No.	4114		3893		3894		3895		3897		4115		4116	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture, per cent	0·3	....	0·5	....	0·5	....	0·9	....	0·3	....	0·4	....	0·9	....
Ash, "	7·9	7·9	11·0	11·1	10·0	10·0	12·8	12·9	10·7	10·8	10·3	10·4	11·9	12·0
Volatile matter, "	2·0	2·0	1·1	1·1	1·0	1·0	1·6	1·6	0·9	0·9	2·3	2·3	2·9	3·0
Fixed carbon, "	89·8	90·1	87·4	87·8	88·5	89·0	84·7	85·5	88·1	88·3	87·0	87·3	84·3	85·0
Ultimate Analysis—														
Sulphur, per cent	1·7	1·7	1·0	1·0	0·9	0·9	1·1	1·1	0·9	0·9	1·0	1·0	1·0	1·0
Calorific Value—														
Calories per gramme, gross	7,230	7,250	6,900	6,930	7,160	7,200	6,780	6,840	7,050	7,070	7,090	7,120	6,900	6,970
B.T.U. per pound, gross	13,010	13,050	12,420	12,470	12,890	12,960	12,200	12,310	12,690	12,730	12,760	12,820	12,430	12,540
Apparent density (water=1·00)	0·84		0·85		0·85		0·85		0·98		0·89		0·92	
Designation of fuel	Mixed sizes		Large size		"Crushed" coke		Nut				Stove		Nut	
Date	February, 1927.		September, 1926								February, 1927.			

TABLE XXIV—Continued

Analyses of Miscellaneous Solid Fuels—Continued

	By-product coke made in Semet-Solvay ovens										"Donner" or "Donnerhanna" by-product coke, made by the Donnerhanna Coke Corporation, Buffalo, N.Y.					
	Hamilton Gas and By-Products Co., Ltd., Hamilton, Ont.						Made at Detroit, Mich.		Made at Buffalo, N.Y.							
Sample No.	3898		3899		4117		4118		4119		3739		4120		4121	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—																
Moisture per cent	0·4	....	1·4	....	0·3	....	0·3	....	0·4	....	0·2	....	0·1	....	0·1	....
Ash "	7·2	7·2	6·8	6·9	9·7	9·7	8·4	8·5	9·2	9·3	10·7	10·7	10·3	10·3	10·5	10·5
Volatile matter "	1·3	1·3	1·7	1·8	2·2	2·2	1·9	1·9	2·8	2·8	1·4	1·4	2·1	2·1	2·3	2·3
Fixed carbon "	91·1	91·5	90·1	91·3	87·8	88·1	89·4	89·6	87·6	87·9	87·7	87·9	87·5	87·6	87·1	87·2
Ultimate Analysis—																
Sulphur per cent	0·6	0·6	0·5	0·6	0·7	0·7	0·6	0·6	0·6	0·7	0·9	0·9	0·9	0·9	0·9	0·9
Calorific Value—																
Calories per gramme, gross	7,410	7,430	7,390	7,490	7,140	7,160	7,290	7,310	7,110	7,140	6,880	6,900	7,050	7,060	6,980	6,990
B.T.U. per pound, gross	13,330	13,380	13,300	13,490	12,850	12,890	13,120	13,160	12,800	12,850	12,380	12,420	12,690	12,700	12,570	12,590
Apparent density (water=1·00)	0·91		0·88		0·87		0·86		0·87		....		0·90		0·95	
Designation of fuel	Stove		Nut		Egg		Nut		Nut				Egg		Nut	
Date	September, 1926				February, 1927						June, 1926		February, 1927			
Remarks													Coke had been exposed out-of-doors for about 1 year.			

TABLE XXIV—Continued

Analyses of Miscellaneous Solid Fuels—Continued

	"Oto" by-product coke, designated as manufactured by Algoma Steel Corporation, Sault Ste. Marie, Ont.								Coke manufactured by Illingworth Carbonization Co., Pontypridd, Wales.		Briquettes made with carbonized Saskatchewan lignite and 10 per cent of "Cohesite" binder, by Tapping Cohesives of Birmingham, England.	
Sample No.	3913		4112		4113		4134		3726		3732	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture per cent	1·4	....	0·8	....	0·4	....	0·3	....	1·0	....	5·4	....
Ash "	11·6	11·8	13·7	13·8	10·5	10·6	10·0	10·0	8·3	8·4	13·3	14·1
Volatile matter "	2·6	2·6	2·3	2·3	2·0	2·0	2·5	2·5	9·6	9·7	22·9	24·2
Fixed carbon "	84·4	85·6	83·2	83·9	87·1	87·4	87·2	87·5	81·1	81·9	58·4	61·7
Ultimate Analysis—												
Sulphur per cent	1·0	1·0	1·8	1·8	0·8	0·8	0·8	0·8	0·9	0·9	0·9	1·0
Calorific Value—												
Calories per gramme, gross	6,950	7,050	6,720	6,780	7,030	7,050	7,090	7,110	7,530	7,610	6,480	6,840
B.T.U. per pound, gross	12,510	12,690	12,100	12,200	12,650	12,690	12,760	12,800	13,560	13,710	11,660	12,320
Fuel ratio	....		....		....		....		8·45		2·55	
Apparent density (water=1·00)	....		0·83		0·87		0·86		....		....	
Designation of fuel	Mostly small		Large sizes		Nut		Mixed sizes					
Date	Oct. 8, 1926		Feb., 1927				April 1, 1927		Autumn of 1925		June, 1926	

TABLE XXIV—Continued

Analyses of Miscellaneous Solid Fuels—Continued

—	Pennsylvania anthracitic coal										Welsh anthracitic coal	
Sample No.	3804		3774		3973		3974		3908		3769	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—												
Moisture.....per cent	4·0	....	4·2	....	0·9	....	0·9	....	4·8	....	2·2	....
Ash "	6·1	6·3	13·5	14·1	17·2	17·3	18·7	18·8	16·4	17·2	5·8	5·9
Volatile matter "	5·7	6·0	6·3	6·6	10·6	10·7	10·6	10·7	5·3	5·6	8·5	8·7
Fixed carbon "	84·2	87·7	76·0	79·3	71·3	72·0	69·8	70·5	73·5	77·2	83·5	85·4
Ultimate Analysis—												
Sulphur.....per cent	1·0	1·0	....	....	....	....	....	....	0·7	0·7	....	....
Calorific Value—												
Calories per gramme, gross	7,540	7,850	6,810*	7,100	7,010*	7,070	6,910*	6,980	6,440	6,770	7,800†	7,980
B.T.U. per pound, gross	13,570	14,130	12,250	12,780	12,610	12,730	12,450	12,560	11,600	12,180	14,040	14,370
Fuel ratio	14·60		12·05		6·70		6·60		13·70		9·80	
Designation of fuel	"D. L. and W." from Scranton.		Furnace		Stove		Nut		Pea		....	
Date	Aug. 25, 1926		July 30, 1926		Nov. 24, 1926		....		Oct. 2, 1926		July 19, 1926	

*Calorific value corrected according to the sulphur content of representative Pennsylvania anthracite.

†Calorific value corrected according to the sulphur content of representative Welsh anthracite.

TABLE XXIV—Continued

Analyses of Miscellaneous Solid Fuels—Continued

—	"Raven" semi-bituminous, or "smokeless," coal from U.S.				"Dilltown smokeless" coal from lower Kittanning seam, Dilltown, Indiana co., Penn., U.S.		Bituminous or "steam" coal from Gilbert-Davis mine, Sewickley seam, Morgantown, Monongalia co., West Virginia, U.S.							
Sample No.	3759		3907		3803		3710		3768 3800		3927		4104	
Moisture condition	R	D	R	D	R	D	R	D	R	D	R	D	R	D
Proximate Analysis—														
Moisture per cent	1·4	....	1·1	....	1·2	....	1·6	....	2·0	....	1·7	....	1·4	....
Ash "	9·2	9·3	7·5	7·6	10·3	10·4	10·9	11·1	11·9	12·1	12·1	12·3	12·4	12·5
Volatile matter "	18·7	19·0	20·5	20·7	21·6	21·9	34·1	34·6	33·9	34·6	33·9	34·5	35·2	35·7
Fixed carbon "	70·7	71·7	70·9	71·7	66·9	67·7	53·4	54·3	52·2	53·3	52·3	53·2	51·0	51·8
Ultimate Analysis—														
Sulphur per cent	2·0	2·0	2·5	2·5	4·6	4·7	1·7	1·7	1·8	1·9	2·0	2·1	....	....
Calorific Value—														
Calories per gramme, gross	7,800	7,910	7,970	8,060	7,630	7,720	7,440	7,560	7,210	7,360	7,270	7,400	....	....
B.T.U. per pound, gross	14,040	14,230	14,350	14,510	13,730	13,900	13,400	13,610	12,980	13,250	13,080	13,310	....	....
Fuel ratio	3·75		3·45		3·10		1·55		1·55		1·55		1·45	
Designation of fuel							"¾ lump"							
Date	July 6, 1926		Oct. 2, 1926		Aug. 21, 1926		April 20, 1926		July 17 and Aug. 20, 1926.		Oct. 20, 1926		February, 1927.	

TABLE XXIV—Concluded

Analyses of Miscellaneous Solid Fuels—Concluded

—	Coal designated as coming from the Cedar River mine, Pacific Coast Coal Co., of Seattle, Washington, U.S.			Charcoal briquettes manufactured from mill waste; carbonized in Hobson retort by Peoples' Fuel Co., Bellingham, Washington, U.S.		Macerated and pressed peat manufactured by process of International Iron & Steel Company, Minneapolis, Minnesota, U.S.		Peat briquette manufactured in Germany; secured through an official of the Canadian Pacific Railway.		Peat briquette manufactured in Denmark; secured through a Montreal coal operator.	
Sample No.	4069			4100		3810		3799		3740	
Moisture condition	R	AD	D	R	D	R	D	R	D	R	D
Proximate Analysis—											
Moisture.....per cent	11·4	10·4	....	1·5	....	15·9	....	10·6	....	10·3	....
Ash.....“	9·8	9·9	11·1	5·2	5·3	10·4	12·4	4·0	4·4	8·1	9·0
Volatile matter.....“	37·3	37·7	42·1	11·1	11·3	52·0	61·8	58·7	65·7	55·0	61·3
Fixed carbon.....“	41·5	42·0	46·8	82·2	83·4	21·7	25·8	26·7	29·9	26·6	29·7
Ultimate Analysis—											
Sulphur.....per cent	0·3	0·3	0·4	0·1	0·2	0·7	0·8	0·2	0·2	0·4	0·4
Calorific Value—											
Calories per gramme, gross	5,910	5,980	6,670	7,520	7,630	4,000	4,760	4,820	5,390	4,490	5,010
B.T.U. per pound, gross	10,640	10,770	12,010	13,530	13,730	7,210	8,570	8,670	9,700	8,090	9,020
Fuel ratio	1·10			7·45		0·42		0·46		0·49	
Apparent density (water=1·00)	....			....		1·19		....		....	
Date	Jan. 31, 1927			Jan., 1927		Aug. 25, 1926		Aug. 17, 1926		June 21, 1926	

TABLE XXV

Screen Analyses of Coke Samples

Wire Screens with Square Openings

Designation		"Besco"; mixed sizes	Ottawa Gas Co., large sizes	Steel Co. of Canada		"Solvay"	
				Stove	Nut	Egg	Detroit nut
Sample No.		4114	3893	4115	4116	4117	4118
Remaining on 3" screen (Lump)	per cent	0·0	28·0	0·0	0·0	0·0	0·0
Passing 3", remaining on 2" (Egg)	"	4·7	47·0	6·7	0·0	24·4	0·0
" 2", " 1½" (Stove)	"	33·8	16·5	67·6	37·4	60·8	28·6
" 1½", " ¾" (Nut)	"	56·3	4·5	24·9	58·4	13·6	67·7
" ¾", " ½" (Pea)	"	4·3	1·0	0·4	2·9	0·5	2·9
" ½" screen (Fines)	"	0·9	3·0	0·4	1·3	0·7	0·8

Designation		"Solvay", Buffalo, Nut	"Donnerhanna", Buffalo		"Oto," Sault Ste. Marie		
			Egg	Nut	Large	Nut	Mixed
Sample No.		4119	4120	4121	4112	4113	4134
Remaining on 3" screen (Lump)	per cent	0·0	0·0	0·0	0·0	0·0	0·0
Passing 3", remaining on 2" (Egg)	"	0·0	46·6	2·7	64·0	0·0	27·8
" 2", " 1½" (Stove)	"	10·5	46·2	59·8	32·6	2·2	59·4
" 1½", " ¾" (Nut)	"	78·2	5·9	34·6	1·3	71·2	10·7
" ¾", " ½" (Pea)	"	9·4	0·0	2·0	0·4	24·3	0·7
" ½" screen (Screenings)	"	1·9	1·3	0·9	1·7	2·3	1·4

PART II

I

GASOLINE SURVEY FOR 1926

P. V. Rosewarne and A. F. Gill

A survey of the gasoline sold in Canada was made by the Fuels and Fuel Testing Division of the Mines Branch in 1923, 1924, and 1925[1]. This report covers a similar survey for 1926. During the latter part of August, 76 samples were collected[2] from wholesalers or distributors in the following cities: Halifax, St. John, Quebec, Montreal, Ottawa, Toronto, London, Winnipeg, Regina, Calgary, Edmonton, Vancouver, and Victoria. These samples were tested for distillation range, iodine value, and specific gravity. The distillation range was determined according to the method recommended by the United States Bureau of Mines[3]. From the results so obtained, a weighted index number was calculated after the method advocated by Gruse[4], with the difference that the index numbers were calculated from temperatures of the distillation range expressed in °F. instead of from temperatures expressed in °C. as was done by Gruse. The iodine values were determined by the Hanus method[5] and the specific gravities were obtained by the Westphal balance at room temperature and the results calculated to 60° F.

---

[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1925.

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

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

[4] Chemical and Metallurgical Engineering, Vol. 29, No. 22, p. 970. Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923, p. 53.

[5] Ellis and Meigs, "Gasoline and other Motor Fuels."

TABLE XXVI

Results of Analyses

Lab. No.	Brand	Distillation Range 1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.	Recovery	Iodine value	Specific gravity	° Be	Index number ° F.
HALIFAX, N.S.													
3845	Red Seal *(b)*......	133	197	223	276	314	370	414	97·9	34	0·755	55·5	1794
3846	Premier *(a)*.......	120	186	210	264	294	342	410	98·0	45	0·744	58·2	1706
3847	White Rose *(b)*....	111	167	195	254	293	359	412	97·0	30	0·736	60·1	1680
	Average.........	121	183	209	265	300	357	412	97·6	36	0·745	57·9	1726
ST. JOHN, N.B.													
3833	White Rose *(b)*....	118	170	195	243	276	329	400	97·8	31	0·736	60·3	1613
3834	Fundy *(c)*.........	117	166	192	253	293	355	407	97·2	26	0·738	59·6	1666
3835	Premier *(a)*.......	133	195	218	266	303	360	405	97·7	32	0·750	56·6	1747
	Average.........	123	177	202	254	291	348	404	97·6	30	0·741	58·8	1676
QUEBEC, QUE.													
3819	Super Power *(d)*...	104	155	182	254	295	356	406	98·1	21	0·739	59·5	1648
3820	Red Seal *(b)*......	109	163	188	258	301	358	402	98·0	22	0·740	59·2	1670
3821	Premier *(a)*.......	110	165	193	259	306	365	410	97·6	24	0·740	59·2	1698
3822	Peerless *(d)*.......	108	155	177	226	259	318	376	97·4	6	0·724	63·3	1511
3823	Queen *(a)*.........	110	161	190	260	304	364	409	97·8	10	0·742	58·7	1688
3824	White Rose *(b)*....	107	159	184	247	298	365	408	97·5	10	0·737	60·0	1661
	Average.........	108	160	186	251	294	354	402	97·7	16	0·737	60·0	1647

TABLE XXVI—Continued

Results of Analyses—Continued

Lab. No.	Brand	Distillation Range								Iodine value	Specific gravity	° Be	Index number ° F.
		1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.	Recovery				
	MONTREAL, QUE.												
3811	Yale (g)...........	105	156	170	222	270	341	405	97·1	6	0·725	63·1	1564
3812	British Motor (d).	102	153	186	261	306	366	414	97·6	9	0·742	58·5	1686
3813	Premier (a).......	107	156	185	260	304	356	401	97·6	19	0·744	58·2	1662
3814	Peerless (d).......	106	155	174	219	260	323	383	97·3	6	0·721	64·1	1514
3815	Queen (a).........	100	144	170	244	291	350	399	97·0	15	0·733	61·0	1598
3816	Shell (e)..........	114	157	177	230	272	340	402	98·0	5	0·727	62·7	1578
3817	Tidioute (f).......	105	150	175	234	275	327	385	98·0	4	0·723	63·8	1546
3818	Sunoco (g)........	117	188	210	287	333	380	420	98·0	60	0·769	52·2	1818
	Average.........	107	157	181	245	289	348	401	97·6	16	0·736	60·5	1621
	OTTAWA, ONT.												
3876	Sunoco L.T. (i)...	117	184	212	278	326	370	402	97·4	55	0·772	51·4	1772
3877	Sunoco H.T. (i)...	111	156	180	238	284	361	415	97·1	7	0·721	64·2	1634
3878	Premier (a).......	108	163	201	261	305	364	405	97·4	13	0·747	57·3	1699
3879	Queen (a).........	104	152	180	249	292	354	399	96·8	17	0·737	60·0	1626
3880	Red Seal (b)......	112	173	199	265	309	362	407	97·2	18	0·748	57·2	1715
3881	White Rose (b)....	102	155	187	262	309	376	434	97·0	12	0·730	61·8	1723
3882	Crown (e).........	98	142	172	267	329	387	430	96·5	22	0·746	57·7	1727
3883	Aviation (e).......	105	155	176	225	265	332	392	97·1	4	0·723	63·6	1545
3884	Peerless (d).......	104	151	172	221	260	317	380	97·2	5	0·719	64·7	1501
3885	Super Power (d)...	106	165	194	261	303	361	407	97·5	12	0·747	57·5	1691
3886	Super Quality (t)..	92	133	159	239	291	356	400	96·5	14	0·729	62·0	1578
3887	Frontenac (j)......	94	144	176	269	330	389	430	96·5	25	0·749	57·0	1738
3919	Marathon (h)......	103	159	183	239	277	336	401	97·2	4	0·727	62·7	1595
3920	Ethyl (a).........	103	160	185	243	281	332	375	97·2	15	0·745	57·9	1576
3921	High Compression (t)............	91	140	167	231	270	322	372	97·1	3	0·718	65·0	1502
	Average.........	103	155	183	250	295	354	403	97·0	15	0·737	60·0	1641

TORONTO, ONT.

3837	Premier *(a)*.......	118	171	200	269	311	364	407	97·5	19	0·748	57·1	1722
3838	Sunoco *(g)*.........	130	193	221	279	327	381	425	97·2	41	0·763	53·5	1826
3839	Peerless *(d)*.......	97	149	177	239	286	352	390	96·8	4	0·724	63·3	1593
3840	Crystal............	118	186	217	279	318	370	418	97·4	6	0·745	58·0	1788
3841	White Rose *(b)*....	106	164	194	266	306	369	431	97·3	25	0·736	60·3	1730
3842	Perfection *(l)*......	110	155	176	223	265	341	398	97·5	20	0·724	63·2	1558
3843	Shell Aviation. *(e)*	105	160	181	230	264	316	367	97·5	2	0·723	63·6	1518
3844	Hi-Test *(h)*.........	105	154	181	242	281	342	393	97·1	4	0·723	63·6	1593
	Average.........	111	167	193	253	295	354	404	97·3	15	0·736	60·3	1666

LONDON, ONT.

3825	Shell *(e)*..........	110	170	205	274	331	396	433	97·3	5	0·743	58·4	1809
3826	White Rose *(b)*....	119	178	197	274	312	365	416	97·5	33	0·740	59·2	1742
3827	White Mule *(r)*....	121	186	211	270	311	367	419	97·8	39	0·742	58·6	1764
3828	High Test *(m)*....	108	153	176	238	282	342	396	97·8	15	0·724	63·3	1587
3829	Super Test *(k)*.....	119	187	211	270	311	362	416	97·7	47	0·743	58·4	1757
3830	Premier *(a)*.......	110	168	193	271	310	364	414	97·5	43	0·739	59·3	1720
3831	Marathon *(h)*......	104	147	170	227	282	374	433	96·5	4	0·721	64·3	1633
3832	British Motor *(d)*.	110	170	195	272	312	368	413	97·5	38	0·740	59·3	1730
	Average.........	113	170	195	262	306	367	418	97·5	28	0·737	60·1	1718

WINNIPEG, MAN.

3856	White Rose *(b)*....	103	156	187	255	299	366	420	97·1	31	0·733	61·0	1683
3857	Radio *(s)*.........	114	160	185	245	292	351	406	98·0	11	0·730	61·9	1639
3858	Premier *(a)*.......	108	165	198	273	311	365	420	98·0	45	0·740	59·2	1732
3859	Red Star *(n)*......	114	159	183	246	289	350	413	98·0	19	0·727	62·6	1640
3860	Lightning *(s)*......	102	148	174	245	296	356	416	97·8	29	0·728	62·3	1635
3861	British Motor *(d)*.	111	171	204	270	312	368	417	97·9	44	0·740	59·1	1742
	Average.........	109	160	189	256	300	359	415	97·8	30	0·733	61·1	1679

TABLE XXVI—Concluded

Results of Analyses—Concluded

Lab. No.	Brand	Distillation Range								Iodine value	Specific gravity	° Be	Index number ° F.
		1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.	Recovery				
	REGINA, SASK.												
3852	Peerless *(d)*.......	111	162	186	248	288	344	404	97·8	19	0·732	61·2	1632
3853	Premier *(a)*.......	120	182	210	267	306	333	396	97·7	32	0·740	59·1	1714
3854	Red Star *(n)*......	108	160	186	251	292	353	407	97·6	29	0·729	62·0	1649
3855	White Rose *(b)*....	96	160	189	264	306	364	424	97·7	33	0·737	59·9	1707
	Average.........	109	166	193	258	298	354	408	97·7	28	0·735	60·6	1677
	CALGARY, ALTA.												
3863	Sunshine *(o)*.......	116	179	208	286	340	416	469	97·6	6	0·748	57·1	1898
3864	Union *(q)*.........	110	175	201	254	296	363	421	98·0	8	0·751	56·3	1710
3865	Premier *(a)*.......	110	166	192	263	307	365	408	97·6	44	0·736	60·2	1701
3866	Royal *(n)*.........	114	176	208	281	326	376	404	97·2	42	0·745	58·0	1771
	Average.........	113	174	202	271	317	380	426	97·6	25	0·745	57·9	1770
	EDMONTON, ALTA.												
3867	British Motor *(d)*.	111	169	198	270	317	373	412	97·5	40	0·741	58·9	1749
3868	Premier *(a)*.......	122	179	204	281	326	376	412	97·3	45	0·745	57·9	1778
3869	North Star *(n)*....	98	141	166	235	290	364	408	96·7	33	0·723	63·7	1604
3870	White Rose *(b)*....	113	169	198	275	321	378	416	97·2	43	0·742	58·7	1757
	Average.........	111	165	192	265	314	373	412	97·2	40	0·738	59·8	1721

VANCOUVER, B.C.

3848	Premier *(a)*.......	121	187	210	268	312	376	430	97·4	14	0·756	55·3	1783
3849	General *(p)*.......	115	179	209	268	311	373	420	97·3	6	0·759	54·5	1760
3850	Shell *(e)*..........	115	174	206	274	323	383	430	97·6	5	0·754	55·6	1790
3851	Union *(q)*.........	99	153	187	260	306	376	430	96·5	6	0·748	57·2	1712
	Average.........	113	173	203	268	313	377	428	97·2	8	0·754	55·7	1762

VICTORIA, B.C.

3873	Shell *(e)*..........	107	172	203	274	324	387	435	97·2	9	0·754	55·7	1795
3874	Premier *(a)*.......	121	181	205	301	354	354	406	97·8	33	0·749	56·9	1709
3875	Union *(q)*.........	91	140	174	258	311	386	430	96·0	10	0·740	59·2	1699
	Average.........	106	164	194	265	312	376	424	97·0	17	0·748	57·3	1735

(a) Imperial Oil Company, Limited.
(b) Canadian Oil Companies, Limited.
(c) Canadian Independent Oil Limited.
(d) British American Oil Company, Limited.
(e) Shell Oil Company, Limited.
(f) Tidioute Refining Company, Limited.
(g) Sun Oil Company, Limited.
(h) McColl Brothers, Limited.
(i) Capital City Oil Company, Limited.
(j) Frontenac Oil Company.
(k) Supertest of London Limited.
(l) Perfection Petroleum Company, Limited.
(m) J. L. T. Hayes.
(n) North Star Oil Company, Limited.
(o) Alberta Refining Company, Limited.
(p) General Oil Company, Limited.
(q) Union Oil Company, Limited.
(r) Western Oil Company.
(s) Pure Oil Company, Minneapolis.
(t) Supertest Company of Ottawa.

TABLE XXVII

Average Results of Analyses by Cities

District	Distillation Range								Iodine value	Specific gravity	Index number ° F.
	1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.	Recovery			
Halifax, N.S.	121	183	209	265	300	357	412	97·6	36	0·745	1726
Montreal, Que	107	157	181	245	289	348	401	97·6	16	0·736	1621
Quebec, Que	108	160	186	251	294	354	402	97·7	16	0·737	1647
London, Ont	113	170	195	262	306	367	418	97·5	28	0·737	1718
St. John, N.B	123	177	202	254	291	348	404	97·6	30	0·741	1676
Toronto, Ont	111	167	193	253	295	354	404	97·3	15	0·736	1666
Vancouver, B.C	113	173	203	268	313	377	428	97·2	8	0·754	1762
Regina, Sask	109	166	193	258	298	354	408	97·7	28	0·733	1677
Winnipeg, Man	109	160	189	256	300	359	415	97·8	30	0·733	1673
Calgary, Alberta	113	174	202	271	317	380	426	97·6	25	0·745	1770
Edmonton, Alberta	111	165	192	265	314	373	412	97·2	40	0·738	1721
Victoria, B.C	106	164	194	265	312	376	424	97·0	17	0·748	1735
Ottawa, Ont	103	135	183	250	295	355	403	97·0	15	0·737	1641
Average*	110	164	191	256	300	360	410	97·4	21	0·739	1681

*This is average value for all the samples tested.

COMPARISON OF RESULTS

It is interesting to compare the foregoing figures with others obtained in somewhat the same way. Table XXVIII gives the average results of 88 samples collected in Canada, presumably in 1916, and reported by the laboratories of the Department of Inland Revenue[1]; the average of 48 samples collected in Canada during 1923[2]; the average of 59 samples collected during 1924[3]; the average of 73 samples collected during 1925[4]; the average of 76 samples collected in 1926; the average of 128 samples collected in United States during July, 1926, and reported by U.S. Bureau of Mines[5]; and the essential features of the specification of motor gasoline adopted by the Specification Board of the United States[6] for the use of the various departments and independent establishments of the United States Government. It will be observed that the gasoline sold in Canada during the present year shows an average of distinctly good quality when judged by the distillation range which is the ordinarily accepted standard.

TABLE XXVIII

Average Results for Comparison

—	Distillation Range							Recovery	Iodine value	Specific gravity	Index number °F.
	1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.				
Canada, 1916	125	170	192	237	270	330	380	......	17	0·732	1579
Canada, 1923	120	170	193	255	296	358	423	97·1	19	0·737	1695
Canada, 1924	113	173	195	249	288	347	410	97·4	18	0·736	1662
Canada, 1925	116	174	199	258	299	359	412	97·0	18	0·739	1701
Canada, 1926	110	164	191	256	300	360	410	97·4	21	0·739	1681
United States, July, 1926	100	.....	194	266	.....	382	421	96·7	......	0·750	......
U.S. Federal Specification	131	.....	221	284	.....	392	437	......	......	......	......

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 76 samples) having the highest end point, and the average of the 8 samples having the lowest end point was obtained, as shown in Table XXIX and Table XXX.

TABLE XXIX

Ten per cent of Samples Having Maximum End Points

Laboratory No.	Distillation Range							Recovery	Iodine value	Specific gravity	Index number °F.
	1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.				
3863	116	179	208	286	340	416	469	97·6	6	0·748	1898
3873	107	172	203	274	324	387	435	97·2	9	0·754	1795
3881	102	155	187	262	309	376	434	97·0	12	0·730	1723
3831	104	147	170	227	282	374	433	96·5	4	0·721	1633
3841	106	164	194	266	306	369	431	97·3	25	0·736	1730
3887	94	144	176	269	330	389	430	96·5	25	0·749	1738
3882	98	142	172	267	329	387	430	96·5	22	0·746	1727
3875	91	140	174	258	311	386	430	96·0	10	0·740	1699
Average	102	155	186	264	316	386	437	96·8	14	0·741	1744

---

[1] Department of Inland Revenue, Canada, Bulletin 362, "Gasoline".
[2] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923.
[3] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1924.
[4] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1925.
[5] U.S. Bureau of Mines, Report of Investigations, Serial No. 2636.
[6] U.S. Bureau of Mines, Technical Paper 323A.

TABLE XXX

Ten per cent of Samples Having Minimum End Points

Laboratory No.	Distillation Range							Recovery	Iodine value	Specific gravity	Index number °F.
	1st drop ° F.	10% ° F.	20% ° F.	50% ° F.	70% ° F.	90% ° F.	End point ° F.				
3839	97	149	177	239	286	352	390	96·8	4	0·724	1593
3817	105	150	175	234	275	327	385	98·0	4	0·723	1546
3814	106	155	174	219	260	323	383	97·3	6	0·721	1514
3884	104	151	172	221	260	317	380	97·2	5	0·719	1501
3822	108	155	177	226	259	318	376	97·4	6	0·724	1511
3920	103	160	185	243	281	332	375	97·2	15	0·745	1576
3921	91	140	167	231	270	322	372	97·1	3	0·718	1502
3843	105	160	181	230	264	316	367	97·5	2	0·723	1518
Average	102	153	176	230	269	326	379	97·3	6	0·725	1533

Table XXXI shows the difference between the average end points of the maximum 10 per cent and minimum 10 per cent of samples collected in Canada in 1916[1], in 1923, in 1924, in 1925 and 1926, together with similar figures obtained by the Bureau of Mines[2] in the United States for the years 1923, 1924, and 1925. The difference between the two averages may be accepted for the purpose of comparison, as a measure of the variation in quality. It will be observed that in 1926 the variation in quality was less than that obtained in the survey of 1925.

TABLE XXXI

Difference Between Maximum and Minimum End Points

—	Canada					United States		
	1916	Aug., 1923	Aug., 1924	Aug., 1925	Aug., 1926	July, 1923	July, 1924	July, 1925
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
Maximum 10 per cent	432	446	459	458	437	471	457	458
Minimum 10 per cent	322	381	358	366	379	400	396	399
Difference	110	65	101	92	58	71	61	59

---

[1] Mines Branch, Dept. of Mines, Canada, Invest. of Fuels and Fuel Testing, 1923.
[2] U.S. Bureau of Mines, Report of Investigations, Serial No. 2740.

SUMMARY

Seventy-six samples of gasoline were collected in August, 1926, from thirteen widely separated Canadian cities, and may be accepted, therefore, as representative of the gasoline sold in Canada at that time.

The analyses and detailed examination of these samples show that the average gasoline sold during 1926 was of good quality, being superior to that sold during 1925 and very nearly equal to that sold in 1924.

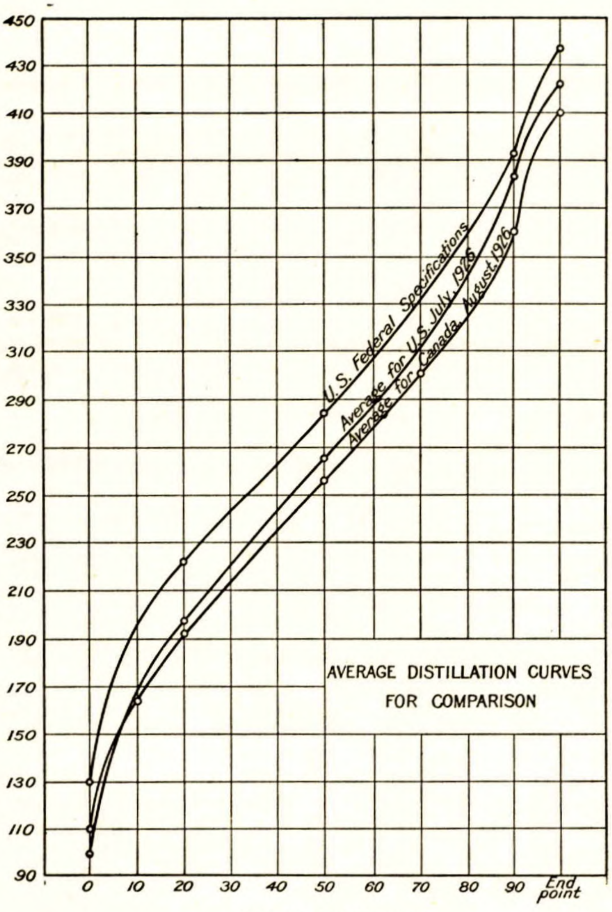


Figure 11. Gasoline: average distillation curves for comparison.

The average distillation curves show that the gasoline sold in Canada during August, 1926, was superior to that sold in the United States during July, 1926, and to the United States Federal specifications for U.S. Government motor gasoline.

The variation in quality was less during 1926 than that during 1925 or 1924.

II

REPORT OF EXPERIMENTS ON THE DEHYDRATION OF BITUMEN EMULSION FROM ALBERTA BITUMINOUS SANDS

P. V. Rosewarne and G. P. Connell

Dehydration experiments were carried out on a sample of "separated" bitumen supplied by Dr. K. A. Clark of the Research Council of Alberta. This bitumen had been obtained from the natural bituminous sands by the hot-water, sodium-silicate method in his separation plant at Edmonton, and contained a fairly large proportion of water in the form of a stubborn emulsion. Although the bitumen may be used satisfactorily in certain commercial refining processes without preliminary treatment, it is necessary to dehydrate such emulsions in order to obtain quantities of the water-free bitumen for examination in the laboratory and for other purposes. Similar emulsions of crude petroleums and other oils also give trouble when distilled in the ordinary way and in this respect the results of the experiments reported here should be of value for oil-water emulsions in general.

Examination of the separated bitumen in the barrel, some time after receiving the sample, showed that considerable water had collected on the surface. A sample taken after pouring off this water had the following approximate composition:—

Bitumen (water-free)	67·7 per cent
Water	28·0 "
Mineral matter	4·3 "

This analysis it will be noticed agreed only roughly with the analyses of several samples of separated bitumen reported[1] by Clark and Blair, the water content of which varied from slightly less than 20 per cent to over 30 per cent, the lowest mineral matter content being less than 3 per cent.

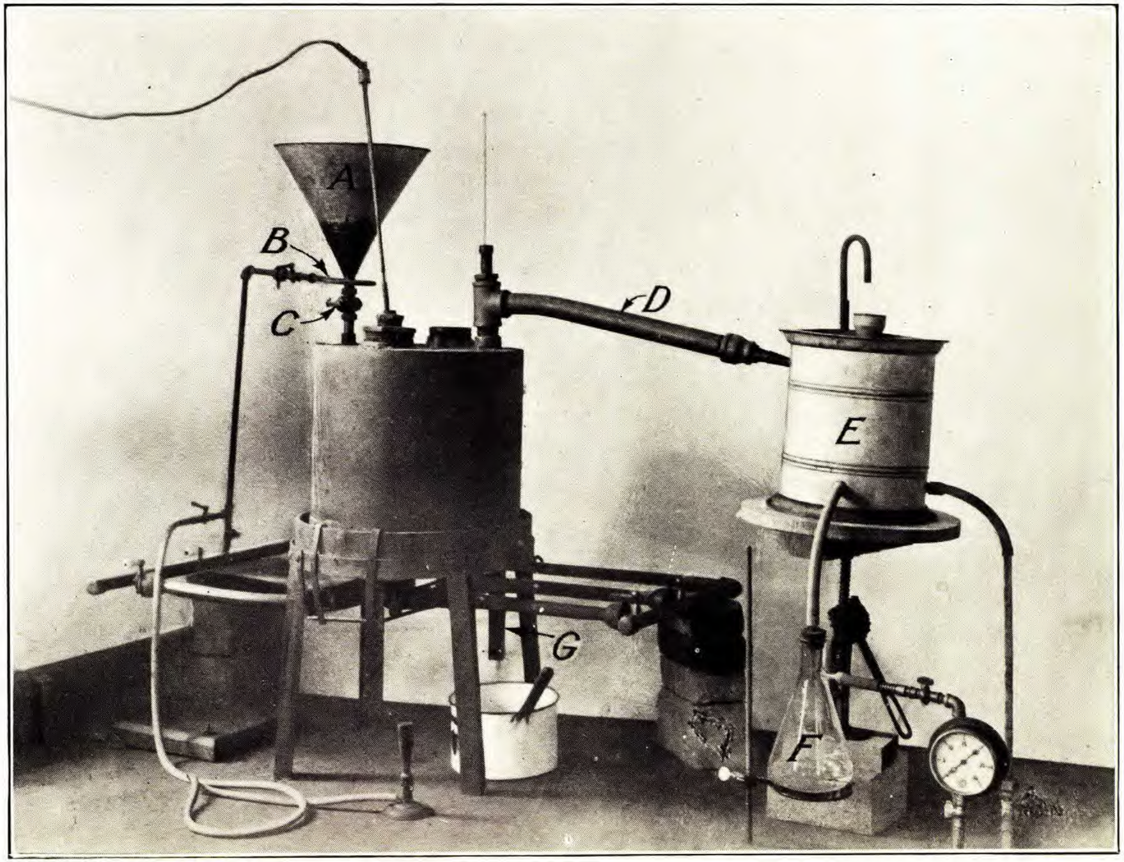
DETERMINATION OF WATER CONTENT AND MINERAL MATTER

The water content of the bitumen was determined according to A.S. T.M., D. 95-24, viz., "Standard Method of Test for Water in Petroleum Products and other Bituminous Materials",[2] using toluene as the solvent. Heat was supplied by an electric heater fitted with a rheostat for controlling the current. In this method the condensed water and toluene drops into the graduated receiver at the bottom of the condenser, the water settling to the bottom and the toluene overflowing and running back into the distillation flask. A sharply defined meniscus indicates the amount of water distilled from the sample of wet bitumen.

---

[1] Sixth Annual Report of the Scientific and Industrial Research Council of Alberta, 1925, p. 47.

[2] The glass part of the apparatus was as shown in A.S.T.M., D. 95-24, and the electric heater was a Precision type, as illustrated in cut 11-425, Fisher Scientific Company catalogue.



View of large laboratory-scale apparatus used in dehydration experiments on bitumen from Alberta bituminous sands.

The results of five determinations of water in the bitumen from the stock barrel were as follows:—

Test	Weight of sample	Water	Water in bitumen
	grammes	c.c.	per cent
1	24·9	7·10	28·5
2	28·7	8·15	28·4
3	23·9	6·15	25·7
4	29·5	7·90	26·8
5	29·6	8·10	27·4

The mineral matter was determined by burning to constant weight a sample of bitumen, water-free by the above method, and calculating the percentage. The percentage of bitumen was obtained by difference.

SMALL LABORATORY-SCALE DEHYDRATION EXPERIMENTS

The water content of a bitumen emulsion is difficult to remove, due partly to the viscosity of the tar, partly to the small difference in specific gravity between the water and the tar, and partly to the remarkable celerity with which the material boils over even when heated most cautiously. Dilution with large quantities of benzene or toluene and subsequent distillation was tried and found satisfactory for laboratory determinations when the distillation was carefully performed, but this method required too much time when fairly large quantities of bitumen were desired. It was further unsatisfactory due to the inflammability of the benzene and toluene vapours. Experiments in which carbon tetrachloride was substituted for benzene and toluene likewise gave unsatisfactory results. By repeated treatment it was possible to reach a point where no water came over with the carbon tetrachloride, but when an attempt was made to raise the temperature of the residual material above the boiling point of water the whole mass foamed over. Furthermore, the use of carbon tetrachloride was unsatisfactory due to its decomposition and the formation of hydrochloric acid with its excessively corrosive properties.

The effect of allowing the material to flow on to a hot surface in an enclosed space, sufficiently large to permit of the bitumen foaming without overflowing, was next tried. The apparatus shown in Figure 12 was procured and set up. This apparatus consisted essentially of a 5-litre pyrex flask of the shape shown and a special short still-head, carrying a copper funnel with a long stem of large bore.

The flask was placed on a sand bath and was heated over an ordinary gas hot-plate. The still-head was made with the vertical part as large as could be conveniently inserted into the neck of the flask. The still-head was attached to the flask by means of a fitted cork. With the aid of tin foil and asbestos rope packing little difficulty was experienced in obtaining a reasonably tight joint. A special short-necked flask with a side arm fused in would probably be more durable and therefore more satisfactory in some respects. The funnel was seven inches in diameter having a long and cylindrical stem of sufficient diameter to leave a small concentric space between the outside of the stem and the inside of the vertical member of the still-head. It was attached to the still-head in the same manner that the latter was fastened into the flask. The funnel was pushed down until the lower end of the stem projected below the lower end of the still-head.

The funnel was made of heavy gauge sheet copper so that it would readily conduct heat down the stem. The upper part of the funnel was heated with an ordinary laboratory gas-ring so that the contained bitumen would flow more readily. It was necessary to maintain the temperature well below that of boiling water in order to avoid danger of frothing. A thermometer served to indicate the temperature. The upper end of the stem was closed with a valve made of a piece of glass tubing drawn to a short taper, and left long enough to extend well above the upper edge of the funnel, where it was held in position by a burette clamp. By means of this valve the flow of bitumen could be regulated as desired. The lower tip of the glass valve was cut off, leaving an opening of about three-eighths of an inch in diameter through which a special long-stemmed thermometer was passed down until the thermometer bulb was about one inch from the bottom of the flask. It was supported in position by a cork at the upper end of the glass tube. This thermometer indicated the temperature of the hot bitumen within the flask. The vapours given off were led through the side arm of the still-head into a condenser and thence to a receiver. A gentle suction was maintained on the apparatus to avoid fumes. A meter and an activated charcoal absorption tube was used as a check on the loss of light oil constituents. Negative results were obtained on subsequent treatment of the charcoal and it was accordingly assumed that the loss of oil was negligible.

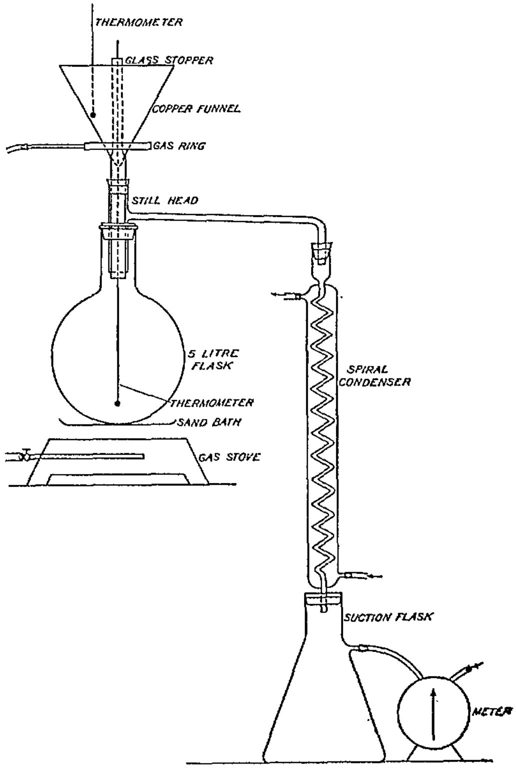


Figure 12. Small laboratory-scale dehydration apparatus for experiments on bitumen from Alberta bituminous sands.

In operation the wet bitumen was charged into the funnel with the glass valve closed, and warmed with a low flame from the gas-ring until its temperature was about 60° C. The 5-litre flask was heated until the air within it was about 135° C. The glass valve was then raised slightly and the warm bitumen allowed to flow slowly down the funnel stem into the flask. The wet bitumen frothed as it came in contact with the hot bottom of the flask but soon subsided as the water was driven off. As soon as it was free from water its temperature rose and the bitumen itself provided a hot surface for the incoming wet material. The rate of feeding and the temperature of the contents of the 5-litre flask were so regulated as to keep a layer of frothing bitumen about 2½ to 3 inches deep on the dry liquid bitumen on the bottom of the flask. By regulating in this way the water was readily distilled over and a minimum of oil was carried over with it. The operation was continued until the flask was over one-half full of dry bitumen. The hot bitumen was then poured into suitable receptacles.

The operation was performed on a quantitative basis by weighing the bitumen charged to the funnel and weighing or measuring the product. The bitumen so obtained was tested for water content by the standard method and found to contain practically no water. A slight milkiness in the first runnings of the toluene was noticed but as no drops of water separated on standing, the water content of the dehydrated bitumen was considered to be nil. Four experimental runs or tests were made, in all of which (with one exception) no serious trouble was experienced from frothing. The data sheet of a typical run is shown below. A summary of the results and a weight balance of the products obtained in four experimental runs are given in Tables XXXII and XXXIII.

Run No. 3

Date and time	Temperature 5-litre flask ° C.	Gas Meter		Temperature of bitumen fed ° C.	Remarks
		Reading, cubic feet	Temperature °F		
a.m.					
9.10	135	37·937			Start.
9.40	170	37·937			
9.50	123	38·000	83		
10.00	106	38·007	83		
10.10	104	38·010	83	40	
10.20	106	38·011	84	45	
10.30	106	38·012	84	50	
10.40	108	38·015	85	58	
10.50	105	38·018	86	64	
11.00	105	38·020	87	66	
11.10	103	38·023	87	62	
11.20	102	38·025	88	58	
11.30	102	38·027	88		Finished feeding tar.
11.40	110	38·029	87		
11.50	205	38·029	88		
12.00	223				

Total bitumen emulsion charged	1091·0	grammes
Total bitumen recovered	654·5	"
Bitumen remaining in apparatus	85·5	"
Total water and oil distillate	335·0	"
Light oil recovered	22·5	"
Water by difference	312·5	"

TABLE XXXII

Summary of the Results Obtained in the Small Laboratory-scale Dehydration Experiments

—	Run No. 1	Run No. 2	Runs Nos. 1 and 2	Run No. 3	Run No. 4
	grms.	grms.	grms.	grms.	grms.
Bitumen emulsion charged	1,083·0	983·5	2,067·0	1,091·0	1,211·5
Products Obtained—					
Dehydrated bitumen recovered	598·5	580·0	-	654·5	740·0
Bitumen left in apparatus	152·5	87·6	-	85·3	111·5
Water and oil distillate	291·5	298·7	590·3	335·1	341·8
Light oil	-	-	26·8	22·7	9·2
Water, by difference	-	-	563·5	312·4	332·6
Gas (calculated weight)	-	1·9	-	2·2	5·4
Loss, by difference	41·0	15·4	-	13·9	12·9

TABLE XXXIII

Weight Balance (Small Laboratory-scale Experiments)

(*Products as a percentage of the bitumen emulsion charged*)

—	Runs Nos. 1 and 2	Runs Nos. 2 and 3	Run No. 4
Dehydrated bitumen	68·6	67·8	70·3
Light oils (water-free)	1·3	2·1	0·8
Water	27·3	28·6	27·4
Gas and loss, by difference	2·8	1·5	1·5

LARGE LABORATORY-SCALE DEHYDRATION EXPERIMENTS

In order to check the results on a larger scale and to obtain a quantity of dehydrated bitumen, larger equipment was designed and built, the operation of which was continuous. This apparatus, as shown in Plate IV, consisted of two steel receptacles, one 3 inches high and 18 inches in diameter, the other 16 inches high and 16 inches in diameter; the latter being inverted and placed within the former. Lead was melted and poured in the lower receptacle to a depth of three-quarters of an inch to act as a seal between the two parts. Openings were provided for the admission of the wet bitumen, for the removal of the water vapour and of the dehydrated bitumen, and for the insertion of a thermometer to indicate the vapour temperature, and for a pyrometer to indicate the temperature of the bottom of the retort. The retort was heated with four gas burners such as are used on ordinary household gas ranges.

The method of operation was as follows: the bottom of the retort was heated until the lead had melted; wet bitumen was charged into the funnel, A, and warmed to about 60 or 70° C. by means of the burner, B; the valve, C, was opened slightly to allow a small trickle of bitumen to fall on the molten lead within the retort; it frothed up and the contained water was quickly vaporized; the water vapour (and some light oil) passed up through the vapour outlet, D, to the condenser, E, the condensate from which was collected in the receiver, F; the bitumen gradually flowed across the surface of the lead in the retort and emerged quite dry from the outlet, G, placed at the opposite side to that at which the wet bitumen entered. A small current of air was drawn up through the retort, the vapour outlet tube and condenser by a pump not shown in Plate IV. This served the double purpose of cooling the outflowing hot bitumen and of aiding in the rapid removal of water vapour from the retort. The rate at which the wet bitumen was fed into the retort was adjusted so that the water was entirely removed by the time the bitumen reached the outlet. Too rapid a rate was indicated promptly by a frothing product. Too slow a rate resulted in a high percentage of oil distillate being recovered with the water in receiver F.

With the apparatus described above 10 gallons of water-free bitumen were obtained in a short time. The products obtained were:—

a. Dry bitumen.
b. Light oil distillate.
c. Water.
d. A residue on the surface of the lead at the conclusion of the run.

The results of the analyses of these four products were as follows:—

(*a*) *Analysis of Bitumen*

Water	none
Ash	3·6 per cent
Bitumen (by difference)	97·4 "
Specific gravity	1·061 "

(*b*) *Analysis of Light Oil Distillate*

Specific gravity at 60° F.	0·915
Degrees Bé	23

Distillation range, Engler method

Volume of sample used....100 c.c.

1st drop	149° C.
10 c.c.	260
20 c.c.	269
30 c.c.	284
40 c.c.	299
50 c.c.	314
60 c.c.	324
70 c.c.	347
80 c.c.	360
90 c.c.	380
End point*	...

Recovery	97·5 c.c.
Coke residue	0·81 p.c. by weight

---

*Cracking occurred before end point was reached.

Distillation range, Hempel Method*

Volume of sample used......300 c.c.

Temperature ° C.	Vol. of Dist. c.c.	Per cent cut	Sum. per cent	Sp. Gr. cut	Deg. Bé. cut			Temperature ° F.
Distillation at 758 mm. pressure.								
At 97–1st drop								
0–75								32–167
75–100								167–212
100–125								212–257
125–150								257–302
150–175								302–347
175–200	3	1·0	1·0					347–392
200–225	12	4·0	5·0	0·846	35·5			392–437
225–250	35·5	11·8	16·8	0·864	32·0			437–482
250–275	40·0	13·3	30·1	0·881	29·0			482–527
Distillation of residue at 40 mm. pressure								
0–200	83	27·7	57·5	0·909	24·0			32–392
200–225	54	18·0	75·5	0·929	20·7			392–437
225–250	34	11·3	86·8	0·947	17·9			437–482
250–275	14·5	4·8	91·6	0·958	16·0			482–527
275–300	16	5·3	96·9	0·970	14·3			527–572

*In this method the procedure adopted was that recommended by U.S. Bureau of Mines, as outlined in their Bulletin No. 207 "Analytical Distillation of Petroleum."

(c) Analysis of Water

Total solids at 105° C.		0·04 per cent
Solids after ignition		0·007 "
Silica	0·0008 per cent	
Ferric oxide Alumina	0·0015 "	
Calcium oxide	0·0004 "	
Sulphur trioxide	0·0036 "	
Total	0·0063 "	

(d) Analysis of Residue

Volatile matter	40·5 per cent
Fixed carbon (by diff.)	9·9 "
Mineral matter	49·6 "

Several batch runs were also made in the apparatus by closing the outlet, G, on the inside with a steel ball attached to a rod, one end of which projected above the retort through a stuffing box. This arrangement permitted the outlet to be opened easily while the bitumen was still hot and gave absolutely no trouble from clogging. The procedure was much the same as when the 5-litre glass flask was used, but permitted a larger quantity to be handled and avoided the danger of handling the large flask containing hot bitumen. A summary and weight balance of four such runs are given in Tables XXXIV and XXXV.

TABLE XXXIV

Summary of the Results Obtained in Batch Runs in the Large Laboratory-scale Dehydration Experiments

—		Run No. 1	Run No. 2	Run No. 3	Run No. 4
Total bitumen charged	grammes	4,488	5,641	5,043	5,726
Products Obtained—					
Dehydrated bitumen recovered	"	2,227	3,170	3,034	3,242
Residue left in apparatus	"	365	459	410	466
Total distillate	"	1,512	1,987	1,512	1,949
Light oils recovered	"	309	422	137	158
Water by difference	"	1,203	1,565	1,375	1,791
Gas and loss, by difference	"	384	65	87	69

TABLE XXXV

Weight Balance (Large Laboratory-scale Experiments)

—	Run No. 1	Run No. 2	Run No. 3	Run No. 4
Dehydrated bitumen recovered*	49·6	55·2	60·2	56·6
Residue in dehydrator	(8·1)	(8·1)	(8·1)	(8·1)
Light oils (water-free)	6·9	7·5	2·7	2·8
Water	26·8	27·7	27·3	31·3
Gas and loss, by difference	8·6	1·5	1·7	1·2

*Products as a percentage of the bitumen emulsion charged.

SUMMARY

1. A method of procedure is given which was found satisfactory for dehydrating, by means of heat, a very stubborn emulsion of water in bitumen.

2. The results of the analyses of the bitumen, both before and after treatment, have been given, together with the methods used for determining the various constituents.

3. Suitable apparatus for large-scale laboratory work, using an intermittent method of operation, and also for semi-commercial scale work, using both an intermittent and a continuous method of operation has been described and illustrated.

4. Data are given from typical runs when the above methods of operation were used.

5. The apparatus and method will probably be found suitable, with minor modifications, for similar operations under many widely differing circumstances and for a wide range of materials.

III

OIL SHALE FROM ROSEVALE, NEW BRUNSWICK

A. A. Swinnerton

In the early part of August, 1925, the writer was sent to the Maritime Provinces in order to obtain a sample of oil shale of good quality for technical-scale testing.

The oil shale selected was from an old tunnel working situated on the farm of H. Stevens, north of his house and about a quarter of a mile east of Rosevale. The tunnel, which had been driven into the bed for 60 to 70 feet with a dip of 20 degrees, was started in 1861-62 and small quantities of shale had been taken out from time to time, the last occasion being about 1912.

The Albert Series, in which the oil shales occur, outcrops in the Baltimore area, at Rosevale (39 miles from Moncton), in an east and west belt about three miles long and one-quarter mile wide. The base and southern limit of the series lies along the foot of Caledonia mountain, and from there the beds dip to the north at regular angles of from 20 to 30 degrees. About 500 feet (vertical thickness) of the beds are exposed, and the remainder is concealed under almost flat-lying, younger formations to the north, east, and west. Most of the beds in this belt are bituminous, but there are three zones, 30 to 50 feet thick, richer than the others, that stand up as low ridges and can be followed along the strike for at least 4,000 feet. Throughout the remaining two miles of the belt there are beds of rich shale which are probably continuations of the zones mentioned above, but this has not yet been proved.

At several points along the strike of each of the zones there is at least one very rich bed, 3 to 7 feet thick. One bed in each of the two upper zones has been proved, locally, by slopes and tunnels, and a 50-ton sample of the upper bed was sent to Scotland in 1908 and retorted by the Pumpherston Oil Company.[1]

Mining

After the tunnel had been cleared of considerable accumulated rubbish the shale was broken down by blasting. It was necessary to board up the sides of the old tunnel to keep the sled on which the shale was drawn out from fouling the sides. A loading-platform was also built. As mined, the shale was loaded directly onto wagons, hauled 9 miles to Baltimore station, and shipped to Ottawa. The shipment weighed approximately 26½ tons, and consisted mostly of large, rectangular lumps, 1 to 2 feet long.

---

[1] Wright, W. J.: "Geology of the Moncton Map-area"; Geol. Surv., Canada, Mem. 129, pp. 49-50.

A. Mining oil shale, Rosevale, N.B. Tunnel entrance with freshly mined shale in the foreground.

B. Mining oil shale, Rosevale, N.B. View from tunnel showing shale and loading platform.

Two samples of the shale as mined and one of the shipment were taken, viz., (1) a channel sample off the face at the beginning of the operations, (2) a sample during the early part of the loading, and (3) a composite sample as unloaded at Ottawa. Part of sample (1) and sample (2) were examined on the spot in a small field-assay retorting apparatus. Sample (3) and the remainder of sample (1) were subsequently examined in the Fuel Testing Laboratories according to the (large assay retort) standard distillation method. The results of the analyses were as follows:—

—	(1) Channel sample from face		(2) Shale sampled during early part of loading	(3) Composite sample as unloaded No. 3240
	Examined in field	Examined in laboratory		
Shale oil (water-free).......per cent by weight	....	15·1	....	15·4
Aqueous distillate.......... "	....	3·2	....	3·2
Gas...................... "	....	13·4	....	8·9
Spent shale................. "	....	68·0	....	72·5
Crude shale oil—				
Specific gravity at 60° F....................	....	0·870	....	0·885
Imperial gals. per ton......................	33	34·7	31	34·7
Gas, cubic feet per ton......................	....	4,700	....	2,330

When freshly mined, the shale was dull black in colour and became brownish on exposure to the air. Chips or flakes of the shale when heated by the flame of a match showed appreciable signs of oil which ignited and burned with a luminous flame. This, along with the results of the examination in the field-assay retort, indicated that the shale mined was of a consistently high quality. Only approximate results were obtained from the retorting in the field owing to the lack of proper facilities for crushing the shale and for controlling the rate of heating the retort. Oil yields varying from plus or minus 1 per cent of the weight of the shale equal to 2 Imperial gallons or so per ton were expected. With this in view, the fact that all four samples showed yields of over 30 gallons per ton, and that the oil yield from the composite sample as unloaded was, as reported in the above table, the same as the yield from the channel sample, showed that the bed mined and the carload shipped were of uniform composition.

Acknowledgment is due to Mr. Mathew Lodge of Moncton, N.B., for his advice and hearty co-operation in locating and mining the shale, and to A. O. Hayes, of the Geological Survey, for his assistance in taking the channel sample during his official inspection of the location.

IV

REPORT ON THE PRITCHARD PROCESS FOR THE DISTILLATION OF OIL SHALE

R. E. Gilmore and A. A. Swinnerton

The main feature of the Pritchard process is the recirculation of the uncondensed gases through the charge, and, according to the patent[1] specifications, relates to the distillation of wood and other substances, having for its object the equalization of the heat throughout the mass of material being treated. It is also known as the Whitaker-Pritchard process, and is further described[2] as a "process whereby destructive distillation may be carried on under definite control"; reference being made to the distillation of organic materials such as wood, coal, shale, and industrial waste. The purpose of circulating the uncondensed gases is to "distribute the heat units through the mass" and to act "as a scavenger and carry out the vapours as rapidly as is desired." Reduction of the time of distillation, increased yields, improvement of quality of the distillates, and smaller refining losses are claimed. Results of tests on wood, cannel coal, and bituminous sands are available,[3] but apparently, as yet, none on oil shale. This report, as the title indicates, has to do with the retorting of Canadian oil shale by the Pritchard process.

The series of tests on oil shale reported here were conducted in September, 1925, in the technical-scale experimental plant of the Pritchard Process Co., Toronto, Ontario. Mr. Glad Thompson, Technical Engineer for the Pritchard Process Co., had immediate charge of the operation of the plant during the tests, under the constant observation and active assistance of the writers. P. V. Rosewarne and H. McD. Chantler, of the Fuel Testing Laboratories, also assisted, the latter during the first test and the former during the last test.

DESCRIPTION OF RETORTING APPARATUS

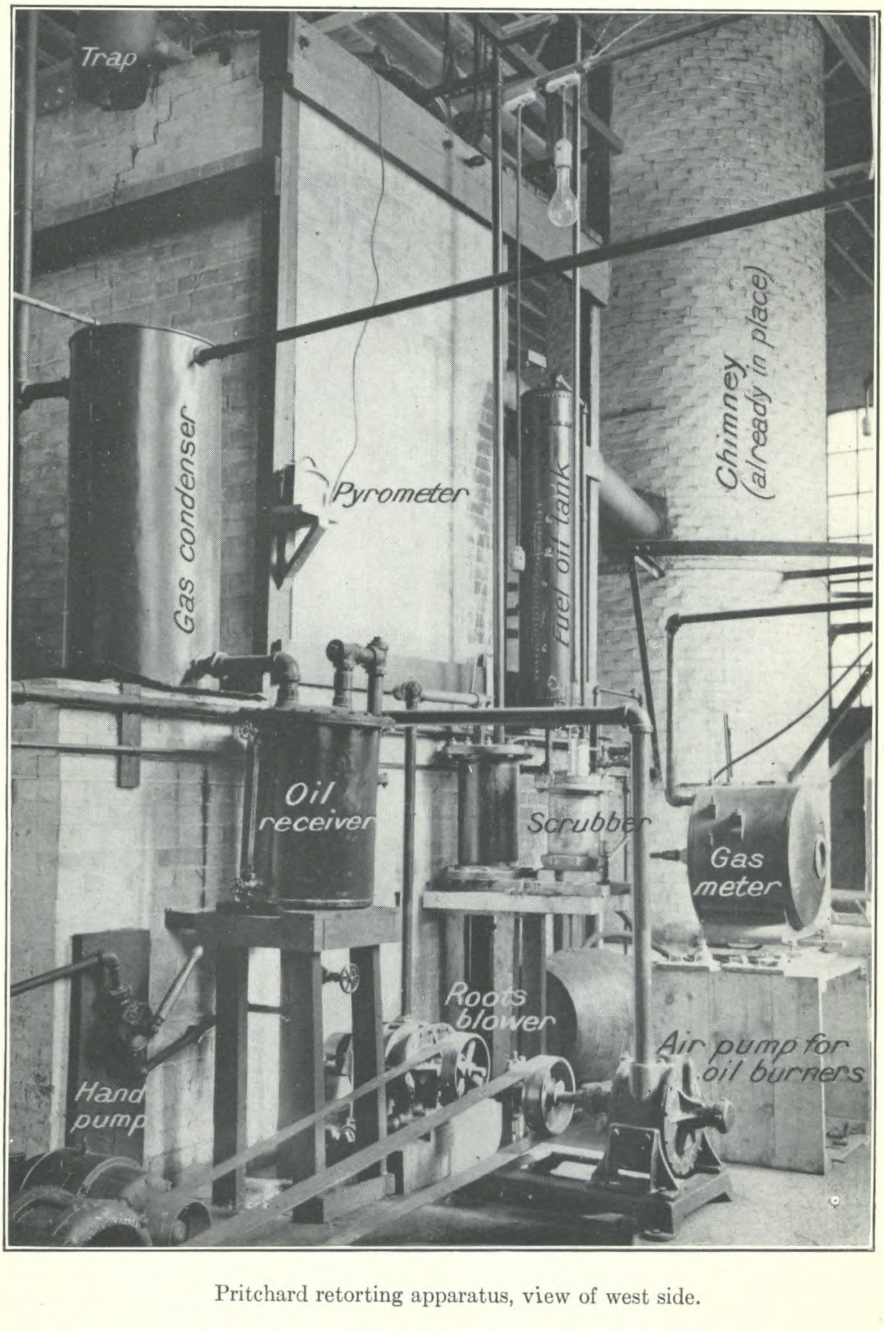
The retort proper consisted of a vertical cast-iron pipe, 24 inches inside diameter, with walls 1½ inches thick, and approximately 14 feet long. The top of the retort was flanged and fitted with a cast-iron lid, capable of being made gas tight by means of asbestos packing and a large screw clamp. The bottom of the retort was in the form of an elbow with the opening at the side of the brick setting and fitted with a gas-tight lid, as at the top. The inside of the retort was fitted centrally with a perforated iron pipe, which served as a basket for holding the charge. The outside

---

[1] Canadian Patent No. 105,468, Oct. 12, 1915.

[2] The Whitaker-Pritchard Process of Destructive Distillation, by Thomas W. Pritchard—Chem. and Met. Engr., Vol. 23, No. 13, p. 664. Also Shale Oil, by R. H. McKee, p. 155.

[3] Gas Age, Vol. 46, No. 7, pp. 261-262, 1920.
Chem. and Ind. 1926, B. 147, Can. Pat. 244,540.
Bituminous Sands of Northern Alberta—S. C. Ells, Mines Branch, Dept. of Mines, Canada, Rept. No. 632, pp. 231-2.



Pritchard retorting apparatus, view of west side.

Pritchard retorting apparatus, view of east side.

diameter of this basket was 22 inches, leaving an annular space of 1 inch between the inner wall of the retort and the basket. The retort had a capacity of 1,500 to 1,600 pounds of shale and was operated intermittently the shale being charged at the top and discharged at the bottom. It was heated externally by means of oil burners and the recirculated gases were preheated in vertical iron tubes placed in the annular flue space between outer walls of the retort and the firebrick insulation.

A diagrammatic sketch of the retort setting and accessory equipment is shown in Figure 13. In this figure, (1) is the retort and (2) the perforated iron basket holding the charge. The course of the gases produced by the destructive distillation of the shale is through the exit pipe (3) to a 3-coil water-cooled copper condenser (5), from which the condensed oils and liquor drop into the receiver (6) to be pumped out as desired by the hand pump (7).

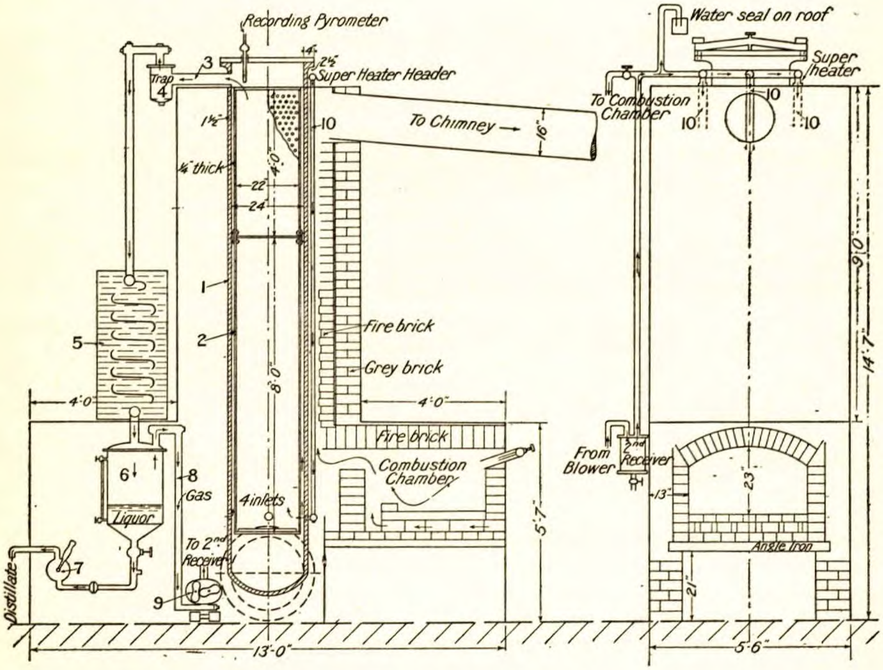


Figure 13. Diagrammatic sketch of Pritchard retort and setting.

Recirculation of the Uncondensed Gases. From the receiver the gases uncondensed in the condensing train are sucked through a "Roots" blower (9) and passed under pressure up to the preheater manifold surrounding the retort near the top, then down through the hot tubes (10) to enter the retort at the bottom through four inlets, and thence upward through the annular space between the walls of the retort and the basket, or up through the lumps of shale contained in the perforated iron basket.

To the condensing train, as shown in Figure 13, was added an oil washer and gas meter, so that instead of bleeding off the gas to the combustion chambers, as shown, the surplus gas was scrubbed and after being metered went to waste.

SHALE USED AND OUTLINE OF TESTS

The oil shale used was obtained at Rosevale, New Brunswick, and a description of the mining and shipping of this shale is given elsewhere.[1] Before re-shipping to Toronto, the large lumps as mined were crushed to 3 inches in size and smaller, a screen analysis of a 100-pound bag picked at random being as follows:—

100	per cent	through	3 -inch	square screen
94·9	"	"	2 -	"
74·6	"	"	1½-	"
56·8	"	"	1 -	"
41·7	"	"	¾-	"
28·2	"	"	½-	"

The apparent specific gravity of crushed shale having the above screen analysis was 1·67 and the weight of a cubic foot was 59 pounds. The analysis of the average sample (No. 3240A), taken during the preparation of the sample for shipment, and the analyses of the shale as charged, are given in Table XXXVI. From the results in this table it will be seen that the quality of the shale in respect to yields of oil, gas, and spent shale, although subject to a slight variation, was quite uniform. Distillation, according to a standard laboratory distillation method, showed an average oil yield of approximately 15 per cent by weight, equal to nearly 35 Imperial gallons per 2,000 pounds of shale. The shale used in the tests in the Pritchard retort may, therefore, be termed a 35-gallon shale.

Three tests were conducted during the latter half of September, 1925. The first test was conducted as a trial run. For the second and third tests certain changes in the apparatus and method of operation were made as thought advisable. The data sheets of the last two runs, along with detailed analyses of the shale charged and the products obtained, are appended. Figure 14 shows the arrangement of the perforated iron basket, the position of shale, and the course of the recirculated gas in second and third tests respectively.

---

[1] Ibid, p. 104.

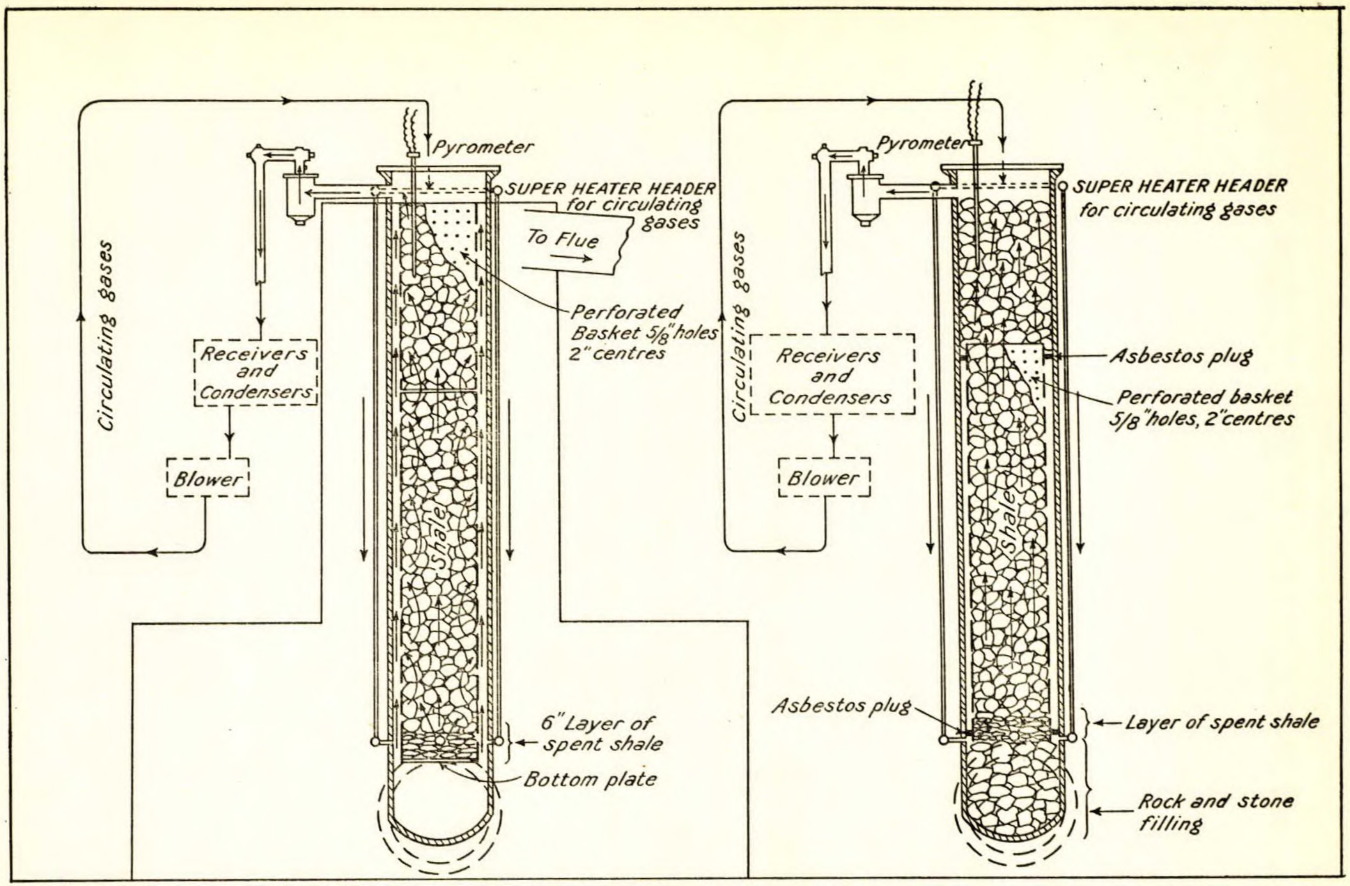


Figure 14. Pritchard retort: showing positions of the perforated iron basket and the course of the circulating gases in Tests Nos. 2 and 3.

OPERATION REMARKS

In all the tests conducted the retort and setting were cold when charged. The distillate was chiefly water, from about two hours after the burners were lit, till the ninth and tenth hour, when the temperature in the centre of the shale at the top of the retort was in the neighbourhood of 700° F. From laboratory distillation tests it had previously been learned that the shale must reach a temperature of at least 750° F. (400° C.) before shale oil would distill off at an appreciable rate, and that the temperature range of 750° to 800° F. was best for the highest rate of flow and yield of oil with minimum uncondensible tar fog. It was therefore decided to keep the temperature of distillation within this range. This was effected by altering the rate of combustion in the oil burners and the speed of the blower in the gas circulation system. These controls varied considerably, but in all three tests the temperature did not appreciably exceed 800° F. until the rate of flow of distillate had reached its maximum and started to decline, after which the temperature was raised to complete the distillation and the blower kept going to sweep out the oil vapours.

At the end of an 18-hour run in the first test, the pyrometer reading exceeded 900° F., and the rate of flow of distillate had materially decreased. Samples of the gas, after passing through the condenser and blower, and before passing into the preheater manifold, were taken off through charcoal absorption tubes for the purpose of determining the light oil content. Samples taken during the latter half of the run showed from 0·4 to 0·5 Imperial gallons of light oils (specific gravity 0·75) per 1,000 cubic feet of gas. This, coupled with the presence of considerable tar fog in both the circulating and exit (surplus) gas, showed inefficient condensing and scrubbing. Tar fog, especially that of a yellowish colour which is produced by ordinary destructive distillation, consists mostly of condensible oils having a density in the neighbourhood of 0·9, the same as the total oil distillate from a given shale. The effect of circulating gas containing such tar fog back through the iron preheater tubes, up through the annular space between the hot walls of the retort and the iron basket containing the shale, and in and through the lumps of hot shale, would be to crack the heavier oil vapours into lighter oil vapours, and into fixed (uncondensible) gas and carbon. That this took place is evidenced by the presence of appreciable quantities of light oils in the recirculated gas and the high fixed carbon content of the spent shale residue. In order to improve the condensation with the apparatus as installed, steps were taken in the next test to slow up the speed of the blower, thus cutting down the rate of gas circulation.

Even after cooling over night with the gas-circulating blower going at low speed, the retort was still too hot to be discharged. The blower was stopped and the bottom plate loosened, and when discharging the spent shale the second day after the run it was noticed that considerable burning in the lower part of the retort had taken place, producing clinkers which could be explained only by the combustion of the fixed carbon in the spent shale. This combustion continued freely during the discharge of the retort due to the air draught in the open retort from bottom to top. The weight of the spent shale was consequently not obtained. The total distillate was allowed to settle two nights and a day, after which the water was drawn off and a practically water-free crude oil obtained. The yield of this settled oil amounted to, roughly, 20 Imperial gallons per ton only, as compared to nearly 35 gallons obtained in the laboratory. On account of this low yield of oil and lacking the spent shale weight, Test No. 1 was accordingly treated merely as a trial run.

For Test No. 2 certain alterations to the apparatus and changes in the method of operation were made. A bubble oil-washer was placed in the surplus gas line immediately in front of the meter, and throughout the run the speed of the blower controlling the rate of recirculation of the uncondensed gas was cut down. It was also necessary to take apart and clean the "Roots" blower, which had become gummed by shale dust, etc. As shown in the data sheet for this test (Table XXXVIII appended) the duration of this run was 26 hours. During the period of maximum oil flow and until the rate of flow materially fell off, the temperature was held around 800° F., after which it was allowed to reach nearly 1000° F. After completion of the run the setting was allowed to cool for 3 days, when the top and bottom plates were removed. Again the spent shale ignited and burned fairly readily, but examination showed that no appreciable combustion had taken place. The still hot, spent shale was removed as quickly as possible, immediately weighed and then quenched with water. The yield of settled oil from this run was still low, viz., 22 Imperial gallons per ton, only 2 gallons higher than in the first test. Since the cutting down of the blower speed had not materially increased the oil yield and since it was still thought that the oil yield suffered by the cracking of the "tar fog" contained in the circulating gas coming into contact with the hot walls of the lower part of the retort, it was decided to make certain changes in the position of the sections of the perforated iron basket.

Accordingly, for Test No. 3 the upper section of the basket was removed and the lower basket raised so that its lower end was above the preheater tube inlets, as shown in the right half of Figure 14. The annular space between the walls of the retort and the basket was plugged so as to cause the circulated gas to pass through the shale instead of passing up along the hot retort walls. Before beginning the test it was necessary to dismantle and steam out the condenser, as the coils were choked. The material removed by steaming consisted of a thick, viscous, pitch-dust mixture, semi-solid at room temperature, but fluid at steam heat, similar to the material that had plugged the blower at the beginning of the previous run. The blower speed, and consequently the rate of gas circulation, was constant throughout the run, the duration of which was 36 hours from the time distillate began to come off. In this run, as shown in Table XXXIX, the hourly rate of the total distillate and the water content of the same were observed and gas samples from both the circulating system and the surplus gas line through the meter were taken at frequent intervals.

SUMMARY OF TESTS Nos. 1, 2, AND 3 IN THE PRITCHARD RETORT

In Table XL is given a summary of the more important details in Tests Nos. 1, 2, and 3 in respect to rate of fuel-oil consumption in oil burners, rate of flow of distillate, average temperatures of shale and circulating gas during the high flow of distillate, average light oil content of the circulating gases, and yields and analyses of the products.

A brief summary of the yields of oil, gas, and spent shale for the three tests may be tabulated here as follows.

Products per ton (2,000 pounds) of Shale Charged

—	Crude shale oil		Gas, cu. ft.	Spent shale, lb.
	Imperial gallons	As per cent of maximum laboratory assay yield		
Test No. 1	20	57	(5,450)	....
Test No. 2	22	63	(5,460)	1,284
Test No. 3	29	83	2,070	1,105

The maximum yield of crude oil obtained in Test No. 3 would be increased to approximately 30 gallons per ton by adding the light oil content of the gas, which would represent a yield of over 85 per cent of the maximum laboratory assay yield. This yield, although representing a fairly good ratio between laboratory assay and commercial yield, was considerably less than that claimed and expected by the owners of the technical-scale retort tested. It is impossible to obtain a reliable weight balance for the first two tests, due to the loss in weight of the spent shale by burning in Test No. 1, and due to the apparent erratic gas yields in Tests Nos. 1 and 2. The high gas yields may be explained to a certain extent by the cracking of the tar fog content of the circulated gas into light oils, carbon, and gas, but the drawing off of the surplus gas at a lower pressure than that maintained on the pressure side of the circulating system and possible leaks of air on the suction side, are probable reasons for the high gas yields in these runs. The results of Test No. 3, however, allow the making of a weight balance sheet as follows:—

Weight of Shale Charged in Test No. 3—1,500 pounds

Products obtained		As per cent weight of shale charged
		per cent
Spent shale	1,105 pounds	73·7
Crude oil	190 "	12·7
Liquor	104 "	7·0
Gas, 1,550 cu. ft. at 18° C., (density 0·75; 0·060 pounds per cubic foot)	93 "	6·3
Loss by difference		0·3
		100·0

HEAT REQUIREMENTS

The fuel-oil consumption was 29, 20, and 17 pounds per hour for Tests Nos. 1, 2, and 3 respectively. From the data for Test No. 3, along with certain assumptions, the heat required for effecting distillation may be roughly estimated. Assuming that in a continuous operation the 1,500 pounds of shale charged in this run could be retorted in approximately the same time as that occupied by the high distillate flow, say 15 hours, the fuel-oil consumption per 100 pounds of shale would be the hourly rate observed, viz., 17 pounds. At 19,000 B.T.U. per pound the heat requirements per 100 pounds of shale would be 300,000 B.T.U. or more. The gas yield in Test No. 3, per 100 pounds of shale, was slightly over 200 cubic feet, which, at 500 B.T.U. per cubic foot, would amount to 100,000 B.T.U. From this it would appear that the heat contained in the shale gas was approximately only one-third of that in the fuel oil consumed to effect distillation in the Pritchard retort tested. However, since no attempt was made by the builders of the retort to install an efficient heating system and no claims were made therefor, this relation of quantity of heat required to effect distillation to that contained in gas produced should not be emphasized.

The amount of gas circulated, as estimated from the speed and capacity of the blower, varied roughly from 50 cubic feet per minute at low speed to 100 cubic feet per minute at high speed. In Test No. 3, where the blower was operated at low speed throughout the run, the gas circulated per hour would be at least 3,000 cubic feet, which would be approximately 8 times the hourly surplus gas produced during the uniformly high oil distillate flow. The sensible heat in this amount of gas at 600° F., as in Test No. 3, would be about 27,000 B.T.U. Assuming that the gas was not heated through the double-walled preheated tubes at an efficiency of over 25 per cent, the heat required hourly to preheat the circulated gas would be over 100,000 B.T.U., which would be equal to heat contained in the shale gas produced. The heat requirements at the high rate of gas circulation would be double this amount. It is therefore evident that the preheating of the gas is an important item, the cost of which increases with the rate of gas circulation. This, coupled with the necessity of supplying extra equipment for effecting efficient condensing and scrubbing of the large amount of gas, is distinctly not a factor in favour of the Pritchard gas circulating process for oil shale as compared with other retorting methods.

Laboratory distillation tests were made on the shale used in the Pritchard retort to check the uniformity of the shale and to determine the advantage, if any, of recirculating the uncondensed gases during the retorting. These tests were made in the large assay retort, those without gas recirculation according to the standard method described on page 72—Investigations of Fuels and Fuel Testing for 1924, and those with gas recirculation in the same retort fitted with a preheater coil as described on page 177 in the 1925 Investigations.

Three different samples were distilled:—

No. 3240A.—Composite sample of shale shipped to Toronto for tests in the Pritchard retort.
No. 3391.—Shale as charged in Test No. 2.—In Pritchard retort.
No. 3387.—Shale as charged in Test No. 3.—In Pritchard retort.

DISCUSSION OF RESULTS

From the summary of these tests as given in Table XXXVI, it will be seen that the shale used in Test No. 3 was of slightly better quality than the composite sample of the shipment and that for Test No. 2 slightly poorer, which accounts for part of the higher oil yield obtained in Test No. 3. The difference in the oil yield by laboratory distillation was 1·3 per cent of the shale retorted, equal to nearly 3 gallons per ton, whereas the difference in the Pritchard retort was 7 gallons. Some of the increased yield in Test No. 3 was also, no doubt, due to the longer duration of the run, but most of the increase was apparently due to alterations made in the position of the perforated iron basket in the retort, allowing a better transfer of heat from the walls of the retort to the interior of the charge.

As also shown in Table XXXVI, a slightly higher weight of oil was obtained in the laboratory (on shale used in Test No. 3) with gas recirculation than without. This agrees with the results reported[1] on a standard (Albert Mines, N.B.) sample of shale. The slightly increased yield however applies only to the crude oil, which on being subjected to laboratory distillation, does not give as high a yield of the more valuable light oils. In this respect the effect of retorting oil shale by means of recirculating the gases is apparently somewhat the same as retorting in the presence of steam, and in the opinion of the writers the use of steam is preferable for oil shale. Steam is said to increase greatly the formation of water-oil emulsions, which become troublesome in subsequent refining, but it is doubtful if such emulsions using steam are any more troublesome than with gas recirculation. With the crude shale oil obtained in the tests in the Pritchard retort, there was considerable water in the form of emulsion, which emulsion was aggravated by shale dust carried over from the retort in the condensing train. Besides being of use to rapidly sweep out the oil vapours, steam both greatly increases the gas yield at the expense of the fixed carbon in the hot spent shale and cools the spent shale for discharging.

With both gas recirculation and steam the aim is to produce maximum yields of a heavy oil, i.e. one with as high a specific gravity as possible. This may be a feature for the production of such products as lubricating oil where minimum decomposition or "cracking" is desired, but for the production of light oils the situation is different. For maximum yields of light oils from which motor fuel may be refined, cracking, with or without pressure, of the crude oil is necessary.

The oil-bearing constituent of the New Brunswick shale used is a solid material known as "kerogen" and the production of oil is believed[2] to take place in two stages, viz., primary and secondary decomposition. The product of the primary decomposition, an intermediate between kerogen and shale oil, is described as an unstable semi-solid. Crude shale oil may, therefore, be considered a secondary decomposition product, the stability of which, apparently, depends on the extent to which primary products have changed to the secondary products. As judged by the insolubility in concentrated sulphuric acid, as shown in Table XXXVI, and other comparative results,[3] the fractions from crude oil obtained by gas

---

[1] Investigations of Fuels and Fuel Testing for 1925, page 176 *et seq.*
[2] Oil Shale; M. J. Gavin—U.S. Bureau of Mines Bull. 210, pp. 44-48.
[3] Investigations of Fuels and Fuel Testing, 1925, p. 178.

circulation show approximately the same results as those from oil by ordinary destructive distillation. In this respect, therefore, there is little improvement, if any, in the quality of the shale oils obtained by gas recirculation.

According to Lyder[1] "the production of crude and refined products from shale and shale oil, throughout the whole operation of retorting and refining—can be considered as nothing more or less than the production and cracking of a heavy bitumen to produce lighter oils." In all oil-shale retorting operations, therefore, cracking is not to be discouraged, and in this connexion the cracking taking place in the Pritchard retort, where the oils were not thoroughly scrubbed out of the gas before being recirculated, may be desirable. If, however, the aim of recirculating the gases in the Pritchard process is to obtain the maximum yield of a heavy shale oil containing a high percentage of primary decomposition products, at reduced (partial) vapour pressures, and thus to discourage cracking, the results are hardly consistent with the objective.

The decomposition of oil shale into shale oil does not proceed with any appreciable speed until a temperature of 400° C. (750° F.) is reached, at which stage the reaction is distinctly endothermic. With exothermic reactions such as are quite noticeable in the carbonization of wood for example, the use of gas recirculation or steam to control the rate of reaction is desirable in order to prevent the decomposition of valuable liquid products into uncondensible gases. Therefore, the more or less negative conclusions outlined above, concerning the merits of the Pritchard process, apply only to its use for retorting oil shale.

Crude shale oil obtained in laboratory distillation tests with recirculation of the uncondensed gases did not show superior refining qualities to the oil obtained by ordinary destructive distillation. There is, therefore, no reason for considering that the shale oil obtained by the Pritchard process would be superior to that obtainable by other retorting processes without gas circulation. That the shale oil so obtained is amenable to refining by pressure cracking is shown by the results of tests conducted in the laboratories of the Universal Oil Products Limited. The crude shale oil used in these tests was that obtained from Tests Nos. 2 and 3 in the Pritchard retort, on which oil a gasoline yield as high as 60 per cent along with 8 per cent of light fuel is reported.[2] Other products are 73 pounds of coke per barrel and 530 cubic feet of gas of comparatively high calorific value.

---

[1] Journal Ind. and Eng. Chem., Vol. 13, No. 8, p. 678.
[2] Ibid, p. 122.

TABLE XXXVI

Results of Laboratory Distillation Tests

(With and without gas recirculation on shale used in Pritchard retort)

Description of sample used	No. 3240A		No. 3391	No. 3387	
	Composite sample of shipment for Pritchard tests		Shale for Pritchard Test No. 2	Shale used in Pritchard Test No. 3	
	No gas circulation	With gas circulation	—	No gas circulation	With gas circulation
Proximate Analysis—					
Moisture....per cent	0·8		0·7	0·8	
Ash.... "	62·1		62·9	61·3	
Volatile matter.... "	33·3		33·1	33·5	
Fixed carbon, by difference.... "	3·8		3·3	4·4	
LABORATORY DISTILLATION TESTS					
Weight Balance of Products—					
Shale oil (water-free)....per cent weight	14·7	15·5	14·1	15·4	16·2
Aqueous distillate.... "	2·7	3·2	2·2	2·2	2·4
Gas.... "	5·5	....	4·7	6·0	....
Spent shale.... "	76·6	75·1	78·6	75·7	73·8
Loss, by difference.... "	0·5	....	0·4	0·7	....
Analysis of Gas—					
Carbon dioxide....per cent	11·8	....	11·5	12·2	*5·3
Saturates as C_2H_4.... "	4·4	....	5·1	4·6	1·9
Oxygen.... "	1·4	....	2·0	1·8	2·5
Carbon monoxide.... "	5·3	....	5·0	6·0	7·8
Methane.... "	46·2	....	45·0	47·5	48·3
Hydrogen.... "	16·4	....	15·3	16·5	13·5
Nitrogen (by difference).... "	14·5	....	10·1	11·4	20·7
Density of gas (air=1)....	0·68	....	0·70	0·70	0·66
B.T.U. per cu. ft. (calculated)....	600	....	600	620	580
Gas, cu. ft. per ton....	2,100	....	1,700	2,300	....
Crude Shale Oil—					
Imperial gallons per ton....	33·6	34·2	32·2	35·2	35·2
Specific gravity at 60° F....	0·878	0·905	0·875	0·875	0·909
Insoluble in concentrated H_2SO_4..per cent	46	43	....	46	43
Fractionation of Crude Oil—					
Up to 150° C....per cent vol.	11·5	4·5	....	....	....
150° C. to 300° C.... "	41·5	30·5	....	....	....
300° C. to end point.... "	41·0	48·0	....	....	....
Specific Gravity of Fractions at 60° C.—					
Naphtha, up to 150° C....	0·738	0·736	....	....	....
Middle oils, 150° C. to 300° C....	0·838	0·828	....	....	....
Heavy oils, 300° C. to end point....	0·919	0·912	....	....	....
Insolubility in concentrated H_2SO_4—					
Crude naphtha....per cent	76	75	....	....	....
Crude middle oils.... "	66	67	....	....	....
Crude heavy oils.... "	44	45	....	....	....

* This analysis is the average of three samples of gas taken in the latter part of Test No. 3, the results of the analyses from the gas circulation runs in the laboratory being unsatisfactory due to leaks in the pump used. Signs of air leaks into the circulating system in Test No. 3 are shown by the high nitrogen content; the corresponding nitrogen content for 3 samples taken in the early part of the run was over 75 per cent.

TABLE XXXVII

Data Sheet of Test No. 1 in Pritchard Retort

Oil Shale Charged, 1,500 pounds.

Toronto, Sept. 17, 1925.

Time	Temperatures			Speed of circulating gas	Gas meter		Fuel oil consumption	Total distillate (oil and water)	Remarks
	Thermometers		Pyrometer in shale at C. °F.	Notch on rheostat of blower motor	Reading cu. ft.	Temperature °C.	Reading on oil tank (inches)	(gallons)	
	Inlet gas at A. °C.	Exit gas at B. °C.							
5.00 a.m.		40			102				Started burners.
9.00	190	233	260						
10.00	225	253	340	1	438			2	Gas sample No. 1.
11.00	242	272	410	2	508			1	
12.00	280	315	490	2	563			1¾	
12.30 p.m.	305	328	550	5	667				Gas sample No. 2.
1.00	305	343	595	5	773			1¾	
1.30	315	352	625	5	916				
2.00	330	359	640	5	1084			2⅛	Oil burners turned down.
2.30	355	365	680	6	1204		0		
3.00	305		710	6	1362			1½	Gas sample No. 3.
3.30	315		720	6	1440				Charcoal gas No. 3.
4.00			725	6					Turned up oil burners.
4.30	320		720	6	1538	30			
5.00	345		750	6	1635			2½	
5.30	350		760	3	1725				Gas sample No. 4.
6.00	360		755	3	1806				
6.30	365		765	3–5	1918			1½	Charcoal gas No. 2.
7.00	370		785	3	2012		41		Fuel-oil tank filled to 0.
7.30	380		800	3	2108				
8.00			825	3	2224			1½	Gas sample No. 5.
8.30			860	3	2320	31			
9.00			880	3	2450			¾	Charcoal gas No. 3.
9.30			900	3–6	2520	31			
10.00			900	6	2616		21	¾	
11.00			910	3	2809			¾	
12.00			880	3–1	3055				
Sept. 18th—10.30			600	1	3820	29		2¼	

Spent shale—Weight not obtained.

Total distillate (oil and water)	191 pounds
Net settled oil after water drawn off	138 "
Crude (settled) oil—Imperial gallons per ton	20

Gas, per meter readings	4,093 cubic feet
Cubic feet gas per ton uncorrected for temperature and pressure	5,450 "

TABLE XXXVIII

Data Sheet of Test No. 2 in Pritchard Retort

Oil Shale Charged, 1,600 pounds. Toronto, Sept. 23, 1925.

Time	Temperatures			Circulating gas				Gas meter		Fuel-oil consumption, reading on oil tank (inches)	Total distillate (oil and water), gallons	Remarks
	Thermometers		Pyrometer in top of shale at C. ° F.	Notch on rheostat of blower motor	Manometer readings			Reading, cubic feet	Temperature, ° C.			
	Inlet gas at A. ° C.	Exit gas at B. ° C.			Inlet gas inches of mercury	Exit gas inches of mercury	Bottom of retort inches of mercury					
11.00 a.m.	....	....	....	....	....	....	....	....	....	....	....	Retort cold—lit burners.
12.00	....	....	....	....	....	....	....	3930	....	....	....	Started exhauster.
1.00 p.m.	85	100	120	1	+¾	+¼	+½	4000	15	....	0·1	
2.00	110	140	190	1	+¾	+¼	+½	4190	....	....	0·3	Notch 1—275 r.p.m.
3.00	125	160	250	1	+¾	+¼	+½	4280	15	....	0·4	
4.00	160	200	320	1–2	+¾	+⅛	+½	4360	....	....	0·6	
5.00	220	230	390	2	+¾	+⅛	+½	4400	17	....	1·0	
6.00	260	235	450	2	+1	+1/16	+¼	4690	....	....	1·2	
7.00	280	240	490	2–3	+¾	+1/16	+¼	4750	17	....	1·2	
8.00	300	260	525	3	+⅝	−⅛	+¼	4910	....	....	1·3	Gas sample No. 1.
9.00	315	280	560	5	....	....	....	5064	....	....	1·5	
10.00	280+	310	680	1	....	....	....	5227	17	....	1·5	Notch 3—330 r.p.m.
11.00	280+	335	790	2	+¾	0	+½	5479	19	....	2·1	Gas sample No. 2.
12.00	280+	330	830	3	+⅝	−1/32	+¼	5865	....	....	1·6	Charcoal gas No. 1 (meter).
1.00 a.m.	260	308	810	3	+⅞	−¼	0	6020	21	....	1·6	
2.00	240	288	780	3	+⅞	−¼	0	6190	21½	....	1·1	Gas sample No. 3.
3.00	220	265	760	3	+¾	−¼	0	6370	22	....	0·9	Charcoal gas No. 2 (meter).
4.00	190	237	720*	2–1	+7/16	0	+¼	6530	23½	....	0·7	Gas samples Nos. 4 and 5.
5.00	170	230	760	....	....	....	....	6634	23	....	0·6	Notch 2 and 1—220 r.p.m.
6.00	170	230	780	....	....	....	....	6793	23	....	0·5	Condenser water, 12·5° C.
7.00	185	235	770	....	....	....	....	6929	23	42	0·7	Fuel tank to 24 inches.
8.00	180	245	800	....	....	....	....	7062	22	48	0·6	
9.00	180	260	830	2	+½	−1/16	+¼	7220	23	....	0·7	Gas sample No. 6.
10.00	260	286	880	....	....	+½	+½	7440	22	....	0·9	Gas at 1st receiver, 20° C.
11.00	280	318	910	6	....	−⅛	+¼	7674	23	....	1·0	Gas sample No. 7.
12.00	325	335	940	6	....	....	+¼	7863	23	....	0·9	
1.00 p.m.	315	333	965	4	+½	−¼	+⅛	8085	....	....	0·8	Notch 2—240 r.p.m.
2.00	310	350	990	2–6	+1	−½	−⅛	8300	23	....	0·7	Notch 6—360 r.p.m. Fires out.

Spent shale	1,284 pounds
As per cent of shale charged	80·3
Total distillate (oil and water)	240 pounds
Net settled oil after water drained off	158 "
Crude (settled) oil—Imperial gallons per ton	22
Gas, per meter readings	4,370 cubic feet
Cubic feet gas per ton uncorrected for temperature and pressure	5,460 "

*This temperature and previous readings subject to a correction of +35° due to pyrometer not being level.

TABLE XXXIX

Data Sheet of Test No. 3 in Pritchard Retort

Oil Shale Charged, 1,500 pounds.

Toronto, Sept. 29-30, 1925.

Time	Temperatures				Circulating gas			Gas meter		Fuel-oil consumption, reading on oil tank. 1"=3⅓ pounds	Distillate		Remarks
	Thermometers		Pyrometer in top of shale, at C, °F.	Temperature at first receiver, °C.	Manometer readings			Reading, cubic feet	Temperature, °C,		Total distillate (oil and water) gallons	Water after settling	
	Inlet gas at A, °C.	Outlet gas at B, °C.			Inlet gas inches of mercury	Exit gas inches of water	Bottom of retort inches of water						
12.00..........	160	120	260	16·5	1⅜	1	....	601+	17·0	....	0·8	gals. 0·8	Burners lit at 8.30 a.m.
1.00 p.m.......	190	155	380	18·0	1⅜	2½	....	610	17·0	....	1·0	0·9	Blower started at 11.00 a.m.
2.00..........	230	205	560	19·5	1½	1	+5¼	630	17·0	0	1·5	1·2	Condenser H_2O—15°C.
3.00..........	240	220	630	19·5	1¼	−1¼	+3	630	17·0	....	1·3	0·8	Gas sample No. 1
4.00..........	240	230	660	19·5	1¼	−3	+2¾	635	17·0	9	0·9	0·6	Charcoal gas No. 1.
6.00..........	248	254	680	19·0	1⅛	−3	+1¾	646	17·0	25	0·6	0·4	Gas sample No. 2
8.00..........	274	260	715	20·0	1⅛	4½	0·7	679	17·0	36	0·7	0·3	Fuel oil at 0—7.10 p.m.
9.00..........	238	265	740	21·0	1¹⁄₁₆	−5	+ ⅛	710	17·0	4	0·9	0·3	Gas sample No. 3.
10.00..........	220	272	745	21·0	1¼	−4½	+ ½	734	17·0	11	1·0	0·3	Charcoal gas No. 2.
11.00..........	210	265	740	20·0	¾	−7¼	+2½	765	17·0	15	0·8	c.c. 730	Gas sample No. 4.
1.00 a.m.......	190	260	740	20·0	1⅛	−3½	+ ¾	826	17·0	29	0·5	600	Gas sample No. 5.
2.00..........	240	268	745	20·0	1	−3	+1¼	855	17·0	2	0·5	625	Fuel oil at 0—1.50 a.m.
4.00..........	290	280	780	21·0	¾	−3½	+1¼	926	17·5	18	1·2	700	Gas sample No. 6.
6.00..........	300	292	800	21·0	1	−4	+ ¾	993	17·5	28	1·1	1,110	Gas sample No. 7.
7.00..........	300	294	800	21·0	1⅛	−4½	+ ¼	1020	17·5	34	1·0	....	Fuel oil at 14"—7.30.
8.00..........	310	287	795	21·0	1	−3½	+ ½	1045	18·0	18	0·9	150	Gas sample No. 8.
10.00..........	325	290	800−	21·5	1	−8½	−5½	1108	18·5	29	1·1	150	Gas sample No. 9.
11.00..........	330	295	800+	21·5	⅝+	−7	−1¾	1145	19·0	36	1·1	100	Charcoal gas No. 4.
12.00..........	335	303	800+	22·5	1¹⁄₁₆	−2¾	−2½	1185	19·5	6	1·0	100	Top of flue gas pipe to chimney, 175° C.
1.00 p.m.......	340	307	810	23·0	1	−3	+1¼	1225	19·5	12	1·0	100	
2.00..........	350	311	820	23·0	1	−2¾	+1⅓	1263	20·0	18	0·9	100	Gas sample No. 10.
3.00..........	360	314	830	23·5	1	−3	+1½	1300	20·5	28	0·8	100	Charcoal gas No. 5.
4.00..........	365	323	845	24·0	1	−2½	+ ½	1350	21·5	24	0·7	....	Gas sample No. 11
5.00..........	380	333	870	24·0	1⅜	+1½	+5¼	1400	20·5	7	0·6	125	Charcoal No. 6.
6.00..........	390	351	900	25·0	1¼	+1½	+6½	1480	20·5	16	0·6	....	Power off 6.45.
8.30.......	....	....	920	....	....	....	....	1600	....	....	....	175	Fire lit at 8.15 p.m.
9.00..........	360	342	930	22·5	1⁵⁄₁₆	−6½	+1	1622	20·0	28	1·0	3,550	Gas sample No. 12—9.20
10.00..........	380	360	940	23·0	1⁵⁄₁₆	−2	− ½	1665	20·0	7	0·4	750	Fuel oil tank 2′ 10" to 0".
11.00..........	370	400	960	24·0	1¼	−5½	− ¾	1726	20·0	16	0·3	1,990	Gas sample No. 13.
Oct. 1— 10.00 a.m.....	190	240	750	19·5	⅝	−8	−5¾	2150	21·0	....	1·0	4,000	Gas samples Nos. 14 and 15.

Spent shale..	1,105 pounds
As per cent of shale charged..............................	75·7 per cent
Total distillate, (oil and water)..........................	294 pounds
Net settled oil after water drawn off......................	190 "
Crude (settled) oil—Imperial gallons per ton..............	29
Gas, per meter readings..................................	1,550 cubic feet
Cubic feet gas per ton uncorrected for temperature and pressure..	2,070 "

TABLE XL

Summary of Tests Nos. 1, 2, and 3: Oil Shale in Pritchard Retort

—		Test No. 1	Test No. 2	Test No. 3
Date of test (1925)		Sept. 17	Sept. 23	Sept. 29–30
Weight of shale charged	lb.	1,500	1,600	1,500
Duration of test	hrs.	19	27	38
Time from beginning of run to high uniform rate of flow of distillate	"	6	6	12
Duration of high uniform rate of distillate, i.e. 1 gallon per hour and over	"	9	10	13
Temperature range in top shale during high distillate flow as per pyrometer readings	° F.	490–820	525–940	745–810
Maximum temperature at end of test	"	910	990	960
Average temperature of circulating gas during high distillate flow—				
Preheated gas to bottom of retort	"	625	535	610
Exit gas at top of retort	"	680	590	550
[1]Speed of gas circulation during high distillate flow		high	medium	low
Average light oil content of circulated gas by charcoal absorption tests—				
Imperial gallons per 1,000 cubic feet		0·45	0·25	(0·60)
Average specific gravity of light oil		0·745	0·700	(0·675)
Average fuel-oil consumption in burners during high distillate flow—				
Inches on tank per hour		8·7	6·0	5·2
Pounds per hour (at 3⅓ pounds per 1 inch)		29	20	17
Products—				
Total distillate (oil and water)	lb.	191	240	294
Settled oil after drawing off water	"	138	158	190
Specific gravity at 60° F. of settled oil		....	0·892	0·883
Baumé equivalent		....	27·0	28·5
Specific gravity of first 3 hourly samples of crude oil		....	0·861	0·852
Specific gravity of last 3 hourly samples of crude oil		....	0·911	0·910
Yield of oil, Imperial gallons per ton		20	22	29
Gas, as per meter readings	cu. ft.	(4093)	(4370)	1550
Cubic feet per ton of shale		(5450)	(5460)	2070
Spent shale discharged	lb.	....	1,284	1,105
As per cent of shale charged	p.c.	....	80·2	73·7
Ash content of spent shale	"	....	71·3	78·2
Volatile matter of spent shale	"	....	16·8	14·7
Fixed carbon (by difference)	"	....	11·9	7·1
Fractionation of crude oil in Engler flask—				
Naphtha, up to 150° C., per cent vol. of crude oil		....	4·5	7·5
Middle oils, 150° C.-300° C., per cent vol. of crude oil		....	46·5	40·0
Heavy oils, 300° C.-end point, per cent vol. of crude oil		....	34·0	38·5
Specific gravity of naphtha fraction at 60° F.		....	0·741	0·744
Specific gravity of middle oil fraction at 60° F.		....	0·842	0·826
Specific gravity of heavy oil fraction at 60° F.		....	0·919	0·903
Naphtha fraction, Imperial gallons per ton		....	1·0	2·2
Middle oil fraction, Imperial gallons per ton		....	10·2	11·6
Heavy oil fraction, Imperial gallons per ton		....	7·5	11·2

---

[1] The capacity listed for the Roots blower used was 150 c.f.m. when the speed was 600 r.p.m. at 1 lb. pressure. Observing the r.p.m. at the different rheostat notches it was calculated that the gas circulated at high speed was approximately 100 c. f. m. and at low speed in the neighbourhood of 50 c. f. m. The rate at medium speed was roughly midway between these limits.

V

CANADIAN SHALE OIL, AND BITUMEN FROM BITUMINOUS SANDS, AS SOURCES OF GASOLINE AND FUEL OIL BY PRESSURE CRACKING

R. E. Gilmore, P. V. Rosewarne, and A. A. Swinnerton

Canada has vast resources of oil shale and bituminous sands, the former occurring in the Maritime Provinces and the latter in Alberta. These deposits have long been considered as potential sources of products generally obtained from crude petroleum. Difficulties hindering the use in Canada of shale oil and bitumen are the higher cost of these crudes as compared with crude petroleum from drilled wells, combined with higher refining losses. However, the recent modifications in refining methods due to pressure-cracking processes appear to alter the situation, and these raw materials may now be seriously considered as sources, to be drawn upon when needed, to help in supplying the rapidly increasing demand for motor fuel.

Samples of Canadian crude shale oil and bitumen from bituminous sands were submitted to the Universal Oil Products Company and to the Kansas City Testing Laboratory for pressure-cracking tests, according to the Dubbs and Cross processes respectively. The results of these tests summarized in this paper will help to decide the value of the crude shale oil and bitumen on a comparative basis with crude petroleum and fuel oils now used as sources of motor fuels by pressure-cracking processes.

Grateful acknowledgment is made to the Universal Oil Products Company of Chicago, particularly to Dr. Gustav Egloff and to Dr. W. F. Faragher for their co-operation and personal attention in testing the sample of shale oil; to Dr. Roy Cross of the Kansas City Testing Laboratory for his co-operation and interest in testing samples of both bitumen and shale oil; and to Dr. K. A. Clark of the Scientific and Industrial Research Council of Alberta for supplying the crude bitumen.

TESTS ON SHALE OIL BY THE DUBBS CRACKING PROCESS

Pressure-cracking tests on a 20-gallon sample of shale oil forwarded from Ottawa were conducted at Riverside, Ill., (near Chicago), in the laboratories of the Universal Oil Products Company, owners and licensers of the Dubbs cracking process. The shale oil used in these tests was obtained from New Brunswick oil shale by destructive distillation in a technical-scale retort[1] of the Pritchard Process Company at Toronto, Ontario, in a series of experimental runs witnessed by the writers. The shale oil submitted, which was a composite sample of that obtained from distillation runs made in Toronto, had a specific gravity of 0·896, equal to 26·3° Bé. and a boiling-point range of 150° to 683° F. On arrival at Chicago the shale oil was "topped" by ordinary distillation prior to charging into the cracking-still to remove the "blending naphtha," which amounted to roughly 23 per cent of the crude shale oil. On the topped oil

---

[1] Ibid, p. 106.

a series of four runs was made at different pressures, two runs, viz., Nos. 410 and 393, by what is termed the non-residuum process and two runs, Nos. 213 and 216, by the residuum process. The tabulation summarizing the results of the cracking data of these four runs, as reported by Dr. Faragher, is inserted in full as follows:—

Plant No.	13	13	11	11
Run No.	410	393	213	216
Pressure, pounds	175	150	150	150
Kind of oil	Topped crude shale oil			
A.P.I. gravity	20·7°	20·1°	20·1°	20·1°
Pressure distillate—				
Per cent of raw oil	64·8	66·8	51·4	40·2
A.P.I. gravity	51·3°	46·9°	52·4°	55·5°
Residuum—				
Per cent of raw oil	None	None	25·9	36·7
A.P.I. gravity	....	....	10·7°	11·7°
Coke, lb./bbl	82	66	60	58
Uncondensed gas, cu. ft./bbl	660	730	418	295
Coke, gas, and loss, per cent (by difference)	35·2	33·2	22·7	23·1
Gasoline (N.E.P.)—				
Per cent of pressure distillate	83·2	72·7	70·9	81·9
Per cent of raw oil	53·9	48·6	40·6	32·9
A.P.I. gravity	51·8°	51·9°	54·1°	55·6°
I.B.P.—E.P. ° F	112–434	121–436	124–434	114–434
Pressure distillate cut °F	440	430	435	445
Gas oil—				
Per cent of pressure distillate	10·5	22·0	13·5	11·5
Per cent of raw oil	6·8	14·7	7·0	4·6
A.P.I. gravity	21·7°	24·2°	25·6°	28·5°
Loss—				
Per cent of pressure distillate	6·3	5·3	7·5	6·6
Per cent of raw oil	4·1	3·5	3·8	2·7
Summary of Yields: (Based on the Crude Shale Oil)				
Blending naphtha, per cent	20·0	23·3	23·3	23·3
N.E.P. cracked gasoline from primary cracking, per cent	43·3	36·5	30·5	24·8
Total gasoline from topping and cracking operations, per cent	63·3	59·8	53·8	48·1

The above results were obtained by a single passage of the shale oil through the cracking-still, and do not show the maximum yields of gasoline and light fuel oil to be expected by recycling as used in commercial practice. Recycling would give higher yields of gasoline and other light oils at the expense of the heavier fuel oil intermediate products.

The comparative yields of the different products by the residuum and non-residuum method of operation and the varying results obtainable by the same process are shown above and below. In general the residuum method of operation, as expected, gave lower gasoline yields with higher yields of residue oils and of better quality than the non-residuum method. By the same method, however, considerable variation in the results was obtained. "By sacrificing 8 per cent of the possible gasoline, the yield and quality of the residuum was increased, as shown by the results obtained in Run 216 over those obtained in Run 213." The higher gasoline yields were obtained in Runs 410 and 393 by the non-residuum method. The yields of both coke and gas in these runs were considered high, "due to direct firing of the experimental still, and a hot bottom during the latter part of the runs." The yields of the N.E.P. gasoline in these runs as a percentage of the topped shale oil were 53·9 and 48·6 per cent respectively, and the "pressure-distillate bottoms" 6·8 and 14·7 per cent respectively. In Run 393 "recycling these bottoms (i.e. the 14·7 per cent) should give an ultimate yield of gasoline from the cracking operations alone of approximately 56 per cent." That is, by recycling, the gasoline yield as a percentage of the topped oil could be raised by nearly 7½ per cent to 43·1 per cent of the original crude shale oil. Adding to this the 21·7 per cent yield of tops as blending naphtha would give, by re-cycling, an overall gasoline yield of 65 per cent or more.

The above data may be further summarized by averaging the results of Runs 213 and 216 according to the residuum process, and of Runs 393 and 410 by the non-residuum process, and showing the results as a percentage of the original crude shale oil.

Products Resulting from Topping and Cracking as per cent Volume of the Crude Shale Oil

—	Residuum Process (Single cycle) Average of Runs 213 and 216	Non-residuum Process (Single cycle) Average of Runs 393 and 410
Crude shale oil used for topping—		
Specific gravity at 60° F.	0·896	0·896
A.P.I. gravity equivalent	26·4°	26·4°
Products of Topping as per cent of Crude Shale Oil		
Topped shale oil as cracking stock	75·2	76·8
Gasoline tops as blending naphtha	23·3	21·7
Loss (by difference)	1·5	1·5
A.P.I. gravity of tops	45·5°	46·5°
Products of Cracking as per cent of Original Shale Oil		
Pressure distillate from cracking-still	34·4	50·6
N.E.P. gasoline by cracking	27·6	39·4
A.P.I. gravity of N.E.P. gasoline	55°	52°
Gas oil (pressure-distillate bottoms)	4·3	8·3
Residuum from cracking-still	23·6	None
Coke, pounds per Imperial gallon	1·7	2·1
Uncondensed gas, cu. ft. per Imperial gallon	7·7	15·2
Total gasoline as motor fuel, per cent	51	61

Analysis and Quality of Gasoline

The refined gasoline obtained from the shale oil, after a triple-acid treatment, followed by the usual plumbite and steam distillation treatments, was reported to be a "water-white, doctor sweet, non-corrosive, and light-stable product." The analyses of the finished gasolines from two of the runs, when examined by the method developed in the laboratories of the Universal Oil Products Company, were reported as follows:—

—	Run No. 410	Run No. 213
	p.c.	p.c.
Unsaturated hydrocarbons	12·4	14·2
Aromatic "	23·1	22·0
Naphthalene "	7·7	5·3
Paraffin "	56·8	58·5

An engine test showed the "gasoline to be the auto-motive equivalent of a Pennsylvania straight-run gasoline in admixture with approximately 5 per cent benzol." Therefore, although it would be slightly better than ordinary straight-run gasoline, it would apparently not have as good anti-knock properties as certain (cracked) gasolines on the market.

Table XLI, abstracted from the copious data supplied by Dr. Faragher, is inserted here as a matter of general interest and for permanent record. In the different sections of this table are shown the comparative qualities in respect to density, distillation range, etc., of the crude shale oil and "topped crude" charged, and of the tops, gasoline, gas oil and residuum products obtained in the four different runs. Figures 15 and 16 show the distillation curves derived from the data from Runs 410 and 213 by the non-residuum and residuum processes respectively.

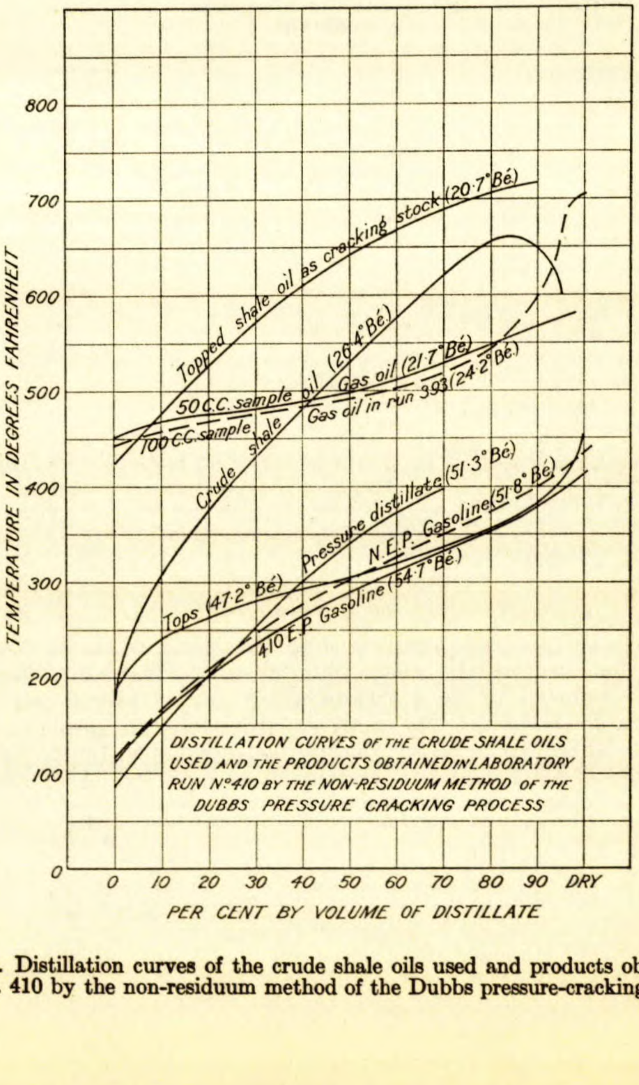


Figure 15. Distillation curves of the crude shale oils used and products obtained in Run No. 410 by the non-residuum method of the Dubbs pressure-cracking process.

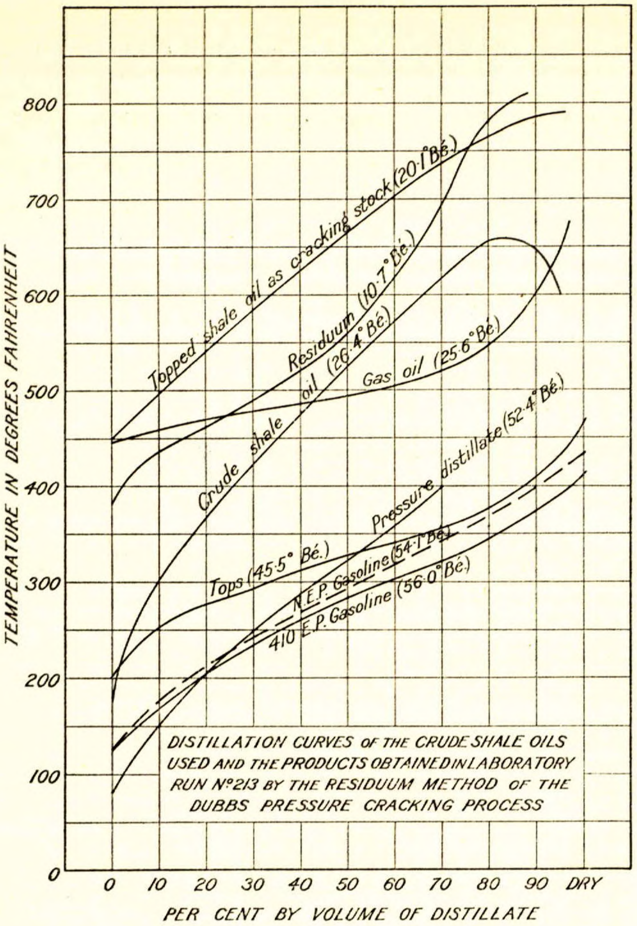


Figure 16. Distillation curves of the crude shale oils used and products obtained in Run No. 213 by the residuum method of the Dubbs pressure-cracking process.

TABLE XLI

Details of Pressure-cracking Tests on Canadian Shale Oil Abstracted from Report by the Universal Oil Products Company

A.—*Analysis of Crude Shale Oil as received and of the Gasoline and Kerosene Fractions obtained by Laboratory Fractionation*

—	Crude Shale Oil			Gasoline	Kerosene
	—	—	A.P.I. gravity	Up to 410° F.	410° to 572° F.
Sample taken.......... c.c.	100	800	....	100	100
Specific gravity at 60° F..........	0·895	0·895	....	0·792	0·856
A.P.I. gravity equivalent..........	26·4	26·4	....	46·7	33·6
Distillation range—					
Initial boiling point.......... ° F.	175	150	....	180	370
5 per cent vol. over at.......... "	263	....	....	220	422
10 " " .... "	300	319	52·7	244	436
20 " " .... "	365	385	43·6	268	446
30 " " .... "	435	448	....	287	460
40 " " .... "	470	508	34·3	302	472
50 " " .... "	523	557	30·9	320	486
60 " " .... "	583	643	26·7	335	500
70 " " .... "	605	655	26·5	352	514
80 " " .... "	655	650	25·0	369	532
90 " " .... "	648	683	24·8	396	560
95 " " .... "	600	....	....	428	594
End point.......... "	655	683	....	472	606
Recovery..........per cent	96	90	....	98	98
Residue in flask.......... "	....	....	....	1	2
Fraction under 410° F.......... "	28	23	46·7	....	....
Fraction 410° to 572° F.......... "	29	30	33·6	....	....
Coke (by weight).......... "	3	....	....	....	....
Coke and pitch.......... "	....	10	....	....	....

B.—*Summary of Topping Operation and Analyses of Tops and Topped Shale Oil*

	Run No. 1		Run No. 2	
	c.c.	per cent	c.c.	per cent
Crude shale oil charged..........	35,000	100·0	35,000	100·0
Gasoline tops produced..........	7,000	20·0	8,120	23·3
Topped shale oil bottoms..........	27,480	78·5	26,390	75·2
Loss..........	500	1·5	490	1·5
	Gasoline tops	Topped oil	Gasoline tops	Topped oil
Specific gravity at 60° F..........	0·790	0·930	0·798	0·933
A.P.I. gravity equivalent..........	47·2	20·7	45·5	20·1
Distillation range—				
Initial boiling point.......... ° F.	187	425	200	450
5 per cent vol. over at.......... "	226	450	236	468
10 " " .... "	242	479	255	495
20 " " .... "	258	522	273	538
30 " " .... "	277	566	293	575
40 " " .... "	291	611	313	615
50 " " .... "	307	643	328	655
60 " " .... "	321	665	343	707
70 " " .... "	337	690	358	739
80 " " .... "	354	640	377	760
90 " " .... "	380	....	408	787
95 " " .... "	409	....	438	....
End point.......... "	452	690	469	787
Recovery..........per cent	98	89	98	96
Residue in flask.......... "	1	....	2	....
Fraction 410° – 572° F.......... "	....	33	....	28
Coke (by weight).......... "	....	9·6	....	3·8

TABLE XLI—Continued

C.—*Summary of Pressure-cracking Tests*

—	Non-Residuum process		Residuum process	
Run No.	(410)	(393)	(213)	(216)
Topped shale oil charged c.c.	8,000	8,000	8,000	8,000
A.P.I. gravity of oil charged	20·7	20·1	20·1	20·1
Maximum pressure in system, lb./sq. in.	175	150	150	150
Duration of run (hours on stream)	4h	4h 10m	3h	2h 23m
Products Obtained				
Pressure distillate recovered c.c.	5,180	5,340	4,110	3,215
As per cent of topped oil charged	64·8	66·8	51·4	40·2
Residuum c.c.	None	None	1,500	2,550
Coke lb.	4·84	4·78	4·24	3·77
Oil content of coke per cent	15·0	31·0	29·0	22·0
Total residuum including the oil extractable from the coke c.c.	....	....	2,070	2,935
Gas (uncondensed) cu. ft.	33·17	36·72	21·06	14·80

D.—*Analyses of Pressure Distillates and of Residuum*

Run No.	(410)	(393)	(213)	(216)
Pressure Distillates—				
Sample taken c.c.	800	800	800	800
Specific gravity at 60° F.	0·772	0·791	0·768	0·755
A.P.I. gravity equivalent	51·3	46·9	52·4	55·5
Distillation range—				
Initial boiling point ° F.	86	87	81	89
10 per cent vol. over at "	150	162	152	145
20 " " "	196	218	202	194
30 " " "	242	267	251	233
40 " " "	290	306	288	268
50 " " "	342	353	324	311
60 " " "	368	389	363	345
70 " " "	398	....	398	390
Gasoline up to 410° F. per cent	74·6	66·3	73·5	74·2
Gasoline up to 440° F. "	83·2	72·7	79·0	81·9
Gas oil above 440° F. "	10·5	22·0	13·5	11·5
Loss "	6·3	5·3	7·5	6·6
Residuum—				
Sample taken c.c.			100	100
Specific gravity at 60° F.			0·995	0·988
A.P.I. gravity equivalent			10·7	11·7
Flash point (cleveland) ° F.			185	188
Fire point (open cup) "			205	215
Distillation range—				
Initial boiling point ° F.			380	404
5 per cent vol. over at "			422	439
10 " " "			437	456
20 " " "			465	480
30 " " "			490	510
40 " " "			525	544
50 " " "			557	594
60 " " "			624	652
70 " " "			692	721
80 " " "			787	755
End point "			807	772
Recovery per cent			88	86
Coke residue (by weight) "			16	16
Fraction up to 572° F. "			53	47

TABLE XLI—Concluded

E.—*Analyses of the Gasoline and Gas-oil Products Derived from the Pressure Distillates*

Run No....................	(410)		(393)		(213)		(216)	
Gasoline...................	410° cut	N.E.P. cut	410° cut	N.E.P. cut	410° cut	N.E.P. cut	410° cut	N.E.P. cut
Sample taken......... c.c.	100	100	100	100	100	100	100	100
Specific gravity at 60° F..	0·758	0·770	0·760	0·770	0·753	0·761	0·742	0·754
A.P.I. gravity..........	54·7	51·8	54·2	51·9	56·0	54·1	58·8	55·6
Distillation range—								
Initial boiling point ° F.	110	112	120	121	124	124	112	114
5 per cent vol. over at "	142	143	157	157	152	152	137	140
10 " " "	163	166	177	180	173	176	154	162
20 " " "	200	205	210	218	203	210	185	196
30 " " "	234	241	241	250	231	240	215	232
40 " " "	262	276	269	280	260	267	244	259
50 " " "	287	302	294	305	282	294	270	284
60 " " "	310	327	315	334	303	318	288	306
70 " " "	332	352	337	355	324	342	306	334
80 " " "	357	374	361	378	345	366	332	366
90 " " "	382	397	390	405	371	395	366	400
95 " " "	402	415	409	422	391	416	389	416
End point............ "	415	434	421	436	412	434	402	434
Recovery......per cent	98	98·5	97	97	98	97·5	97·5	98
Residue........ "	1	1	1	1	1	1	1	1

Run No....	(410)	(393)	(213)	(216)
Gas Oil (bottoms)—				
Sample taken.................................. c.c.	50	100	100	50
Specific gravity at 60° F...........................	0·923	0·908	0·900	0·883
A.P.I. gravity..................................	21·7	24·2	25·6	28·5
Distillation range—				
Initial boiling point.......................... ° F.	450	442	444	454
5 per cent vol. over at..................... "	....	453	454	
10 " " .... "	468	459	460	480
20 " " .... "	475	467	470	490
30 " " .... "	482	476	476	495
40 " " .... "	490	483	484	502
50 " " .... "	497	492	493	509
60 " " .... "	510	500	506	522
70 " " .... "	525	518	520	539
80 " " .... "	550	545	546	567
90 " " .... "	570	601	602	653
95 " " .... "	....	687	665	....
End point................................ "	580	703	675	702
Recovery...............................per cent	98	98	98	98
Residue............................... "	2	2	2	2

TESTS ON BITUMEN FROM BITUMINOUS SANDS AND ON SHALE OIL BY THE "CROSS" CRACKING PROCESS

Bitumen

Pressure-cracking tests on a sample of bitumen from Alberta bituminous sands were made in the Kansas City Testing Laboratory at Kansas City, Mo., according to the Cross process. The bitumen used was part of a barrel-lot sample supplied to the Fuel Testing Laboratories by Dr. K. A. Clark of the Scientific and Industrial Research Council of Alberta, who had obtained it from the natural bituminous sands by the hot-water, sodium-silicate method in his separation plant at Edmonton. Before being forwarded to Kansas City it was dehydrated in Ottawa by a special laboratory-scale apparatus, the operation and results of which are published elsewhere[1] in this report.

The separated bitumen sent from Edmonton contained considerable water in the form of an emulsion and some mineral matter. The average results of three dehydration experimental runs were:—

Bitumen (water-free)	65·7 per cent by weight
Mineral matter	4·0 " "
Water	28·8 " "
Gas and loss (by difference)	1·5 " "

In the dehydration runs variable quantities of light oil distilled over with the water, depending on the temperature of the dehydrating-still. The water-free bitumen, therefore, consisted of two parts, viz., light oil "tops," and a heavy dehydrated bitumen, the latter containing the bulk of the mineral matter present in the original crude bitumen. In the preparation of the 5-gallon sample for the cracking tests, tops, having a gravity of 23° Bé. and a distillation range of 300° to 714° F., and amounting to roughly 12 per cent by volume of the water-free bitumen, were obtained. The sample of dehydrated and topped bitumen forwarded to Kansas City had a specific gravity of 1·061 and amounted to 80 per cent by volume of the water-free bitumen and to approximately 56 per cent by volume of the original bitumen emulsion. The dehydrated bitumen was first distilled in a fire still, the products obtained being:—

Coke (ash content 11 per cent)	31·9 per cent by weight
Gas oil distillate	67·3 " volume

The gas oil termed "charging stock" was then cracked according to the Cross process to produce a synthetic crude. The laboratory cracking test apparently consisted of determining the effect of one cycle through the "furnace" under a pressure of 700 pounds and a temperature of 875° F., from the results of which the final yields by recycling may be estimated. The summary of the cracking test reported by Dr. Roy Cross of the Kansas City Testing Laboratory is included as follows:—

---

[1] Ibid, p. 96.

Summary of Cracking Test

Gravity of charging stock	25·5° Bé.
Gravity of synthetic crude	29·1° Bé.

Products and yields	First cycle	Ultimate with re-cycling
Gasoline	41·8 per cent	65·0 per cent
Recharging stock	48·1 "	....
Fuel oil	8·7 "	28·0 "
Loss (gas and carbon)	1·4 "	7·0 "
Gasoline		
Gravity	52·3° Bé.	53·0° Bé.
End point	437° F.	437° F.
Fuel Oil		
Gravity	1·080 (Sp. Gr.)	4·0° Bé.
Safe Commercial Yields		
Motor gasoline	....	60·0 per cent
Fuel oil	....	30·0 "
Loss	....	10·0 "

The above yields are percentages by volume of the gas-oil charging stock representing approximately 67 per cent of the dehydrated bitumen. Summarizing the fire-still (coking) results and what Dr. Cross terms "safe commercial yields," we have the following figures as percentages of the dehydrated topped bitumen as submitted for cracking tests:—

Coke	32 per cent	by weight
Motor gasoline (0·6 x 67%)	40 "	by volume
Fuel oil (0·3 x 67%)	20 "	"

The tops removed in the dehydrating operation were, as shown above, somewhat similar in gravity to the gas oil used as cracking stock, and on the assumption that equal "safe commercial yields" of motor gasoline and fuel oil could be obtained, the total yields of the cracked products as a percentage of the original water-free bitumen may be summarized and tabulated as follows:—

——	Per cent volume of original bitumen (water-free basis)
Tops from dehydrating operation	12 per cent
Dehydrated bitumen to fire still	80 "
Motor gasoline (53° Bé.)	
From dehydrated bitumen (0·8 x 40%)	32·0 per cent
From tops (0·6 x 12%)	7·2 "
Total motor gasoline (to nearest %)	39
Fuel oil (4° Bé.)—	
From dehydrated bitumen (0·8 x 20%)	16·0 per cent
From tops (0·3 x 12%)	3·6 "
Total fuel oil (to nearest %)	20

From this it appears that the yields for the topped bitumen as charged may be applied directly to the dehydrated (separated) bitumen. The yields of gasoline and fuel oil reported[1] by cracking a similar bitumen at 90 pounds pressure and 750° F., according to the single-cycle method of examining such products in the laboratory, according to the Dubbs process, were 37 and 17 per cent, respectively, on the water-free basis.

Quality of Gasoline from the Bitumen. According to Dr. Cross the refined gasoline has "remarkably good anti-detonating properties." This agrees with the report[2] of Egloff and Morrell to the effect that the gasoline from bitumen from bituminous sands is a "superior motor fuel having an aromatic equivalent of 30 per cent."

Shale Oil

A 5-gallon sample of crude shale oil obtained from New Brunswick shale by destructive distillation in the Pritchard retort was also forwarded to the Kansas City Testing Laboratory, where it was submitted to pressure-cracking tests similar to those conducted on the bitumen.

The shale oil submitted was first topped to give "tops" and topped shale oil, amounting to 25 per cent and 75 per cent by volume, respectively. Nothing further was done with the tops which was considered as the "naphtha" cut suitable for blending with gasoline. The topped shale, termed "charging stock", was then cracked to produce a "synthetic crude." As with the bitumen the cracking test consisted of determining the effect of one cycle through the furnace under a pressure of 700 pounds and a temperature of 875° F., from the results of which the yields to be expected by recycling were estimated. The summary of the cracking test, as reported is as follows:—

Summary of Cracking Test

Gravity of shale oil	26·8° Bé.
Gravity of charging stock	20·6° Bé.
Gravity of synthetic crude	25·4° Bé.

Products and yields	First cycle	Ultimate with recycling
	per cent	per cent
Gasoline	29·8	55·0
Recharging stock, 21·3° Bé	43·6	
Fuel oil	17·3	30·0
Loss (gas and carbon)	9·3	15·0
Gasoline		
Gravity	54·1° Bé	54·1° Bé
End point	437° F.	437° F.
Fuel Oil		
Gravity	1·100	1·050
Safe Commercial Yields		per cent
Gasoline	....	50·0
Fuel oil	....	35·0
Loss	....	15·0

---

[1] Egloff and Morrell: "Cracking of Bitumen Derived from Alberta Tar Sands"; Canadian Chem. and Met., Feb., 1917, page 33.

[2] Loc. cit.

The above yields are percentages by volume of the topped shale oil. Adding to the gasoline produced by cracking the naphtha "tops" and expressing the yields of total (motor fuel) gasoline and fuel oil under two heads, viz., the estimated maximum by recycling and "safe commercial yields" respectively, we have the following:—

—	Percentage by volume of the crude shale oil tested	
	"Safe commercial yields"	Estimated maximum by recycling
Motor fuel (54° Bé.)—	per cent	per cent
Gasoline by cracking (0·75 x 50% and 0·75 x 55% respectively)......	37½	41¼
Naphtha by topping..	25	25
Total gasoline as motor fuel (to nearest per cent)...............	63	66
Fuel oil (specific gravity 1·05)—		
(0·75 x 35% and 0·75 x 30% respectively).........................	26	22

The above yields of total gasoline are, it will be noticed, in close agreement with those reported by the Universal Oil Products Company, where for Run No. 410 the total gasoline by topping and cracking was over 63 per cent and for Run No. 393 the estimated maximum obtainable by recycling was around 65 per cent.

YIELD OF PRODUCTS BY PRESSURE CRACKING PER TON OF OIL SHALE RETORTED

A yield of 30 Imperial gallons of crude shale oil is considered a good commercial yield per ton (2,000 pounds) of shale retorted. Using the minimum and maximum figures given above, the yields of gasoline as motor fuel and of fuel oil that may be expected from a ton of shale by pressure cracking of the crude shale oil obtained may be calculated and tabulated as follows:—

Gasoline as motor fuel................................	15 to 20 Imperial gallons
Light fuel oil..	2 to 7 "

In addition to these products from 50 to 80 pounds of coke, along with 300 to 700 cubic feet of gas per barrel (35 Imperial gallons) of crude shale oil would be obtainable as by-products.

SUMMARY

This report, a summary of pressure-cracking tests on Canadian crude shale oil, and on bitumen from bituminous sands, according to the Dubbs and Cross processes respectively, shows that these raw materials are important sources of motor fuel. Gasoline yields of 60 to 65 per cent by volume of the crude shale oil, equal to roughly 18 to 20 Imperial gallons per ton of shale retorted, and about 40 per cent by volume of the dehydrated bitumen, are reported. The total yield of gasoline and fuel oil amounted to over 80 per cent of the crude shale oil tested and to nearly 60 per cent of the bitumen. Other products from these oil and bitumen raw materials are, appreciable quantities of good quality coke and uncondensed gas of high calorific value. The quality of the gasoline from the shale oil may be considered good and that from the bitumen exceptionally good.