

# CANADA

## DEPARTMENT OF MINES

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

### MINES BRANCH

JOHN MCLEISH, DIRECTOR

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## INVESTIGATIONS IN 1921

### FUELS AND FUEL TESTING

*(Testing and Research Laboratories)*

- (a) Lignite carbonization: by J. H. H. Nicolls and Harold Kohl.
- (b) Notes on the burning quality of kerosene oils for illuminating purposes: by P. V. Rosewarne.
- (c) The lubricating value of cod liver oil: by P. V. Rosewarne.
- (d) Preliminary report on the investigation of oil shales: by A. A. Swinnerton.
- (e) Preliminary report on the investigation of peat fuel conducted by the Joint Peat Committee of the Federal Government and the Government of the Province of Ontario, from January 1, 1921, to March 31, 1922, together with a statement of plans of the work to be done during the year 1922: by B. F. Haanel.

*(Annual Summary Report of the Mines Branch, pp. 205-252 and 319-333.)*



OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1923

No. 590.

## FUELS AND FUEL TESTING DIVISION

## I

## LIGNITE CARBONIZATION

## CONTINUATION AND REVIEW OF SMALL SCALE EXPERIMENTS

J. H. H. Nicolls and Harold Kohl

*Introductory.*—The main purposes of these small scale experiments on the lower grade Canadian coals were (a) to obtain information concerning the nature of the carbonized residues produced by their destructive distillation; (b) by means of this information to indicate whether the increase in heating value of any one of the coals would warrant its carbonization, and, if so, at what temperature it should be carbonized.

In the Mines Branch Summary Reports<sup>1</sup> for the years 1917 to 1920 the account of the carbonization experiments on Canadian fuels was each year brought up to date. The earlier reports dealt mainly with the lignite coals from the Estevan area in Saskatchewan, upon which both small and large scale laboratory experiments were carried out. Subsequent reports described small scale experiments on the lower grade Alberta coals, and a sample of peat from Alfred, Ontario.

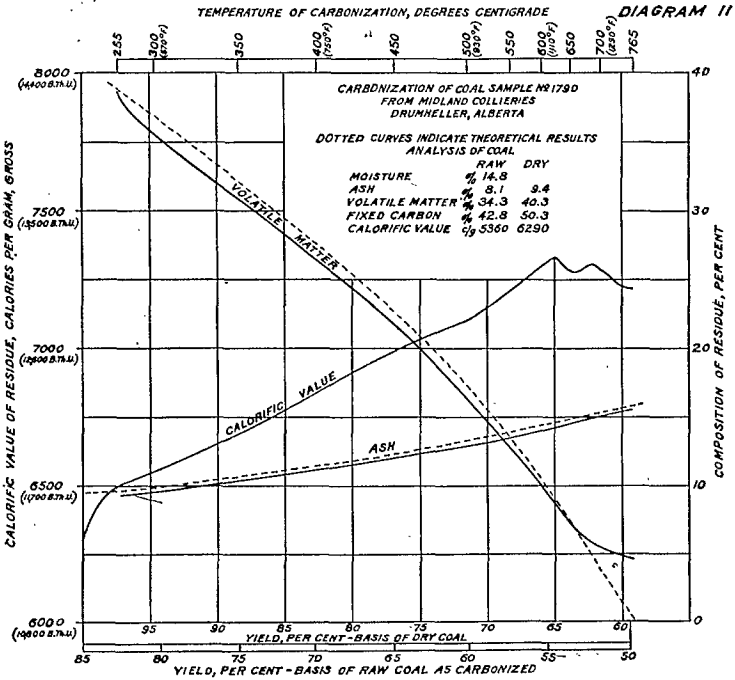
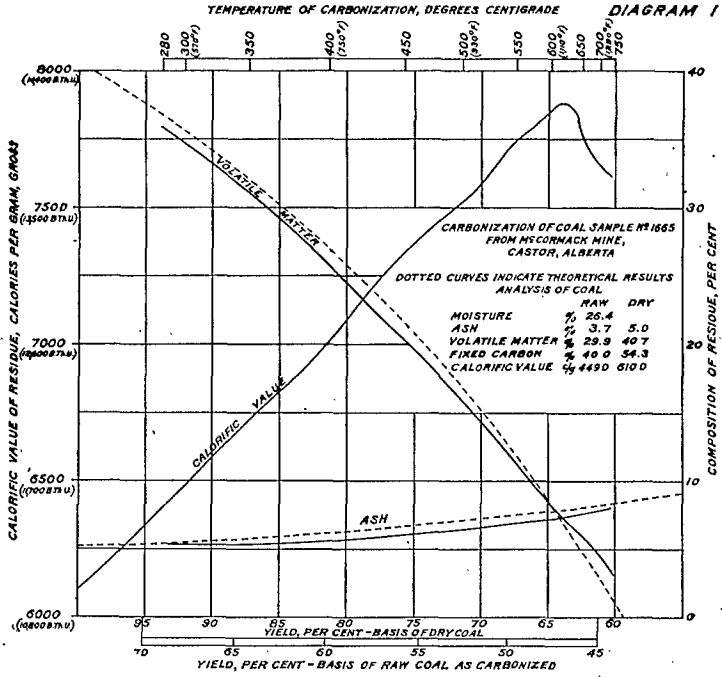
The present report describes small scale carbonization experiments upon the following five Canadian coals:—

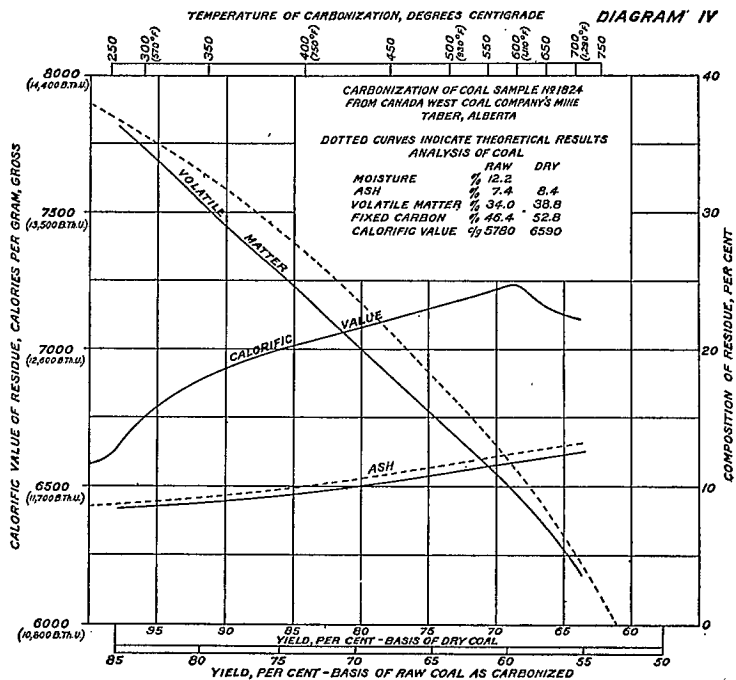
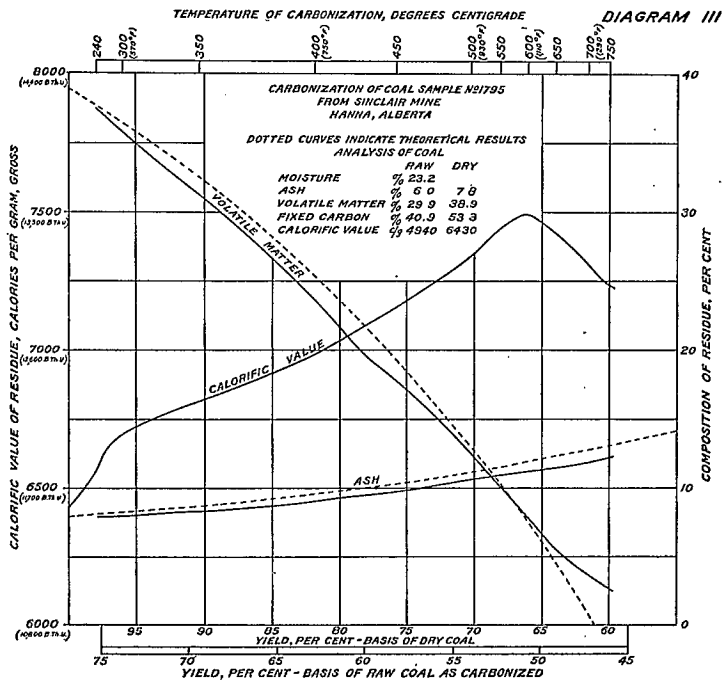
- No. 1665—From McCormack mine, Castor, Alta.
- No. 1790—From Midland collieries, Drumheller, Alta.
- No. 1795—From Sinclair mine, Hanna, Alta.
- No. 1824—From Canada West Coal Co., Taber, Alta.
- No. 1875—From Goodlands, Man.

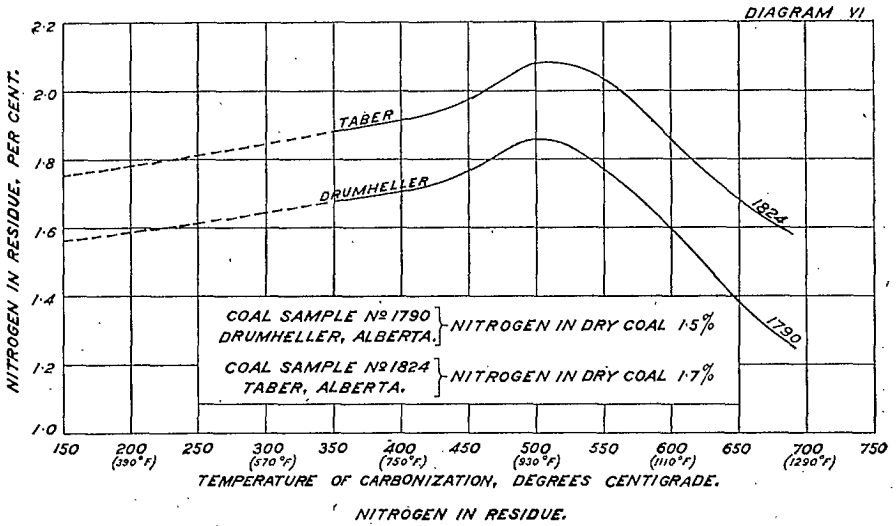
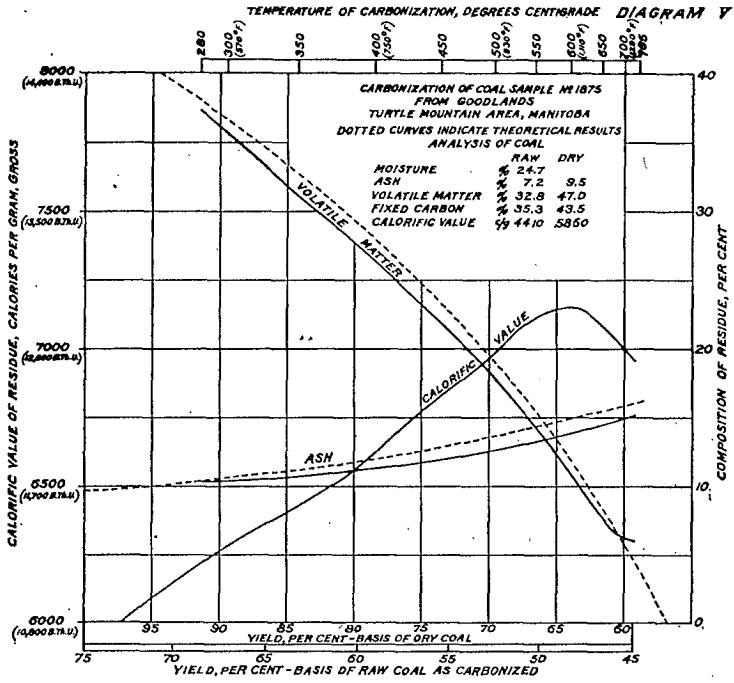
The account of these experiments is followed by a resumé of all the small scale laboratory experiments referred to above. In the resumé comparisons are drawn between the lignites from Saskatchewan and those from Alberta, which in turn are compared with Alfred peat.

*Experimental.*—The fuels were carbonized in the form of small briquettes. A small quartz crucible was filled with these and placed inside a retort, which was heated to the desired temperature in a bath of molten lead. In order that a reducing atmosphere should be present throughout the test, the air in the retort was displaced by coal gas at the beginning of the operation. The outlet tube of the retort dipped just below the surface of a water seal, from which the gas passed to the outer air, thus ensuring that carbonization took place practically at atmospheric pressure. The apparatus is more fully described in the Mines Branch Summary Reports for 1918 and 1920.

<sup>1</sup>Mines Branch Summary Reports, 1917, p. 55; 1918, p. 90; 1919, p. 30; 1920, p. 39.







*Discussion of Results.*—The results of the experiments are given in Tables I to V, and graphically indicated in Diagrams I to V. The curves were plotted from the experimental results, and to a certain extent rounded off, and from these rounded curves the figures in the tables were obtained. In each case the fuel was carbonized in the raw state, but, for the sake of uniformity, the curves were plotted against the yields calculated to be obtainable from the dried fuel.

As was found to be the case in nearly all previous series, the determined percentages of ash and volatile matter in the carbonized residues were lower than the calculated values. These were calculated from the analyses of the original coals and the determined yields of residue. As was mentioned in a previous report,<sup>1</sup> freshly carbonized residue will absorb air and moisture rapidly, so that the yield calculated from its weight after cooling would be higher than the correct value. On this account also the composition of the residue as analysed would differ from that of the residue as removed from the lead bath, in that it would contain more volatile matter and slightly less ash and fixed carbon. This, however, would not account for the divergence between the percentages of volatile and ash as determined and those computed from the yield calculated from the weight of residue.

In referring to the diagram for the Castor coal it will be observed that the calorific value rises to an unusual extent, the increase at the optimum temperature, 620° C., being almost thirty per cent. This is far greater than the rise for any other coal, and almost as high as that for peat. Furthermore, the curve is exceptionally regular, and not bowed out in places as is the case with most of the other coals. This indicates that decomposition occurs uniformly with rise of temperature. Unfortunately this coal was slightly more weathered than most of the other coals carbonized, as it was kept in a finely ground condition (though in a sealed jar) for one year before the tests were made. This however would probably have little or no effect on the results of carbonization, unless it should slightly lower the calorific value.

In the case of the Drumheller coal the calorific value curve was found to be abnormal above the optimum temperature, 620° C., in that it rose into a second peak. It followed a normal course, dropping until 650° C. was reached, but then it rose again until 685° C. was attained, after which it again dropped. The maximum temperature reached was 765° C., up to which point the curve dropped gradually from the second peak. Owing to the abnormal character of the curves, check carbonizations were made at intervals of 10 or 15 degrees between 600° and 700° C., some of these after two or three months had elapsed since the first series. As a final and very severe test, the following procedure was adopted. The coal was carbonized at 650° C. for two hours, according to the regular procedure, and part of the residue removed for determination of calorific value; the retort was then closed, and carbonization continued for two hours at 685° C., after which the calorific value of the remaining residue was determined. Owing to adverse conditions, such as opening the retort between the first and second carbonizations, it was not anticipated that

<sup>1</sup>Mines Branch Summary Report, 1918, pp. 91 and 92.

the increase in calorific would be as large as when separate tests were made. It was therefore very satisfactory to find that the average increase for several experiments was 15 to 20 calories. As a result of these tests it was assumed that at 650° C. there was a change in the nature of the volatile matter given off, its calorific value being decreased, with a corresponding increase in that of the residue.

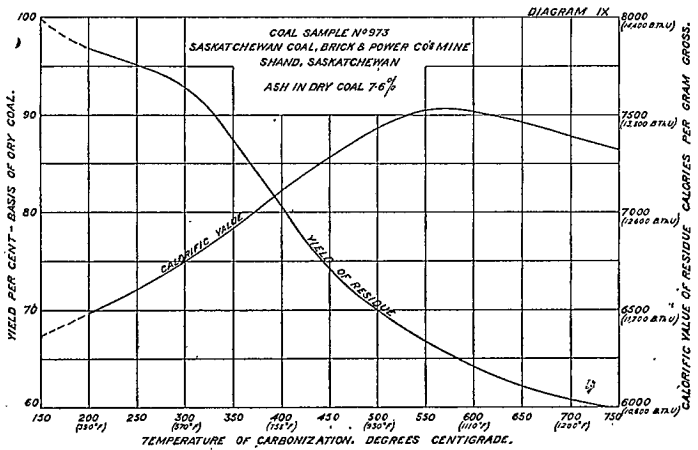
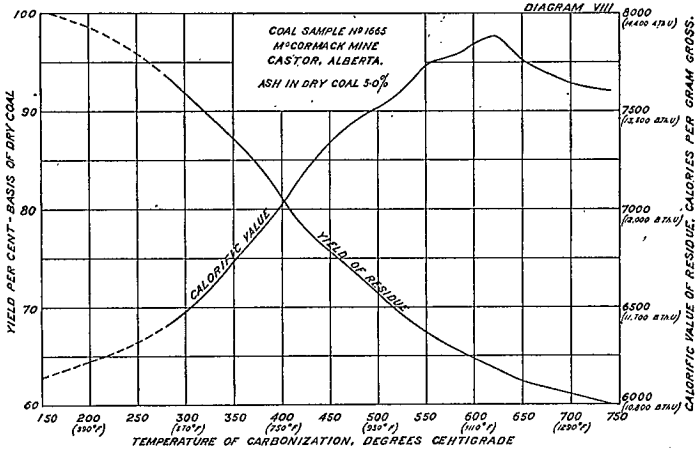
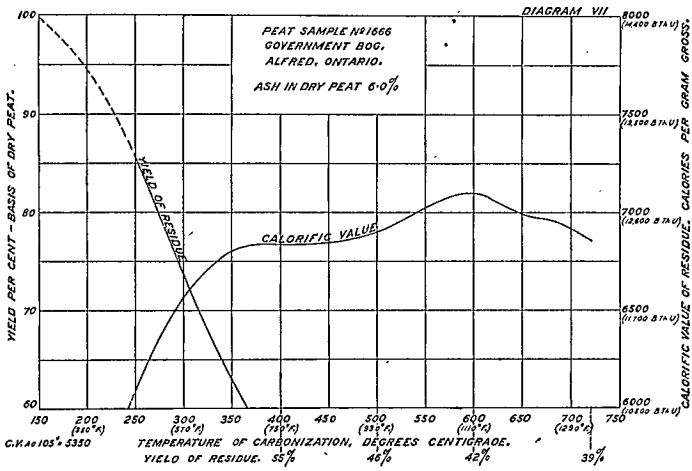
It had been observed that, after carbonization at 500° C. and higher temperatures, there was, on opening the retort, a stronger odour of ammonia from this Drumbeller coal than from the other fuels carbonized. Therefore, as the first step in the investigation of the abnormality above referred to, determinations were made of the percentages of nitrogen left in the residues at various temperatures. These are indicated in Diagram VI, where they are compared with the percentages remaining in the Taber coal, which behaved normally on carbonization. While these results are incomplete without the ammonia yield, they indicate that the nitrogen content is not an important factor in the case under consideration. Investigation of the abnormal behaviour of this coal is to be continued, and the results published at some future date.

The curves for the remaining three coals, particularly that from Hanna, are apparently normal. Unless subsequent investigations should reveal a valuable yield of by-products, there would probably be no advantage in carbonizing the Taber coal. On the other hand, it would most likely be economically feasible to carbonize the very low grade coal from Goodlands, Manitoba, since the calorific value of this fuel is increased by 22 per cent on carbonization.

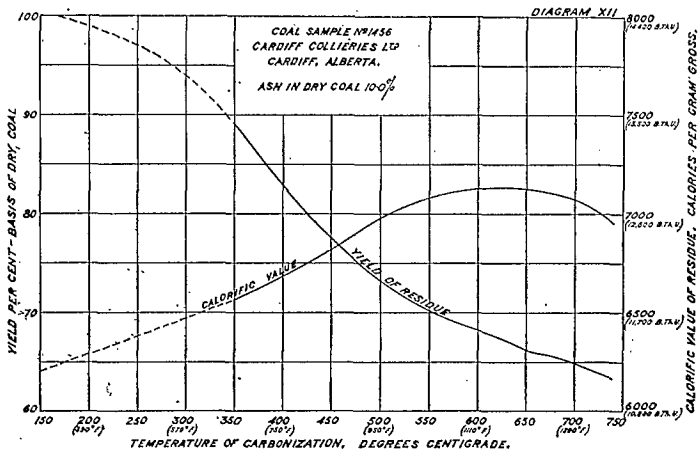
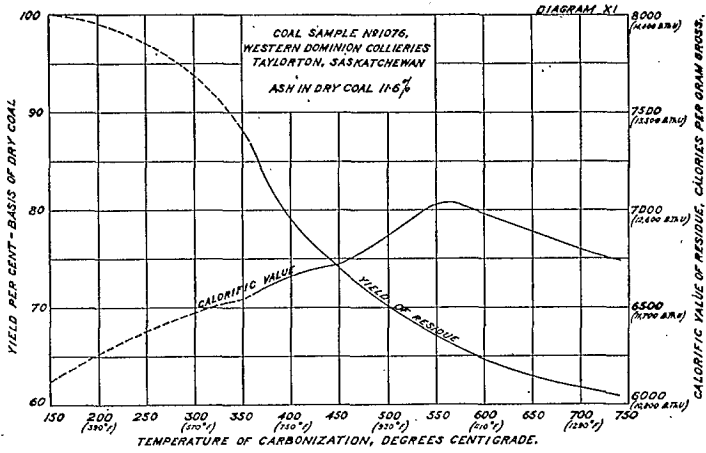
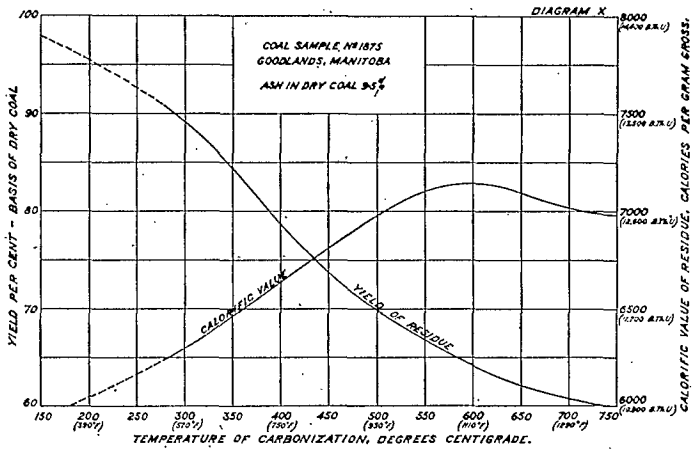
The above experiments complete the twelve series of small scale laboratory tests as originally planned. In order to compare the behaviour of the several coals on carbonization, Diagrams VII to XVIII have been prepared. In these diagrams the yields, calculated to be obtainable from the dried fuels, and calorific values have been plotted against temperatures.

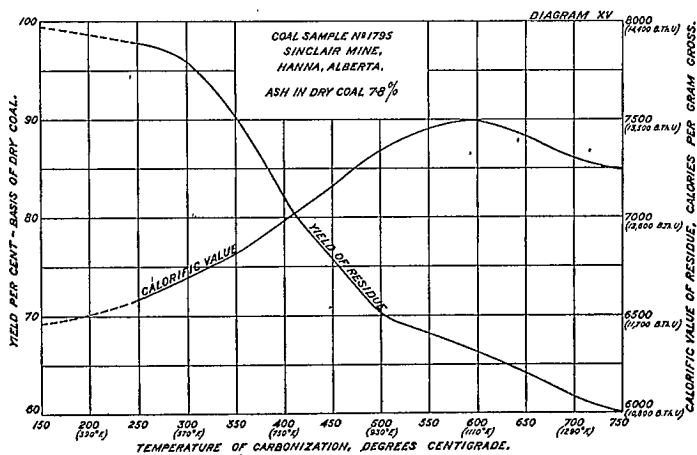
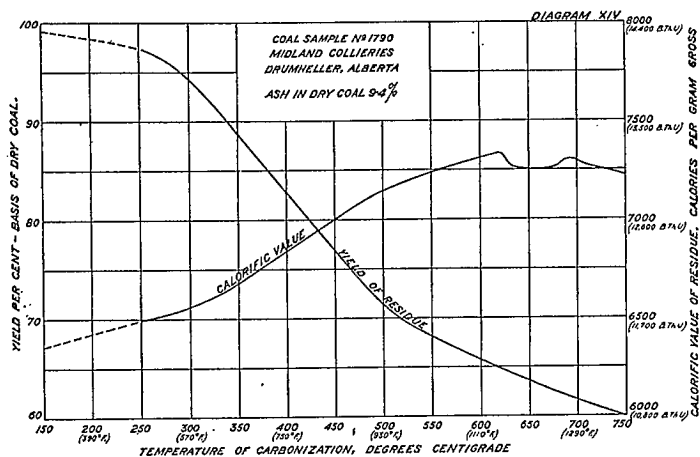
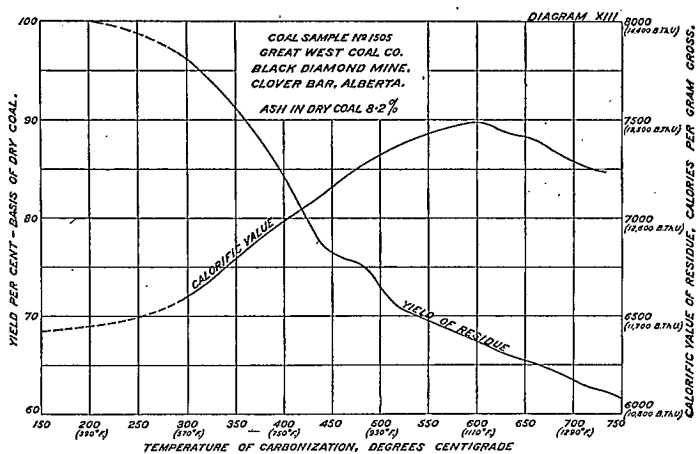
It will be observed that the ash content of the dried fuel is included in the legend for each curve, for the following reason. In numerous instances it has been found that, in the case of samples from the same colliery or for coals similar in composition, increase in ash content decreases not only the calorific value of the fuel as it stands, but also decreases its calorific value when calculated on an ash and moisture free basis. It should therefore be borne in mind when comparing the curves that the percentages of ash in the fuels vary from 5.0 to 11.6, which in itself would account for a considerable discrepancy. Furthermore, in considering a fuel with a high ash content, it should be realized that a low ash fuel from the same source would probably have an even greater calorific value that would be indicated by calculation.

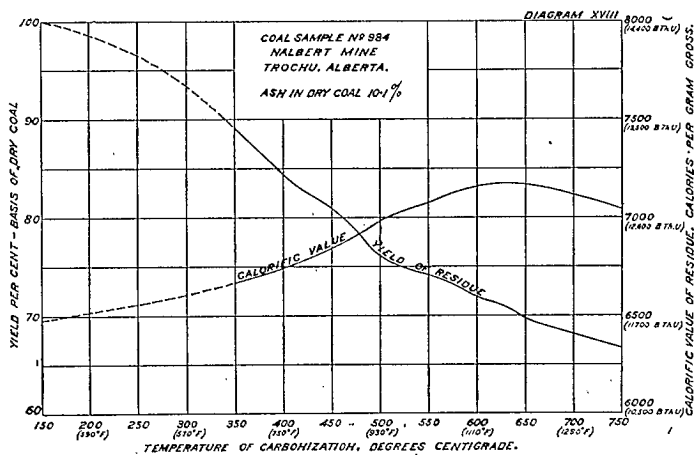
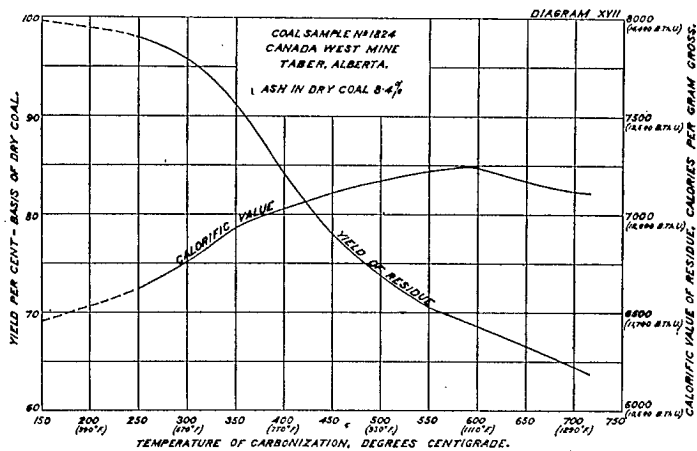
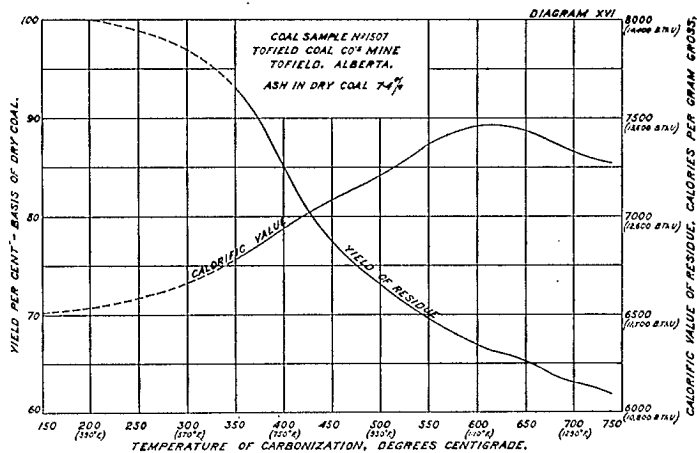
Table VI shows the yields, calorific values and percentage increases in calorific value, at 400° C. and the optimum temperature for each of the twelve fuels carbonized. The temperature 400° C. was originally selected for the reason that the calorific curve for peat flattened very considerably at that point; it was subsequently retained as being conveniently intermediate between the point of initial decomposition and the optimum temperature. By the latter term is meant the temperature at which the carbonized residue has its highest calorific value.











The percentage increases in calorific value for the Alfred peat and the Castor coal are exceptionally high, while those for the Shand and Goodlands coals also form a distinct group. Generally speaking, the Alberta coals give a considerably lower percentage increase than those from Saskatchewan and Manitoba. The Taylorton (Saskatchewan) coal seems to be out of place among the Alberta coals, but this misplacement may be due to its high ash content.

In Table VII is given a comparison between the percentage increases in calorific value of the carbonized residue calculated on the basis of the dry fuel and that calculated on the raw fuel basis. In the latter instance the proportions of the increase due respectively to oven drying and to carbonizing are indicated. Generally speaking, the moisture contents indicated represent the average for several samples from the same mine; this does not, however, hold for the Drumheller coal, where the moisture indicated is at least 3 per cent lower than the average. The Goodlands coal, when carbonized, contained 24.7 per cent of water, but, as the average moisture content of samples from the same deposit was 31.7 per cent, the latter figure was used in the table. The moisture content indicated for the Alfred peat approximates that for the air-dried fuel, whereas the peat as excavated from the bog contains as much as 90 per cent of water. It is to be noted that in this table all the calorific values are expressed as British Thermal Units per pound.

In Table VIII is shown the available heat in the residue as a percentage of the available heat in the original fuel. This is shown at various temperatures, for each of the twelve fuels, and is identical with the "Thermal Efficiency" referred to in a previous report.<sup>1</sup> It may perhaps be best explained by the following calculation:—

Assume that 50 grams of coal, with a calorific value of 6,000 calories per gram, yields a residue of 40 grams with a calorific value of 7000 calories. Then the available heat percentage is:—

$$\frac{7000 \times 40 \times 100}{6000 \times 50} = 93.3 \text{ per cent.}$$

Diagrams XIX and XX show graphically these available heat percentages for six representative fuels, and, while there are one or two divergences, it will be noted that most of the curves follow approximately the same path. The curves are plotted against temperature in one instance, and yield in the other. Except in the case of peat, the differences obtained are not of much account.

*Summary Remarks.*—The principal object of these small scale experiments has been brought about; namely, the determination of the changes produced in the calorific value of certain fuels by carbonization at various temperatures and at atmospheric pressure. These changes are indicated by diagrams and tables for the five coals most recently examined. In addition, a resumé is given of small scale experiments upon eight coals from Alberta, two from Saskatchewan, one from Manitoba, and a sample of Ontario peat. Comparisons are drawn between these by means of a series of diagrams and tables.

<sup>1</sup> Mines Branch Summary Report, 1918, p. 93.

DIAGRAM XIX

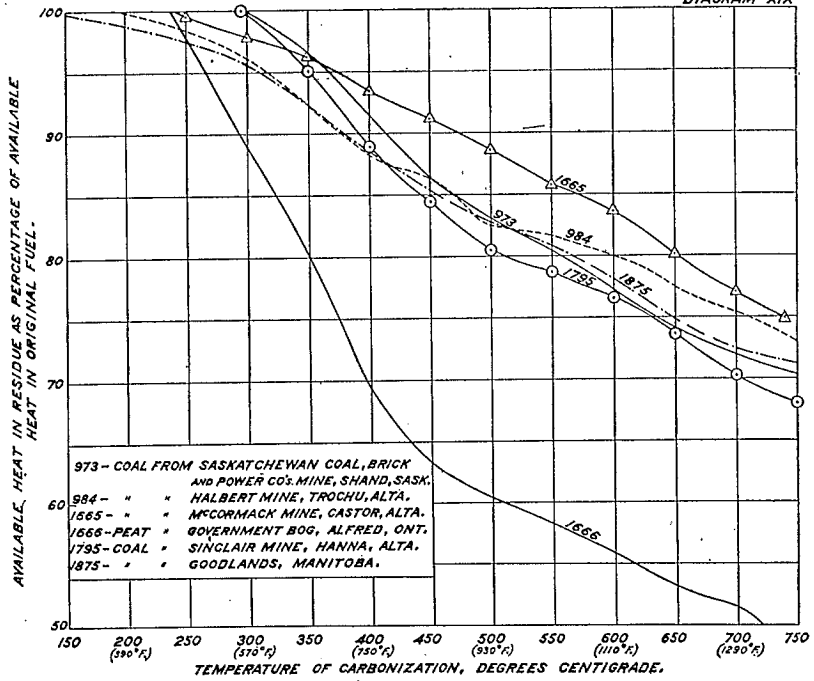
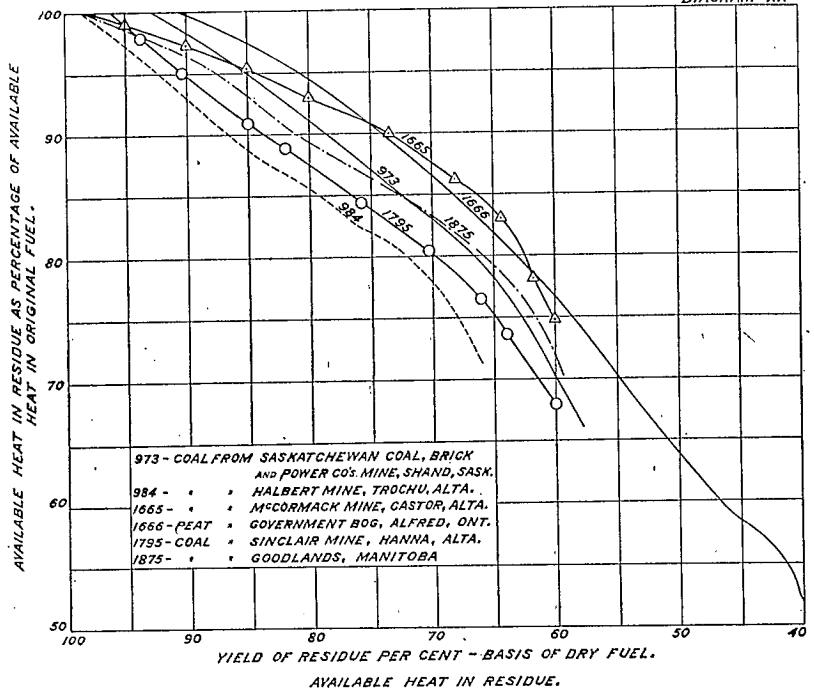


DIAGRAM XX



The lignite coals dealt with in this report may be divided into two main classes, (1) those from Manitoba and Saskatchewan, and (2) lignites of a somewhat higher grade, or "domestic" coals from Alberta. It should be noted that, while sub-bituminous and higher grade coals also occur in Alberta, it is only with the "domestic" coals that this report is concerned.

The coals from Manitoba and Saskatchewan contain over 30 per cent moisture, and disintegrate on exposure, which detracts very considerably from their value when in the raw state. Carbonization of these low grade coals not only remedies this deficiency, but also raises their calorific value from 4200 calories (7500 B.Th.U.) in the raw state, or 6100 calories (11000 B.Th.U.) in the dry state, to 7200 calories (13000 B.Th.U.), increases respectively of 73 per cent and 27 per cent. They therefore appear to require a heat treatment before they can be used other than locally as a household fuel.

The Alberta coals, on the other hand, contain from 15 per cent to 25 per cent moisture, and do not disintegrate quite so readily as those of the lower grade. Carbonization of these, excepting the Castor coal, raises their fuel value on an average 40 per cent (25 per cent to 53 per cent) above that of the raw fuel, or 15 per cent (10 per cent to 17 per cent) above that of the dried fuel. Therefore the question of by-products would probably have to be taken into account when considering heat treatment of any of these coals.

It will be noted that (as shown in Table VII) over 50 per cent of the increase in calorific value caused by carbonization, calculated on the raw fuel basis, is due to loss of moisture. This holds good except for the peat and the Drumheller coal, which do not represent the average run of raw fuel, and for the Castor coal which appears to be abnormal. The increases due to loss of moisture range from 44 per cent to 65 per cent of the total increases in calorific, but vary too much to serve as a basis of division between the different coals. They are, however, of interest in showing the comparative values of the coals for any such use as powdered fuel, where a low moisture content is desirable.

With respect to the maximum increase in calorific value of the carbonized residue, the eleven coals may be roughly classed as follows:—

(a) Nos. 1875, 973 and 1076—from Goodlands, Manitoba, and Shand and Taylorton, Saskatchewan—show an average increase in calorific value of 74.7 per cent on the raw basis, and 19.6 per cent on the dry basis. Their calorific values average as follows: raw fuel, 4140 calories (7460 B.Th.U.), dried fuel, 6050 calories (10890 B.Th.U.), carbonized residue, 7240 calories (13030 B.Th.U.).

(b) No. 1665—from Castor, Alberta—shows an increase in calorific value of 75.6 per cent on the raw basis, or 29.2 per cent on the dry basis. It has the following calorific values: raw fuel, 4490 calories (8080 B.Th.U.), dried fuel, 6100 calories (10980 B.Th.U.), carbonized residue, 7880 calories (14180 B.Th.U.). In this case the low ash content of the sample may be significant.

(c) Nos. 1456, 1505, 1790, 1795, 1507—Alberta coals from Cardiff, Clover Bar, Drumheller, Hanna and Tofield, respectively—show an average increase in calorific value of 48.6 per cent on the raw basis, or 16.5 per cent on the dry basis. Their calorific values average as follows: raw fuel, 4970 calories (8950 B.Th.U.), dried fuel, 6340 calories (11400 B.Th.U.), carbonized residue, 7380 calories (13280 B.Th.U.).

(d) Nos. 1824 and 984—from Lethbridge and Trochu, Alberta—show an average increase in calorific value of 30.0 per cent on the raw basis and 10.7 per cent on the dry basis. Their calorific values average as follows: raw fuel, 5550 calories (9990 B.Th.U.), dried fuel, 6520 calories (11720 B.Th.U.), carbonized residue, 7210 calories (12970 B.Th.U.).

The above conclusions were deduced from very small scale experiments. They indicate relatively the nature of the residue to be expected from the carbonization of any of the coals tested, and the temperatures at which the operation may best be carried out. Besides the increased calorific value of the residue, other factors must be taken into account in deciding whether any coal is suited for carbonization. Among these may be mentioned the yield of by-products, such as gas and tar oils, and the fitness of the carbonized residue for briquetting purposes. It is with these important factors in view that large scale laboratory experiments are now being carried out.

TABLE I  
Coal Sample No. 1665, McCormack Mine, Castor, Alta.

Temperature, degrees C.	Yield of residue	Heat in residue as percentage of heat in original fuel	Analysis of residue			
			Calorific value, calories per gram	Ash	Volatile matter	Fixed carbon
.....105°.....	% 100.0	% 100.0	6100	% 5.0	% 40.7	% 54.3
.....280°.....	93.7	98.4	6400	5.0	35.9	59.1
.....300°.....	91.8	98.0	6485	5.1	34.9	60.0
.....350°.....	87.2	96.2	6730	5.3	30.8	63.9
.....400°.....	81.2	93.4	7020	5.6	25.9	68.5
.....450°.....	75.7	91.1	7330	6.1	20.0	73.9
.....500°.....	71.3	88.5	7520	6.5	15.7	77.8
.....550°.....	67.3	85.7	7740	6.9	12.3	80.8
.....600°.....	64.7	83.5	7850	7.4	8.1	84.5
.....620°.....	63.8	82.4	7880	7.5	6.7	85.8
.....650°.....	62.4	80.0	7765	7.7	5.6	86.7
.....700°.....	61.1	76.9	7640	8.1	3.9	88.0
.....740°.....	60.1	74.8	7605	8.2	3.2	88.6

TABLE II

Coal Sample No. 1790, Midland Collieries, Drumheller, Alta.

Temperature, degrees C.	Yield of residue	Heat in residue as percentage of heat in original fuel	Analysis of residue			
			Calorific value, calories per gram	Ash	Volatile matter	Fixed carbon
.....105°.....	% 100.0	% 100.0	6290	% 9.4	% 40.3	% 50.3
.....255°.....	97.5	100.0	6500	9.2	39.0	51.8
.....300°.....	94.6	97.4	6555	9.6	35.4	55.0
.....350°.....	88.4	93.0	6700	10.4	30.7	58.9
.....400°.....	82.6	89.4	6840	11.1	26.3	62.6
.....450°.....	76.8	85.8	6990	12.0	21.8	66.2
.....500°.....	71.4	80.7	7100	12.8	16.2	71.0
.....550°.....	68.2	78.2	7210	13.4	12.6	74.0
.....600°.....	65.9	76.4	7300	14.0	9.9	76.1
.....620°.....	65.6	74.0	7325	14.2	9.0	76.8
.....650°.....	63.7	73.9	7270	14.6	7.0	78.4
.....685°.....	62.0	73.2	7300	14.9	5.7	79.4
.....700°.....	61.4	71.7	7275	15.0	5.2	79.8
.....750°.....	59.6	68.6	7220	15.4	4.6	80.0



TABLE III

Coal Sample No. 1795, Sinclair Mine, Hanna, Alta.

Temperature, degrees C.	Yield of residue	Heat in residue as percentage of heat in original fuel	Analysis of residue			
			Calorific value, calories per gram	Ash	Volatile matter	Fixed carbon
.....105°.....	% 100.0	% 100.0	6430	% 7.8	% 38.9	% 53.3
.....240°.....	97.9	100.0	6565	7.9	37.2	54.9
.....300°.....	96.1	100.0	6690	8.0	35.8	56.2
.....350°.....	90.4	95.1	6810	8.3	31.2	60.5
.....400°.....	81.9	88.9	6985	9.1	24.0	66.9
.....450°.....	75.8	84.3	7160	9.8	17.8	72.4
.....500°.....	70.2	80.3	7340	10.5	12.8	76.7
.....550°.....	68.1	78.7	7440	10.8	10.3	78.9
.....600°.....	66.0	76.5	7490	11.2	8.1	80.7
.....650°.....	64.0	73.6	7420	11.6	5.4	83.0
.....700°.....	61.6	70.2	7305	11.9	4.0	84.1
.....750°.....	60.0	67.9	7220	12.3	2.9	84.8

TABLE IV

Coal Sample No. 1824, Canada West Mine, Taber, Alta.

Temperature, degrees C.	Yield of residue	Heat in residue as percentage of heat in original fuel	Analysis of residue			
			Calorific value, calories per gram	Ash	Volatile matter	Fixed carbon
.....105°.....	% 100.0	% 100.0	6585	% 8.4	% 38.8	% 52.8
.....250°.....	98.2	99.0	6620	8.4	36.6	55.0
.....300°.....	96.0	98.5	6750	8.5	34.5	57.0
.....350°.....	91.4	95.5	6900	8.8	30.2	61.0
.....400°.....	84.2	89.3	7020	9.5	23.7	66.8
.....450°.....	77.8	83.5	7110	10.3	18.0	71.7
.....500°.....	73.5	79.8	7170	11.0	14.1	74.9
.....550°.....	70.6	77.7	7210	11.4	11.4	77.2
.....600°.....	68.5	75.2	7240	11.8	9.5	78.7
.....650°.....	66.5	72.2	7160	12.1	7.0	80.9
.....700°.....	64.2	69.8	7110	12.4	4.2	83.4
.....715°.....	64.0	69.0	7110	12.5	3.8	83.7

TABLE V  
 Coal Sample No. 1875, Goodlands, Manitoba

Temperature, degrees C.	Yield of residue	Heat in residue as percentage of heat in original fuel	Analysis of residue			
			Calorific value, calories per gram	Ash	Volatile matter	Fixed carbon
.....105°.....	% 100·0	% 100·0	5860	% 9·5	% 43·5	% 47·0
.....280°.....	90·9	96·5	6200	10·3	37·0	52·7
.....300°.....	89·5	95·7	6280	10·4	35·6	54·0
.....350°.....	84·2	92·4	6420	10·6	31·2	58·2
.....400°.....	78·5	88·5	6640	11·3	26·2	62·5
.....450°.....	73·7	85·5	6820	11·8	21·8	66·4
.....500°.....	69·8	82·4	6990	12·5	17·8	69·7
.....550°.....	66·8	80·5	7100	13·2	14·2	72·6
.....600°.....	64·0	78·4	7140	13·9	11·0	75·1
.....650°.....	61·6	75·4	7090	14·5	8·0	77·5
.....700°.....	60·0	72·6	7000	14·9	6·0	79·1
.....750°.....	59·5	71·2	6980	15·1	5·0	79·9

TABLE VI

Fuel	C.V. of dry fuel, calories per gram.	Yield <sup>1</sup> at 400° C.	C.V. of residue at 400° C.	Percentage increase C.V. at 400° C.	Optimum <sup>2</sup> temperature, degrees C.	Yield <sup>1</sup> at op. temp.	C.V. of residue at op. temp.	Percentage increase C.V. at op. temp.
No. 1668. Alfred peat.....	5350	% 55	6840	27.9	600°	% 42	7090	32.5
No. 1665. McCormack mine, Castor, Alta.....	6100	81	7020	15.1	620°	64	7880	29.2
No. 973. Saskatchewan Coal, Brick and Power Co., Shand, Sask.....	6250	80	7120	13.9	570°	66	7530	20.5
No. 1875. Goodlands, Manitoba.....	5860	79	6640	13.3	600°	64	7140	21.8
No. 1076. Western Dominion Collieries, Taylorton, Sask.....	6050	79	6650	9.9	560°	66	7050	16.5
No. 1456. Cardiff Collieries, Ltd., Cardiff, Alta.....	6100	83	6700	9.8	620°	67	7130	16.9
No. 1505. G. W. Coal Co's. Black Diamond mine, Clover Bar, Alta.....	6390	83	6970	9.1	600°	67	7490	17.2
No. 1790. Midland Collieries, Drumbeller, Alta.....	6290	82	6840	8.7	620°	65	7320	16.4
No. 1795. Sinclair mine, Hanna, Alta.....	6430	82	6985	8.6	590°	68	7490	16.5
No. 1507. Tofield Coal Co's. mine, Tofield, Alta.....	6480	84	6960	7.4	600°	67	7470	15.3
No. 1824. Canada West Coal Co., Taber, Alta.....	6590	84	7020	6.4	600°	68	7240	9.9
No. 984. Halbert's mine, Trochu, Alta.....	6430	84	6730	4.7	630°	71	7170	11.5

<sup>1</sup>Yields indicated are those from dried fuel.

<sup>2</sup>Temperature at which highest calorific value is obtained.

TABLE VII

Fuel	Moisture, per cent	C.V.—B.Th.U. per lb.			Percentage increase C.V. of residue at op. temp.			
		Raw fuel	Dry fuel	Residue at op. temp.	Basis of dry fuel	Basis of raw fuel		
						Due to loss of moisture	Due to carbon- izing	Total
No. 1666. Alfred peat.....	25.0	7220	9630	12760	32.5	33.4	43.4	76.8
No. 1665. McCormack mine, Castor, Alta.....	26.4	8080	10980	14190	29.2	35.9	39.7	75.6
No. 973. Saskatchewan Coal, Brick and Power Co., Shand, Sask.....	31.8	7670	11250	13550	20.5	46.7	30.0	76.7
No. 1875. Goodlands, Man.....	31.7	7190	10530	12850	21.8	46.5	32.3	78.8
No. 1076. Western Dominion Collieries, Taylorton, Sask.....	31.3	7490	10890	12690	16.5	45.4	24.0	69.4
No. 1456. Cardiff Collieries Ltd., Cardiff, Alta.....	23.6	8390	10980	12830	16.9	30.9	22.0	52.9
No. 1505. G. W. Coal Co's. Black Diamond mine, Clover Bar, Alta.....	21.5	9040	11500	13480	17.2	27.2	21.9	49.1
No. 1790. Midland Collieries, Drumheller, Alta.....	14.8	9650	11310	13180	16.4	17.2	19.4	36.6
No. 1795. Sinclair mine, Hanna, Alta.....	23.2	8890	11570	13480	16.5	30.2	21.4	51.6
No. 1507. Tofield Coal Co., Tofield, Alta.....	24.5	8800	11660	13450	15.3	32.5	20.4	52.9
No. 1824. Canada West Coal Co., Taber, Alta.....	12.2	10420	11860	13030	9.9	14.0	11.3	25.3
No. 984. Halbert's mine, Trochu, Alta.....	17.3	9580	11570	12910	11.5	20.8	14.0	34.8

TABLE VIII

## Available Heat in Residue as Percentage of Available Heat in Original Fuel

Temperature, degrees C.	No. 1666 Alfred, Ont.	No. 1665 Castor, Alta.	No. 973 Shand, Sask.	No. 1875 Good- lands, Man.	No. 1076 Taylor- ton, Sask.	No. 1456 Cardiff, Alta.	No. 1505 Clover Bar, Alta.	No. 1790 Drum- heller, Alta.	No. 1795 Hanna, Alta.	No. 1507 Tofield, Alta.	No. 1824 Taber, Alta.	No. 984 Trochu, Alta.
.....300°.....	% 89.0	% 98.0	% 100.0	% 95.7	% 100.0	% 100.0	% 99.3	% 97.4	% 100.0	% 99.6	% 98.5	% 96.6
.....350°.....	80.0	96.2	96.6	92.4	95.5	96.0	96.6	93.0	95.1	97.6	95.5	92.3
.....400°.....	69.3	93.4	91.4	88.5	87.1	90.9	92.0	89.4	88.9	91.0	89.3	88.3
.....450°.....	63.2	91.1	86.3	85.5	82.3	86.8	86.5	85.8	84.3	84.6	83.5	86.4
.....500°.....	60.4	88.5	83.1	82.4	79.5	83.9	82.3	80.7	80.3	81.0	79.8	82.5
.....550°.....	58.1	85.7	80.4	80.5	78.0	81.6	80.1	78.2	78.7	79.0	77.7	81.6
.....600°.....	55.7	83.5	77.1	78.4	74.4	79.5	78.6	76.4	76.5	76.7	75.2	79.8
.....650°.....	53.2	80.0	74.1	75.4	71.4	77.3	75.7	73.9	73.6	74.7	72.2	77.4
.....700°.....	51.4	76.9	71.8	72.6	69.5	75.3	72.3	71.7	70.2	71.3	69.8	75.3
.....750°.....	47.0	74.4	70.0	71.2	67.0	72.0	69.5	68.6	67.9	68.9	67.0	73.0

## II

## NOTES ON THE BURNING QUALITY OF KEROSENE OILS FOR ILLUMINATING PURPOSES

P. V. Rosewarne

## INTRODUCTION

An investigation of the burning qualities of kerosene oils was undertaken at the laboratory of the Fuels and Fuel Testing Division of the Mines Branch, in order to obtain first hand information concerning the relations between the chemical constituents, the physical characteristics and the burning qualities of the oils. Three samples of commercial kerosene were obtained through local dealers who were handling the product of different refiners, and a series of experiments was begun in order to ascertain the test or tests which would indicate the burning qualities most accurately, and which could be performed with a small sample of the oil in a laboratory without elaborate equipment. At the present time the work is not complete, but a preliminary report is appended.

The analyses in Table I define some of the physical characteristics of the kerosene used in the experiments, and indicate the amount of some of the impurities present. The discussion of the results indicates what interpretations have been placed upon similar characteristics and impurities in other oils, by authorities in the past.

## CHEMICAL AND PHYSICAL EXAMINATION

The samples of kerosene obtained gave the results shown in Table I.

TABLE I.

Test	Sample No. 1890	Sample No. 1891	Sample No. 1892
Flash point.....	134°F. (56.7°C.)	136°F. (57.8°C.)	114°F. (45.6°C.)
Viscosity at 80°F. (26.7° C.).....	30.0 Secs.	30.8 Secs.	28.8 Secs.
Iodine value.....	22.6	12.6	15.4
Specific gravity at 60°F. (15.6° C.).....	0.8095	0.7910	0.800
Sulphur content.....	0.057%	0.025%	0.037%
Colour.....	Stand. white	Super white	Super white

## DISCUSSION OF RESULTS

Bacon and Hamor<sup>1</sup> claim that the best oil for burning has the following characteristics (presumably in this order of desirability, although they do not say so definitely):—

1. Satisfactory flash point.
2. Lowest viscosity.
3. Lowest iodine absorption value.
4. Highest specific gravity.
5. Lowest sulphur content.
6. Best colour.

NOTE.—This investigation was undertaken immediately after having received several small samples of kerosene from the Tidal and Current Survey, Department of the Naval Service, with the request that the samples be analysed in order to determine as far as possible the one least likely to smoke when burned in a lamp.

<sup>1</sup> Bacon and Hamor, "American Petroleum Industry," page 876.

**Flash Point.**—The flash point was determined in the standard Pensky-Martens, closed test apparatus, and in all cases was considerably above the minimum set for kerosenes which may be sold in Canada,<sup>2</sup> namely, 85° F. (29.4° C.). An oil flashing at the minimum temperature would be rated as having a satisfactory flash point. The regulations specify that the flash point be determined in the Abel tester, but the customary practice was followed by first determining the flash point in the Pensky-Martens tester, and only using the Abel tester when the temperature observed was close to the minimum. This method of procedure is followed because the Abel tester is not suitable for a rapid determination unless the flash point is less than 100° F. (37.8° C.).

A low flash point indicates the presence of too large a proportion of the more volatile hydrocarbons, and these would make the oil unsafe to use because of the possibility of the vapours being ignited in the lamp bowl and causing an explosion. Holde<sup>3</sup> draws attention to the statement of Engler, that explosive mixtures form in the lamp reservoir at a temperature about 8° C. higher than that of the flash point observed in the Abel tester. There is, however, very little likelihood of obtaining to-day an oil with too low a flash point, as the lighter fractions have been removed, since they are more valuable than the heavier ones.

**Viscosity.**—The viscosity was determined in the standard Redwood viscometer.<sup>4</sup> From the results it was found that No. 1892 had the lowest viscosity and No. 1891 the highest. According to Redwood<sup>5</sup> the viscosity of an oil affords, in some cases, a useful indication of its burning quality, but he omits to say in what way this operates. Holde<sup>6</sup> states that the viscosity of a kerosene opposes the rise of the oil in the wick by increasing the resistance in the capillaries. This statement supplies a reason for Bacon and Hamor's claim that the best illuminating oil has the lowest viscosity.

**Iodine Value.**—The iodine value, which is a comparative measure of the amount of unsaturated hydrocarbons present, was determined according to the Hanus method for gasoline.<sup>7</sup> The lowest iodine value was given by sample No. 1891, and the highest by No. 1890. Holde<sup>8</sup> refers to the experiments of Weger, who claims that the presence of unsaturated hydrocarbons of the olefine, benzene, and partially hydrated cyclic series cause a red coloration of the flame, and thus the flame appears darker. Bacon and Hamor,<sup>9</sup> in referring to the Edeleanu process of refining oil, state that the sulphur dioxide "dissolves unsaturated hydrocarbons and certain aromatic hydrocarbons which are responsible for the unsatisfactory burning and odour of certain kerosenes." It would appear, therefore, that the presence of unsaturated hydrocarbons in an illuminating oil interferes with the proper burning of the oil.

<sup>2</sup> Redwood, "A Treatise on Petroleum", Vol. III, page 79.  
 McGill, Bull. 362, Dept. Inland Revenue of Can. "Gasoline", page 5.  
<sup>3</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 58.  
<sup>4</sup> Redwood, "A Treatise on Petroleum", Vol. II, page 275.  
<sup>5</sup> Redwood, "A Treatise on Petroleum", Vol. II, page 212.  
<sup>6</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 55.  
 Ubbelohde, Petrol., 4, 861 (1909).  
 Engler, Levin and Stepanoff, Grundlagen der Lampentheorie, 1906.  
<sup>7</sup> Ellis and Meigs, "Gasoline and other Motor Fuels", page 41.  
<sup>8</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 65.  
<sup>9</sup> Bacon and Hamor, "American Petroleum Industry", page 594.



**Specific Gravity.**—The specific gravity was determined by the hydrometer method. Sample No. 1891 had the lowest, and No. 1890 the highest specific gravity. The influence of different specific gravities is negligible<sup>10</sup> when considering the amount of oil that can be raised by the wick. A high specific gravity indicates the possible presence of a large percentage of heavy hydrocarbons,<sup>11</sup> or of aromatic hydrocarbons.<sup>12</sup> Redwood<sup>11</sup> states that an undue proportion of heavy hydrocarbons has an injurious effect on the burning quality of an oil. It would seem, therefore, since it has been shown that aromatic hydrocarbons and also heavy hydrocarbons are undesirable in an illuminating oil, and since these two classes tend to increase the specific gravity, that Bacon and Hamor are in error in stating that the best burning oil has the highest specific gravity.

**Sulphur.**—The sulphur content was determined by the following modification of the combustion method<sup>13</sup>: About 1.3 grams of the sample was burned in an atmosphere of oxygen at a pressure of 500 pounds per square inch in an Emerson calorimeter bomb, in the presence of about 10 cubic centimeters of water. After the oil was burned, the interior of the bomb was rinsed out with water, the washings acidified with hydrochloric acid, the sulphate precipitated as barium sulphate, and the percentage of sulphur calculated. The sulphur content of the oils is shown in Table II.

TABLE II.

Test	Sample No. 1890	Sample No. 1891	Sample No. 1892
	%S	%S	%S
Test 1.....	0.059	0.029	0.031
Test 2.....	0.055	0.020	0.040
Average.....	0.057	0.025	0.037

Much has been written concerning sulphur in petroleum and kerosene oils. Some authorities<sup>14</sup> point out the excessive cost of purifying a crude petroleum having a high percentage of sulphur, some,<sup>15</sup> the vile odour of sulphur compounds such as are found in petroleum, while others<sup>16</sup> dwell on the chemical constitution of the various compounds containing sulphur.

It is universally recognized that a petroleum to be valuable must have a low sulphur content. There is, however, a very confusing lack of agreement among authorities concerning the relations between the sulphur

<sup>10</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 55.

<sup>11</sup> Redwood, "A Treatise on Petroleum", Vol. II, page 216.

<sup>12</sup> Campbell, "Petroleum Refining", page 183.

Bacon and Hamor, "American Petroleum Industry", page 595.

<sup>13</sup> Redwood, "A Treatise on Petroleum", Vol. II, page 319.

Hicks, "Mineral Oil Testing", page 60.

Holde-Mueller, "Examination of Hydrocarbon Oils", page 41.

Guttentag, "Petrol and Petroleum Spirits", page 90.

Campbell, "Petroleum Refining", page 49.

Bacon and Hamor, "American Petroleum Industry", page 128.

Cross, "Handbook of Petroleum, Asphalt and Natural Gas", page 332.

<sup>14</sup> Bacon and Hamor, "American Petroleum Industry", page 609.

Redwood, "A Treatise on Petroleum", Vol. II, page 48.

<sup>15</sup> Bacon and Hamor, "American Petroleum Industry", page 609.

Southcombe, "Chemistry of the Oil Industry", page 46.

Cross, "Handbook on Petroleum, Asphalt and Natural Gas", page 136.

Holde-Mueller, "Examination of Hydrocarbon Oils", page 62.

<sup>16</sup> Redwood, "A Treatise on Petroleum", Vol. I, page 239.

Southcombe, "Chemistry of the Oil Industry", page 46.

content of an illuminating oil and the burning qualities of that oil. The results of burning kerosene oils which contain sulphur were collected from various sources, and are summarized as follows:—

Sulphur compounds in kerosene oils: emit an offensive odour;<sup>15</sup> have a deleterious effect on plants, hangings and bindings, when the kerosene is burned in a room in which they are present;<sup>17</sup> cause unsatisfactory burning;<sup>18</sup> cause a white deposit on the glass chimney of the lamp;<sup>19</sup> do not affect illuminating power of the oil unless a derivative of sulphuric acid;<sup>20</sup> cause carbonization of the wick.<sup>21</sup>

No offensive odour was noticeable from any of the three samples of oils tested. The effect on plants, hangings and bindings would be proportional to the amount of sulphur present. Bacon and Hamor do not say in what way sulphur causes unsatisfactory burning. The white deposit on the chimney seems to be a definite result, directly due to sulphur, which can be easily observed. Campbell<sup>22</sup> claims that the removal of all but a trace of sulphurous bodies causes a marked reduction in the amount of the deposit. No other authority available makes any reference to this filming on the chimney. The incrustations on the wick are apparently composed of carbon and are often referred to as toadstools. According to Holde they are due to the presence of esters of sulphuric acid in the oil.

Since the determination of sulphur by the method outlined above includes all the sulphur present, irrespective of the form of combination in which it occurs, it is evident that a small percentage of sulphur so obtained, indicates an illuminating oil more free from the defects just mentioned than an oil having a larger percentage of sulphur. However, the determination of total sulphur cannot be used to distinguish which particular defect, or defects, will be present when the oil is burned.

**Colour.**—The colour of the samples was determined in Wilson's chromometer. Colour tests for illuminating oils have lost their former importance because various oils on the market to-day are dark-coloured, and nevertheless are quite satisfactory. Exposure to sunlight causes kerosenes to become darker in colour, but does not affect their burning qualities.<sup>23</sup>

#### EXPERIMENTAL

**Apparatus.**—The apparatus used consisted of a simple optical bench and shadow photometer; a lamp with an ordinary hinge burner using woven cotton wick, five-eighths of an inch in width; ordinary glass lamp chimneys to fit the above burner; an amyl acetate lamp; a five candlepower, carbon, incandescent, electric light bulb and receptacle; a voltmeter; and a sling psychrometer.

<sup>15</sup> Bacon and Hamor, "American Petroleum Industry", page 609.

Southcombe, "Chemistry of the Oil Industry", page 46.

Cross, "Handbook of Petroleum, Asphalt and Natural Gas", page 136.

Holde-Mueller, "Examination of Hydrocarbon Oils", page 62.

<sup>17</sup> Redwood, "A Treatise on Petroleum", Vol. II, page 318.

Gill, "Oil Analysis", page 20.

<sup>18</sup> Bacon and Hamor, "American Petroleum Industry", page 609.

<sup>19</sup> Campbell, "Petroleum Refining", page 84.

<sup>20</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 64.

Graefe, *Petrol*, 1, 606 (1905).

<sup>21</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 64.

Heussler and Demstedt, *Zeitschrift für Angewandte Chemie*, 17, 264 (1904).

Campbell, "Petroleum Refining", page 181.

<sup>22</sup> Campbell, "Petroleum Refining", page 84.

<sup>23</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 52.

The optical bench was merely a planed board, 6 feet long and 8 inches wide, and marked off in divisions of one centimeter. The shadow photometer consisted of an iron rod, and a piece of board, 2 feet long and 8 inches wide, covered with a large piece of white paper for a screen. The amyl acetate lamp was constructed of metal with a cylindrical bowl somewhat after the design of a Hefner lamp. It was mounted on a block of wood of sufficient height to bring the flame to approximately the same level as that of the kerosene lamp. The electric bulb and its receptacle were also mounted on a block of wood of about the same height.

**Burning Qualities.**—The meaning of the rather vague term, burning qualities, may be made more clear by stating that a good illuminating oil should have, as a rule, the following qualities:—

- (a) Minimum smokiness of flame.
- (b) Minimum tendency to form incrustations on the wick.
- (c) Minimum tendency to form depositions on the chimney.
- (d) Low rate of change of illuminating power.
- (e) High illuminating power.

**Smokiness.**—Campbell<sup>24</sup> states that certain oils are very easily affected by slight irregularities in the supply of air to the flame, and smoking of the chimney follows. Continuing, he states<sup>25</sup> that the presence of aromatic and heavy hydrocarbons causes smoking, since after the removal of these constituents by the Edeleanu process the oil does not smoke. Later, he states that the liquid sulphur dioxide used in the process mentioned above also dissolves certain sulphur containing constituents. These two statements make it uncertain whether aromatic hydrocarbons or sulphur compounds cause an oil to smoke. Bacon and Hamor<sup>26</sup> state that liquid sulphur dioxide "dissolves the unsaturated and certain aromatic hydrocarbons, which are responsible for the unsatisfactory burning and odour characteristic of certain kerosenes." The same authorities<sup>27</sup> state that sulphur causes "unsatisfactory burning." If, therefore, an oil burns unsatisfactorily because it smokes, then it would seem reasonable to expect that smokiness is caused by the presence of either sulphur compounds or unsaturated aliphatic hydrocarbons, or aromatic hydrocarbons, or a combination of two or more of these factors.

A method to determine the tendency of an oil to smoke when burned in an ordinary lamp was tried, but it was found to be unsatisfactory with the oils used. Further investigations are to be made along this line.

**Burning Tests.**—Campbell<sup>28</sup> claims that the only practical test of kerosene is to burn the oil in a lamp, similar to the one in which it is to be used, and to note the diminution of the flame and the incrustation on the wick. An ordinary oil lamp with a large bowl was obtained, and portions of the three samples of kerosene were burned in this lamp. The time for each test was approximately 7 hours. The appearance of the wick and of the glass chimney was noted at the end of the test. Duplicate tests were made, and the results are shown in Table III. From these results it is evident that sample No. 1891 is most satisfactory for burning; that No. 1890 is least satisfactory; and that No. 1892 is intermediate in value.

<sup>24</sup> Campbell, "Petroleum Refining", page 85.

<sup>25</sup> Campbell, "Petroleum Refining", page 180 et seq.

<sup>26</sup> Bacon and Hamor, "American Petroleum Industry", page 594.

<sup>27</sup> Bacon and Hamor, "American Petroleum Industry", page 609.

<sup>28</sup> Campbell, "Petroleum Refining", page 84.

Bacon and Hamor, "American Petroleum Industry", page 876.

TABLE III

Test	Sample No. 1890	Sample No. 1891	Sample No. 1892
Chimney discoloured—			
Test 1.....	Yes	Very slightly	Slightly
Test 2.....	Yes	Very slightly	Slightly
Wick incrusted—			
Test 1.....	Yes	No	Slightly
Test 2.....	Yes	No	Slightly
Time—			
Test 1.....	7.0 hrs.	7.0 hrs.	7.5 hrs.
Test 2.....	7.0 hrs.	5.9 hrs.	7.1 hrs.
Total oil burned—			
Test 1.....	169 grms.	169 grms.	170 grms.
Test 2.....	160 grms.	137 grms.	181 grms.
Oil burned per hour—			
Test 1.....	24.2 grms.	24.2 grms.	22.7 grms.
Test 2.....	22.9 grms.	23.2 grms.	25.5 grms.
Average.....	23.6 grms.	23.7 grms.	24.1 grms.

**Change in Illuminating Power.**—Preliminary experiments were conducted in order to measure the change in illuminating power. Although corrections were made for change of voltage of the electric current supplied to the standard lamp, and for change due to barometric pressure and humidity of the atmosphere, it was found that the use of more elaborate equipment was necessary in order to secure concordant results.

**Illuminating Power.**—Since unsatisfactory results have been obtained in determining the change in illuminating power, it was decided to postpone a determination of illuminating power until more precise apparatus was available.

#### COMPARISON OF RESULTS

By combining Table I and Table III, the results of the physical and chemical examination, and the results of the burning tests, are brought together for comparison in Table IV.

TABLE IV

Test	Sample No. 1890	Sample No. 1891	Sample No. 1892
Smoke.....	None	None	None
Chimney discoloured.....	Yes	Very slightly	Slightly
Wick incrusted.....	Yes	No	Slightly
Oil burned per hour.....	23.6 grms.	23.7 grms.	24.1 grms.
Flash point.....	134°F. (56.7°C.)	136°F. (57.8°C.)	114°F. (45.6°C.)
Viscosity at 80°F. (26.7°C.).....	30.0 Secs.	30.8 Secs.	28.8 Secs.
Iodine value.....	22.6	12.6	15.4
Specific gravity at 60°F. (15.6°C.).....	0.8095	0.7910	0.800
Sulphur content.....	0.057%	0.025%	0.037%
Colour.....	Stand. white	Super. white	Super. white

Since sample 1891, when burned, deposits the thinnest film on the chimney and the least incrustation on the wick, it may be said (in the absence of definite results as to tendency to smoke and rate of change of illuminating power), to have the best burning qualities.

The flash point is apparently not indicative of the burning qualities of these oils, since the flash point of No. 1890 and of No. 1891 is much higher than that of No. 1892, although it is apparent that No. 1892 has better burning qualities than No. 1890.

Although there seems to be a distinct interrelation between viscosity, oil burned per hour, and change of illuminating power, the experiments were too few to establish the fact clearly. Further experiments are to be carried out to supplement those already performed.

The iodine value, on the other hand, seems significant. It was found that No. 1891 had the lowest iodine value, that No. 1890 had the highest, and that No. 1892 had an intermediate value. Thus, since actual burning tests showed that No. 1891 was the best oil and that No. 1890 was the worst, it is evident that in this case the lowest iodine value indicates the best oil.

A comparison of the remaining results in Table IV also shows that the lowest specific gravity and the lowest sulphur content indicates the best oil, for the reason given for the iodine value. It is interesting to note that the results of the experiments agree in one respect with the conclusion arrived at theoretically, namely, that the best burning oil has the lowest specific gravity. If further work on a large number of different illuminating oils substantiates the preliminary results obtained from the three oils used, it will then be possible to determine the value of an oil for burning purposes by means of chemical and physical analysis.

#### CONCLUSION

Some of the burning qualities of three different samples of oil have been determined by means of an actual burning test and the results compared with the results of a chemical and physical examination.

The oil showing the most satisfactory result in the burning test had the following chemical and physical characteristics:—

- (a) The lowest iodine value.
- (b) The lowest specific gravity.
- (c) The lowest sulphur content.

The investigation is to be continued in order to include a larger number of different illuminating oils, and in order to obtain more precise information regarding the illuminating power and the effect upon it of various external conditions.

### III

#### THE LUBRICATING VALUE OF COD LIVER OIL

P. V. Rosewarne

##### INTRODUCTION

An investigation of the lubricating value of cod liver oil was undertaken in the Division of Fuels and Fuel Testing following an enquiry of the Air Board of Canada for available information respecting "the possible use of cod liver oil as a lubricant in aero engines and a comparison of the lubricating properties of cod liver oil with say pharmaceutical castor oil."

Though the results of the investigation are not positive so far as the

lubricating value of cod liver oil is concerned, nevertheless in view of the use of castor oil as a lubricant, and the apparent paucity of literature upon the subject, the laboratory tests on both these oils appear to be of sufficient interest to justify the following brief record of the investigation.

A summary of the constituents and general characteristics of the two oils, as stated in the literature, may be of value.

#### CHARACTERISTICS OF CASTOR AND COD LIVER OIL

Castor oil is a vegetable oil expressed from the seeds of the castor oil plant. The oil contains the glycerides of palmitic and ricinoleic acids, as well as those of several other fatty acids.<sup>1</sup> Ricinoleic acid is peculiar to castor oil. Castor oil is classed as a non-drying oil;<sup>2</sup> it solidifies at from  $-10^{\circ}\text{C.}$  to  $-18^{\circ}\text{C.}$ ; its saponification value is not less than 177, nor more than 187;<sup>3</sup> its iodine value is 83 to 90; it decomposes at  $300^{\circ}\text{C.}$ ; it is only partially soluble in petroleum distillates.<sup>4</sup>

Cod liver oil is a marine animal oil obtained from the livers of the cod, and other fish. The oil contains the glycerides of palmitic, stearic, clupanodonic<sup>5</sup> and other more complex acids. Clupanodonic acid is characteristic of all fish oils. Cod liver oil solidifies at from  $0^{\circ}\text{C.}$  to  $-10^{\circ}\text{C.}$ ; its saponification value is not less than 179, nor more than 192; its iodine value is from 135 to 168;<sup>6</sup> stearine separates out on standing.<sup>7</sup>

#### REQUIREMENTS FOR A GOOD LUBRICANT

Before discussing the results it is to be noted that a good lubricant should possess the following characteristics:—

- (a) Sufficient viscosity, or "body," to keep the moving surfaces apart under the maximum pressure.
- (b) Chemical inertness, in respect to oxidation and corrosive action on the metals of the bearings.
- (c) A low coefficient of friction.
- (d) Greatest possible capacity for carrying away heat, so that the bearings may remain cool.
- (e) A high temperature of decomposition.
- (f) A low solidifying point.

It is unlikely, however, that any one oil or grade of oil will be found to give the best results in every particular. In choosing an oil for a particular machine it is necessary therefore to obtain a lubricant that possesses the quality or qualities which enables the machine to function properly under operating conditions. For that, the two characteristics first mentioned in the above list are fundamental. The remaining four will vary in importance according to the operating conditions. For instance, it is conceivable that an oil having a slightly higher coefficient of friction and a lower solidifying point is to be preferred in some cases, to another oil having a lower coefficient of friction and a higher solidifying point.

<sup>1</sup> J. B. Cohen, "Theoretical Organic Chemistry".

<sup>2</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 360.

<sup>3</sup> British Pharmacopoeia, 1914.

<sup>4</sup> Lewkowitsch, "Analysis of Oils, Fats and Waxes", Vol. II, page 399.

<sup>5</sup> Lewkowitsch, "Analysis of Oils, Fats, and Waxes", Vol. I, page 210.

<sup>6</sup> Holde-Mueller, "Examination of Hydrocarbon Oils", page 370.

<sup>7</sup> Laucks, "Commercial Oils", page 78.

## RESULTS OF TESTS

The castor oil for the tests was of two grades, (a) commercial oil of good quality, (b) pharmaceutical oil of best quality. The cod liver oil used was of the grade known as "Norway Cod Liver Oil." The laboratory tests gave the results shown in Table I.

TABLE I

Test	Castor oil		Cod liver oil
	(a) grade	(b) grade	
Viscosity, Redwood at 100°F. (37.8°C.).....	980 Secs.	1068 Secs.	131.5 Secs.
125°F. (51.7°C.).....	460 "	522 "	90.0 "
150°F. (65.6°C.).....	242 "	285 "	68.4 "
175°F. (79.4°C.).....	146.4 "	153.4 "	56.1 "
210°F. (98.9°C.).....	85.7 "	88.0 "	46.5 "
250°F. (121.1°C.).....	56.2 "	57.2 "	.....
300°F. (148.9°C.).....	43.0 "	44.0 "	35.9 "
Friction test by Thurston oil tester—			
Pressure per sq. inch.....		40 lbs.	40 lbs.
Speed per minute.....		814 ft.	896 ft.
Maximum temperature.....		257°F. (125°C.)*	194°F. (90°C.)
Volume of oil used.....		1 (approx.)	5 (approx.)
Coefficient of friction at 194°F. (90°C.).....		0.05	0.02
Corrosion test on—			
(a) soft brass.....	Corroded	Corroded	Discoloured
(b) cold rolled steel.....	Discoloured	.....	No effect
Gumming test.....	Very slowly	Very slowly	Gums quickly
Flash point (Pensky-Martens, closed test).....	446°F. (230°C.)	450°F. (232°C.)	386°F. (197°C.)
Total acidity.....	6.1%	1.7%	1.1%
Free mineral acids.....	None	None	None
Saponification value.....	184	185	191
Iodine value.....	90	85	154

\*The machine was stopped, in order to avoid injury to the bearing, when the thermometer read 257°F.; the temperature was still rising.

## DISCUSSION OF RESULTS

**Viscosity.**—The viscosity of an oil is a measure of the degree of its fluidity, and is closely related to its internal friction. This close relation between viscosity and internal friction, usually expressed as the coefficient of friction, has given rise to a theory that has been very widely accepted as true, namely, that for all speeds and pressures, except for very low speeds and very high pressures, the coefficient of friction is proportional to the viscosity.<sup>8</sup> Battle<sup>9</sup> states that viscosity is also a measure of the combined effects of cohesion and adhesion; that cohesion helps to maintain the film by holding together the particles forming the oil; and that adhesion helps to maintain the film by clinging persistently to the surfaces to be lubricated. Since oils are used for lubrication at widely varying temperatures, the relation between viscosity and temperature is important. If an oil is intended for use at high temperatures, a large variation of viscosity with a change of temperature is undesirable, for the following reasons:—

- (a) At ordinary temperatures the oil is so thick that it is inconvenient to handle, in order that it may be of sufficient body at working temperatures.

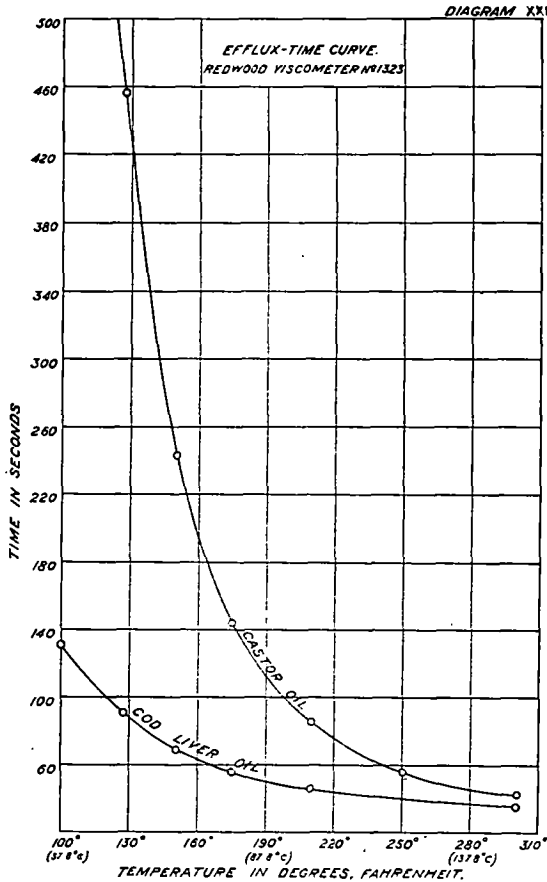
<sup>8</sup> Archbutt and Deeley, "Lubrication and Lubricants", page 84.

<sup>9</sup> Battle, "Lubricating Engineer's Handbook", page 24.

<sup>10</sup> Archbutt and Deeley, "Lubrication and Lubricants", pages 59 and 77.

- (b) The pipes and oil ducts of a lubricating system must be large enough to handle the viscous lubricant at ordinary temperatures.
- (c) The coefficient of friction tends to be high<sup>10</sup> when starting up a cold machine, and consequently the machine requires a high starting torque.

Accordingly, a lubricant for any machine should possess a viscosity high enough to maintain a lubricating film satisfactorily under the maximum pressure developed, but it should not have any excess viscosity, because that would increase the internal friction, and, if the machine operates at a high temperature, the viscosity should not change greatly with a change of temperature.



The high viscosity of castor oil would therefore indicate its value as a lubricant for heavy machines working at ordinary temperatures. On the other hand, the low viscosity of cod liver oil would seem to make it suitable for light or medium weight machines. In common with many of the more viscous oils the viscosity of castor oil varies greatly with a



change of temperature,<sup>11</sup> while cod liver oil changes comparatively little. The viscosities found are plotted in Diagram XXI, and the curves show graphically this difference in viscosity with change of temperature.

**Frictional Tests.**—Because of the general application of the theory that the coefficient of friction of an oil is proportional to its viscosity, and because the viscosity is more easily determined than the coefficient of friction, the viscosity is usually taken as an index to the coefficient of friction. However, an actual test of the lubricating properties is often of value, and accordingly castor oil and cod liver oil were tested in the laboratory on a Thurston oil tester.<sup>12</sup>

In discussing a frictional test it must be remembered that an oil tester cannot duplicate the conditions found in all machines. In an internal combustion engine, for instance, there are enormous fluctuations of pressure and relatively large quantities of oil flowing over the bearings; in an oil tester the pressure is constant and small quantities of oil are used. Then, too, no attempt is made in the latter to determine the amount of wear on the bearings, other than what can be deduced from the rate of increase of the temperature of the bearings. For these reasons a frictional test in the laboratory cannot give more than indications regarding the value of an oil for lubricating a particular machine, unless the conditions obtaining in the machine closely approximate those in the tester.

The results obtained from the test are in agreement with the indications given by the viscosity determinations and with the theory mentioned above, namely, that the coefficient of friction is proportional to the viscosity. The coefficient of friction of castor oil was found to be much higher than that of cod liver oil at the same temperature. It was also shown conclusively that cod liver oil is unsuitable as a lubricant for heavy machines, because the bearing of the tester "seized" in a very short time after the supply of that oil was stopped, while castor oil permitted the tester to run at the same speed and pressure more than twice as long without any indication of "seizing." There was no equipment available for studying lubricants under heavy pressures at very low speeds.

In addition, experience has shown that castor oil in the hands of many users gives good lubrication under severe operating conditions.

**Corrosion Tests.**—For this test strips of polished brass and steel were immersed in samples of the oils, the temperature being maintained at about 400° F. (204° C.) for 48 hours. The fact that cod liver oil has little or no effect on brass and steel would recommend its use as a lubricant, other things being equal, in place of castor oil, which shows a distinctly corrosive action under the same conditions.

**Gumming Tests.**—The oils were tested for gumming by placing a few drops on a flat surface and heating to a temperature of 248° F. (120° C.) for 8 hours. The results obtained were similar to those of Holde as reported by Archbutt and Deeley,<sup>13</sup> in that it was found that cod liver oil gums or dries much more quickly than castor oil. Theoretically, the fact that cod liver oil contains a relatively large proportion of unsaturated compounds,<sup>14</sup> as shown by the high iodine value, and is readily oxidized,<sup>15</sup> indicates a decided tendency to gum. This tendency would greatly lower the value of an oil for lubricating purposes, because the oil pipes and ducts

<sup>11</sup> Archbutt and Deeley, "Lubrication and Lubricants", page 192.

<sup>12</sup> Redwood, "Treatise on Petroleum", Vol. II, page 297.

<sup>13</sup> Archbutt and Deeley, "Lubrication and Lubricants", page 305.

<sup>14</sup> Lewkowitsch, "Analysis of Oils, Fats and Waxes", Vol. I, page 60.

<sup>15</sup> Encyclopaedia Britannica, Vol. VI, page 636.

would soon clog, to say nothing of the greatly increased friction on,<sup>16</sup> and possible danger to the bearings when a machine on which it has been used is started after standing idle for some time. The gumming property of cod liver oil as it is sold to-day is so great as to almost in itself preclude the use of that oil as a lubricant. Moreover, it is stated that the greater the amount of resin or gum formed by an oil, the more carbon will be deposited in the cylinder of an internal combustion motor.<sup>17</sup>

A series of experiments are being undertaken by this laboratory in order to obtain further information regarding those constituents of cod liver oil that cause gumming, and to investigate methods for its removal or conversion to non-gumming products.

**Flash Point.**—The flash point of castor oil was found to be satisfactory in every way. The flash point of cod liver oil was found to be slightly below the figure usually required by specifications for mineral oils to be used in internal combustion engines,<sup>18</sup> namely, 400° F. (204.4° C.), and it would accordingly have a greater tendency to burn off the cylinder walls of the engine during the power stroke of the piston. Presumably it would not burn off enough to allow the metal parts to come in contact except under unusual circumstances. The flash point indicates that there would be no appreciable fire risk in handling or storing cod liver oil.

**Acidity.**—No free mineral acid was found in either cod liver oil or castor oil. There was considerable difference in the amounts of organic acid found in the two samples of castor oil. For determining the amounts of organic acid present the customary practice was followed, namely, the organic acids were calculated in all cases as if they had the same molecular weight as oleic acid. The acid actually present in castor oil is likely ricinoleic, and that in cod liver oil clupanodonic. The corrosive effect is dependent upon the characteristics of the acid present rather than upon the amount. A small amount of one kind may cause more corrosion, under given conditions, than a large amount of another kind of acid. For this reason acidity determinations are only of value when different samples of the same kind of oil are compared, or when the relative corrosive value of the acids present in the two kinds of oil compared is known. In the case under discussion, castor oil has a larger percentage of acid (calculated as oleic acid) and also has a more corrosive action on brass and steel.

**Saponification Value.**—The saponification values obtained indicate that the different samples of oil may be considered to be unadulterated, since in every case the value obtained approaches the upper limit specified for that particular oil. The adulterants usually added tend to lower the saponification value.

**Iodine Value.**—The iodine values found indicate that the samples of pharmaceutical castor oil and cod liver oil are pure according to the standard set by the British Pharmacopœia. As mentioned above, a high iodine

<sup>16</sup> Ainsman, *Jour. Soc. Chem. Ind.*, 14, 282 (1895).

<sup>17</sup> Gill, "Oil Analysis", page 45.

<sup>18</sup> Department of Militia and Defence of Canada, "Provisional Specifications for Lubricating Oil for Motor Cars". U.S. Bureau of Mines, "Report of Committee on Standardization of Petroleum Specifications".

value indicates a large percentage of unsaturated compounds, and this in turn suggests the possibility of the absorption of oxygen to form gums or resins, which would destroy the lubricating qualities of an oil.

**Setting Point.**—The solidifying point is slightly lower for castor oil than for cod liver oil, and therefore the advantage would be with the former whenever the oil is to be used as a lubricant at low temperatures.

**Solid Matter.**—The two samples of castor oil remained clear on standing. It was found, however, that a flocculent precipitate was formed in cod liver oil on standing. The cod liver oil was perfectly clear at the beginning of the test. Laucks<sup>19</sup> states that under such conditions stearine separates. The precipitate, which was not analysed to determine its composition, would tend to clog the screens and pipes of the oiling system.

Further investigations on stearine from cod liver oil are being carried out and will be published in due time.

**Solubility.**—The insolubility of castor oil in petroleum distillates gives it an advantage over other oils, such as cod liver oil and all mineral oils,<sup>20</sup> when it is to be used in an internal combustion motor. This advantage is more pronounced in cold weather, when some of the heavier distillates of the fuel condense in the combustion chamber if the cylinder is not up to proper heat.<sup>21</sup> This condensed fuel runs down the cylinder walls, past the piston rings, and mixes with the lubricating oil. If the latter is miscible in all proportions with the distillate, it is soon diluted so much under favourable conditions, that a considerable change in body is apparent. Obviously, if the two liquids are not miscible such a result is impossible.

#### SUMMARY AND CONCLUSION

(a) Cod liver oil as a lubricant would be suitable for light weight machines were it not for its excessive gumming properties. Castor oil is a more suitable lubricant than cod liver oil for heavy weight machines, since it can support greater pressures, is more durable, and it does not gum.

(b) Cod liver oil has a low coefficient of friction and permits cool bearings, but requires a large supply of oil to the moving parts. Castor oil has a higher coefficient of friction, but does not require a large supply of oil.

(c) Cod liver oil has little or no corrosive action on brass or steel. Castor oil corrodes brass at high temperatures.

(d) Cod liver oil has a lower flash point than castor oil. It is high enough, however, to be fairly satisfactory.

(e) Cod liver oil solidifies at a higher temperature than castor oil.

(f) Solid matter separates from cod liver oil. Castor oil remains clear.

(g) Cod liver oil is miscible with gasoline. Castor oil is only partially miscible.

(h) Cod liver oil as sold at the present time is not a suitable lubricant for aeroplane engines now in use.

<sup>19</sup> Laucks, "Commercial Oils", page 78.

<sup>20</sup> Lewkowitsch, "Analysis of Oils, Fats and Waxes", Vol. III, page 64.

<sup>21</sup> U.S. Air Service, "Lubrication for Airplane Engines", page 23.

## IV

PRELIMINARY REPORT ON THE INVESTIGATION OF  
OIL SHALES

A. A. Swinnerton

## INTRODUCTION

A special study on Canadian oil shales was begun at the Fuel Testing Laboratory in September, 1919, and the results obtained were included in the Mines Branch Summary Report for that year.

The following report contains, in detail, the results of the examination of various oil shale samples sent in by officers of the Department, and by others, and also a full description of the method employed.

All methods for the extraction of oil in commercial quantities from oil shales depend on heat treatment, and among the factors which may affect the character of the shale oil are the following:—the size and kind of retort used; the size of the charge used; and the pressure and nature of the atmosphere within the retort. The best process to employ is not necessarily the one that gives the maximum yield of oil; but the process that gives the maximum yield of oil most suitable for refining purposes is all important, and it was with this objective that the investigation work in this laboratory on oil shales was planned and is being carried out.

According to the original programme, the investigation called for a study of different methods of examining oil shales for their oil yielding qualities with special attention to the nature of the oils obtained. The programme was therefore considered to consist of three parts or stages; first, a study of the different retorting processes on a laboratory scale in order to obtain the maximum oil yield; second, a preliminary examination of the products; third, a more thorough study of the shale oil obtained.

Among the experiments carried out in the early part of the investigation and belonging to part one were the following: (a), the distillation of a given oil shale sample in iron vessels heated by gas flame as used by Leverin<sup>1</sup> for Canadian oil shales, and by the field men of the United States Geological Survey;<sup>2</sup> (b), the distillation of the oil shale sample with and without steam in a specially designed retort surrounded by electric heating elements; and (c), the distillation of the oil shale sample in an electrically heated lead bath furnace, as was used for the lignite carbonization experiments. The experiments under (a) and (b) proved unsatisfactory, due mainly to uneven heating, but those under (c) gave quite satisfactory results. In this apparatus the much desired temperature control was obtainable on a fairly large sized sample of oil shale, and in a few of the runs sufficient oil and other products were obtained for examination, thus allowing some preliminary work to be carried out according to part two of the investigation. Most of the experimental runs in this lead bath apparatus were made at atmospheric pressure. A few runs were, however, made at reduced pressure, and the use of steam was tried.

Further experiments are being made, under part one of the programme outlined, in which the shale is being treated at various pressures in the presence of gases other than air and steam, such, for instance, as hydrogen

<sup>1</sup> Mines Branch Summary Report, 1909, page 153.

<sup>2</sup> United States Geological Survey, Bulletin 641, page 148.

and hot producer gas. The digestion of the oil shale in heavy, high-boiling, petroleum oil, followed by extraction with kerosene and distillation of the residue, according to the Ryan process, is also being tried. These runs are being made on a scale sufficiently large to allow of the preliminary examination of the products according to part two. In future work, parts one and two will be carried out simultaneously, and when the programme for these two parts has been completed, the third part, namely, the more thorough study of the shale oils obtained by the more promising processes will be undertaken, and the results of the completed investigation will, it is hoped, form the basis of a separate bulletin.

A total of 101 samples of oil shale have been examined at the Fuel Testing Laboratory during this period. Of these, 43 samples were submitted by W. J. Wright of the Geological Survey, 28 from Albert Mines, N.B., and 15 from various outcrops along Frederick Brook, N.B. A summary of the results of the analyses and distillations is given in their Memoir 129,<sup>3</sup> pp. 46, 47. Of the remaining 58 samples, 21 were sent in by S. C. Ells of the Mines Branch, from the Pasquia Hills district, Manitoba and Saskatchewan, and 37 were sent in by private individuals from the following localities:—10 samples from Nova Scotia; 3 from New Brunswick, 3 from Quebec, 7 from Ontario, 5 from Manitoba, 8 from British Columbia, and 1 from the North West Territories.

These samples were examined after the preliminary experiments had been carried out, on the form of the retort, on the method of heating, and on the effect of steam and of reduced pressure on the oil yield. It was accordingly considered that sufficient experience and data had been obtained to warrant undertaking the examination of these samples for their oil yielding qualities. In most cases the samples used were large enough to yield sufficient oil and other products on which to make a preliminary examination.

#### DISCUSSION OF PROCEDURE

The method used may be called a temperature-controlled destructive distillation process in which the reaction proceeds at a predetermined temperature and rate and at atmospheric pressure. This process was chosen because a method at atmospheric pressure seemed more directly applicable to commercial practice than one where reduced or increased pressures were used, and because the preliminary experiments indicated that this method, from among the many tried, was the most reliable for the examination in the laboratory of oil shale samples for their oil yielding qualities. In the apparatus used check results on a given sample were repeatedly obtained, and, according to the weight-balance records, total yields of products approaching 100 per cent of the sample taken were secured. The yield of oil and some of the physical properties, including distillation ranges of the shale oil obtained, are given in the following pages in tabular form. In this connection the results must be considered as comparative and based on a standard oil shale sample, namely, No. 1517 from Albert Mines, N.B., yielding an average of 13.6 per cent of its weight of crude shale oil (that is, nearly 32 imperial gallons per 2,000 lb. ton).

The moisture and ash content of the oil shale samples were found according to standard methods for coal analysis. The calorific value was

<sup>3</sup>Geology of the Moncton map area, pages 46, 47.

determined by mixing a known quantity of a standardized anthracite coal with a finely ground shale and burning the mixture in an Emerson oxygen bomb calorimeter in the usual way. The nitrogen content of the shales was determined by the Kjeldahl method, and the theoretical yield of ammonium sulphate was calculated from the results obtained. The yield of ammonium sulphate given in the tables was calculated on the assumption that 60 per cent of the nitrogen<sup>4</sup> can be recovered commercially. In the destructive distillation tests of the shales no attempt was made to obtain the maximum amount of ammonium sulphate. The crude oil figures reported herewith include the wet oil emulsion and the aqueous distillate from the shale. The water-free oil is the crude oil dehydrated by settling. The dehydrated or water-free oil yields were obtained by slightly warming and agitating the crude oil and then allowing it to settle overnight in a separatory funnel. After running off the water, the oil left was practically water-free. The figures for specific gravity of the oil are corrected to 60° F. The gas yields obtained by distillation are corrected to 60° F. and 30 inches mercury pressure.

#### DESCRIPTION OF DISTILLATION METHOD USED

The apparatus used consisted of a  $\boxplus$  section iron retort, a lead bath electric furnace with temperature control, a tubular iron condenser, a gas

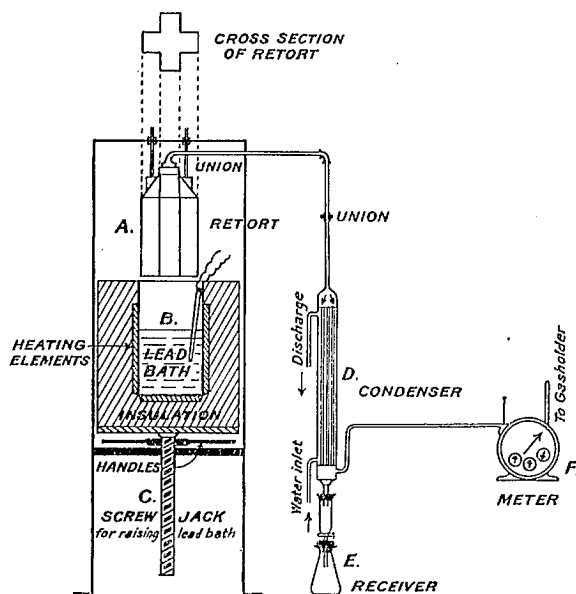


FIG. 12. Apparatus for oil shale distillation.

meter, and gas holders. The capacity of the retort was about 3,500 grams of shale and so designed that no part of the charge was more than  $1\frac{1}{4}$ " from the walls of the retort. The temperature lag between the hot lead

<sup>4</sup> R. W. Ellis, Joint Report on the Oil Shales of New Brunswick, Nova Scotia and the Oil Shale Industry of Scotland. Part I, page 40. Mines Branch, 1919.

bath and the centre of the charge was thus materially reduced. A special feature of the electrically heated lead bath was that the maximum temperature could be observed at all times by means of a pyrometer, so that the temperature of the bath, and consequently the rate of the decomposition reaction, could be closely followed. A diagrammatic sketch is given in Figure 12, and a more detailed description of the furnace may be found on pages 99-101 of the Summary Report for 1918.

To make a distillation run the following procedure is carried out. The sample is first prepared by crushing to about pea size, a certain amount of fines always being present. The retort A is charged with about 3,300 grams of this prepared shale and the exit pipe is attached by the union at the top of the retort. By means of the four hanging rods the retort is suspended from the top of the angle iron frame and connected with the condenser as in Figure 12. The lead bath B has meanwhile been heated to about 450° C. and is now raised by means of the screwjack C, so that it surrounds the retort. The immersion of the retort cools the lead bath to about 350° C. at which temperature the moisture from the charge comes off freely and the shale is being heated up rapidly, ready for temperature control during the decomposition reaction period.

About 50 to 60 minutes after the immersion of the retort the bath reaches a temperature slightly exceeding 400° C, at which temperature the oil is coming off freely, and from this point on the rate of heating and the consequent rate of distillation is controlled so that all the oil fog disappears before leaving the condensing train. At the end of about 2 hours the temperature of the bath has been slowly raised to about 450° C. when the oil distillate is at its maximum flow. During the course of about 2 hours more the bath is slowly raised to 550° C. in order to insure that the last traces of oil are distilled off. During the last hour the gas rate remains fairly constant, while the flow of the liquid distillate gradually ceases. No attempt is made to work for maximum yield of gas in the lead bath apparatus here described.

From observations during the 1919 series of experiments on oil shale from Albert Mines, and also during the runs on oil shales here reported the following comments may be made:—

(a) At lead bath temperatures 350° C. to 400° C. during the first hour the liquid distillate, which begins to show about 15 minutes after the immersion of the retort, is appreciable, and varies from 5-10 cc. per 5 minute interval.

This liquid distillate, besides containing practically all the water from the charge, also contains considerable shale oil. The gas flow is also noticeable, and after the first rush due to the expansion of the air in the system, varies from 0.06 to 0.12 c.f. per hour. The temperature of the interior of the charge, that is, at parts of the shale farthest away from the walls of the retort, has by this time reached about 250° C.

(b) At 400° to 450° C. (5) bath temperatures, during the second hour, the oil flow increases from about 10 c.c. per 5 minute intervals to as high as 35 to 40 c.c. and remains at this maximum for approximately 15 minutes. The gas rate meanwhile increases to a maximum of about 4 c.f. per hour. It is at this point that the rate of heating is slowed down in order to avoid excessive

<sup>5</sup> Pyrometer temperatures here recorded are subject to a correction of  $\pm 5^\circ \text{C}$ .

tar fog. While the bath temperature is held in the neighbourhood of 450° the maximum rate of flow of both the oil and the gas continues for about a quarter of an hour as mentioned, when the centre of the charge reaches about 400° C. During the next 30 minutes, while the interior temperature does not exceed 425° C., the oil flow decreases to less than 5 c.c. every five minutes. The end of the third quarter of the third hour is now reached. From the beginning of the run the shale during its decomposition reaction which proceeds from the retort walls to the centre of the charge, is at no period subjected to a temperature exceeding 425° to 435° C. The gas rate meanwhile decreases from its maximum flow to about 1 c.f. per hour.

(c) During the last 75 minute period of a four hour run, while the bath is raised from 450° to 550° C., the liquid distillate decreases rapidly to less than 1 c.c. every five minutes, and then ceases to flow. The gas rate however remains constant at about 1 c.f. per hour, as above, until the temperature of the centre of the charge at the end of the run is raised to that of the lead bath.

The rates of flow for oil and gas given above apply in general to a shale yielding approximately 30 imperial gallons per 2,000 lbs., and in particular to sample No. 1517 from Albert Mines.

Assuming that the temperature of the inner walls of the iron retort is approximately the same as the lead bath, the difference in temperature between the retort and the charge farthest away from the walls, at the end of the second hour, is about 60°, and it takes approximately one hour from the time the bath reaches, say 400° C., until the centre of the charge has reached the same temperature. The temperature gradient decreases to about 50° at the end of the third hour, when the run is practically finished so far as the oil is concerned.

In view of the following significant observations, viz.: (a) that the increase in the oil flow begins as the temperature of the bath reaches 400° C.; (b) that this oil flow reaches and maintains its desired maximum until the interior of the charge is raised to about 400° C., and (c) that it is apparently necessary to raise the temperature of the interior of the charge only say 25 to 35° C. above 400° C. in order to distil over practically all the oil; it is evident that the temperatures to be employed in order to obtain maximum yields of oil, as the main product from oil shale, are within a fairly narrow range, and that the optimum decomposition temperature is in the close neighbourhood of 400° C.

It is interesting to note that McKee and Ryder<sup>6</sup> in their report of small scale theoretical work on oil shales, check the above observations closely. Their results apparently prove that the decomposition of the kerogen constituents of oil shales takes place within the narrow temperature range of 745° F. (395° C.) and 767° F. (408° C.). These, of course, were temperatures within the retort, and on a very small sample of finely ground shale. It is also interesting to note that their yield of total oil was greater at 425° C. than it was at 410° C. or lower, although this extra yield was only 0.6 per cent of the original shale, and the higher yield contained less heavy bitumen, which they call a first decomposition product, and more light oil, termed by them a secondary decomposition product.

<sup>6</sup> J. Ind. and Eng. Chem. Vol. 13, No. 7, p. 613 et seq.  
J. Ind. and Eng. Chem. Vol. 13, No. 8, p. 678 et seq.



## EXPERIMENTAL

In order to determine that the method used in examining the oil shale samples here reported could be checked, three extra runs were made on a sample of Albert Mines shale, which has been reported as run 7, page 29, Mines Branch Summary Report for 1919. This run, No. 7, is reported again as No. 1 in the following table. Runs 2 and 3 were made approximately two years after No. 1, and run 4 about six months later than Nos. 2 and 3. The working sample had meanwhile been kept in a sealed container.

The crude oil figures as used in the weight balance table are significant. In run No. 1, since the water content of the crude wet oil was not checked, the dehydrated oil figure for this run is omitted in the table below.

TABLE I.

**Distillation Results of Four Experimental Runs on Sample No. 1517; Oil Shale from Albert Mines**

Run No.	Weight balance (p.c. wt. of shale)				Gas and oil yields (per 2,000 lbs.)			
	Crude oil	Gas	Residue	Un-accounted for	Gas		Dehydrated oil	
					Cu. ft.	Density	Sp. Gr.	Imp.g'l.
	p.c.	p.c.	p.c.	p.c.	Air=1			
1.....	13.4	3.5	82.8	0.3	1,308	0.69	0.852	.....
2.....	13.6	2.8	82.8	0.8	1,035	0.68	0.870	29.9
3.....	13.8	3.0	82.4	0.8	1,120	0.71	0.872	30.2
4.....	13.7	3.5	82.1	0.7	1,040	0.74	0.879	30.2

For reporting the results of the analyses and distillations, the oil shale samples are grouped as follows:—

Group I. Samples marked 1-15 from Tunnel No. 1, Albert Mines, N.B.

Group II. Samples marked 16-18 from Tunnel No. 2, Albert Mines, N.B.

Group III. Samples marked 19-28 from Tunnel No. 3, Albert Mines, N.B.

Group IV. Samples marked 29-47 from Frederick Brook outcrops, Albert Mines, N.B.

Groups I to IV inclusive were sent in by W. J. Wright, of the Geological Survey.

Group V. 21 samples, from Pasquia hills, Saskatchewan district, by S. C. Ells, of the Mines Branch.

Group VI. 37 samples, submitted from various localities, by private individuals.

Figure 13 gives the location of the samples taken by W. J. Wright in the Albert Mines oil shale area, N.B.

Two tables are given for each group, for groups I to IV, the first table reporting the ordinary analyses of the samples and the second table the gas and oil yields by distillation. One table only is given for groups V and VI.

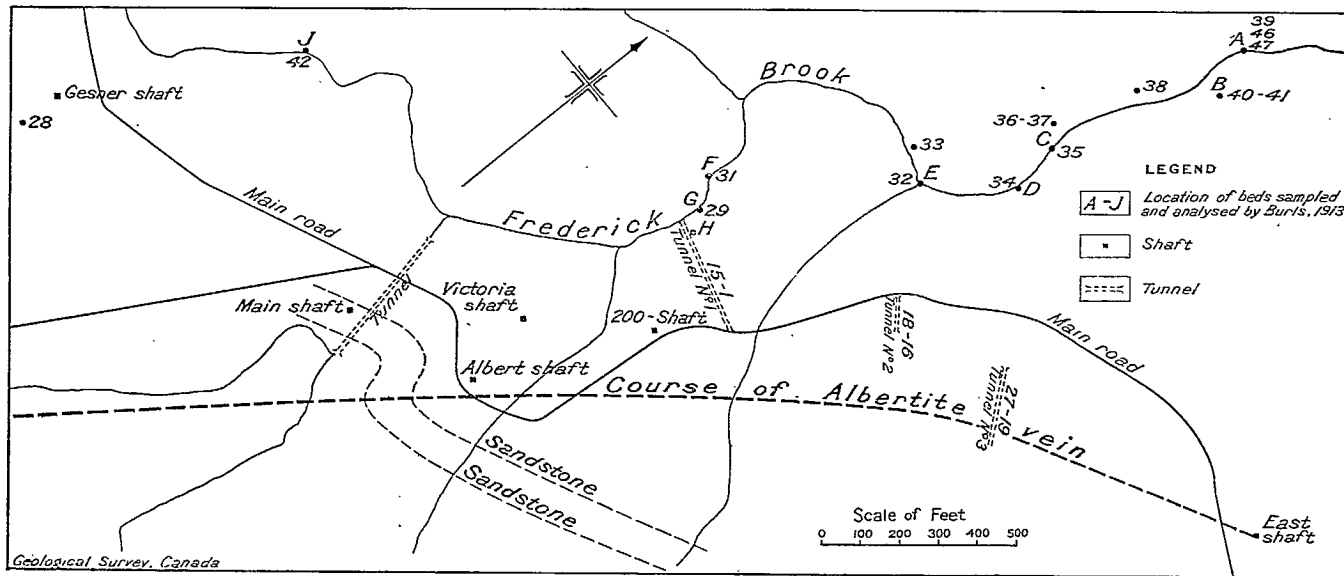


FIG. 13. Drawing showing portion of Albert mines oil shale area, New Brunswick.

## GROUP I.—TUNNEL No. 1, ALBERT MINES, N.B.

## Oil Shale Analyses

Sample No.	Sample mark	Location (See Fig. 13)	Ash p.c.	C. V. B.Th.U. per lb.	Nitrogen p.c.
1518.....	1	Albert Mines, N.B.....	68.6	3,240	0.45
1519.....	2	".....	72.0	2,540	0.40
1520.....	3	".....	68.4	2,970	0.44
1521.....	4	".....	68.2	2,430	0.44
1522.....	5	".....	76.0	2,450	0.37
1523.....	6	".....	69.5	2,380	0.43
1524.....	7	".....	79.1	1,370	0.35
1525.....	8	".....	75.5	1,710	0.43
1526.....	9	".....	73.9	2,170	0.42
1527.....	10	".....	80.3	1,025	0.32
1528.....	11	".....	71.0	2,790	0.40
1529.....	12	".....	75.0	2,790	0.53
1530.....	13	".....	66.0	2,570	0.43
1531.....	14	".....	79.3	1,105	0.29
1532.....	15	".....	80.8	1,295	0.50

## Oil Shale Distillations

Sample	Oil			Gas			Ammonium sulphate (calc.) lbs. per 2,000 lbs.
	Yield Imp. gals. per 2,000 lbs.		Sp. gr. (water free)	Yield cu. ft. per 2,000 lbs.	Density Air=1	C. V. B.Th.U. per cu. ft.	
	Crude	Water free					
1.....	26.3	21.9	0.854	920	0.59	620	25.4
2.....	22.4	19.8	0.839	1,030	0.50	550	22.5
3.....	26.2	22.0	0.839	1,120	0.67	560	24.8
4.....	25.8	21.2	0.834	1,300	0.60	560	24.8
5.....	23.1	18.5	0.849	670	0.55	610	20.9
6.....	22.7	17.1	0.824	1,160	0.62	510	24.3
7.....	14.3	8.7	0.824	820	0.59	530	19.8
8.....	16.3	9.1	0.816	1,060	0.63	460	24.3
9.....	20.7	14.7	0.869	700	0.66	640	23.7
10.....	11.2	5.6	0.874	430	0.63	500	18.4
11.....	28.5	21.3	0.844	930	0.61	600	22.6
12.....	27.1	19.5	0.839	990	0.69	470	29.9
13.....	25.5	20.3	0.839	1,190	0.56	620	24.3
14.....	12.9	8.1	0.839	560	0.60	550	16.4
15.....	16.7	8.7	0.834	950	0.69	350	28.2

## GROUP II.—TUNNEL No. 2, ALBERT MINES, N.B.

## Oil Shale Analyses

Sample No.	Sample mark	Location (See Fig. 13)	Ash per cent	C. V. B.Th.U. per lb.	Nitrogen per cent
1533.....	16	Albert Mines.....	67.6	2,000	0.36
1534.....	17	".....	66.8	3,450	0.61
1535.....	18	".....	82.5	670	0.33

## Oil Shale Distillations

	Oil			Gas			Ammonium sulphate (calc.) lbs. per 2,000 lbs.
	Yield Imp. gals. per 2,000 lbs.		Sp. gr. water free	Yield cu. ft. per 2,000 lbs.	Density Air=1	C. V. B. Th. U per cu. ft.	
	Crude	Water free					
16.....	20.1	16.5	0.859	980	0.74	510	20.3
17.....	30.5	23.9	0.839	940	0.60	650	34.4
18.....	10.6	6.0	0.854	470	0.65	420	18.6

## GROUP III.—TUNNEL No. 3, ALBERT MINES, N.B.

## Oil Shale Analyses

Sample No.	Sample mark	Location (See Fig. 13)	Ash per cent	C. V. B.Th.U. per pound	Nitrogen per cent
1536.....	19	Albert Mines.....	72.2	2,680	0.44
1537.....	20	".....	88.2	90	0.33
1538.....	21	".....	79.1	880	0.26
1539.....	22	".....	68.5	2,930	0.42
1540.....	23	".....	83.3	630	0.47
1541.....	24	".....	86.5	70	0.45
1542.....	25	".....	78.1	1,025	0.41
1543.....	26	".....	75.1	1,710	0.38
1544.....	27	".....	75.5	1,260	0.41
1545.....	28	(Gesner shaft).....	76.0	1,700	0.31

## Oil Shale Distillations

Sample	Oil			Gas			Ammonium sulphate (calc.) lbs. per 2,000 pounds
	Yield Imp. gals. per 2,000 lbs.		Sp. gr. water free	Yield cu. ft. per 2,000 lbs.	Density Air=1	C. V. B.Th.U. per cu. ft.	
	Crude	Water free					
19.....	27.2	19.8	0.854	370	0.64	580	24.8
20.....	15.4	Trace	.....	240	.....	.....	18.6
21.....	11.6	7.6	0.857	380	0.71	540	14.7
22.....	30.0	24.4	0.844	900	0.62	640	23.7
23.....	11.2	5.6	0.849	550	0.79	400	26.5
24.....	12.4	Trace	.....	440	0.90	380	25.4
25.....	14.6	9.2	0.849	770	0.83	280	23.1
26.....	20.4	14.2	0.839	790	0.44	590	21.4
27.....	15.2	8.8	0.860	560	0.77	330	23.1
28.....	18.2	12.4	0.859	640	0.70	460	17.5

GROUP IV.—FREDERICK BROOK OUTCROP, ALBERT MINES, N.B.  
Oil Shale Analyses

Sample No.	Sample mark	Location (See Fig. 13)	Ash per cent	C. V. B.Th.U. per pound	Nitrogen per cent
1546.....	29	See accompanying map.....	73.0	1,560	0.45
1547.....	31	"	63.0	3,040	0.44
1548.....	32	"	76.5	1,495	0.58
1549.....	33	"	75.4	2,720	0.48
1550.....	34	"	73.8	1,655	0.49
1551.....	35	"	65.1	4,105	0.60
1552.....	36	"	77.3	1,880	0.50
1553.....	37	"	78.0	1,440	0.25
1554.....	38	"	69.0	3,460	0.58
1555.....	39	"	68.0	3,545	0.54
1556.....	40	"	65.3	4,210	0.66
1557.....	41	"	81.2	820	0.21
1558.....	42	"	68.2	4,090	0.71
1587.....	46	"	75.8	2,230	0.41
1588.....	47	"	83.5	1,235	0.30

## Oil Shale Distillations

Sample	Oil			Gas			Ammonium sulphate (calc.) lbs. per 2,000 lbs.
	Yield Imp. gals. per 2,000 lbs.		Sp. gr. water free	Yield cu. ft. per 2,000 lbs.	Density Air=1	C.V. B. Th. U. per cu. ft.	
	Crude	Water free					
29.....	18.5	12.7	0.854	700	0.70	440	25.4
31.....	27.0	23.8	0.844	820	0.62	770	24.8
32.....	19.7	17.3	0.869	900	0.75	450	32.7
33.....	19.5	16.7	0.864	930	0.72	480	27.1
34.....	14.4	13.2	0.864	1,330	0.82	370	27.7
35.....	22.4	16.6	0.834	1,180	0.43	630	33.9
36.....	14.5	12.7	0.884	1,000	0.75	480	28.2
37.....	12.3	11.3	0.864	470	0.83	540	14.1
38.....	32.0	28.0	0.874	1,485	0.88	580	32.7
39.....	26.2	25.2	0.864	1,060	0.70	750	30.5
40.....	27.7	26.5	0.864	1,350	0.72	660	37.8
41.....	6.0	4.8	0.864	1,180	0.98	720	11.9
42.....	40.2	32.2	0.859	1,550	0.52	570	40.0
46.....	17.6	16.6	0.854	1,080	0.92	440	23.1
47.....	10.7	9.1	0.855	900	0.60	500	16.9

GROUP V.—PASQUA HILLS DISTRICT, SASKATCHEWAN AND  
MANITOBA

## Oil Shale Distillations

Sample No.	Location	Oil yield Imp. gals. per 2,000 lbs.		Sp. gr. oil Water free	Gas yield cu. ft. per 2,000 lbs.	Ammonium sulphate* lbs. per 2,000 lbs.
		Crude	Water free			
1825	Man River.....	20.9	5.7	0.954	840	5.4
1827	".....	13.4	5.0	0.964	570	2.9
1830	".....	15.2	6.1	0.951	890	6.7
1831	".....	15.3	5.5	0.946	800	4.8
1826	".....	18.0	5.1	0.950	750	8.7
1828	".....	18.5	5.8	0.942	700	3.1
1837	".....	16.1	9.4	0.954	700	2.2
1838	".....	11.9	6.5	0.944	500	2.9
1840	".....	17.8	4.0	0.945	620	2.9
1842	".....	14.9	Trace			
1843	".....	15.6	Trace			
1850	Carrot river.....	13.2	6.0	0.959	730	1.7
1851	".....	12.4	4.9	0.958	600	2.8
1852	".....	10.4	3.2	0.953	410	2.3
1853	Jordan river.....	24.4	10.9	0.964	1,130	3.0
1858	Cracking river.....	22.5	10.9	0.957		2.6
1860	".....	21.1	9.1	0.957	900	2.8
1861	".....	22.1	8.9	0.957	880	2.8
1862	".....		7.0	0.966		
1863	".....	24.4	12.8	0.949	920	4.5
1895	Ochre river.....	12.5	4.1	0.953	500	1.0

\*The yield of  $(\text{NH}_4)_2\text{SO}_4$  from these samples was obtained directly by passing the gases through dilute sulphuric acid.

GROUP VI.—MISCELLANEOUS SAMPLES  
Oil Shale Analyses and Distillations

Sample No.	Location	Moisture %	Volatile matter %	Ash %	Nitrogen %	C.V. B.Th.U. per lb.	Oil yield	
							Imp. gals. per 2,000 lbs.	Water free
1572	Abitibi river, Ont.....	0.4	26.4	61.4	0.20	420		1.6
1573	" " .....	1.4	11.7	84.8	0.37	1,180		5.6
1575	" " .....	1.7	10.2	86.6	0.41	1,070		3.9
1514	Saanich, B.C.....	1.2	6.8	88.2	0.19	.....	Trace	
1576	Sydney, N.S.....	0.9	44.3	50.6	0.36	3,460		13.5
1579	Indian mountain, N.B.....	0.6	0.6	85.5	0.15	.....	Trace	
1633	Pasquia hills, Man.....	.....	.....	74.8	.....	2,690		4.0
1637	" " .....	.....	.....	62.9	.....	1,990		4.0
1517	Albert Mines, N.B.....	0.7	31.4	65.8	0.8	4,210		30.1
1707	Fernie, B.C.....	1.6	7.1	91.4	.....	.....		.....
1708	" " .....	1.5	6.6	91.2	.....	240		.....
1709	" " .....	1.8	9.0	90.6	.....	.....		.....
1714	" " .....	1.3	14.8	84.3	.....	.....		.....
1715	" " .....	1.3	14.1	85.5	.....	.....		.....
1723	New Glasgow, N.S.....	1.8	18.2	69.5	0.7	4,000		16.0
1728	Manitoulin island, Ont.....	0.3	36.3	63.2	0.15	1,730		4.8
1729	" " .....	0.5	33.2	66.2	0.20	1,710		8.1
1730	Northern Manitoba.....	10.1	18.7	67.6	.....	.....	Trace	
1734	British Columbia.....	1.7	13.2	82.8	0.28	.....		5.0
1735	" " .....	1.7	35.9	63.7	0.30	.....		4.0
1777	Mafekin well, Man.....	1.0	33.1	65.7	.....	890		.....
1778	New Glasgow, N.S.....	0.8	33.9	58.4	.....	.....		50.4
1779	" " .....	0.7	31.5	46.1	.....	.....		29.8
1780	" " .....	1.0	21.8	72.0	.....	.....		17.9
1781	Westville, N.S.....	0.5	31.4	62.2	.....	.....		.....
1812	Cape Breton, N.S.....	1.1	14.2	84.7	0.54	970		.....
1813	" " .....	1.0	7.7	92.2	0.37	.....		.....
1814	" " .....	0.6	13.6	85.4	0.70	.....		.....
1815	" " .....	1.1	12.8	85.7	0.65	.....		.....
1873	Ericksdale, Man.....	3.2	8.9	83.8	.....	.....	Trace	
1894	Cantamout stn., N.B.....	1.0	10.9	85.6	.....	.....		2.0
1881	Mackenzie River dist.....	.....	.....	.....	.....	.....		7.0
1920	Metagami river, Ont.....	.....	.....	.....	.....	.....		10.0
1921	" " .....	.....	.....	.....	.....	.....		10.0
1913	Gaspe peninsula, P.Q.....	.....	.....	.....	.....	.....	Trace	
1918	" " .....	.....	.....	.....	.....	.....		.....
1922	" " .....	.....	.....	.....	.....	.....		24.0

EXAMINATION OF THE OIL AND GAS

A total of 46 distillation tests were made on the oil obtained from the oil shale samples, by the method described in the earlier part of this report. Since samples from the same area gave oils, which on distillation gave quite similar results, the distillation range of every oil is not reported here. In Table II, however, is given the distillation range of fourteen different oils, the first twelve from shale of the Albert Mines, N.B., area, and No. 1895 from Pasquia hills, Saskatchewan. Figure 14 shows the curve plotted from the average of these fourteen shale oils.

The method followed in examining these oils was the same as used for standard gasoline distillations, where 100 c.c. of the sample to be examined are distilled from an Engler flask of standardized dimensions at the rate of about 5 c.c. per minute.

Table II also gives the analyses of the gases from the fourteen different oil shales and their average. Future reports on the investigation of Canadian oil shales will include more details of the properties of the shale oils obtained by various methods of extraction.

TABLE II  
Oil Distillation Ranges

Sample	1	4	7	10	16	21	28	31	36	39	42	47	201	1895	Average
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
1st drop at.....	112	100	127	140	93	114	95	119	94	107	99	107	119	79	108
10 per cent.....	168	148	157	167	153	162	146	159	146	152	157	163	172	149	157
20 ".....	200	182	178	198	210	194	175	189	183	176	201	208	210	170	192
30 ".....	235	214	202	227	242	231	222	220	223	206	238	245	243	221	226
40 ".....	262	243	223	244	279	265	252	252	268	234	278	282	266	254	255
50 ".....	286	268	245	268	309	292	275	279	300	272	308	301	292	281	282
60 ".....	309	289	262	294	334	315	304	301	317	311	337	327	315	301	305
70 ".....	331	309	273	320	353	341	327	325	357	344	358	347	339	336	329
80 ".....	348	332	293	359	374	363	363	342	386	363	382	367	357	350	353
90 ".....	382	362	324	385	389	379	366	373	400	388	394	386	378	361	376

## Gas Analyses

Sample	1	4	7	10	16	21	28	31	36	39	42	47	201	1895	Average
	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Carbon dioxide....	8.5	4.4	5.5	5.2	11.9	7.3	5.4	3.1	12.8	7.5	5.7	16.8	13.9	28.0	9.7
Ethylene.....	7.3	6.7	5.5	6.0	7.4	7.1	6.1	8.6	10.6	8.7	5.5	4.5	4.1	3.8	6.5
Oxygen.....	2.7	4.0	5.3	5.6	3.9	4.2	6.9	3.1	3.0	1.8	1.1	2.3	4.3	2.6	3.7
Carbon monoxide..	2.7	2.3	2.1	2.4	2.2	1.9	2.5	1.4	4.1	2.7	3.8	4.7	3.1	2.2	2.7
Methane.....	40.3	36.1	32.6	30.7	32.0	36.4	28.7	58.0	23.1	57.6	35.3	29.6	36.5	29.7	36.3
Hydrogen.....	29.6	25.9	30.5	29.5	18.8	17.5	20.9	14.3	22.1	8.0	37.5	38.1	20.2	8.3	22.6
Nitrogen.....	8.9	20.6	18.5	24.2	23.8	25.6	29.5	11.5	24.3	13.7	11.1	4.0	17.9	25.4	18.5
Inflammable gas..	79.9	71.0	70.7	65.0	60.4	62.9	58.2	82.3	59.9	77.0	82.1	76.9	63.9	44.0	68.1
B.Th.U. per cu. ft. (calc.).....	620	560	530	500	510	540	460	770	480	750	570	500	500	390	550



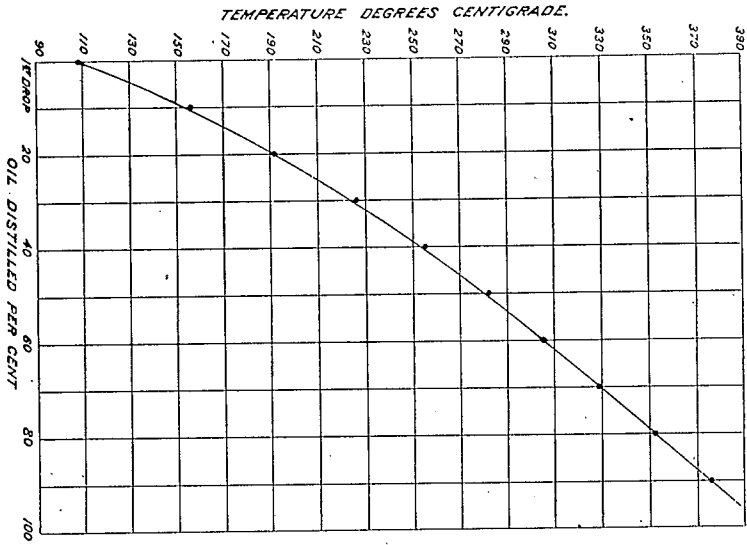


Fig. 14. Average distillation curve of shale oils from Table II.

## APPENDIX

### PRELIMINARY REPORT

(On the investigation of Peat Fuel conducted by the Joint Peat Committee for the Federal Government and the Government of the Province of Ontario, from January 1, 1921, to March 31, 1922, together with a statement of plans of the work to be done during the year 1922.)

**B. F. Haanel,**  
*Secretary to the Committee.*

*Introductory.*—The Peat Committee, shortly after their appointment early in 1918, carefully examined all existing reports and records concerning the manufacture of peat into a domestic and industrial fuel, and concluded that the air-dried machine peat process was the only economic one known to exist which gave promise of ultimate success when employed under conditions obtaining in Canada. To adapt this process to Canadian conditions the Committee found that new types of peat manufacturing machinery, capable of performing the different operations required in the course of manufacture, had to be developed. Consequently, the investigation inaugurated by them resolved itself into: first, design and construction; second, development; and third, operation of machines capable of operating under severe and adverse conditions with the employment of the minimum number of labourers and with the minimum charge for repairs and maintenance.

The preliminary reports issued by the Peat Committee from their appointment in 1918 up to and including the year 1920 dealt with the design, construction, development and operation of the two different types of peat machines—designated as plants Nos. 1 and 2—which the Committee decided offered the greatest promise of success. The investigation also included the design, construction and development of a small peat machine capable of being operated by one man and two boys, suitable for the manufacture of peat fuel—on a small scale—by individual farmers or groups of farmers, or small communities. This machine, during this period, also passed more or less successfully through the stages of design, construction and development.

As a result of the progress made up to the end of 1920, the Committee were in a position to make in their preliminary report for that year the statement: "Although it is not possible for the Peat Committee to state at this time that peat fuel can or cannot be manufactured in Canada on a commercial basis, the results of the investigation so far conducted enable them to arrive at the following conclusions:—

1. That the Anrep plant (No. 1), as it stands, is in no sense commercial.
2. That the Moore Plant (No. 2) under certain conditions can be employed commercially for the manufacture of peat fuel.
3. That the Anrep excavating element is the superior of the two and the logical one to employ, while—
4. The Moore spreading system is far more efficient and is the logical spreading system to employ."

Based on these conclusions recommendations were made for conducting the investigation through the season of 1921, and for concluding the same during the season of 1922-23. These were as follows:—

1. That a portable belt conveyer be constructed for operating in conjunction with the Anrep excavating element for the purpose of combining the best elements of the two types of machines.
2. To develop and commercially try out a small farmer's peat machine.
3. To operate the Moore plant throughout the entire working season on a strictly commercial basis, with the least number of men and without the supervision of the expert staff, in order to obtain valuable information and data concerning overhead costs, actual costs of laying fuel on the field, harvesting same and transporting to stock pile and loading into cars for shipment. Also to determine the loss in time through breakages, etc. It was also desirable that this machine be operated in order that sufficient peat fuel be manufactured to supply the market already created.

#### PREPARATIONS FOR 1921 OPERATIONS

This report is concerned chiefly with the recommendations just cited, and includes a somewhat detailed analysis of the results obtained with Plant No. 2, which was operated on a strictly commercial basis during the entire season in accordance with the above programme. This plant was not put into perfect condition inasmuch as this would have involved the redesigning and reconstructing of the caterpillar elements, an expense which the peat committee did not feel warranted in incurring, hence the results obtained are inferior to what would be expected were these known defects of the machine removed.

#### OPERATIONS DURING 1921

#### Improved Plant No. 4

On June 1 the first carload of the new conveyer parts arrived at Alfred station, and during the same month the remainder of the conveyer parts arrived at the bog. The assembling of the conveyer parts was immediately begun, and the installation of the entire plant was sufficiently far advanced on August 5 to enable the conveyer to be turned over under its own power, and on August 20 excavated peat was delivered to the belt of the portable conveyer. The time from August 20 to August 26 was spent in making adjustments in order to permit the belt conveyer, spreader and excavator to work in harmony, and on August 26 a very fair demonstration of the operations of the entire plant was made in the presence of the Peat Committee and others.

*Portable Belt Conveyer.*—The portable belt conveyer which takes the peat from the excavator and delivers it continuously to the spreader is of novel design and may even be described as a daring venture on the part of those responsible for the conception of the idea. Nothing of its kind had ever before been constructed, and although stationary belt conveyers of longer spans are in successful use, the attempt to employ a portable belt conveyer of the dimensions of this conveyer has never been made, so a great deal of credit is due to the engineer of the Peat Committee and to those responsible for the carrying out of the design and construction for

the remarkable success which was achieved almost on the very day when the conveyer was completely assembled. The conveyer is 850 feet long and is composed of ten 85 foot latticed girder sections connected together, forming a flexible bridge member which is carried on eleven caterpillar elements, all of which are operated from the main caterpillar near the excavating element. This bridge supports a rubber-covered belt which is 850 feet between centres, thus making a total length of belt of 1,700 feet. Fears were entertained that the conveyer would get seriously out of line and throw the belt off when attempts were made to move it under its own power over the field, but these fears were entirely unfounded. In order to lay on the field ten tons an hour of standard peat fuel it is necessary to move the belt conveyer every  $1\frac{1}{2}$  hour a distance of 13 feet 6 inches parallel to the line of travel of the excavating element, and this means a lateral movement of 108 feet in a working day of ten hours. The conveyer system, in fact, was put through a very severe test, a more severe test than it will ever be called upon to withstand in actual practice, and not only did it maintain its line, but, in general, its behaviour far exceeded the expectations of its designers. The spreader, which was designed and constructed for use with this conveyer system, was based upon the experience and results obtained with the spreader used on the Moore system. This spreader also had a very severe trial, and proved entirely satisfactory, with the exception of a few minor mechanical details which will be changed. The quality of the peat laid on the field by this improved plant is better than anything that has ever been obtained before at Alfred. Plate XIV shows the belt conveyer in place for operation. Plate XV shows the new spreader attached to the belt conveyer. Plate XVI is another view of the belt conveyer system and excavator, in the far distance, and shows the unloading device for delivering the peat from the belt into the hopper of the spreader. Plate XVII shows one of the caterpillar elements, of which there are eleven, and also the take-up pulley at the extreme outboard end of the conveyer. Plate XVIII shows the peat fuel which was laid on the field with this new machine. This plate shows very clearly the effect of the improved longitudinal and cross cutters. It will be seen that the peat blocks are separated by a considerable space, and that this increases the drying surface over that obtained with former methods for cutting. This improved method of longitudinal and cross cutting it is believed will greatly improve the quality and resisting properties of the peat, as well as materially reduce the time required for drying down to 25 per cent or 30 per cent moisture.

### Plant No. 2—Moore Plant

This plant was constructed from original designs prepared by Mr. Moore, which were, before the formation of the Peat Committee, submitted to the Minister of Mines of the Federal Government who decided that it should be constructed. In designing this plant Mr. Moore's objective was the reduction to as great an extent as possible of the number of labourers required to operate the plant, and his design showed a great many novel features which it was believed would realize this end. Neither this plant, nor any plant of similar design, had previously been constructed, and it therefore devolved upon the government, and later the Peat Com-

mittee, to construct and develop it into a successful machine. The advantages which were claimed for this design at the time the design was presented were:—

1. Lower cost of plant for a given output as compared with the Anrep system.
2. Reduction in number of men required to operate, namely, seven men, compared with 15 or more for the Anrep system.
3. Four boys required to perform the operation of cubing, which required not less than 12 workers with the Anrep system.
4. Number of men required for harvesting reduced by one-half.
5. Fuel not loaded on railway cars automatically left in storage piles instead of remaining spread over the drying field.
6. No delays incurred in moving tracks or bringing machine back to starting point, which delays are responsible for the loss of 25 per cent to 30 per cent of the total working time, when the Anrep system was employed.
7. Extremely direct route of the peat from the working face to the drying field will permit using much less transmission machinery, and will provide more regular feed to the macerater and, therefore, increase its output.

The government, and later the Peat Committee, after carefully considering these claims were convinced that the design possessed sufficient merit to warrant experimenting with a full sized unit, and consequently the construction of this machine was authorized at the same time as the Anrep plant.

*Erection of Plant on Bog.*—Although the contract to construct this plant was given sufficiently early in the season to insure its erection on the bog in time to give the plant a complete mechanical test during the summer of 1918, failure on the part of the contractors to meet their obligations made it impossible to begin erection until late in the fall of 1918. Consequently it was not possible to investigate the mechanical behaviour of the plant until the spring and summer of 1919.

During this year the Moore plant had a severe mechanical trial, in the course of which a certain amount of peat was manufactured. This trial disclosed many weaknesses and faults in design, which were remedied to as great an extent as possible during the winter. The following year, 1920, the Moore plant was operated for the manufacture of peat fuel throughout the entire working season. That season's investigation demonstrated to the satisfaction of the Peat Committee that the original claims enumerated above were not borne out in every particular. For example, it was found that harvesting operations could not be performed with this machine without seriously reducing its capacity for making peat fuel. But a still more serious defect was disclosed, namely, the excessively long working face which this type of machine requires for laying down a season's production of peat fuel. In order to lay down one ton of peat fuel the Moore machine must travel a linear distance of 56 feet. This not only means that the entire weight of the machine, excavating element, conveyer and spreader must be moved that distance, but also that in performing a season's work it will be necessary for the machine to travel approximately

60 miles. This is a very severe handicap for any machine, inasmuch as the wear and tear on the entire plant to perform this excessive travel would be abnormal. Moreover, the fact that a very long working face, approximately two miles in length, is required to lay down a season's production of fuel, will limit its employment to a very few bogs. Even on bogs where such a machine could be employed it would be impossible to operate economically more than one unit to advantage. Another defect should be mentioned, namely, the difficulty of keeping the machine on the line of excavation. It has been observed that in order to keep the machine on this line, and insuring that the excavator buckets remove a constant quantity of peat, a very skilful operator is required, and even then the quantity of peat excavated in a unit of time may not be constant.

*Novel feature of the Moore Machine.*—The novel feature possessed by this machine is the method employed for transporting the excavated peat from the macerater to the spreader. This is accomplished by a belt conveyer which is flexibly attached to the middle of the main platform carrying the excavator and macerater. This belt conveyer is about 180 feet long, and is formed of a box girder about 30 inches square. The inside end of this girder is attached to the main platform, the balance of the weight being supported on a caterpillar element situated approximately 100 feet out, which is operated in unison with the caterpillars on the main machine through the medium of a power shaft connected to the caterpillar driving mechanism on the main machine. The spreader is attached to this belt conveyer at any desired position and is dragged along by the main machine. When one row is completed the direction of the main peat machine is reversed and the spreader is removed to the opposite side of the girder and shifted the required distance along the conveyer. After this row is completed the main machine is again reversed and the operation repeated until the requisite number of rows representing the season's output are laid on the field.

Plate XIX shows the belt conveyer with the spreader in position near the end farthest removed from the line of excavation, and the entire plant at the end of the working face ready to be reversed. This plate also shows clearly the peat laid on the ground. Plate XX shows a close up view of the spreader in the above position, and clearly illustrates the operation of the cutting devices. It also shows the position of the spreader when the maximum number of rows are laid. The elevator at the extreme end of the girder is used to convey the dried peat to stack or small tram cars.

When the last row is completed the machine must either stop or else the first row laid down must be sufficiently dry for harvesting in order that the spreader may be placed in its original position and the operation of laying down peat again proceeded with as described. Plate XX shows also the device for unloading the peat from the conveyer belt to the hopper situated at the centre of the spreader. This hopper delivers into a box the full width of the spreader (12 feet) which is provided with a 14 inch standard spiral conveyer, one-half of which is right hand and the other left hand, both sections tapering from the full size at the centre to practically nothing at the ends. This spiral is rotated by power received from the transmission shaft, which extends the full length of the bridge work

and insures that the peat fed in the hopper will be spread in a sheet of uniform thickness. The depth of the opening for the discharge of the peat on the field may be adjusted from 3 inches to 6 inches, and this opening extends over the full length of the box. By means of this regulation the thickness of the sheet of peat laid on the bog can be varied to suit conditions.

*Drying field required for season's output.*—For an average production of 60 tons per day of ten hours, this machine must travel 3,360 lineal feet, and since a maximum of about 40 days is required for complete drying, allowing for Sundays, it is necessary to provide a drying field which will permit the laying out of approximately 120,000 feet of spreader section, that is 120,000 feet by 12 feet (the width of the spreader) times the depth of the peat spread. The belt conveyer is of sufficient length to provide for the laying down of 12 rows. The drying field for ten hours per day operation should, therefore, be 10,000 feet long in order to insure the complete drying of an average production of 60 tons of fuel per day. This is one of the chief drawbacks of the Moore plant. The working face provided for this machine at Alfred was 8,000 feet long, but this did not permit of the complete drying of the fuel and at the same time the production of the quantity of peat fuel for which the machine was designed.

*Harvesting.*—When the machine was developed on paper it was considered possible to employ the above conveyer for harvesting the dried peat at the same time that the peat slop was being laid on the field, but this operation it was found could not be efficiently performed without further experimentation. In short, all attempts to employ the conveyer for harvesting the dried peat fuel resulted in a decrease in the quantity of peat produced. Other methods of harvesting were consequently resorted to.

*Difficulties encountered and improvements made.*—The most serious difficulties encountered in connection with the operation of the Moore plant were occasioned by the caterpillar elements. When these were designed the engineer had very little data to guide him, since no machine capable of performing the operations required of a peat machine had ever before been designed for travelling over a spongy surface on caterpillar elements, consequently, serious defects were observed almost immediately in the design of the caterpillars and the mechanism driving them, and also in the method employed for steering the machine. Consequently, most of the time and money which has been spent on alterations and improvements to this machine were expended on the caterpillar elements. As a matter of fact the caterpillar difficulties have not yet been eliminated. They could easily be improved, but it was not considered necessary to rebuild the caterpillars for the purpose of completing the investigation of this machine, since it was decided, at the close of 1921, to cease operating the Moore plant.

Minor difficulties were also encountered in the excavating element, and in other portions of the plant, but these were or could be eliminated without much trouble.

#### CONCLUSIONS ARRIVED AT AT THE END OF THE SEASON OF 1920

At the conclusion of the field operations at the beginning of the fall of 1920 a large amount of data was available for comparing the relative merits of the Moore and Anrep plants.

1. It was clearly demonstrated that the Moore plant showed a marked economy in labour over the Anrep plant, but that in spite of this economy the Moore plant could not compete with the Anrep plant, provided the Anrep plant were equipped with an improved delivery and spreading system.
2. It also appeared from the observations made during the operation of the Moore plant that the maximum length of the bridge work which can be supported by a single caterpillar had been practically reached and that any extension of this bridge work would make the machine altogether too cumbersome. Twelve rows of peat, therefore, appears to be the maximum number of rows which can be spread with a machine of the Moore type. As stated before, a linear travel of 56 feet is required in order to lay down one ton of standard peat fuel, and a working face 10,000 feet long for a ten hour shift and 20,000 feet long for two ten hour shifts. If it were possible to lengthen the belt conveyer bridge work to accommodate double the number of rows of peat laid, that is to say, the laying of 24 rows instead of 12, the length of the working face would be cut in two. This would remove certain of the difficulties under which the plant labours, but, as stated, it does not appear that the length of the belt conveyer can be sufficiently increased without making the entire plant too cumbersome and unwieldy.
3. The advantage which it was also expected the Moore plant would have over the Anrep plant in harvesting did not materialize. This was due to two causes: (a) When harvesting operations were being carried on as originally intended a stoppage anywhere along the line from the excavator to dumping into storage meant a stoppage of the entire equipment. (b) Variations in the weather could not be provided for, that is, an exceptionally dry spell would permit the drying of the fuel to proceed too far before the fuel could be harvested, and if the weather were abnormally wet there was the further danger of the whole plant being stopped or held up waiting for the fuel on the ground to dry. On account of these two difficulties it was decided that it would be more efficient to harvest the production of the Moore plant with the harvesting equipment employed with the Anrep plant—even though this equipment was not designed for operation in connection with the former—than to attempt to harvest with the machine itself as was originally intended.
4. The quality of the fuel manufactured during the early part of the season compared unfavourably with that produced by that of the Anrep plant. This was in part due to the inferior quality of peat in that portion of the bog where the Moore plant operated, but it was also partially due to the fact that the long working face over which the machine takes only one complete cut before a complete row is laid down, is likely to freeze to a considerable depth in a cold winter, and that the first rows which are made from the peat excavated from a frozen face would produce peat of an inferior quality. In the case of the Anrep plant the excavation is made over a very short working



face, consequently, it is possible to dig away the frozen face before the operation of making peat is begun. A certain quantity of peat manufactured with the Moore plant during the season of 1920 was of inferior quality due to this cause.

5. In order to carry out in the most economical manner the various operations in the manufacture of peat fuel, according to the air-dried machine-peat process, it is necessary that the plant and machinery employed be as simple as possible, since it is not feasible to have skilled workmen on hand to operate a plant which may be situated at some not easily accessible point, and which, moreover, can operate for only a part of the year. Any peat plant, therefore, which requires for its operation skilled labour suffers a severe handicap. The Moore plant to a certain extent is under this handicap, since to operate it to the best advantage more skilful and more careful operation is required than with the Anrep plant. Moreover, the uniformity and quality of the fuel laid down by the former depends to a large degree on the care exercised by the operator. This applies to a certain extent also to the Anrep plant, but its operator has a much better control over his machine and does not therefore require to exercise the same degree of skill.

On account of the above defects, which were observed in the operation of the Moore plant and the defects which were noticed in the spreading system employed with the Anrep plant, the Peat Committee decided to recommend that the best features of both plants be incorporated into a combination plant. The following table gives the principal data obtained during the operation of the Moore plant during 1919, 1920, and 1921.

TABLE I

	1919	1920	1921
Total length of working season exclusive of Sundays.....		105 days	107 days
Total days actual operation.....		(a) 41 days	62.3 days
Unavoidable lost time.....		18.4 days	12.4 days
Percentage of season.....		17.5 p.c.	16.6 p.c.
Avoidable lost time.....		45.6 days	32.3 days
Percentage of season lost through delays which might have been eliminated.....		43.4 p.c.	30.1 p.c.
Distance travelled, about.....	45,000 ft.	149,250 ft.	242,250 ft.
Fuel laid down.....	(b) 500-600 tons	(c) 2,665 tons	(d) 3,889.5 tons
Fuel laid down per hour average.....		3.4 tons	5.2 tons
Total labour cost to operate plant.....	\$1,023.82	(e) \$4,603.33	\$3,380.27
Total labour cost for repairs.....		\$1,138.50	\$700.77
Labour cost to lay out, per ton.....		(f) 1 75	0.869
Cost of cubing per ton.....		(g)	0 20
Total labour cost ready to harvest.....			1.07
Total labour cost if troubles eliminated.....			0.807
Maximum day production.....		53.6	70 tons

(a) Does not include 180 hours night work which is included to arrive at average production per hour in 1920.

(b) This distance travelled should have produced 800 tons but no fuel was made during the first three or four cuts when working face was being opened up.

- (c) It is estimated that 2,935 tons of fuel were made by No. 2 in 1920 on a basis of 50 lineal feet of row laid out per ton, and harvesting records would seem to confirm this figure, but 1921 records show it requires 56 lineal feet of row to produce one ton of 30 per cent moisture fuel, and this figure has been used so as to make a fair comparison with 1921. The apparent greater production in 1920 is accounted for by the fact that the fuel harvested was not dried down to 30 per cent moisture content.
- About 1,600 tons of fuel made by No. 2 in 1920 sold for \$4 per ton.  
 About 200 tons of fuel made by No. 2 in 1920 was used for fuel.  
 About 365 tons of fuel made by No. 2 in 1920 was not dry enough to harvest.
- (d) Estimates of fuel made in 1921 on basis of 56 lineal feet of movement of spreader check very closely with actual weights.
- |   |              |
|---|--------------|
| Total fuel weighed into storage.....                        | 3,194.5 tons |
| Total fuel used for fuel.....                               | 221.0 "      |
| Total fuel wasted on field in harvesting.....               | 116.0 "      |
| Total fuel left on field not dry.....                       | 358.0 "      |
|   | 3,889.5 tons |
| Known loss in production through this spreading, about..... | 450.0 "      |
|   | 4,330.5 tons |
- Theoretical production for 242,250 feet at 56 feet per ton..... 4,326.0
- (e) This figure includes \$735 cost of night shift and \$700 paid to two additional men over regular shifts who were necessary to look after suction hose through which water was drawn to the boiler. For a fair comparison with 1921 this latter figure should be subtracted from the total, making cost per ton.
- (f) .....\$1.47.
- (g) Cost of turning and cubing in 1920 for the first part of the season was done by day labour. A great deal of work was done on old frozen peat in an attempt to save it, and the total cost for turning and cubing in 1920 is abnormally high and any figure given would be misleading. In the latter part of the season cubing was done by contract for 20 cents per ton.

TABLE II  
 Summary Trouble Sheet Plant No. 2, 1921

Cause	Unavoidable		To be expected		Due to known defects which could have been eliminated	
	hrs.	mins.	hrs.	mins.	hrs.	mins.
1. Weather.....	26	45				
2. Turning.....	..	..	..	..	11	55
3. Cross ditches.....	..	..	..	..	3	15
4. Oiling.....	..	..	..	..	7	20
5. Move from field to field.....	..	..	..	..	20	40
6. Engine.....	..	..	4	0	4	35
7. Excavator element.....	..	..	10	0	14	45
8. Roots in excavator.....	..	..	1	45	..	..
9. Chains.....	..	..	8	0	52	17
10. Belt.....	..	..	1	10	..	..
11. Spreader.....	..	..	12	0	39	35
12. Cross cutter.....	..	..	4	5	..	..
13. Ties.....	..	..	..	10	..	..
14. Sprockets.....	..	..	8	20	..	..
15. Clutches.....	..	..	4	0	8	5
16. Gears.....	..	..	1	0	..	..
17. Late starting.....	..	..	..	..	0	50
18. No steam.....	..	..	..	..	10	30
19. No water.....	..	..	..	..	14	33
20. No fuel.....	..	..	..	..	..	40
21. Roots in macerater.....	..	..	15	0	22	15
22. Iron in macerater.....	..	..	10	0	31	45
23. Variable speed.....	..	..	13	..	13	10
24. Loader.....	..	..	..	..	25	0
25. Stackers.....	..	..	..	..	0	45
26. Harvesting.....	..	..	..	..	3	40
27. Repairs.....	..	..	18	20	36	45
	26	45	97	50	322	20
	2.675 days		9.78 days		32.23 days	

During 1919 this plant was given a mechanical test and only a small quantity of fuel was manufactured in the course of experimentation. In 1920 an effort was made to operate the plant during a full working season. The total length of the working season, exclusive of Sundays, was 105 days, and the total days during which the machine was actually operated was 41. It will be noted that the total days of actual operation during 1921 were greatly increased and that the unavoidable lost time was reduced from 18.4 days in 1920 to 12.4 days in 1921, which corresponds to 17.5 per cent and 11.6 per cent respectively of the entire working season. The avoidable lost time during 1921 was notably decreased under that of 1920, namely, from 30.1 per cent to 43.4 per cent. A very large increase will be noted in the lineal distance travelled by the plant in 1921 as compared with that travelled in 1920, and the average fuel laid down per hour in 1921 is notably higher than that laid down in 1920, namely, 5.2 tons, which is about 8/10ths of a ton from the maximum which was expected. It would appear, therefore, from the results of these three seasons that this plant could be brought to a high degree of efficiency, and that most of the mechanical troubles experienced could be entirely eliminated, which would make it possible to lay on the field the requisite quantity of fuel during an entire working season, provided a 10,000 foot working face was available. It is necessary at this point to direct attention to the fact that no attempt was made to put the machine in perfect condition for operation during the season of 1921, since to do so would involve a large expenditure of money which the Committee could not recommend. This machine, therefore, began operations under a severe handicap, which was in no sense decreased as the season advanced.

Regarding the total labour costs to operate the plant in 1921 as compared with 1920, it will be noted that for a greater production of fuel the labour cost is one-third less and that the cost for repairs is also in the vicinity of one-third less than in 1920, but the decrease in labour cost is more noticeable in the costs calculated per ton of fuel laid down, namely, in 1921 \$.869 while in 1920 it was \$1.75. This shows a reduction of approximately 50 per cent. If the troubles above mentioned were eliminated the labour costs for laying down a ton of fuel would be reduced to practically 81c. In 1921 the maximum daily production realized was 70 tons, while that of 1920 was 53.6 tons. The total quantity of fuel manufactured during 1921 was 3,889 net tons of 2,000 lbs., 450 tons were lost through spreading; the total production was consequently 4,439 tons. This checks very closely with the theoretical quantity which should have been produced for a lineal travel of 242,250 feet, namely, 4,326 tons. Table No. II gives a summary of the troubles experienced with the machine during the season of 1921, the time lost and the reasons therefor.

### Costs

While this investigation is being conducted for the purpose of developing machinery capable of performing all the operations required to convert the raw peat substance of a bog into a marketable fuel with the greatest degree of efficiency, such efforts would result in nothing but waste in time and money were the cost of the fuel so produced too great to permit competition with other classes of available fuel now on the market.

The main objective has, therefore, been to develop machinery which can not only perform the various mechanical operations in the most efficient manner possible, but also produce a fuel at an economic cost. This has not proven to be a simple problem. The removal of one difficulty which barred the road to success often introduced another equally or more serious, and, as often happens in the development and refining of processes and their application commercially, the Peat Committee were confronted with the fact that the refining of mechanical appliances can be carried to a point where the saving resulting from the higher efficiency of labour-saving devices is more than offset by the increased cost. Consequently, the problem with which this investigation is chiefly concerned, resolved itself into the co-ordination of manual labour and mechanical labour-saving devices so that the human element and the mechanical element would be properly balanced.

In order to produce a low grade fuel like peat from a very low grade substance such as raw peat, which contains about 90 per cent water and only 10 per cent combustible matter and ash by weight, with machinery capable of performing the various operations, to a large degree, automatically, the output of finished fuel per unit of time must be as large as possible. This implies a large and powerful manufacturing unit which in itself introduces a serious difficulty, viz.: overhead costs.

Plant No. 2 was complete with labour-saving devices which partially defeated the very object for their introduction, and its elimination as a machine for manufacturing peat fuel on a commercial scale generally was partly due to their defects. A detailed estimate of the total cost of one ton of standard peat fuel as manufactured by this machine as it stands would consequently be of little or no value. In the light of the experience gained during two complete seasons operations, a new machine of the Moore type could be built at a much lower cost than was possible with the original machine, and, moreover, the new machine would have incorporated into its design improvements which would correct many of the defects of the former, and would as a result be far more efficient and under special conditions even prove a commercial success.

With the results and records of operation now at the disposal of the Committee it is possible to roughly estimate the cost of producing standard peat fuel with plant No. 2—redesigned and rebuilt. However, it must be understood that these costs are subject to revision in the final report, when detailed estimates of the costs of a complete plant will be obtained.

The estimated cost of making fuel with the Peat Committee Plant No. 2 is based on these conditions:—

1. Plant rebuilt in light of all knowledge gained.
2. Plant is electric motor driven.
3. 10,000 feet working face available.
4. Minimum wages 35c. per hour.
5. 100 days minimum working season.
6. 10 hour shift.

And that the capacity of the machine when redesigned and rebuilt will reach an average of 60 tons of standard peat fuel per day for 100 days. There is no reason to doubt that this, and even a greater production would under these circumstances be realized. For convenience the details of the estimates are placed under the following headings:—

- A. Capacity of machine.  
 B. Cost if operated by electric motors—power supplied from stationary steam generating plant.  
 C. Costs if plant is driven by self-contained steam plant.  
 D. Costs if plant is driven by semi-Deisel engine.

The subject matter under these heads is sufficiently clear to require no further explanation

*A. Capacity of Machine:—*

Plant No. 2 moved 242,250 feet in 1921 in 62.3 days elapsed time, of which 4 days were spent in shifting to new position.  
 Therefore Plant No. 2 moved 242,250 feet in 1921 in 58.3 days actual travel, or 415.5 feet per hour. But observed speed of travel of machine was over 8 feet per minute, or 480 feet per hour.  
 Therefore Plant No. 2 lost 7.75 days during 1921 operation not recorded in trouble sheet. Of this the greatest part was due to holding back when using its own harvester, and from travel records it is estimated this amounted to 4-5 days and the balance, say 3.75 days, was lost due to short delays which were unrecorded.  
 There is no reason why an improved No. 2 plant should not sustain a rate of travel of 8 feet per minute when in motion, equal to 480 feet per hour, equivalent to production of 8.5 tons of fuel per hour.

Known unavoidable delays.....	=11.6 p.c.	
Unrecorded delays.....	= 3.6 "	
Delays due to shifting machine to new position on the field (on 10,000 ft. face).....	1.8 "	
<b>Total delays.....</b>	<b>17 "</b>	
Therefore		
Capacity of plant should be 83 p.c. of 8.6 tons.....		7.0 tons per hour
or per 100 days.....		7,000 tons
Deduct for fuel.....	400 tons	
left on ground 3 p.c.....	210 "	
waste at loading 5 p.c.....	350 "	
Say.....		1,000 tons
Net amount available on cars.....		<u>6,000 "</u>

*B. Cost if operated by electric motors—power being supplied from stationary steam generating plant.*

*1. Production Cost: Items which vary as the number of tons manufactured:—*

Cost of raw materials on royalty basis per ton.....	0.05
Operation—	
Runner per day.....	5.00
Man in excavator.....	3.50
Spreader.....	3.50
Spare man.....	5.00
Electrician and mechanic.....	7.50
Fireman.....	4.00
Water boy and messenger.....	1.50
<b>Total per day.....</b>	<b>30.00</b>

Allowing 25 days to open up and close down for winter, 125 days at \$30 per day—Total labour cost \$3,750, or per ton.....	0.625
Supplies, oil, etc.....	0.015
Turning by contract.....	0.15
Harvesting to storage or railway cars.....	0.60
<b>Total production cost.....</b>	<b>1.44</b>

## 2. Overhead:—

Estimated capital investment—	
No. 2 machine complete with motor drive.....	\$10,000 00
Harvester for same.....	1,200 00
16 lb. track 12,000 ft.....	5,000 00
12 lb. track 2,000 ft.....	600 00
Harvester cars 12.....	1,500 00
Locomotive.....	1,500 00
Storage and loading equipment.....	3,000 00
Railway siding.....	1,500 00
Office, machine shop, power house and transmission....	15,000 00
<b>Total capital layout.....</b>	<b>\$39,300 00</b>
Add for under estimate and emergencies 10 p.c.....	3,930 00
<b>Total, say.....</b>	<b>\$45,000 00</b>
<b>Total production cost.....</b>	<b>1.44</b>
For capital charge write off for all purposes—	
20 p.c. of \$45,000.00.....	\$ 9,000 00
or per ton for 10 hour shift.....	1.50
for 16 hour shift.....	0.95
for 20 hour shift.....	0.75
For executive overhead charge—	
Manager for year.....	\$2,400 00
Clerk 8 mos. at \$75.....	600 00
Office expenses.....	600 00
<b>Total.....</b>	<b>3,600 00</b>
Or per ton on 10 hr. shift.....	0.60
16 hr. shift.....	0.37½
20 hr. shift.....	0.30
Add to re-handle from storage to cars.....	0.35
<b>Total cost for 10 hr. shift.....</b>	<b>3.89</b>
16 hr. shift.....	3.11
20 hr. shift.....	2.84

## C. Similar Costs, if plant driven by self-contained steam plant:—

Raw material.....	0.05
Production cost—	
Fireman.....	4 00
Engineer.....	7 50
Runner.....	4 00
Man in excavator.....	3 50
Man to get fuel.....	3 50
Man on spreader.....	3 50
Spare man.....	5 00
Mechanic helper.....	3 50
Water boy.....	1 50
<b>Total.....</b>	<b>36 00</b>

Or for 125 days—\$4,500.00 per ton.....	0-75
Add supplies.....	0-015
Turning.....	0-15
For mechanic if manager and mechanic not same man.....	0-10
Harvesting.....	0-60
<b>Total production cost.....</b>	<b>1-665</b>
<b>Overhead—</b>	
No. 2 machine complete with steam power.....	\$15,000 00
Harvester 1.....	1,200 00
Track 16 lb.....	5,000 00
Track 12 lb.....	600 00
Cars.....	1,500 00
Locomotive.....	1,500 00
Storage and loading equipment.....	3,000 00
Siding.....	1,500 00
Office and machine shop.....	2,500 00
<b>Total.....</b>	<b>31,800 00</b>
Plus 10 p.c.....	3,180 00
<b>Say.....</b>	<b>35,000 00</b>
Or for 10 hours—overhead charges per ton.....	1-17
Executive overhead charge same.....	0-60
Re-handle charge same.....	0-35
<b>Total.....</b>	<b>3 79</b>

*D. Similar Cost, if driven by semi-Deisel engine:—*

Raw material.....	0-05
<b>Production cost—</b>	
Engineer.....	\$7 50
Runner.....	4 00
Man in excavator.....	3 50
Man on spreader.....	3 50
Spare man.....	5 00
Mechanic.....	6 00
Mechanic helper.....	3 50
Water boy.....	1 50
<b>Total.....</b>	<b>\$34 50</b>
Or for 125 days—\$4,312.50 per ton for 6,400.....	0-68
Supplies.....	0-025
Turning.....	0-15
Harvesting.....	0-60
<b>Total production.....</b>	<b>1-505</b>
<b>Overhead—</b>	
Total capital investment not greater than for steam	
Or annual charge of \$7,000 for 6,400 tons or per ton.....	1-10
Total executive charge same as for steam or annual charge of	
\$3,600 for 6,400 tons or per ton.....	0-56
Re-handling charge.....	0-35
Oil fuel 1 gal per H.P. at 11c.—per ton.....	0-11
<b>Total.....</b>	<b>3-62½</b>
<b>Summary—</b>	
Separate steam driven power plant.....	3-89
Self contained steam driven power plant.....	3-79
Self contained crude oil engine.....	3-62½

FARMER'S PLANT

Plant No. 3 is in design a miniature Moore-Anrep combination plant. The method of supporting the excavating and macerating element is based on the principle employed with the Anrep system, while the delivery and spreader system employs the principles so successfully demonstrated

in the Moore plant; but in order to combine the features of these two plants on a small and economical scale new problems arose which had to be solved. In the course of its development many discouragements were experienced, and it appeared at one time as if the entire design would have to be changed; but an alteration to the excavating macerating element, and a rebalancing of the other parts of the machine, together with the installation of a more powerful motor eradicated many of the worst difficulties, and a few further changes put the machine into such condition that the Committee see no reason why it cannot be successfully operated during the coming season.

Like the larger machines, this small peat plant must also provide means to excavate, macerate and spread the pulped peat on the ground. In order to carry out these operations in the most simple and economical manner an effort was made to design an element which would combine, in one, the operations of excavating and macerating.

As the machine now stands it is expected that its average hourly capacity will be between 1 and 2 tons of standard peat fuel. This will amount to 10 to 20 tons during a working day of 10 hours. The machine is very simple to operate and can be easily handled by one man and two boys.

#### MACERATING

The degree to which maceration can be economically conducted has an exceedingly important bearing on the quality of the fuel produced. It is therefore essential that every effort be made in attempting the manufacture of peat fuel according to the wet process to obtain the highest degree of maceration consistent with economy. The results which have been obtained during the past three years have led the Peat Committee to conclude that the Anrep macerater as at present constructed is not entirely satisfactory for operation where a high rate of production is required, since it has been their experience that a large amount of the time which has been lost during a limited season of 100 days during which it is possible to manufacture peat fuel, has been due to stoppages of the plant through choking or breaking of the macerater with roots and pieces of iron, which now and again find their way into it. To avoid loss of time through such stoppages, the Committee made arrangements with the Jeffrey Manufacturing Company, of Montreal, to experiment with a swing hammer shredder which they were led to believe might prove successful for macerating peat. This shredder arrived at the plant too late for experimentation, but a few minutes demonstration run, which it was possible to carry out, showed that the maceration obtained with this machine was far superior to that possible with the Anrep macerater. This shredder will be tried early in the spring of 1922, and if it is found unsatisfactory, two Anrep maceraters placed in parallel will be employed. Arrangements for installing them are now under way. This will make it possible to obtain the maximum production of peat fuel during an entire working day, and will avoid stoppages, since it is not probable that both maceraters will be choked up at the same time. Moreover, while one is being cleaned the other can be overloaded for a short time, thus insuring the delivery of a more or less continuous supply of peat to the belt conveyer.



## LOSS OF PEAT FUEL THROUGH FIRE

On November 8 fire was discovered in the stock pile of fuel which contained a portion of this season's production, a quantity of fuel manufactured last season, and several hundred tons of broken frozen peat and fines. The fines were stored in this pile preparatory for shipment as a fertilizer filler and soil conditioner. The portion of the stock pile where steam and smoke were seen to issue was immediately opened up and efforts made to quench the incandescent fuel thus exposed. Towards the evening of this day it appeared to those in charge that the fire had been put out, or at least got under control, since smoke ceased to issue from any part of the pile. But a rising wind soon revived the fire, which broke out in other parts of the pile, and though strenuous efforts were made to locate the seat of the fire, this proved impossible, since it spread with great rapidity when it reached the good peat fuel, where an abundant supply of air was available. The meagre and inadequate equipment available which could be used for fighting a fire proved of little avail, and efforts to cut the pile in two, in an attempt to separate the burning peat from the good peat fuel, failed owing to a change in the direction of the wind, which blew the poisonous gases resulting from incomplete combustion on to the workers and necessitated their hasty withdrawal. Consequently it was possible to salvage only a very small quantity of fuel.

Prior to November 8 the superintendent of operations and the engineer of the Peat Committee, who examined the stock pile on many occasions, had no reason whatever to suspect that the peat was on fire, and moreover, the great rapidity with which it developed appears to indicate that it was of very recent origin.

A thorough investigation failed to reveal the cause. It may have been due to carelessness on the part of a labourer, or to a spark from a locomotive, which, lodging in the fines, was covered by freshly dumped cars and slowly ignited the fines at a considerable depth. But the theory that the fire was the result of spontaneous combustion can be given little credence since there is no record of a peat fire originating in this way in European countries, where it is the practice to store great quantities of peat in this manner.

Hereafter the peat will be stored in separate piles. This will permit a fire to be attacked more efficiently—should a fire ever occur again—and at the same time insure the minimum loss, inasmuch as a fire in one pile would be confined to that pile.

However unfortunate such a loss may be, no blame, in light of the evidence obtained, can be attached to any member of the staff responsible for the conducting the investigation at Alfred.

The stock pile before burning was over 22 feet high, from 30 feet to 40 feet in width at the top, and about 100 feet in width at the bottom. These dimensions will give some idea of the difficulties encountered in the attempt which was made to cut the pile in two.

It is estimated that the loss by fire was:—

Quality		Quantity	Estimated value
1921	Good peat fuel.....	1,780 tons	\$8,500
1920	Poor disintegrated fuel.....	600 "	1,800
	Screenings.....	100 "	300
	Damage to trestle.....		400
			\$11,000

## SALE OF FUEL MANUFACTURED

The Peat Committee has met with considerable difficulty in disposing to the best advantage of the fuel manufactured. This has been occasioned partly by the nature of the work which the Peat Committee is conducting, namely, an investigation which is concerned more with the development of the machinery for manufacturing peat fuel than with the product. Consequently, the quality of the fuel placed on the market has not in certain instances been of the best. In order to dispose of the fuel made during a season in the most economical manner it has been found impossible to avoid shipping a certain portion of inferior fuel with the good fuel, and a small quantity of the former has therefore found its way into households and has given rise to a certain amount of dissatisfaction. While it is necessary to call attention to this fact it is gratifying to know that the complaints of inferior fuel have been exceedingly few, and that by far the major portion of the fuel sold since the inauguration of the Peat Committee's investigation, so far as the Committee could ascertain, has given complete satisfaction.

The operation of two experimental machines with the consequent laying out of fuel on two sections of a bog widely separated, made it impracticable to install harvesting and loading apparatus which would enable these operations to be carried out in the most economical manner. The installation of the proper facilities for efficiently harvesting and handling the fuel manufactured would have involved a comparatively large capital expenditure, which the Peat Committee did not feel warranted in incurring, on account of the temporary character of the work they are conducting. Harvesting operations will be discussed under a separate heading.

The policy of the Peat Committee is to dispose of the fuel manufactured to householders, in order to introduce this fuel for domestic purposes. A considerable portion, however, was sold for heating office buildings, and to a certain extent the government buildings of Ottawa, but care was taken not to permit the fuel, in wholesale lots, to get into private hands.

The selling of the fuel in Ottawa and Ottawa district was put in the hands of a selling agent, who undertook to dispose of the entire output. The agreement which the Peat Committee made with him called for the production of 4,000 tons, but this agreement was broken by both the sales agent and the Peat Committee; first, by the former in not accepting delivery of peat as required, and later in the season by the Committee owing to the fire which destroyed a large portion of the season's output. The selling and distribution of peat fuel presents certain problems which must be worked out independently. They are, however, all practical problems which can be handled more satisfactorily by business men. Peat sales for 1921 were as follows:—

Raw peat sold in cars.....	1,160 tons at \$5.00	\$5,800 00	
Locally.....	125 "	5.00	625 00
Old peat sold in cars.....	18 "	2.50	} 300 00
	85 "	3.00	
Screenings sold in cars.....	113 "	3.00	339 00
Peat on hand saved from fire and sold for future delivery, estimated.....	50 "	3.75	187 50
Approximate total sales.....		\$ 7,251 50	
Less contract in connection with sales in Ottawa and			
	Hull, estimated.....	\$460 00	
	Joliette Steel Company.....	248 75	
	Car screenings to fuel testing station.....	71 16	
		<u>\$759 91</u>	<u>759 91</u>
			<u>\$8,491 59</u>

## HARVESTING

The harvesting of the finished peat fuel, which comprises the operations of taking the fuel off the ground, loading onto small tram cars, transporting these to loading trestle, and unloading small cars onto storage pile or into freight cars for shipment, has presented many problems, certain of which must be worked out independently. Prior to the war these operations have been largely performed by hand labour, but during and since the war labour conditions have changed very materially, as regards wages, and in order to carry out these operations in the most efficient and economical manner, manual labour must be replaced to the largest extent by mechanical devices. When the Peat Committee undertook this investigation they were of the opinion that the harvesting of a season's production of fuel would not present any problems of an unusual nature and that the ordinary methods could be employed without increasing unduly the cost of the fuel. As the investigation proceeded, however, it has been discovered that harvesting constitutes one of the most important problems, second only to the manufacture of the fuel itself, and that if this operation is not conducted in the most economical manner possible, the economies realized from the development of peat fuel manufacturing machinery will be more than offset by the cost of the former.

As time permitted close attention was given to the problems presented in harvesting, and automatic devices were designed, constructed and tried for performing certain operations heretofore performed by manual labour. While considerable progress has been made in this direction, the problem is by no means entirely solved and economies in advance of those so far obtained may be expected. Harvesting a season's production of the No. 4 plant—the combined Moore-Anrep plants—can be performed at a less cost than was the case with plant No. 2, but with the latter plant little attention was paid to this particular problem, when it was realized that harvesting could not be performed economically by the machine itself. If plant No. 2 had proved satisfactory for commercial operations, generally, instead of for special isolated cases, attention would have been paid to the problem of harvesting a season's production of fuel laid down with that machine.

The peat investigation was undertaken at a time when the cost of raw materials entering into the construction of peat machines and general equipment required for the peat manufacturing plant were inordinately

high. At this time also labour wages reached the highest level. To-day these conditions have materially changed. Peat manufacturing machinery and other equipment required can be purchased for practically 50 per cent of war prices, and labour wages have also dropped materially. The figures of cost which have been prepared for this report are consequently based on higher labour wages than it is expected will obtain during the season of 1922-23.

#### METEOROLOGICAL OBSERVATIONS WITH REFERENCE TO DRYING

Meteorological observations, including precipitation, temperature, and barometric pressure, have been made during the season of 1920 and 1921. A full record of these observations, as well as a complete report on the drying of peat fuel as observed at Alfred will be included in the final complete report. It will suffice to say here that the observations covering the last two seasons have shown that the maximum period during which peat fuel can be manufactured—that is, laid on the ground and dried sufficiently for shipment—is 100 working days.

It has been ascertained that peat manufacturing operations can begin as early as May 1, and continued up to August 25.

#### OUTLINE OF INVESTIGATION 1922-1923

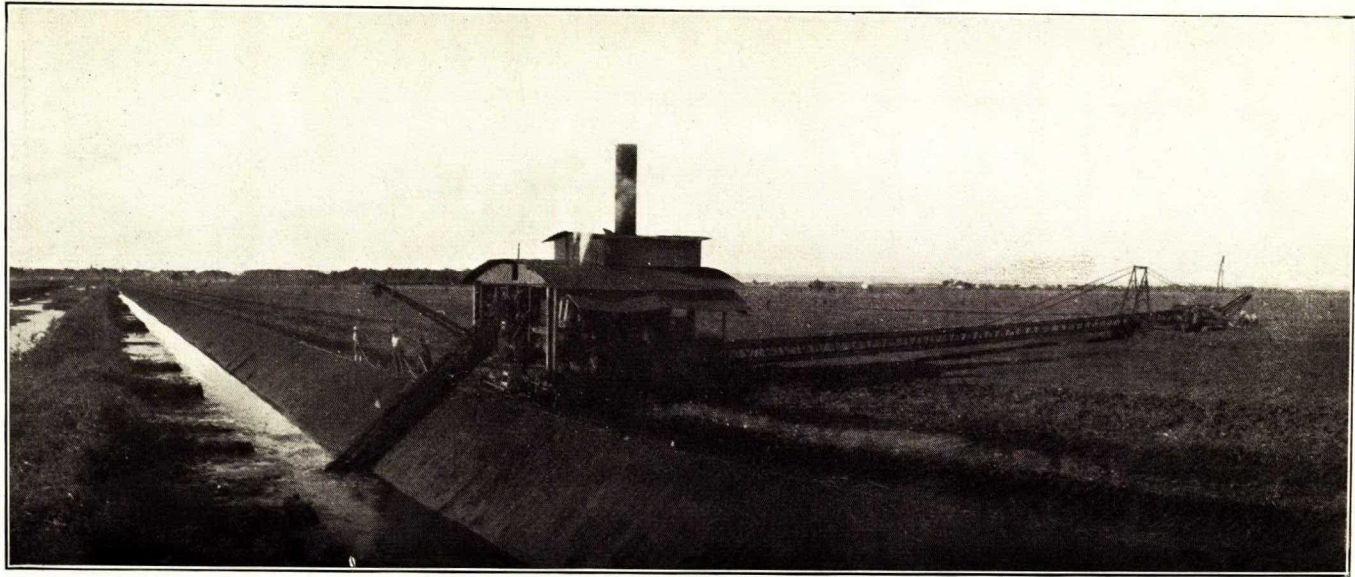
In accordance with the programme submitted in the spring of 1921, the investigation for 1922 will be confined to the operation of the new combination plant and the small plant No. 3 on a commercial scale, the former through an entire working season, and the latter for a sufficient period to demonstrate its value for the work it was designed to perform. The Jeffrey swing hammer shredder, which was shipped to the bog last fall too late for experimentation will be thoroughly tested early this spring, and if the results are satisfactory it will be employed during the working season for macerating the peat excavated by the combination plant. It is not expected that any new equipment will be purchased, nor will any construction be undertaken with the exception of that involved in the replacing of the loading and storage facilities, which were destroyed by fire. Additional machinery which may be required to carry to completion the investigation will, if possible, be rented instead of purchased. Arrangements have already been made to rent at a nominal cost an engine for operating the Hammermill shredder in case it is satisfactory, or the two Anrep macerators in parallel. This engine, if purchased, would have cost the Committee considerably over \$2,000, while on the rental basis it will involve an expenditure of approximately \$400 to \$500.

Just as soon as the snow is off the ground the new combination plant will be put into condition for beginning commercial operation about May 1. Plant No. 2 will be dismantled, with the exception of the boiler and propelling engine, which it is proposed to employ for supplying the extra power required to operate the new plant.

The harvesting equipment has already been overhauled so that this is in order for the coming season's work. In order to render the combination plant commercial in every respect an hourly average production of ten tons of saleable peat fuel must be maintained throughout a working season of 100 days. There is no reason to believe, however, that this

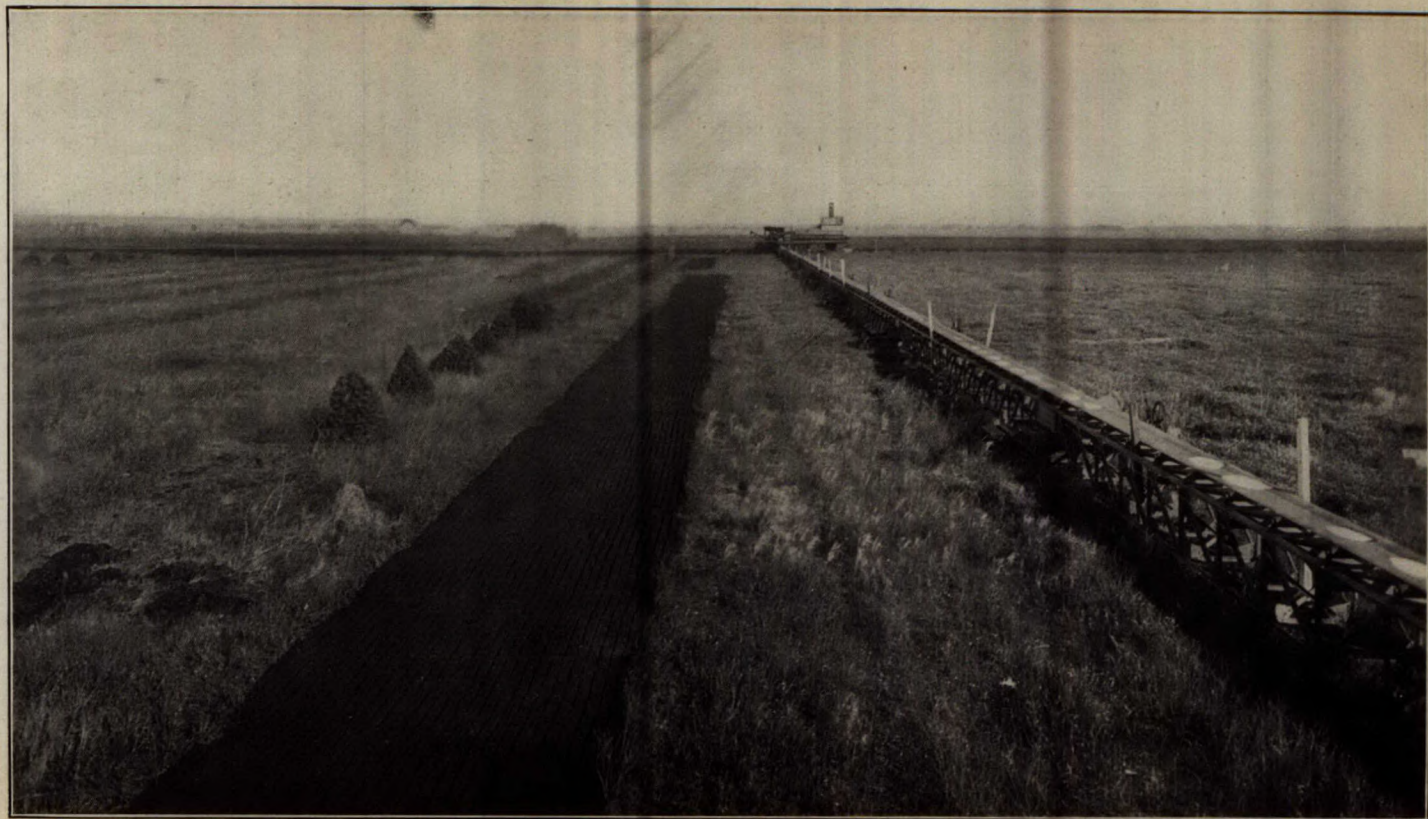
production will not be realized. An hourly production of ten tons of saleable peat fuel for ten hours a day and for a working season of 100 days means laying on the field a greater quantity than 10,000 tons of finished peat fuel. To accomplish this a longer working face will be required than was necessary for the Anrep plant as it was originally operated, and to provide the additional working face it is planned to operate on both sides of the main excavation according to the accompanying plan. This shows two drying fields, Nos. 1 and 2. It also shows the semi-permanent tracks which will be laid for harvesting purposes, and the permanent tracks at both ends of the field for shifting the belt conveyer from No. 1 drying field to No. 2.

At the conclusion of the working season in 1922 the preparation of the final report of the operations of the Peat Committee since the inauguration of the investigation in 1918 will be immediately begun.



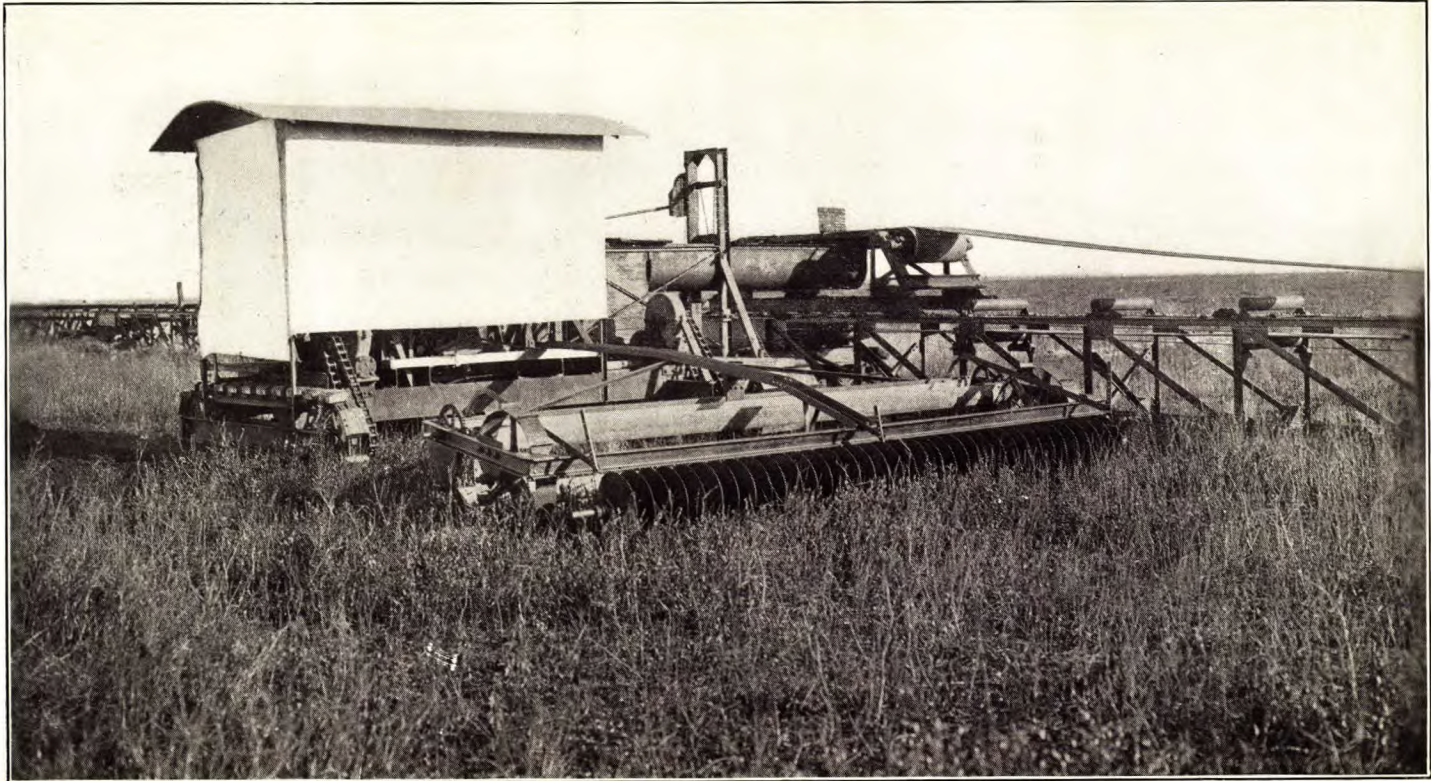
Plant No. 2 in operation





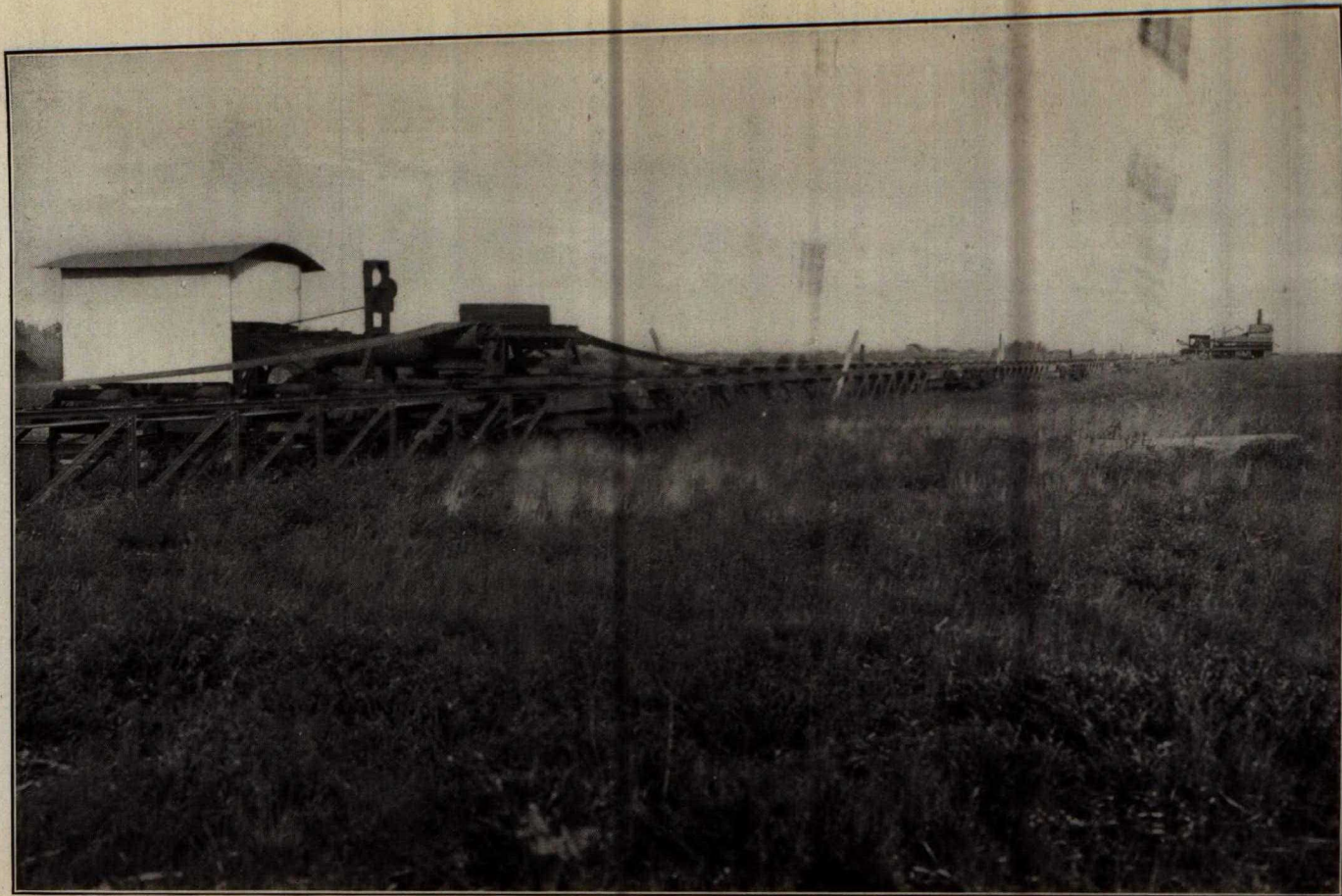
Belt conveyer in place for operation





New spreader attached to the belt conveyer





Belt conveyer system and excavator showing unloading device for delivering the peat from the belt into the hopper of the spreader





One of the caterpillar elements, and take up pulley at extreme outboard end of the conveyer



PLATE XVIII



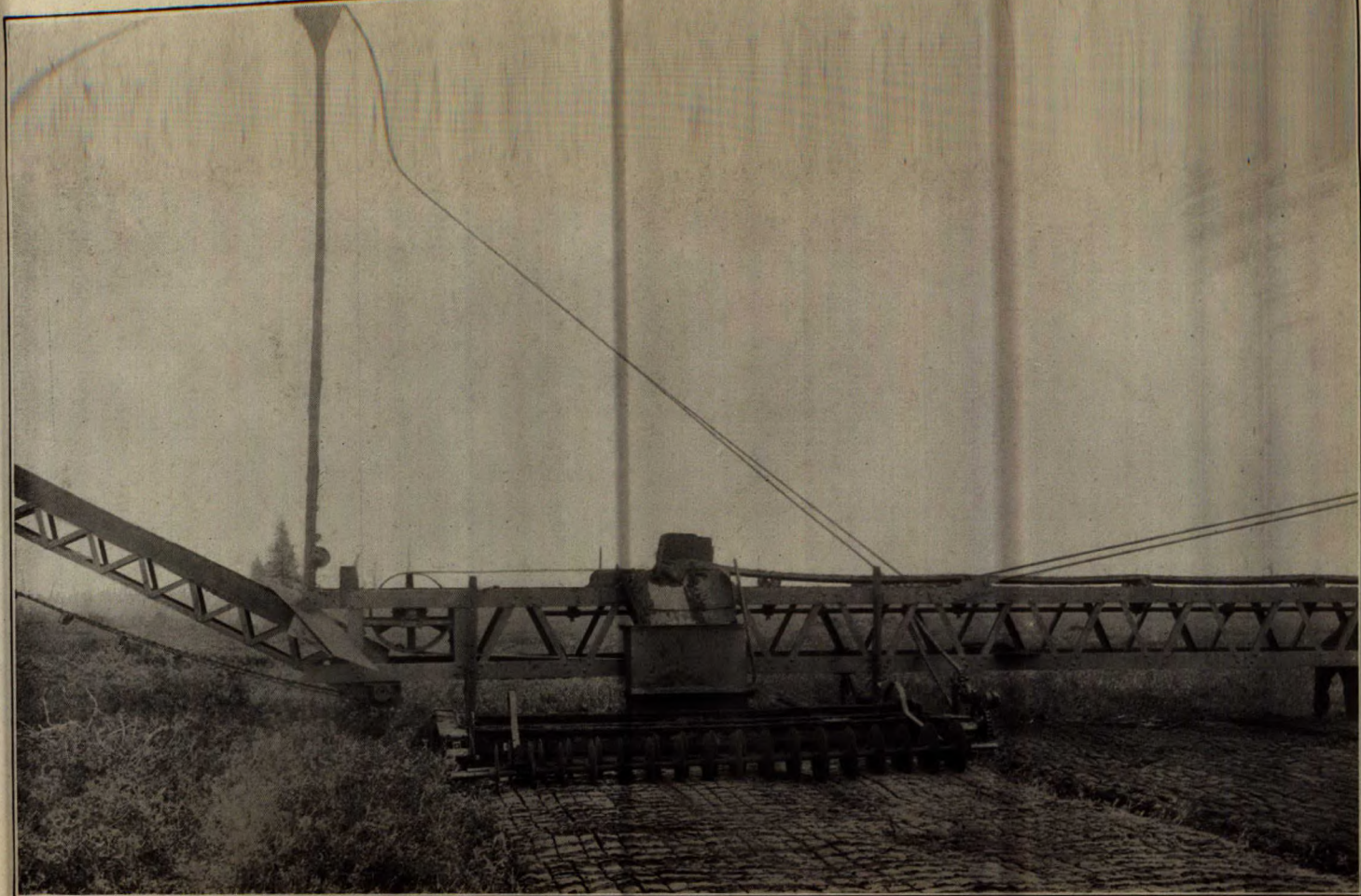
Peat fuel laid on the field. This plate shows very clearly the effect of the improved longitudinal and cross cutters





Belt conveyer with spreader in position near the end farthest removed from the line of excavation, and the entire plant at the end of the working face ready to be reversed





Close up view of spreader showing operation of the cutting devices; also position of the spreader when the maximum number of rows are laid. The elevator at the extreme end of the girder is used to convey the dried peat to stack or small tramcars.



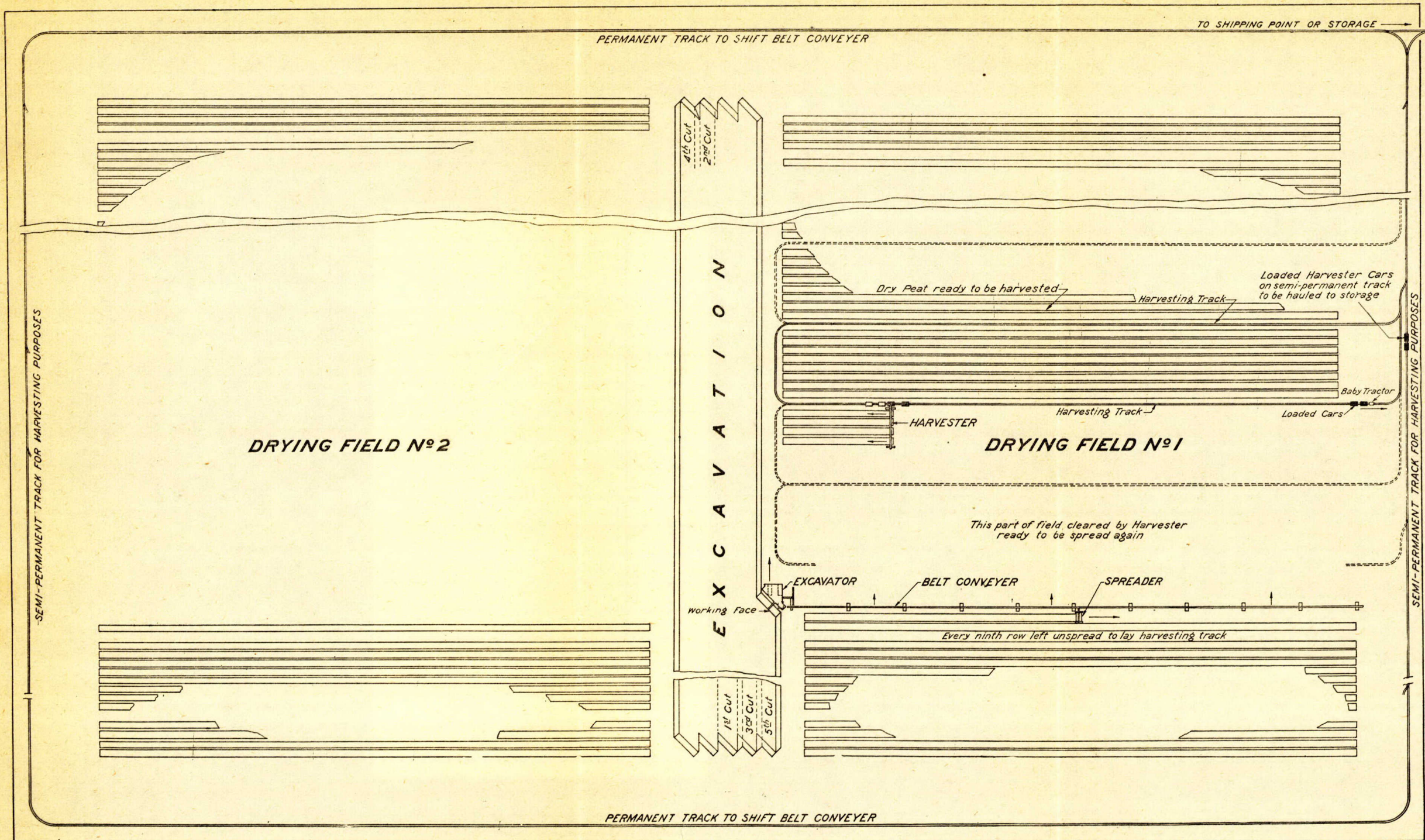


FIG. 15. General plan of operation for single unit Anrep-Moore machine peat manufacturing plant.