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Report of Investigations--Carbonization Section - 128

Physical and Chemical Survey Report No. 59

Study of Coal From

Michel Mine, B Seam, CrowsNest Pas Area, B.C.

Operated By

The Crow's Nest Pass Coal Co. Ltd., Fernie, B.C.

By

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Fuel Research Laboratories

LBL

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I

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Michel Mine, B Seam worked in the Crowsnest area in the Michel Creek district 24 miles Northwest of Fernie, British Columbia, by the Crow's Nest Pass Coal Co. Ltd., of Fernie, British Columbia. This study is part of the investigation dealing with the Physical and Chemical characteristics of the mines operating in the Province of British Columbia. Fifty-seven reports have already been issued on the Physical and Chemical survey of Canadian coal seams, and, accordingly, this present investigation was conducted in the same manner as that adopted for the previous studies. The report is, therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The run-of-mine coal from the B Seam was sampled by an official from the Fuel Research Laboratories in the presence of a representative from the operating company. The combined sample, which weighed approximately 2,100 pounds, was bagged for shipment to the Fuel Research Laboratories at Ottawa. In addition to the above, channel samples were taken at various locations. These were also shipped to Ottawa for examination, the results of this study appearing as an appendix to this report.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railways for the aid given in connection with the collection of the samples of coal herewith reported.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the B Seam was collected at the tipple, a representative portion being taken from the various working places at the time of sampling. In this manner, a sample of run-of-mine coal weighing approximately 2,100 pounds and representative of the output of the mine was collected. This sample was used for the screening test, standard round-hole screens made from 1/4" plate being employed. The results of this test are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two - or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by a modification of the method for determining the apparent gravity of coke as outlined in the Gas Chemists' Handbook. The results of the above two tests are also presented in Table I

TABLE I

Screen Analysis Specific Gravity and Bulk Density

Screen Sizes	As Received % By weight	As Received % Cumu-lative	Specific Gravity	Bulk Density (lbs./cu.ft.)	Ash %
Plus - 4 in.	7.8	7.8			6.4
2 - 4 in.	14.2	22.0	1.30	40.00	11.5
1½ - 2 in.	3.1	25.1	1.40	42.50	10.4
1 - 1½ in.	7.1	32.2	1.37	43.50	14.8
3/4- 1 in.	4.5	36.7	1.33	43.00	13.8
1/2- 3/4 in.	6.5	43.2	1.32	42.50	12.2
1/4- 1/2 in.	10.6	53.8	1.29	42.25	11.9
1/8- 1/4 in.	12.5	66.3	1.26	41.00	10.0
No. 48 - 1/8 in.	21.6	87.9	1.22 (both sizes, bracketed)		9.1
0 - No. 48	12.1	100.0			9.1
Mine Run		100.0		60.00	11.0
0 - 4 in.		92.2		58.25	12.7
1/8 - 4 in.		58.5		51.25	13.5
3/4 - 4 in.		28.9		46.00	12.3
0 - 3/4 in.		63.3		53.00	9.4
0 - 1½ in.		74.9		53.00	11.5
0 - 1/8 in.		33.7	1.22	48.00	8.7

	As Received
Weight of Sample.........lbs.	2100.0
Average Size of Coal as Received at Ottawa......in.	1.147

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.) with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal", has been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls and G.P. Connell, Mines Branch publication No.762. This tentative method was used for testing the relative "size stability" of single sizes. The term "size stability" is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index"1/.

The results of the friability study of the run-of-mine coal from the B Seam are shown in Table II. The samples of the single sizes and the mixed sizes which were tested are as follows: 2" to 3"; 3/4" to 4", and 0" to 4"; in all three samples were tested.

4. Grindability

For the determination of the grindability, or the ease of pulverizability, of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Co. has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coals from the B Seam.

1/ Quoted from the above mentioned publication of the Mines Branch
2/ "Tentative Method of Test for Grindability of Coal By The Hardgrove Machine Method" A.S.T.M. Designation D 409-35T.

TABLE II

Size Stability (Friability)

Sizes tested and number of drops	Screen analysis of coal before and after dropping; percent weight retained on: Round hole screens 3"	2"	1½"	1"	3/4"	1/2"	Square -½"		Average size of coal before and after test inches	Size stability per cent
Single Sizes										
2 to 3" lumps(1)*									2.500	
2 drops		40.0	15.0	11.5	4.5	5.0	24.0		1.537	61.5
Mixed Sizes:										
3/4 - 4 in.										
Sample (1)	17.7	31.5	10.7	24.6	15.5				2.039	
2 drops	8.7	22.1	11.7	15.8	9.6	9.6	22.5		1.461	71.7
4 drops	5.8	18.7	8.8	15.0	9.2	9.6	32.9		1.236	60.6
0 - 4"	3"	2"	1½"	1"	3/4"	1/2	1/4"	-1/4"		
Sample(1)	5.5	9.9	3.4	7.7	4.9	7.1	11.5	50.0	0.790	
2 drops	4.3	8.9	4.3	5.9	5.1	5.9	13.6	52.0	0.721	91.3
4 drops	4.3	5.9	3.8	6.4	4.7	5.9	13.2	55.8	0.644	81.5

* This and other bracketed figures in this column are the numbers of fifty-pound test averaged.

TABLE III

Grindability

Screen Size Tested	Hardgrove Index
0 - 4 in.	95.5
0 - 3/4 in.	101.7
0 - 1/8 in.	108.6

For comparison, three samples of varying screen-size prepared from the run-of-mine coal, were selected for testing as follows:

0 - 4 in.	Composite
0 - 3/4 in.	Slack, and
0 - 1/8 in.	Slack

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

III

Chemical Properties

The various screen sizes obtained from the screening tests of the coal from the B Seam were subjected to certain chemical and physico-chemical analyses as follows.

1. The Proximate Analyses including the sulphur and the calorific value which are shown in Table IV

2. The Ultimate Analyses for the selected size mixture which are presented in Table V.

3. The Sulphur Forms in the coal which were determined according to the accepted Powell method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid; the pyritic sulphur by oxidation with nitric accid, and the organic sulphur by the difference between the inorganic sulphur and the total sulphur, the results being presented in Table VI.

4. The Distribution of Fusain the importance of fusain with respect to its influence on the spontaneous combustion of coal, and its effect on the coking properties of the coal necessitates a study of the quantitative distribution of this petrographic coal constituent. The Carbonization Section of the Fuel Research Laboratories have adopted the Heathcoat method, with certain modifications, for determining fusain. This method takes advantage of the fact that, in bituminous coals, fusain is more resistant to oxidation than the other coal constituents; hence after oxidizing the insoluble humic material to an alkaline-soluble humic substance, the more resistant fusain is collected by filtration. The results of this test, together with the forms of sulphur for the samples examined are shown in Table VI.

5. The Fusibility of the Ash including the Melting Range, and Softening and Fluid Intervals of the Ash, which are given in Table VII; the data on temperature lags being presented because of their bearing on the clinkering properties of the ash.

6. The Chemical Analyses of the Ash which are shown in Table VIII.

Table IV

Chemical Analyses of Coal

Proximate, Sulphur, and Calorific Value

Screen Sizes	Moisture (as rec'd)	Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/lb.
		Dry Basis				
Plus 4 in.	1.3	6.4	26.0	67.6	0.8	
2 - 4 in.	1.2	11.5	27.3	61.2	0.7	
1½ - 2 in.	1.1	10.4	27.5	62.1	0.6	
1 - 1½ in.	1.0	14.8	26.2	59.0	0.8	
3/4 - 1 in.	1.0	13.8	25.6	60.6	0.7	
1/2 - ¾ in.	1.1	12.2	25.5	62.3	0.6	
1/4 - ½ in.	1.1	11.9	25.2	62.9	0.7	
1/8 - ¼ in.	1.1	10.0	25.5	64.5	0.7	
No. 48 x 1/8	1.2	9.1	25.3	65.6	0.8	
0 - No. 48	1.1	9.1	26.0	64.9	0.7	
Mine Run	1.2	11.0	25.6	63.4	0.7	13,570
0 4 in.	1.2	12.7	25.9	61.4	0.7	13,465
1/8 4 in.	1.2	13.5	25.2	61.3	0.7	13,285
3/4 4 in.	1.2	12.3	25.6	62.1	0.7	13,535
0 ¾ in.	1.2	9.4	25.6	65.0	0.7	14,005
0 1½ in.	1.1	11.5	25.3	63.2	0.7	13,685
0 1/8in.	1.1	8.7	25.9	65.4	0.7	14,225

Table V

Ultimate Analyses

Sample	Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
	Dry Basis					
0 - 4 in	76.8	4.8	0.7	1.4	3.6	12.7

Table VI

Sulphur Forms
(as received basis)

	Total Sulphur % of Coal	Sulphate Sulphur % of coal	Sulphate Sulphur % of sulphur	Pyritic Sulphur % of coal	Pyritic Sulphur % of sulphur	Organic Sulphur % of coal	Organic Sulphur % of sulphur	Fussain % of Pure Coal
0 - 4 in.	0.67	0.00	0.00	0.069	10.3	0.601	89.7	2.23
1/8 - 4 in.								2.35
0 - 1½ in.								2.21
0 - 1/8 in.								1.73

TABLE VII

Fusibility of Ash

	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus - 4 in.	1880	1995	2100	220	115	105	6.4
2 - 4 in.	1880	1950	2050	170	70	100	11.5
1½ - 2 in.	1840	1930	2210	370	90	280	10.4
1 - 1½ in.	1900	1990	2240	340	90	250	14.8
3/4 - 1 in.	1890	2040	2270	380	150	230	13.8
1/2 - 3/4 in.	1890	2050	2370	480	160	320	12.2
1/4 - 1/2 in.	2000	2270	2520	520	270	250	11.9
1/8 - 1/4 in.	2260	2460	2635	375	200	175	10.0
No. 48 - 1/8 in.	2450	2560	2710	260	110	150	9.1
0 - No. 48	2260	2460	2630	370	200	170	9.1
Mine Run	1850	2000	2250	400	150	250	11.0
0 - 4 in.	1900	2040	2250	350	140	210	12.7
1/8 - 4 in.	1920	2120	2300	380	200	180	13.5
3/4 - 4 in.	1885	2080	2250	365	195	170	12.3
0 - 3/4 in.	2030	2375	2600	570	345	225	9.4
0 - 1½ in.	2210	2400	2580	370	190	180	11.5
0 - 1/8 in.	2240	2550	2720	480	310	170	8.7

TABLE VIII

Chemical Analyses of Ash

Sample	SiO_2	Fe_2O_3	Al_2O_3	$CaO+MnO$	MgO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	Total
0 - 4 in.	47.3	19.1	20.2	3.8	1.6	Nil	1.9	0.9	0.7	4.5	99.9

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float and sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1-1/2-in. slack prepared from the run-of-mine coal, is presented in several tables and has been plotted as shown in the accompanying curves. The method used for plotting the data is patterned after that of J.R. Campbell of the American Rheolaveur Corporation, to which has been added the "Specific Gravity Distribution" curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves representing the following information:

Curve 1, which is the cumulative float ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ±.10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized as in the following tables:-

±.10 Curve Per Cent	Degree of Difficulty	Preparation
2 - 7	Simple................	Almost any process; high tonnage
7 - 10	Moderately difficult..	Efficient process; high tonnage
10 - 15	Difficult.............	Efficient process; medium tonnage
15 - 20	Very difficult........	Efficient process; low tonnage
20 - 25	Exceedingly difficult.	Very efficient process; low tonnage
Above 25	Formidable............	Limited to a few exceptionally efficient processes

For the ordinary study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal, and refuse fractions of which are studied for their various properties. If a horizontal line is drawn from this point on Curve 4 (Specific Gravity Curve) the point at which it cuts the other lines represents the following:-

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However as the total sulphur of the coal is low a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction in ash, which is possible under varying conditions of washing the 1½ in. slack are presented in Figure I. Figure II presents the sizing curve and the ash and sulphur contents of the various screen sizes, as well as the data obtained by washing the mixed coal fraction at a selected gravity of 1.50. This includes the ash contents of the floats at this gravity, as well as the quantity recovered at the percentage of ash in the sinks.

All of the data used in the construction of the curves are presented in the following tables:

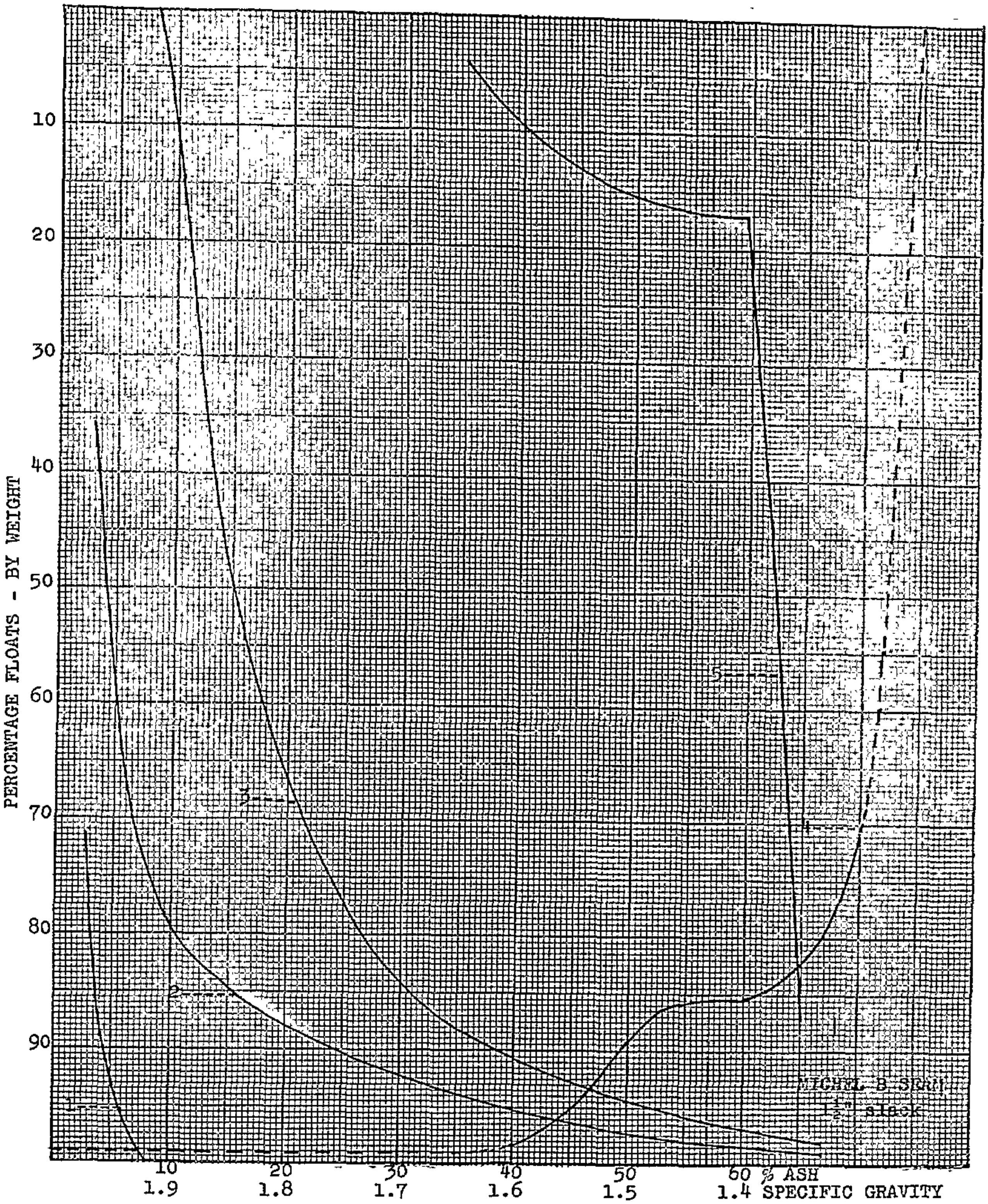


FIG. I - Washability Curves for Michel B Seam Coal - Ash

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

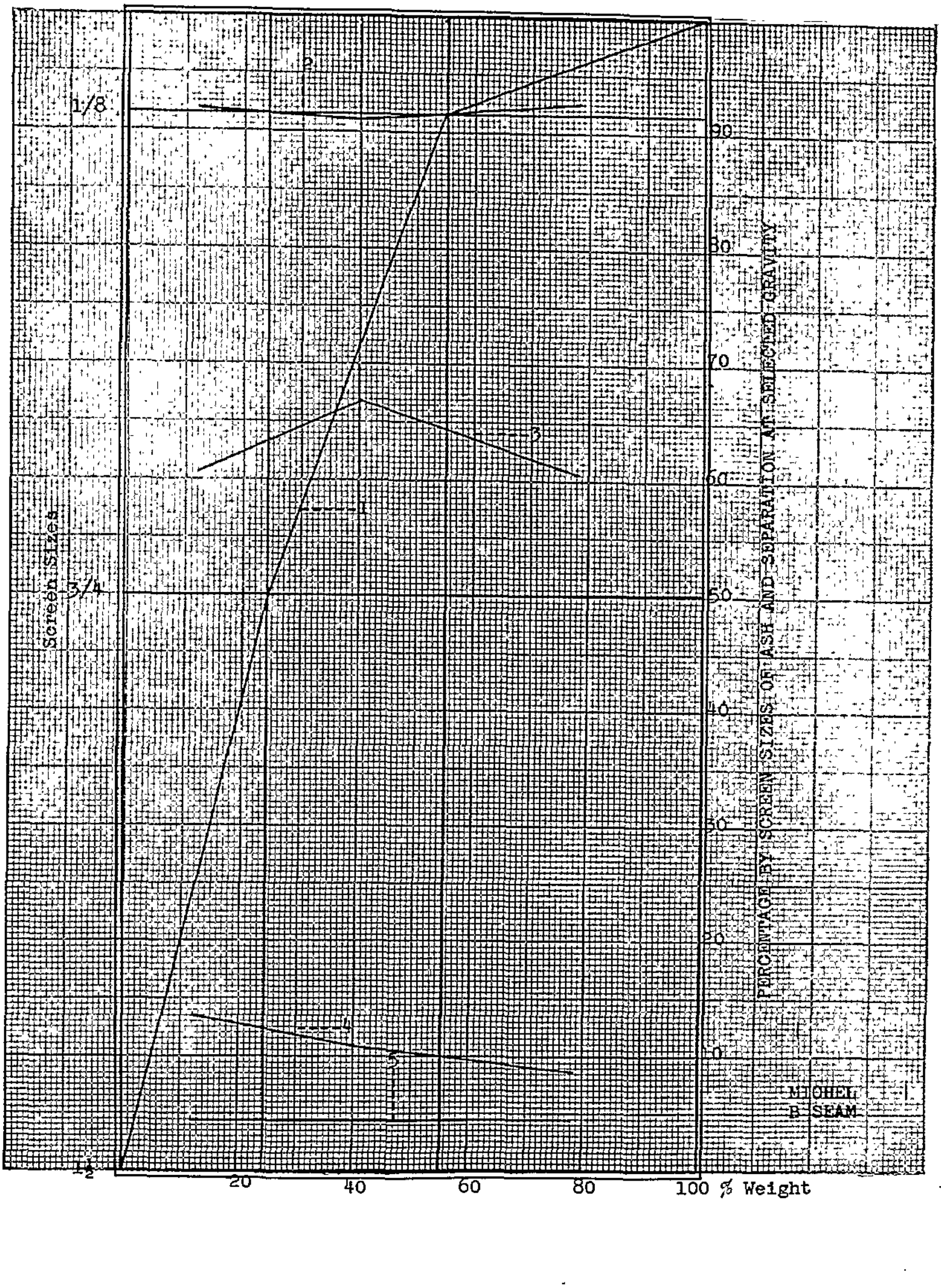


FIG. II - Curves showing screen analysis and Washing Data on Screen Sizes for Michel B Seam Coal.

Curve 1 - Sizing curve
Curve 2 - Percentage float at 1.50 specific gravity
Curve 3 - Percentage ash in sinks at 1.50 specific gravity
Curve 4 - Percentage ash in screen sizes.
Curve 5 - Percentage ash in floats at 1.50 specific gravity.

TABLE IX

Float and Sink Data on 1½" Slack

– Ash –

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
	Floats 1.30	71.6	2.7	71.6	2.7	100.0	8.1	1.35	87.0
Sinks 1.30	" 1.40	13.9	9.5	85.5	3.8	28.4	21.6	1.40	17.0
" 1.40	" 1.50	2.9	20.2	88.4	4.3	14.5	33.1	1.45	17.2
" 1.50	" 1.60	9.9	31.1	98.3	7.0	11.6	36.4	1.55	13.1
" 1.60		1.7	67.0	100.0	8.1	1.7	67.0	1.65	4.0
Curve No.		4	2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
	Floats 1.30	2.8	26.5	70.7	Good	0.8	2500	2610	2700	200	110	90
Sinks 1.30	" 1.40	9.7	24.1	66.2	Good	0.7	2200	2375	2620	420	175	245
" 1.40	" 1.50	20.4	23.9	55.7	Fair	0.9	2260	2390	2450	190	130	60
" 1.50	" 1.60	31.5	22.1	46.4	Poor	1.2	2735	2810	2870	135	75	60
" 1.60		67.2	21.3	11.5	Non-coking	0.8	1850	1990	2230	380	140	240

Table XI

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight..................%	100.0	88.8	11.2
Proximate Analysis(D.B.)			
Ash.....................%	11.5	4.2	62.2
Volatile Matter.........%	25.3	26.0	20.5
Fixed Carbon............%	63.2	69.8	17.3
Sulphur.................%	0.7	0.8	0.6
Calorific Value BTU/lb..	13,685	14,900	----
Fusion Point of Ash....°F	2400	2570	2150
Melting Range of Ash...°F	370	440	350
Coking Properties.......	Good	Good	Non-coking

Table XII

Fussain in Raw Coal, Clean Coal, and Refuse

	Fussain-% of Pure Coal
1½" Slack (Raw)	2.21
Clean Coal: Floats	2.14
Refuse: Sinks	6.15

Table XIII

Screen Analysis and Chemical Analysis (Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. Weight %	Ash %	Sulphur %	F.P.A. °F
3/4 - 1½ in.	24.2	24.2	14.4	0.7	2010
1/8 - 3/4 in.	30.8	55.0	11.2	0.7	2300
0 - 1/8 in.	45.0	100.0	8.7	0.7	2550

Table XIV

Float and Sink Data on Screened Sizes

Using a Selected Gravity of 1.50

	Floats				Sinks			
	Weight %	Ash %	Sulphur %	F.P.A. °F	Weight %	Ash %	Sulphur %	F.P.A. °F
3/4 - 1½ in.	91.7	4.5	0.7	2100	8.3	60.8	0.3	2050
1/8 - 3/4 in.	91.1	4.4	0.7	2600	8.9	66.9	0.6	2150
0 - 1/8 in.	92.5	4.4	0.9	2680	7.5	60.3	0.8	2170

V

Coking Properties

1. "Swelling Index" Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories, which has been outlined and published by the Mines Branch1/. This test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the "Swelling Index" is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

Samples of the raw and washed 1½ in. slack from the B Seam were subjected to the above test, the results being shown in Table XV.

2. "Caking Index" Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are more capable of withstanding a higher admixture of inert material, and will yield a carbonized residue of definite crushing strength than are the more inferior coals. This phenomenon has been thoroughly studied and methods have been developed for the determination of the "Caking index". While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the "caking value" is of importance when it is desired to mix inert carbonaceous material or non-coking coals with coking coals.

The method developed by Gray, in which 25-gramme mixtures of coal and sand, in varying proportions are carbonized in

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant By-Product Coke" by R.A. Strong, E.J. Burrough and E. Swartzman--Mines Branch publication No. 737-2 illium crucibles at 950 C., has been adopted as a standard at the Fuel Research Laboratories. The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designated as the "Caking index". The higher the "caking index", the greater the coking properties. The results of this test, as applied to the run-of-mine coal from the B Seam is shown in Table XV.

Table XV

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

as indicated by a

"SWELLING INDEX" TEST

	1½ in. Slack As Received	1½ in. Slack After Washing
Volatile Matter at 600 C (D.B.)	16.9	19.6
Swelling Index	843	1415
Section--Coke Classification Chart	Border of II and I	Border of II and III
Specific Volatile Index	187	188
Section--Coal Classification Chart	Border of F & G Orthobituminous	
Ash per cent in coal (dry)	11.5	4.2
PHYSICAL PROPERTIES OF BY-PRODUCT COKE-		
Size on wharf (% on 3" screen		40.0
Size on wharf (Breeze: %-1/2"		2.0
Shatter test (Index: % on 2" screen	55.0	60.0
Shatter test (Breeze: %-1/2"	3.0	2.0
Abrasion test (Index: % on 1½" screen	90.0	95.0
Abrasion test (Dust: %-1/16"	3.0	2.0
Density (App. Specific Gravity	0.95	0.90
Density (Lbs. per cubic foot	26.0	25.0
Transverse shrinkage	very poor	Fair
Appearance of natural surface	steel gray	steel gray
Shape	square	square
Strength	hard	hard
Cross fracture	Med. to large amt. square	Med. Amt. square
Longitudinal	Med. Amt.	Small to Med. Amt.
Cell structure	dense	dense
Sponge	very little	very little
Pebbly seam	none	none
REMARKS	This coal approaches the Pocahontas type of blending coal & cannot be used alone in by-product coke ovens	Washing materially improves the contracting properties of the coal, but it remains a borderline product in so far as 100% use in by-product ovens

Caking Properties

	Gray Caking Index
Run-of-Mine Sample	60

VI

Summary and Discussion of Results

The run-of-mine sample of coal from the Michel mine operating on the B seam in the Crowsnest Area, Michel Creek district, was collected at the mine by sampling at the tipple. In this way, approximately 2,100 pounds of coal, considered to be representative of the output of the coal at this mine, was collected and shipped to the Fuel Research Laboratories for the investigation as to the Physical and Chemical properties.

Physical Properties--

The results of the screening test on the run-of-mine coal which was conducted at the Fuel Research Laboratories, are shown in Table I, which contains the percentages of the various screened sizes on the "as received" basis, i.e. as received at Ottawa. On this basis, it will be noted that 33.7% of the coal was below 1/8-in. in size, 7.8% was above 4-in. in size, 14.2% 2 - 4 in. in size, the remaining 44.3% being distributed between the other sizes. The amount of dust, i.e., material passing a 48-mesh screen, was very high in quantity, amounting to 12.1% of the total coal. The average size of the run-of-mine coal "as received" was 1.147 in., yielding 63.3% of 3/4-in slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results of the run-of-mine coal agree very well with other coals of similar ash contents, the individual screen sizes above 1/8-in. having uniformly lower bulk density than mixtures of these sizes.

The results of the friability tests on the coal from the B Seam are shown in Table II. One single size and two mixed sizes prepared from the run-of-mine coal were tested according to the method described in publication No. 762 of the Mines Branch. The table contains the results of a two-drop test on the various sizes studied, as well as the results of a four-drop test on the mixed size samples. This latter procedure is preferred for mixed sizes because of the cushioning effect on the fines. In the 0 - 4 in.

coal, after four drops, the size stability was 81.5%, whereas, the "size stability" of the 3/4 - 4 in., after only two drops, was 71.7%. It is noteworthy that the single size tested had a relatively low size stability, namely: 61.5% for the 2 - 3 in. lumps.

The grindability indices for three sizes of coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method, which has been described in Mines Branch publication No. 737-1. The finer sizes are evidently more easily pulverized than the coarser sizes, but in all cases this test indicates a material which should be very easily pulverized.

Chemical Properties--

The Proximate and Ultimate Analyses of the various screen sizes are shown in Table IV and V respectively. It will be noted, referring to Table IV, that the ash content of the various sizes retained on a 1/8 in. screen and passing a 4 in. screen is fairly uniform, varying from 10.0% to 14.8%. The sizes passing a 1/8 in. screen are uniformly lower in ash content, while the plus 4-in. coal contains even less ash, with 6.4%. The composites vary in ash content according to the proportion of the sizes included, the run-of-mine coal yielding 11.0% ash, whereas the 1/8 - 4 in. lump uields 13.5% ash. The sulphur content is quite low and uniform for all the sizes, ranging from 0.6% to 0.8% with an average for the run-of-mine amounting to 0.7%.

The volatile matter of the run-of-mine coal is medium, and based on the "Specific Volatile Index"1/ method of classification, this coal has an index of approximately 188, which places it on the border of F and G of the orthobituminous coals and approaching the metabituminous. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is medium Volatile Bituminous.

1/ "Classification of Coals Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 725-2

Table V gives the ultimate analyses of the 0 - 4 in. mixture of sizes indicating a high carbon and low oxygen coal.

Table VII shows the results of the ash fusion determinations, including the melting range and the softening and fluid intervals for the various sizes of coal;whereas, Table VIII gives the chemical analyses of the ash of a composite of sizes. It will be noted that the Softening Temperature of the ashes for the sizes retained on a ½ in. screen are uniformly low varying from 1930°F to 2270°F., whereas, the finer sizes are medium in fusion varying from 2460 to 2560°F. The flow interval (range from softening to fluid temperature) for the various sizes is medium, varying from 100°F. to 320°F., the average for the run-of-mine sample amounting to 250°F.

The forms of sulphur for a composite prepared from the run-of-mine coal are shown in Table VI. The pyritic sulphur is quite low, amounting to 0.069% of the total coal in the 0 - 4 in. size i.e., 10.3% of the total sulphur is due to the presence of pyrite. This is to be expected in a coal which contains less than 1% of total sulphur.

The distribution of fusain in the coal from the B Seam is also shown in Table VI. It will be noted that the fusain content of the coal is low in quantity, being 2.23% in the 0 - 4 in. size. It is evidently very uniformly distributed throughout all the larger sizes, there being some reduction in the fines, the 0 - 1/8 in coal having a fusain content of 1.73%. This is an unusual feature as in most coal studied the soft fusain tends to concentrate in the fines.

Laboratory Washing Tests--

The washing tests on the coal from the B Seam were conducted in the standard manner on a sample of 1½ inch slack prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be notted that the 1½ in. slack contains 2.7% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 71.6% of the coal is recovered. The inherent sulphur is low, amounting to 0.8%.

Washing this coal at a specific gravity of 1.50, which according to the ±.10 specific gravity distribution curve represents simple wet washing, resulted in the production of 98.3% of clean coal having 4.2% of ash and 0.8% sulphur. The softening temperature of the ash increased from 2400 to 2570°F. by washing These results are shown in Table XI which gives the chemical analyses of the raw coal, the clean coal, and the refuse. Table XII gives the fusain content and of the above three samples. It will be notted that the refuse shows a decided concentration of fusain which is not accompanied by an increase in sulphur. The clean coal indicates a small decrease in fusain with an no change in total sulphur. The relatively low proportion of sulphur remaining in the refuse indicates the absence of finely disseminated pyrite in the fusain. Tables XIII and XIV show that the finer sizes of the 1½ in. slack may be washed to the same ash content but with an attendant lower refuse loss than the larger sizes. The 3/4 - 1½ in. coal is reduced in ash to 4.5% with a refuse loss of 8.3%, the 1/8 - 3/4 in. coal is reduced in ash to 4.4% with a refuse loss of 8.9%, whereas the fines, material through a 1/8 in. screen, may be experimentally washed as easily as the larger sizes, the ash being reduced to 4.4% with a refuse loss of 7.5%. The sulphur, which is low in all the sizes, is not reduced on washing. The ash fusion temperatures of the various sizes are slightly increased by washing, indicating, as may be seen in Table X, that the inherent ash has a high fusion temperature, whereas the extraneous ash has a low fusion temperature.

<u>Coking Properties</u>--

The phenomenon of coking, whereby a bituminous coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or "caking". Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value "swelling index" is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the 1½ in. slack before and after washing, are shown in Table XV. It will be noted that the "swelling index" of the raw coal is 843, and, on the basis of this test, indicates a coal that would result in the production of a very good coke when processed in by-product ovens. However, its shrinkage properties are poor and result in a product that would give difficulty in discharging. Washing results in material improvement in the shrinkage characteristics, the swelling index of the coal increasing to 1415. However, the washed product remains a borderline coal in so far as ease in discharge is concerned. This washed coal, however, when blended with high volatile coals, should be satisfactory for coke production in standard by-product ovens.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The "caking index" determined by this method, and described in Section V, does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories, but, as yet, no definite correlation has been established. The result of the caking index test on a sample of the run-of-mine coal from the B Seam is shown in Table XV, the index being 60. This value indicates a good caking coal.

4

Appendix

Study of Channel Samples

I Samples Collected

The Michel B seam coal varies in analysis both vertically through the deposit and also laterally from one location to another. In view of the importance of this variation in relation to the preparation and use of the coal, it was decided to study channel samples of the seam in addition to the regular tipple sample of run-of-mine coal collected for the Physical and Chemical Survey.

Channel samples from six different locations in the mine were collected as follows:

(A) From No. 2 room off No. 11 incline

(B) From the 6th West Entry

(C) From No. 5 incline, No. 11 room

(D) From No. 5 incline-between No. 11 room and bottom of incline

(E) From the South level roadway between No. 5 level and face

(F) From the South level face

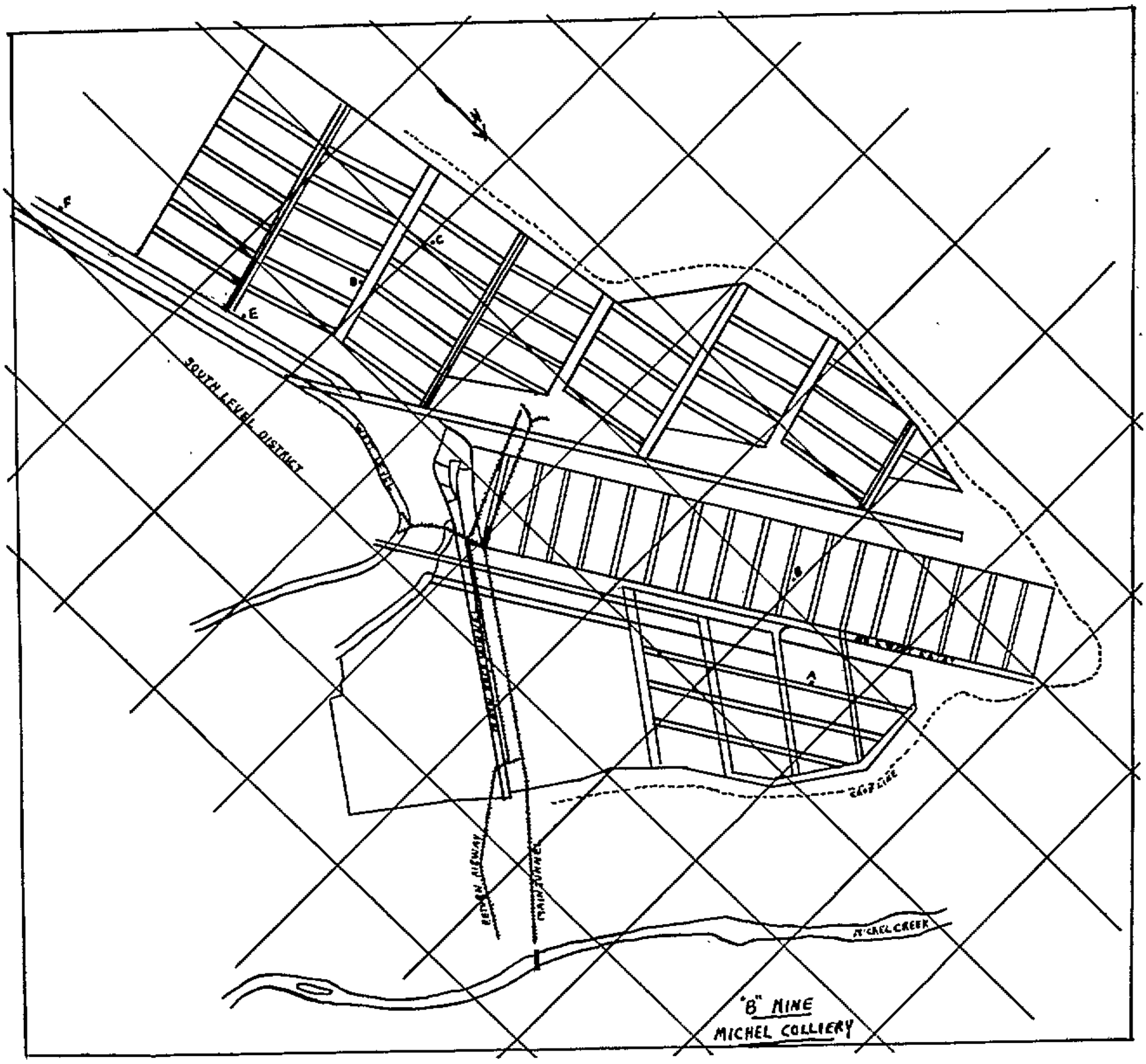
These locations are indicated on the Mine plan, Figure 1.

Each channel sample was divided into two or three sections vertically, depending upon either marked differences inthe coal itself, or upon separation by dirt bands. These sections were as follows:

(A) No. 2 Room off 11 Incline
- (a) 11 in. of top coal, containing a 2 in. band of plactic shale.
- (b) 57 in. of middle coal
- (c) 12 in. of bottom coal, including 1 in. shale   Total thickness - 80 in.

(B) 6th West Entry
- (a) 11 in. of top coal, containing a 3 in. band of plastic shale, black in colour
- (b) 70 in. Middle coal
- (c) 12.in. bottom coal, including 1½ in. shale Total thickness - 93 in.

(C) No. 5 Incline, No. 11 room
- (a) 10 in. top coal, including a 2 in. band of black plastic shale.
- (b) 32 in. of middle coal
- (c) 13 in. of bottom coal, including a 2 in. shale band.   Total thickness - 55 in.



"B" MINE
MICHEL COLLIERY
SOUTH LEVEL DISTRICT
RETURN AIRWAY
MAIN TUNNEL

FIGURE I

(D) No. 5 Incline-between 11 Room and bottom of Incline
(a) 8 in. of top coal, including 3 in. of plastic black shale.
(b) 41 in. of middle coal
(c) 13 in. of bottom coal, including 1½ in. shale band. Total thickness - 62 in.

(E) South Level Roadway - between 5 level and face
(a) 2 in. top plastic shale material (not sampled)
(b) 30 in. top coal
(c) 28 in bottom coal (no visible shale band)
Total thickness - 58 in.

(F) South Level, face
(a) 2 in. of top coal, including 1 in. of slickensided shale and 1 in. of plastic black shale.
(b) 29 in. of middle coal.
(c) 27 in. of bottom coal (no visible shale band)
Total thickness - 58 in.

The seam has two marked impurities; one, a black clay band of 1 to 3 inches in thickness, occuring at or near the roof, and referred to as "gumbo" and the other a shale bnad 1 to 2 inches in thickness, located approximately 12 inches from the floor of the seam and referred to as a "sulphur" band. Samples of both of these were taken in addition to the above sections.

II Analyses

The proximate analyses, sulphur contents and ash fusibilities of the various channel samples are shown in the following series of tables. All the analyses, with the exception of ash fusibility, were calculated for the composites of the sections of each channel sample.

Table I

Analysis - Dry Basis	A No. 2 Room off 11 Incline			Composite
	Top Coal 11 in.	Middle Coal 57 in.	Bottom Coal 12 in.	Total 80 in.
Ash ....%	25.6	4.0	20.2	9.4
Volatile Matter....... %	21.2	26.7	28.4	26.2
Fixed Carbon.......... %	53.2	69.3	51.4	64.4
Sulphur.............. %	0.6	0.7	0.5	0.7
Coking Properties......	Good	Good(Swollen)	Good	Good
Ash Fusibility.........				
Initial...........°F	2850+	1950	1880	2030
Softening.........°F	+	2150	1950	2150
Fluid............°F	+	2290	2050	2300

Table II

Analysis-Dry Basis	B-6 West Entry			Composite
	Top Coal 11 in.	Middle Coal 70 in.	Bottom Coal 12 in.	Total 93 in.
Ash...............%	20.4	2.9	12.0	6.2
Volatile Matter....%	22.2	26.2	28.0	25.9
Fixed Carbon.......%	57.4	70.9	60.0	67.9
Sulphur............%	0.6	0.7	0.6	0.7
Coking Properties..	Good	Good	Good	Good
Ash Fusibility.....				
Initial......°F	2850+	2080	1810	2050
Softening....°F	+	2260	1970	2350
Fluid........°F	+	2550	2200	2550

Table III

Analysis-Dry Basis	C-6 Incline-#11 Room			Composite
	Top Coal 10 in.	Middle Coal 32 in.	Bottom Coal 13 in.	Total 55 in.
Ash...............%	25.3	5.2	7.2	9.3
Volatile Matter....%	21.3	26.0	26.2	25.2
Fixed Carbon.......%	53.4	68.8	66.6	65.5
Sulphur............%	0.5	0.6	0.7	0.6
Coking Properties..%	Good	Good	Good	Good
Ash Fusibility.....				
Initial.......°F	2800	2350	2490	2800
Softening.....°F	2850+ ~~2580+~~	2650	2810	2850+
Fluid.........°F	+	2840	2850+	2850+

Table IV

Analysis-Dry Basis	D-5 Incline-Between #11 Room & bottom of Incline			Composite
	Top Coal 8 in.	Middle Coal 41 in.	Bottom Coal 13 in.	Total 62 in.
Ash...............%	17.6	4.5	15.5	8.5
Volatile Matter....%	22.6	25.9	28.2	26.0
Fixed Carbon.......%	59.8	69.6	56.3	65.5
Sulphur............%	0.6	0.6	0.6	0.6
Coking Properties..	Good	Good	Good	Good
Ash Fusibility.....				
Initial.......°F	2850+	2300	2040	2140
Softening.....°F	+	2430	2150	2260
Fluid.........°F	+	2520	2300	2450

Table V

Analysis-Dry Basis	E South Level Roadway Between 5 Level and Face Top Coal 30 in.	Bottom Coal 28 in.	Composite Total-58 in.
Ash...............%	4.7	7.2	5.9
Volatile Matter...%	25.7	25.2	25.5
Fixed, Carbon......%	69.6	67.6	68.6
Sulphur...........%	0.7	0.6	0.7
Coking Properties.	Good	Good	Good
Ash Fusibility....			
Initial......°F	1930	2500	2260
Softening....°F	2090	2850+	2450
Fluid........°F	2370	+	2710

Table VI

Analysis-Dry Basis	F - South Level Face Top Coal 2 in.	Middle Coal 29 in.	Bottom Coal 27 in.	Total Composite 58 in.
Ash...............%	52.9	5.2	7.3	7.8
Volatile Matter...%	14.0	25.6	26.2	25.5
Fixed Carbon......%	33.1	69.2	66.5	66.7
Sulphur...........%	0.3	0.7	0.6	0.6
Coking Properties.	Poor	Good	Good	Good
Ash Fusibility....				
Initial......°F	2690	1990	2330	2140
Softening....°F	2830	2100	2575	2240
Fluid........°F	2850+	2300	2850+	2470

Table VII

Analysis-Dry Basis	Impurities "Gumbo"	"Sulphur" band
Ash...............%	31.0	43.8
Volatile Matter...%	20.2	45.0
Fixed.............%	48.8	11.2
Sulphur...........%	0.5	0.4
Coking Properties.	Poor	Poor to Fair
Ash Fusibility....F		
Initial......°F	2850+	2040
Softening....°F	+	2280
Fluid........F	+	2340

III Discussion of Results

As indicated in Figure 1, the channel samples from B seam, Michel Colliery, have been taken from the mine in both the North and the South districts. Samples A and B were taken from the North district, this being that portion of the mine in which the original development had been started. Samples C,D,E, and F are in the South Level district where the most recent development has been taking place. The section of the coal seam between these two districts is not being mined at present.

Each channel sample were divided from roof to floor into two or three sections depending either upon differences in the coal itself or upon separation by dirt bands. Figure 2 gives a diagramatic representation of the channel samples collected, showing the vertical sections and indicating the ash and volatile matter of these sectional samples.

It should be notted that the seam varies appreciably in thickness, the channel samples collected ranging from 55 in. to 93 inches. From the samples studied it is apparent that the coal seam is thicker in the North district than in the South district. The North district channel samples show an average seam thickness of 86.5 inches, whereas the South district samples indicate an average seam thickness of 58 inches.

The division of the seam into roof, middle and floor coal appears to be very clearly defined in the North district (Samples A and B). In the South district there is apparently less differentiation. Examination of the ash contents of the sections, shown in Figure 2 indicates that, in the North district (A and B) the roof and floor coal are high in ash, but in the South district the ash contents of these sections are much lower and in some cases approach the middle band of clean coal.

The volatile matter contents of the low ash sections are fairly uniform throughout the whole portion of the seam sampled, varying from 25.2% to 26.7%. However, some irregularity occurs in the high ash roof and floor sections. In samples A,B, and D, the high ash floor samples are accompanied by a high

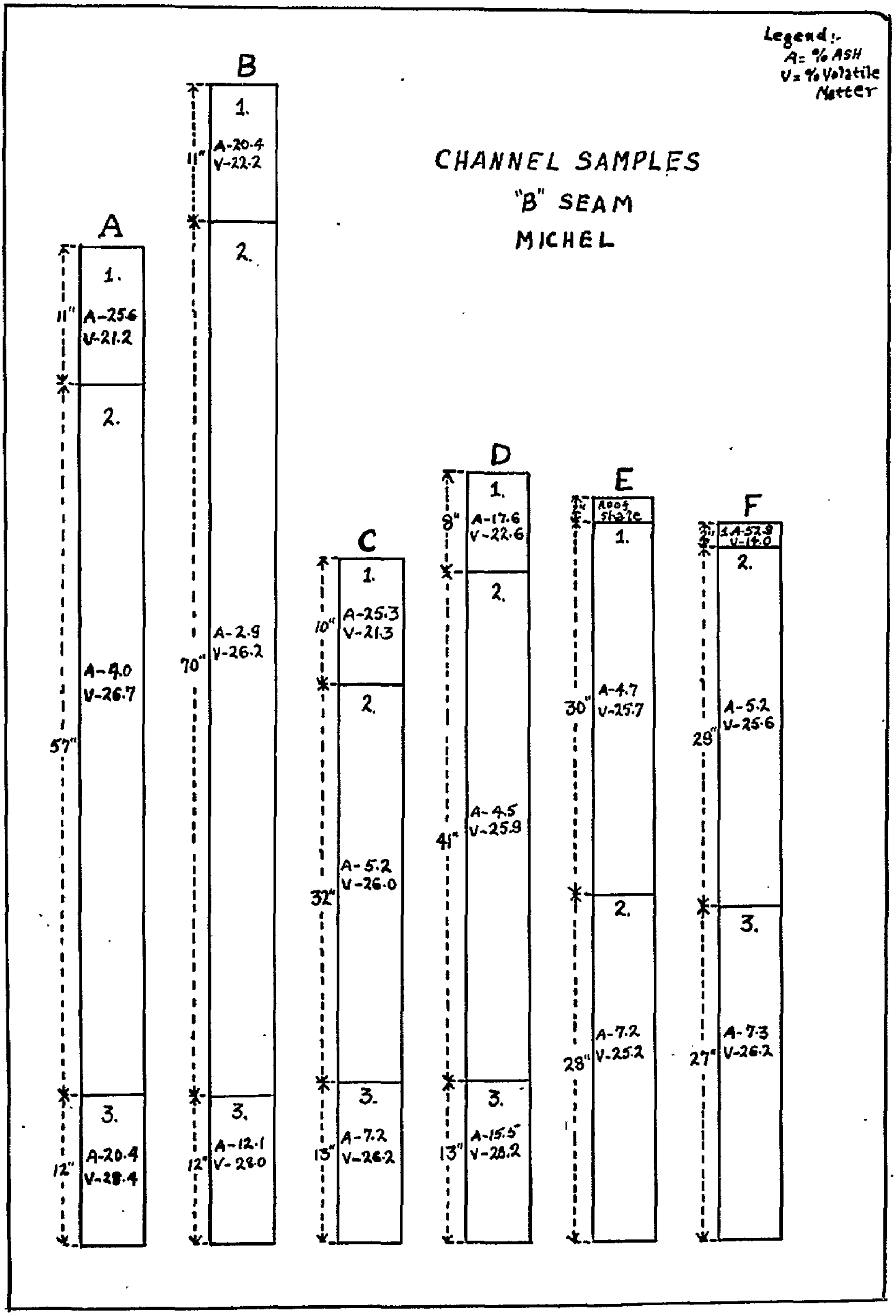

Legend:-
A= % ASH
V= % Volatile Matter
CHANNEL SAMPLES
"B" SEAM
MICHEL
A
1.
11"
A-25.6
V-21.2
2.
57"
A-4.0
V-26.7
3.
12"
A-20.4
V-28.4
B
1.
11"
A-20.4
V-22.2
2.
70"
A-2.9
V-26.2
3.
12"
A-12.1
V-28.0
C
1.
10"
A-25.3
V-21.3
2.
32"
A-5.2
V-26.0
3.
13"
A-7.2
V-26.2
D
1.
8"
A-17.6
V-22.6
2.
41"
A-4.5
V-25.9
3.
13"
A-15.5
V-28.2
E
Roof Shale
1.
30"
A-4.7
V-25.7
2.
28"
A-7.2
V-25.2
F
A-52.8
V-14.0
2.
28"
A-5.2
V-25.6
3.
27"
A-7.3
V-26.2

FIGURE II

volatile matter content of approximately 28%. Determination of the carbon dioxide (CO_2) liberated from the various sections of coal sample D, gave the following results:

	% CO_2
1. Top Coal	1.3
2. Middle Coal	1.2
3. Bottom Coal	3.8

These results definitely indicate that the high volatile matter content of the bottom coal samples in question is due, to a great extent, to the presence of a large quantity of Carbon dioxide. The source of the gas is the limestone impurities in the ash, which on heating break down to form carbon dioxide, with the accompanying loss of weight and increase in the reported volatile matter content of the section samples.

Examination of the analysis of the so-called sulphur band see Table VII, which occurs about 12 inches from the floor of the seam indicates a similar characteristic, where an exceedingly high ash product (43.8%) is exceptionally high in volatile matter (45.0%). Conversely the sample of so-called "Gumbo" taken near the roof shows a more normal volatile matter content (20.2%) for a product with 31.0% ash.

The ash fusibility of the coal varies both vertically and from one location to the other. Generally speaking it may be said that the North district coal shows uniformly a low ash fusibility, whereas the South district coal varies from low to high ash fusibility in the channel sections. The sections from samples A and B in the North district show similar characteristics. The top coal has a high ash fusibility, namely 2850+°F, and the middle and bottom coal have a low ash fusibility averaging about 2080°F. The samples from the South district appear to be divided into two groups, those from the 5 incline area, yielding a product which, has on the average, a relatively high ash fusibility, whereas those samples from the south levell range from low to high ash fusibility. All the sections of the 5 incline samples (c and d), with the exception of the bottom coal of the D sample indicate medium to high ash fusibility. The sections of the South level samples (E and F) show similar characteristics, the top coal having a low ash fusibility, whereas the bottom coal has a high ash fusibility.

Certain irregularities in the ash fusibility of some of the sections have been noted. In samples A,B, and D, although the top and bottom sections are both high in ash, the top coal has a high ash fusibility, but the bottom sections contain ash with a low temperature of fusibility. The results, quoted previously, on the carbon dioxide liberated from the various sections, indicate that the bottom coal is high in carbonates. As the carbonates in coal are usually due to presence of limestone, the resultant high lime content of the bottom coal would account for the low ash fusibility in comparison to the top coal. Comparing the samples of impurities taken from the top and bottom coal sections indicates a similar situation; the so-called "Gumbo" from the top coal has a high ash fusibility, whereas the so-called "sulphur" band, taken from the bottom coal, has a low ash fusibility. Reduction of the mineral matter in the coal by washing should aid in raising the ash fusion temperatur by the reduction of the lime impurities.

An examination of the analysis of the composite of each channel sample, ~~dew~~ shown in Tables I to VI, inclusive, indicates that run-of-mine coal should not vary to any great extent in so far as ash and volatile matter content are concerned. The ash varies from 5.9% to 9.4% with an average of 7.7%, while the volatile matter ranges from 25.2% to 26.2% with an average of 25.7%. The Ash fusibility values for the six channel samples vary considerably ranging from 2150°F to 2800+°F; three samples were below 2300°F two were within the 2300-2500°F range and only one was over 2850°F. It may be concluded that if the run-of-mine coal, from all the places was equally represented in the output, it would yield coal having a fusibility below 2300°F. As suggested above, however, washing may tend to increase the temperature of ash fusibility due to the elimination of material high in lime.

4

Report of Investigations--Carbonization Section - 129

Physical and Chemical Survey Report No. 59

Study of Coal From

Michel Mine, No.3 Seam, Crowsnest Area, B.C.

Operated By

The Crow's Nest Pass Coal Co. Ltd., Fernie, B.C.

By

R.A. Strong, E. Swartzman, E.J. Burrough
and J.H.H. Nicolls

Fuel Research Laboratories

LBL

October 1939

Physical and Chemical Survey Report No. 59

Study of Coal From

Michel Mine, No.3 Seam, Crowsnest Area, B.C.

Operated by

The Crow's Nest Pass Coal Co. Ltd. Fernie, B.C.

Table of Contents

I

INTRODUCTION

The following report deals with a Physical and Chemical study of samples of coal from the Michel Mine, No.3 Seam worked in the Crowsnest area in the Michel Creek district about 24 miles Northeast of the town of Fernie, British Columbia, by the Crow's Nest Pass Coal Co. Ltd., of Fernie, B.C. This study is part of the investigation dealing with the Physical and Chemical characteristics of the mines operating in the Province of British Columbia. Fifty-eight reports have already been issued on the Physical and Chemical survey of Canadian coal seams, and, accordingly, this present investigation was conducted in the same manner as that adopted for the previous studies. The report is, therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The run-of-mine coal from the mine was sampled by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 2,000 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

In addition to the above, channel samples were taken at various locations. These were also shipped to Ottawa for examination the results of this study appearing as an appendix to the report.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railways for the aid given in connection with the collection of the samples of coal herewith reported.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Michel Mine, No.3 Seam was collected at the tipple, a representative portion being taken from the various working places at the time of sampling. In this manner, a sample of run-of-mine- coal weighing 2,026 pounds was collected and considered to be representative of the output of the mine. This sample was used for the screening test, standard round-hole screens made from 1/4" plate being employed. The results of this test are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two - or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by a modification of the method for determining the apparent gravity of coke as outlined in the Gas Chemist's Handbook. The results of the above two tests are presented in Table I.

Table I

Screen Analysis, Specific Gravity and Bulk Density

Screen Sizes*	As Received % By weight	As Received % Cumulative	Specific Gravity	Bulk Density (lbs./cu.ft.)	Ash %
Plus - 4 in.	14.8	14.8	[redacted]	41.00	9.5
2 - 4 in.	14.4	29.2	1.34	43.50	13.0
1-1/2 - 2 in.	3.5	32.7	1.41	42.75	14.8
1 - 1-1/2in.	7.2	39.9	1.38	44.25	14.6
3/4 - 1 in.	3.70	43.6	1.38	45.50	15.5
1/2 - 3/4 in.	6.0	49.6	1.36	44.75	15.9
1/4 - 1/2 in.	11.7	61.3	1.33	45.00	14.8
1/8 - 1/4 in.	11.5	72.8	1.28	42.25	12.6
No.48 - 1.8 in	16.3	89.1	1.28	51.25	11.2
0 - No.48	10.9	100.0			12.2
Mine Run		100.0		61.50	12.0
0 - 4 in.		85.2		60.00	13.2
1/8 - 4 in.		58.0		52.50	13.6
3/4 - 4 in.		28.8		47.00	15.5
0 - 3/4 in.		56.4		48.00	12.8
0 - 1-1/2in.		67.3		60.00	14.0
0 - 1/8 in.		27.2		51.25	11.3

* All screens 1/8 in. and larger are round hole. Screen No.48 is Tyler 48 mesh with nominal aperture of 0.295 mm.

	As Received
Weight of Sample..........lbs.	2026.5
Average Size of Coal after Shipment from mine to Ottawa......................in.	1.551

3. Friability

Friability which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.) with R.E Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoptions of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Chatter Test for Coal" has been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No.762. This tentative method was used for testing the relative "size stability" of single sizes. The term "Size stability" is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index".1/

The results of the friability study on the run-of-mine coal from the No.3 Seam are shown in Table II. The samples of the single size and the mixed sizes which were tested are as follows: 2" - 3": 3/4" - 4", and 0" - 4": in all, three samples were tested.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgreve of the Babcock & Wilcox Co. has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coals from the Michel Mine, No.3 Seam.

1. Quoted from the above mentioned publication of the Mines Branch.
2. "Tentative Method of Test for Grindability of Coal by the Hard" grove Machine Method, A.S.T.M. Designation D 409-35".

Table II

Size Stability (Friability)

Sizes tested and number of drops	Screen analysis of coal before and after dropping; percent weight retained on								Average size of coal before and after test inches	Size stability per cent
	Round hole screens						Square			
	3"	2"	1½"	1"	3/4"	1/2"	-1/2"			
Single Sizes										
2 to 3" lumps(1)*									2.500	
2 drops		56.0	13.5	9.5	4.0	3.0	14.0		1.844	73.8
Mixed Sizes										
3/4 - 4 in.										
Sample(1)	17.9	36.1	10.2	25.0	10.8				2.117	
2 drops	15.8	21.7	12.1	12.9	12.9	8.8	15.8		1.677	79.2
4 drops	11.3	17.9	12.1	12.9	11.7	10.4	23.7		1.443	68.2
0 - 4 in	3"	2"	1¼"	1"	3/4"	1/2"	1/4"	-1/4"		
Sample(1)	4.7	12.2	4.1	8.4	4.3	7.0	13.7	45.6	0.837	
2 drops	3.4	11.5	3.8	7.7	5.1	6.0	13.2	49.3	0.765	91.4
4 drops	3.4	10.2	4.3	6.5	4.6	6.0	14.0	51.0	0.725	86.6

* This and other bracketed figures in this column are the numbers of fifty-pound tests averaged.

Table III

Grindability

Screen Size Tested	Hardgrove Index
0 - 4 in.	93.4
0 -3/4 in.	90.6
0 -1/8 in.	102.4

For comparison, three samples of varying screen-size prepared from the run-of-mine coal, were selected for testing as follows:

0 - 4 in. Composite

0 - 3/4 in Slack, and

0 - 1/8 in Slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the No.3 Seam were subjected to certain chemical analyses as follows:

1. The Proximate Analyses including the sulphur and the calorific value which are shown in Table IV.

2. The Ultimate Analyses for the selected size mixture which are presented in Table V.

3. The Sulphur Forms in the coal which were determined according to the accepted Powell method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid, the pyritic sulphur by oxidation with nitric acid, and the organic sulphur by the difference between the inorganic sulphur and the total sulphur, the results being shown in Table VI.

4. The Distribution of Fusain The importance of fusain with respect to its influence on the spontaneous combustion of coal, and its effect on the coking properties of the coal necessitates a study of the quantitive distribution of this petrographic coal constituent. The Carbonization Section of the Fuel Research Laboratories have adopted the Heathcoat method, with certain modifications, for determining fusain. This method takes advantage of the fact that, in bituminous coals, fusain is more resistant to oxidation than the other coal constituents; hence after oxidizing the insoluble humic material to an alkaline-soluble humic substance, the more resistent fusain is collected by filtration. The results of this test for the samples examined are shown in Table VI.

5. The Fusibility of the Ash including the Melting Range and Softening and Fluid Intervals of the Ash, which are given in Table VII; the data on temperature lags being presented because of their bearing on the clinkering properties of the ash.

6. The Chemical Analyses of the Ash which are shown in Table VIII.

Table IV

Chemical Analyses of Coal

Proximate, Sulphur, and Calorific Value

Screen Sizes	Moisture (as rec'd)	Dry Basis Ash %	Volatile Matter %	Fixed carbon %	Sulphur %	Calorific Value BTU/lb.
Plus - 4 in.	1.2	9.5	21.2	69.3	0.8	------
2 - 4 in.	1.0	13.0	20.9	66.1	0.8	------
1-1/2 - 2 in.	1.0	14.8	20.0	65.2	0.8	------
1 - 1-1/2in.	1.1	14.6	20.8	64.6	0.8	------
3/4 - 1 in.	1.1	15.5	20.1	64.4	0.7	------
1/2 - 3/4 in.	1.1	15.9	19.3	64.8	0.8	------
1/4 - 1/2 in.	1.2	14.8	21.1	64.1	0.7	------
1/8 - 1/4 in.	1.1	12.6	21.5	65.9	0.9	------
No.48 - 1/8 in.	1.1	11.2	22.1	66.7	0.9	------
0 - No.48	1.0	12.2	22.0	65.8	1.0	------
Mine Run	1.1	12.0	21.2	66.8	0.8	13,580
0 - 4 in.	1.1	13.2	21.2	65.6	0.9	13,370
1/8 - 4 in.	1.1	13.6	20.9	65.5	0.8	13,360
3/4 - 4 in.	1.1	15.5	20.7	63.8	0.7	13,040
0 - 3/4 in.	1.1	12.8	21.5	65.7	0.8	13,480
0 - 1-1/2in.	1.1	14.0	21.2	64.8	0.8	13,320
0 - 1/8 in.	1.1	11.3	22.1	66.6	1.0	13,655

Table V

Ultimate Analyses

Sample	Dry Basis Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
0 - 4 in.	76.1	4.6	0.9	1.3	3.9	13.2

Table VI

Sulphur Forms and Fusain

	Total Sulphur % of Coal	Sulphate Sulphur % of coal	Sulphate Sulphur % of sulphur	Pyritic Sulphur % of coal	Pyritic Sulphur % of sulphur	Organic Sulphur % of coal	Organic Sulphur % of sulphur	Fusain % of Pure Coal
0 - 4 in.	0.87	0.0	0.0	0.04	4.6	0.83	95.4	2.09
1/8- 4 in.								2.53
0 - 1½ in.								1.64
0 - 1/8in.								1.42

Table VII

Fusibility of Ash

Screen Sizes	Initial Deformation °F	Softening Temperature °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F	Ash %
Plus - 4 in.	2380	2850+	2850+	470+	470+	+	9.5
2 - 4 in.	2690	2850+	2850+	160+	160+	+	13.0
1-1/2 - 2 in.	2680	2850+	2850+	170+	170+	+	14.8
1 - 1-1/2 in.	2700	2850+	2850+	150+	150+	+	14.6
3/4 - 1 in.	2740	2850+	2850+	110+	110+	+	15.5
1/2 - 3/4 in.	2700	2850+	2850+	150+	150+	+	15.9
1/4 - 1/2 in.	2680	2850+	2850+	170+	170+	+	14.8
1/8 - 1/4 in.	2750	2850+	2850+	100+	100+	+	12.6
No. 48 - 1/8 in.	2850+	2850+	2850+	----	----	+	11.2
0 - No. 48 .	2700	2850+	2850+	150+	150+	+	12.2
Mine Run	2730	2850+	2850+	120+	120+	+	12.0
0 - 4 in.	2730	2850+	2850+	120+	120+	+	13.2
1/8 - 4 in.	2660	2850	2850+	190+	190	+	13.6
3/4 - 4 in.	2700	2850+	2850+	150+	150+	+	15.5
0 - 3/4 in.	2700	2850+	2850+	150+	150+	+	12.8
0 - 1-1/2 in.	2700	2850+	2850+	150+	150+	+	14.0
0 - 1/8 in.	2700	2850+	2850+	150+	150+	+	11.3

Table VIIII

Chemical Analysis of Ash

Sample	SiO_2	Fe_2O_3	Al_2O_3	CaO+ MnO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	Total
0 - 4 in.	58.2	3.7	29.5	1.5	1.1	Nil	1.8	1.1	1.7	1.2	99.8

IV

LABORATORY WASHING TEST

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float and sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1-1/2 in. slack prepared from the run-of-mine- coal, and the 1-1/2 to 4 in. lumps, which are presented in several tables have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation, to which has been added the "Specific Gravity Distribution" curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the $\pm.10$ specific gravity distribution curve, represents a measure of the comparative difficults of separation accodding to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized as in the following table:

+.10 Curve	Degree of Difficulty	Preparation
Per Cent		
2 - 7	Simple..............	Almost any process; high tonnage
7 - 10	Moderately difficult	Efficient process; high tonnage
10 - 15	Difficult...........	Efficient process; medium tonnage
15 - 20	Very difficult......	Efficient process; low tonnage
20 - 25	Exceedingly difficult......	Very efficient process; low tonnage
Above 25	Formidable..........	Limited to a few exceptionally efficient processes.

For the ordinary study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. If a horizontal line is drawn from this point on Curve 4 (Specific Gravity Curve) the point at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the sulphur in this coal is very low, it was not necessary to study this constituent with respect to washing.

Curves showing the reduction of ash, which is possible under varying conditions of washing the 1-1/2 in. slack, are presented in Figure I. Figure II presents the sizing curve and the ash contents of the various screen sizes, as well as the data obtained by washing the mixed coal fractions at a selected gravity of 1.50. This includes the ash and contents of the floats at this gravity, as well as the quantity recovered and the percentage of ash in the sinks. Figure III gives the ash washability curves for the 1-1/2 in. to 4 in. lumps. All of the data used in the construction of the curves are presented in the following tables:-

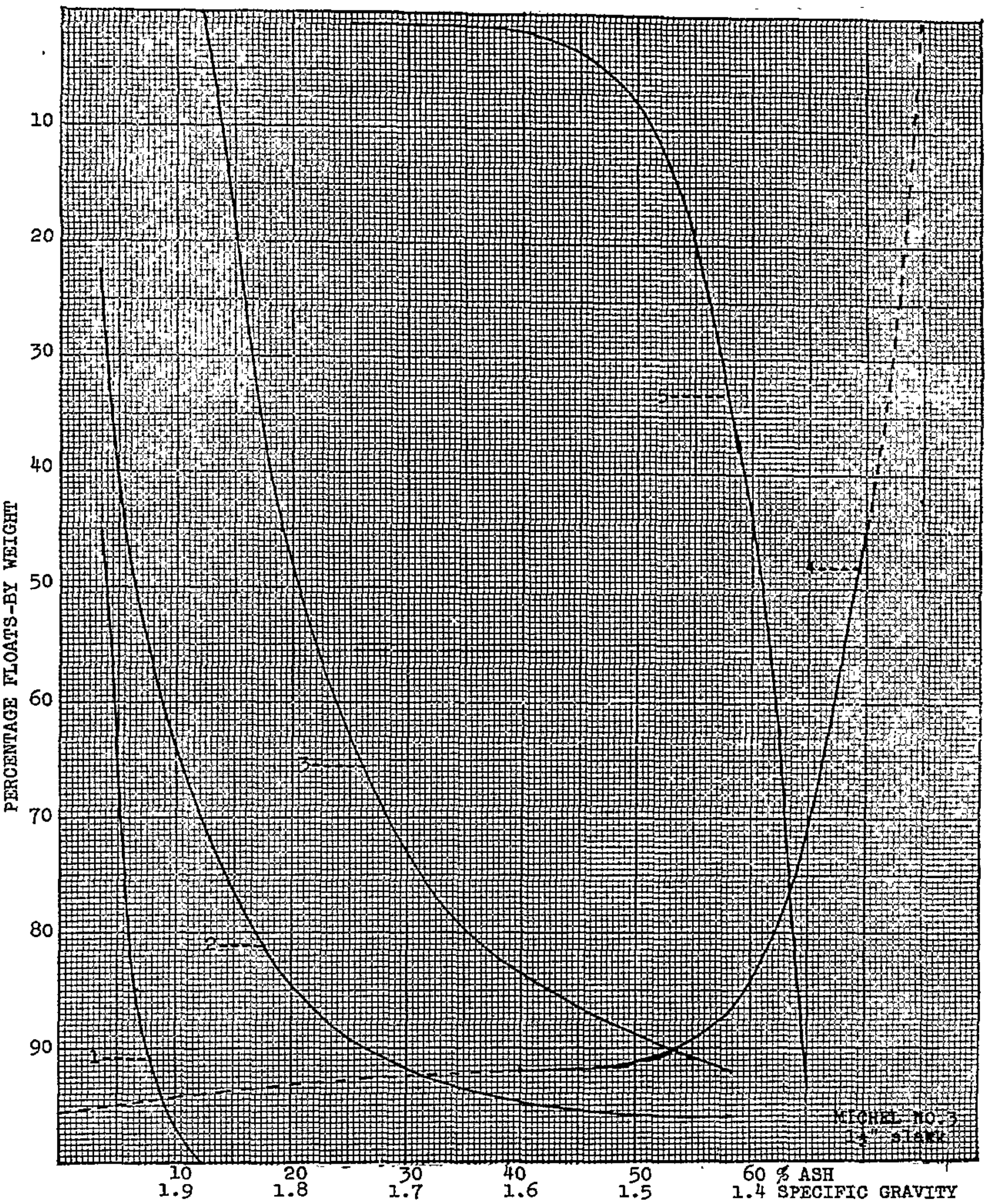


FIG. I - Washability Curves for Michel No.3 Seam Coal - Ash

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

/

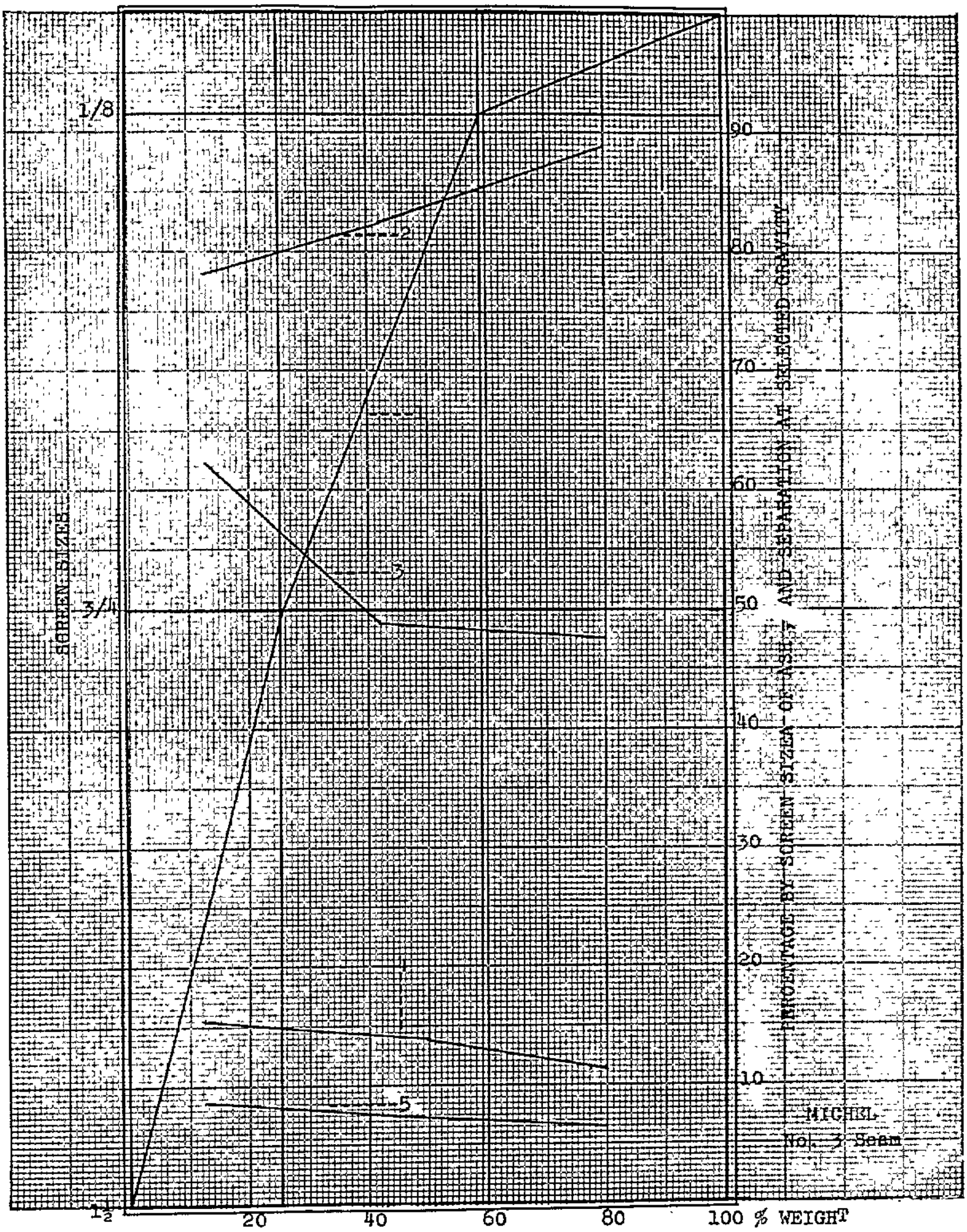


FIG. II - Curves showing screen analysis and Washing Data On Screen Sizes for Michel No.3 Seam Coal.

Curve 1 - Sizing curve
Curve 2 - Percentage float at 1.50 specific gravity.
Curve 3 - Percentage ash in sinks at 1.50 specific gravity
Curve 4 - Percentage ash in screen sizes.
Curve 5 - Percentage ash in floats at 1.50 specific gravity.

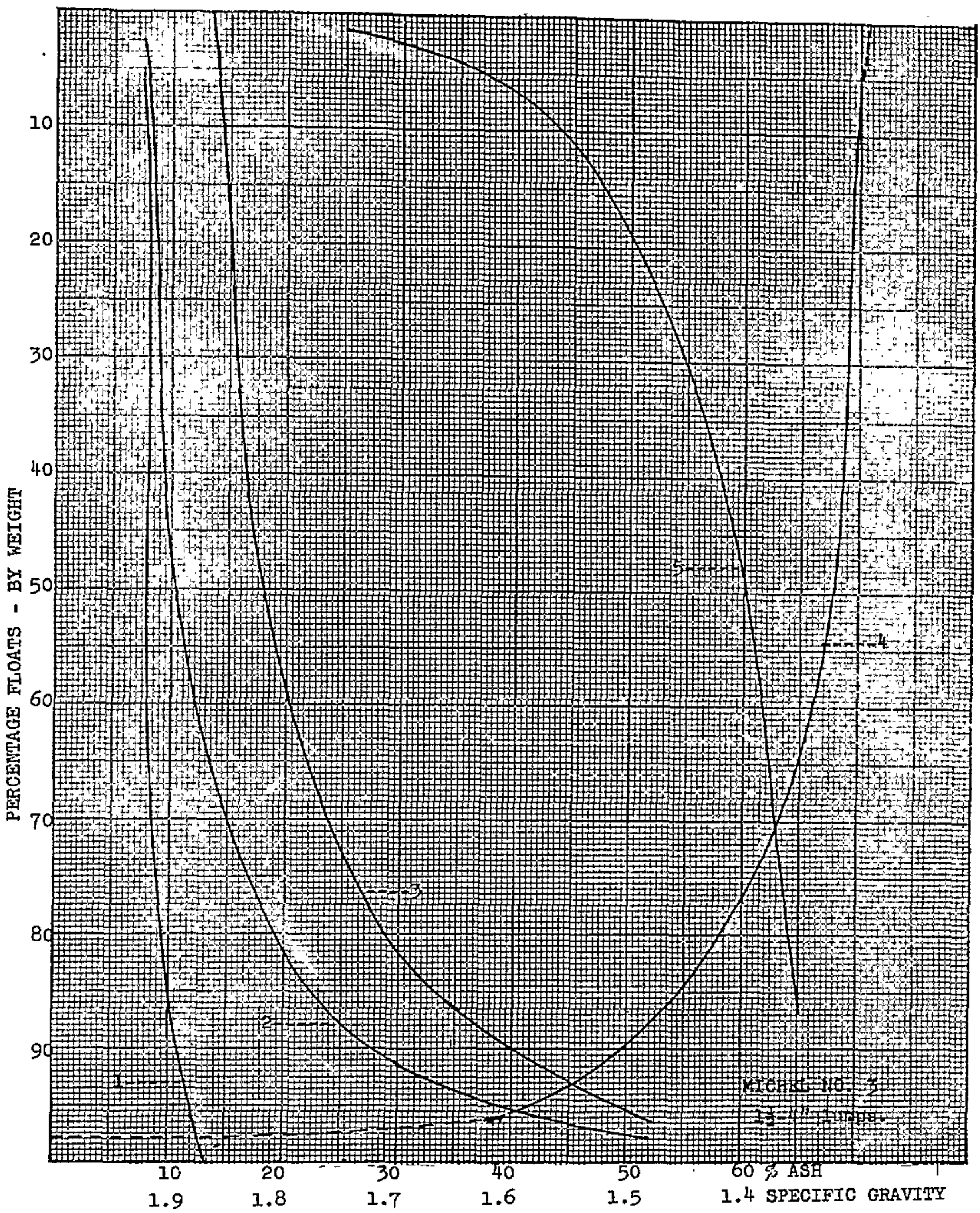


FIG. III - Washability Curves for Michel No. 3 Seam Coal - $1\frac{1}{2}$" - 4" Lump -- Ash.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

Table IX

Float and Sink Data on 1½" Slack - Ash

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
	Floats 1.30	45.1	3.5	45.1	3.5	100.0	12.1	1.35 1.40	93.5 41.6
Sinks 1.30	" 1.40	39.7	10.2	84.8	6.6	54.9	19.1	1.45	21.7
" 1.40	" 1.50	6.0	23.3	90.8	7.7	15.2	42.3	1.55	2.9
" 1.50	" 1.60	1.2	30.9	92.0	8.0	9.2	54.7	1.65	1.0
" 1.60		8.0	58.3	100.0	12.1	8.0	58.3	1.75	0.9
Curve No.	4		2	1,2,4	1	3	3	5	5

Table X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack
(Dry Basis)

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
	Floats 1.30	3.6	23.6	72.8	Good	1.0	2660	2850	2850+	190+	190	+
Sinks 1.30	" 1.40	10.3	21.5	68.2	Good	1.0	2850+	2850+	2850+	----	---	----
" 1.40	" 1.50	23.6	19.8	56.6	Fair to Good	1.0	2850+	2850+	2850+	----	---	----
" 1.50	" 1.60	31.3	20.3	48.4	Poor	1.2	2700	2850+	2850+	150+	150+	+
" 1.60		59.0	15.1	25.9	Agglomerate	0.7	2680	2850+	2850+	170+	170+	+

Table XI

Float and Sink Data on 1¼"–4 in. lump

– Ash –

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
							1.35	[illegible]
Floats 1.30	4.9	7.5	4.9	7.5	100.0	13.4	1.40	83.6
Sinks 1.30 " 1.40	72.2	9.1	77.1	9.0	95.1	13.7	1.45	29.9
" 1.40 " 1.50	9.4	22.0	86.5	10.4	22.9	28.1	1.55	12.3
" 1.50 " 1.60	9.6	24.5	96.1	11.8	13.5	32.4	1.65	4.4
" 1.60	3.9	51.8	100.0	13.4	3.9	51.8	1.75	1.2
Curve No.	4	2	1,2,4	1	3	3	5	5

Table XII

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight.......................%	100.0	85.7	14.3
Proximate Analysis (Dry Basis)			
Ash.........................%	14.0	7.6	50.6
Volatile Matter.............%	21.2	22.2	15.9
Fixed Carbon................%	64.8	70.2	33.5
Sulphur.....................%	0.8	0.8	0.6
Calorific Value BTU/lb.....	13320	14340	----
Fusion Point of Ash........°F	2850+	2850+	2850+
Melting Range of Ash.......°F	150+	+	300+
Coking Properties...........	Good	Good	Poor

Table XIII

Fusain in Raw Coal, Clean Coal, and Refuse

		Fusain % of Pure Coal
1-1/2 " Slack (Raw)		1.64
Clean Coal:	Floats	1.71
Refuse:	Sinks	6.18

Table XIV

Screen Analysis and Chemical Analysis (Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. Weight %	Ash %	Sulphur %	F.P.A. °F
3/4 - 1-1/2 in.	25.1	25.1	15.3	0.8	2850+
1/8 - 3/4 in.	34.5	59.6	14.2	0.8	2850+
0 - 1/8 in.	40.4	100.0	11.3	100	2850+

Table XV

Float and Sink Data on Screened Sizes Using a Selected Gravity of 1.50

	Floats				66 Sinks			
	Weight %	Ash %	Sulphur %	F.P.A. °F	Weight %	Ash %	Sulphur %	F.P.A. °F
3/4 - 1-1/2 in.	78.2	8.7	0.8	2850	21.8	62.3	0.6	2850
1/8 - 3/4 in.	82.3	7.6	1.1	2850+	17.7	48.8	0.6	2850
0 - 1/8 in.	88.8	6.4	0.9	2850+	11.2	47.7	0.7	2850+

V

COKING PROPERTIES

1. "Swelling Index" Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories, which has been outlined and published by the Mines Branch.1/ This test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the "Swelling Index" is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

Samples of the raw and washed 1-1/2 in. slack from the No.3 Seam were subjected to the above test, the results being shown in Table XVI.

2. "Caking Index" Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. This phenomenon has been thoroughly studied and methods have been developed for the determination of the "caking index". While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the "caking value" is of importance when it is desired to mix inert carbonaceous material or non-coking coals with coking coals.

The method developed by Gray, in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C., has been adopted as a standard at the Fuel Research Laboratories. The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to

1/ "A Laboratory Test On Coals for Predicting the Physical Properties of the Resultant By-Product Coke" - by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No.737-2.

support a weight of 500 grammes, is designated as the "caking index". The higher the "Caking Index" the greater the coking properties. The results of this test, as applied to the run-of-mine coal from the No.3 Seam, are shown in Table XVI.

Table XVI

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

As indicated by a

"SWELLING INDEX" TEST

	1-1/2 in. Slack As received	1-1/2 in. Slack After Washing
Volatile Matter at 600°C. (D.B) ......%	15.6	17.1
Swelling Index.........................	880	1023
Section --Coke Classification Chart....	Border of II & I	II
Specific Volatile Index................	197.6	194.7
Section--Coal Classification Chart.....	H - Metabituminous	
Ash per cent in coal (dry).............	14.0	7.6
PHYSICAL PROPERTIES OF BY-PRODUCT COKE		
Size on wharf(% on 3" screen..........	25.0	30.0
(Breeze: %-1/2".........	2.5	2.0
Shatter Test (Index: % on 2" screen..	55.0	60.0
(Breeze: %-1/2".........	3.0	2.5
Abrasion test(Index:% on 1½" screen..	85.0	90.0
(Dust: %-1/16..........	3.5	3.0
Density (App. Specific Gravity..	0.95	0.90
(Lbs. per cubic foot....	26.0	25.0
Transverse shrinkage................	Very Poor	Fair
Appearance of natural surface........	Steel grey	Steel grey smooth
Shape............................	square	square
Strength.........................	Hard	Hard
Cross fracture......................	Med. to large amt. square	Med. to large amt. square
Cell structure......................	dense	Dense
Sponge............................	Very little	Very little
Pebbly seam......................	none	none
TYPE OF TEST.....................		
REMARKS..........................	This coal approaches the Pocahantas Type of blending coal and can not be used alone in by-product coke ovens	Washing improves the contraction characteristics of the coal, but not sufficiently. Thiscoal cannot be used alone in by-product ovens

Caking Properties

	Gray Caking Index
Run-of-Mine Sample.........	45

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Michel Mine, No.3 Seam operated by The Crow's Nest Pass Coal Co., Ltd. in the Crowsnest area, British Columbia, was collected at the mine by sampling at the tipple. In this way, 2,026 lbs. of coal, considered to be representative of the output of the coal from this seam was collected and shipped to the Fuel Research Laboratories for the investigation as to the Physical and Chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories are shown in Table I, which contains the percentage of the various screened sizes on the "as received" basis. On this basis it will be noted that 27.2% of the coal was below 1/8-in. in size, 14.8% was above 4-in. in size, 14.4% 2 - 4 in. in size, the remaining 43.6% being distributed between the other sizes. The amount of dust, i.e., material passing a 48-mesh screen, was very high in quantity amounting to 10.9% of the total coal. The average size of the run-of-mine coal "as received" was 1.551 inches yielding 56.4% of 3/4-in. slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results of the run-of-mine coal agfee very well with other coals of similar ash contents, the individual screen sizes above 1/8 in. having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the No.3 Seam are shown in Table II. One single size and two mixed sizes prepared from the run-of-mine coal were tested according to the method described in publication No.762 of the Mines Branch. The table contains the results of a two-drop test on the various sizes studies, as well as the results of a four-drop test on the mixed size samples. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines. In the 0 - 4" coal, after four drops, the "Size stability" was 86.6%, whereas, the "size stability" of the 3/4" to 4", after only two drops, was 79.2. It is noteworthy that the single size tested had a relatively low size stability, namely 73.8% for the 2" - 3" lumps.

The grindability indices for three sizes of coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method which has been described in Mines Branch publication No.737-1 although the finer sizes of the coal appear to be more easily pulverized than the coarser sizes, it is quite evident that the coal as a whole should pulverize very readily.

Chemical Properties

The proximate and ultimate Analyses of the various screen sizes are shown in Tables IV and V respectively. It will be noted, referring to Table IV, that the ash content of the various sizes with the exception of the plus 4 in. lump is fairly uniform, varying from 11.2% to 15.9%. There appears to be an increase in ash content in the intermediate sizes, showing a increase from 9.5% for the +4 in. lump to 15.9% for the 1/2-3/4 in. size, and then a decrease to 11.3% for the 0 - 1/8 coal. The composites vary in ash content according to the proportion of the sizes included, the run-of-mine coal yielding 12.0% of ash, whereas the 3/4" to 4" lumps yields 15.5% ash. The sulphur content is low and uniform for all the sizes ranging from 0.7% to 1.0% with an average for the run-of-mine amounting to 0.8%.

The volatile matter of the coal is low to medium and, based on the "Specific Volatile Index" 1/ method of classification, this coal has an index of approximately 196 which places it in Section H of the metabituminous blending coals. According to the A.S.T.M. classification Designation D 388-36T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is Medium Volatile Bituminous.

Table V gives the Ultimate Analyses of the 0 - 4 in. composite. The coal is a fairly high carbon and low oxygen material.

Table VII shows the results of the ash fusion determinations

1/ Classification of Coals Using Specific Volatile Index" by R.A. Strong, E.J. Burrough & E. Swartzman-Mines Branch publication #725-2 including the melting range and the solftening and fluid intervals for the various sizes of coal; whereas Table VIII gives the chemical analyses of the ash of a composite of sizes. It will be noted that the Softening Temperatures of the ashes for the various sizes are very uniformly high, all showing a value of 2850+°F.

The forms of sulphur for the 0 - 4 in. composite prepared from the run-of-mine coal are shown in Table VI. The pyritic sulphur is very low, amounting to 0.04% of the total coal i.e., 4.6% of the total sulphur is due to the presence of pyrite.

The distribution of fusain in the coal from the No.3 Seam is also shown in Table VI. It will be noted that the fusain content of the coal is low in quantity, being 2.09% in the 0" - 4" size. It is evidently very uniformly distributed throughout all the larger sizes, there being some concentration in the larger sizes, the 1/8 - 4 in. coal showing a fusain content of 2.53% as against 1.42% for the 0 - 1/8 in. fines.

Laboratory Washing Tests

The washing test on the coal from the No.3 Seam were conducted in the standard manner on a sample of 1-1/2 in. slack, prepared from the run-of-mine coal and on the 1-1/2 in to 4 in. lumps. The results are given in a series of tables and curves shown in section IV. Referring to Tables IX and X, it will be noted that the 1-1/2 in. slack contains 3.5% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 45.1% of the coal is recovered. The sulphur is low and practically all inherent material. Washing this coal at a specific gravity of 1.50, which according to the ±.10 specific gravity distribution curve represents simple wet washing resulted in the production of 85.7% of clean coal having 7.6% of ash and 0.8% sulphur. The softening temperature of the ash was not changed by washing remaining at 2850+°F. These results are shown in Table XII which gives the chemical analyses of the raw coal, the clean coal, and the refuse. Table XIII gives the fusain content of the above three samples. It will be noted that the refuse shows a decided concentration of fusain. The clean coal indicated no decrease in fusain and no decrease in total sulphur. Tables XIV and XV show that the finer sizes of the 1-1/2 in. slack may be washed to a slightly lower ash content with an attendant lower refuse loss than the larger sizes. The 3/4 - 1-1/2 in. coal is reduced in ash to 8.7% with a refuse loss of 21.8% whereas, the 1/8 - 3/4 in. coal is reduced in ash to 7.6% with a refuse loss of 17.7%. The fines, material through an 1/8 in. screen, may be experimentally washed as easily as the larger sizes, the ash being reduced to 6.4% with a refuse loss of 11.2%. The various sizes react in a similar manner to sulphur reduction. The ash fusion temperature of the various sizes are not altered by washing, remaining high.

Referring to Table XI and Figure III, it will be noted that the 1-1/2 - 4 in. lumps prepared from the run-of-mine coal are not as amenable to washing, as the 1-1/2 in. slack. The inherent ash is high as indicated by the material floating at a specific gravity of 1.30. There was only 4.9% of this coal containing 7.5% ash. From the data and the curves it will be readily seen that this lump coal may be easily washed at a gravity of 1.55 to yield a product containing approximately 10.5% ash with a refuse loss amounting to about 7% of the total coal washed.

Coking Properties

The phenonemon of coking, whereby a bituminous coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or "caking". Various methods have been introduced for the determination of these two properties with a view to predicting the the reaction of a coal in by-product ovens. A Method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No.737-2. The calculated value

"Swelling Index" is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the 1-1/2 in. slack before and after washing, are shown in Table XVI. It will be noted that the "Swelling Index" of ~~hte~~ the raw coal is 880, and, on the basis of this test, indicates a coal that would result in the production of a very good coke when processed in by-product ovens. However, it should be noted, this coal could only be used when blended with high volatile coals, because of its poor shrinkage characteristics. Washing results in substantial impreovement in the coking properties, the swelling index of the coal increasing to 1023. This washed coal when blended with high volatile coals, should be very satisfactory for coke production in standard by-product ovens.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The "Caking Index" determined by this method, and described in Section V, does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The results of the caking index test on a sample of the run-of-mine coal from the No.3 Seam are shown in Table XVI. The index for the coal is 45 indicating a good caking coal.

Appendix

Study of Channel Samples

I <u>Samples Collected</u>

Usually a coal seam varies in quality both vertically through the deposit and also laterally from one location to another. In view of the importance of this variation in relation to the preparation and use of the coal, it was decided to study channel samples of No.3 seam in addition to the regular tipple sample of run-of-mine coal collected for the Physical and Chemical Survey.

Channel samples from three different locations in the mine were collected as follows:

(A) From No.4 Incline - at the Face

(B) From No.3 room off No.9 Incline

(C) From the new chute at the foot of No.12 Incline

These locations are indicated on the Mine plan, Figure 1.

Each channel sample was divided into three sections vertically, depending upon either marked differences in the coal itself, or upon separation by dirt bands. These sections were as follows:

(A) <u>No.4 Incline - at the face</u>
(a) 57 in. Top coal
(b) 60 in. Middle coal
(c) 15 in. Bottom coal. This portion had no definite partings, and was much slickensided
Total thickness = 132 in.

(B) <u>No. 3 room off No. 9 Incline</u>
(a) 19 in. Top coal
(b) 49 in. Middle coal
(c) 48 in. Bottom coal - No visible impurties
Thickness = 116 in.

(C) <u>New Chute at the foot of No.12 Incline</u>
(a) 36 in. Top coal
(b) 42 in. Middle coal
(c) 39 in. Bottom coal
Total thickness = 117 in.

This seam apparently differs considerably in appearance from either "A or B", inasmuch as it is more uniform, visible impurities being entirely absent save from a few lenses of stone occuring occasionally.

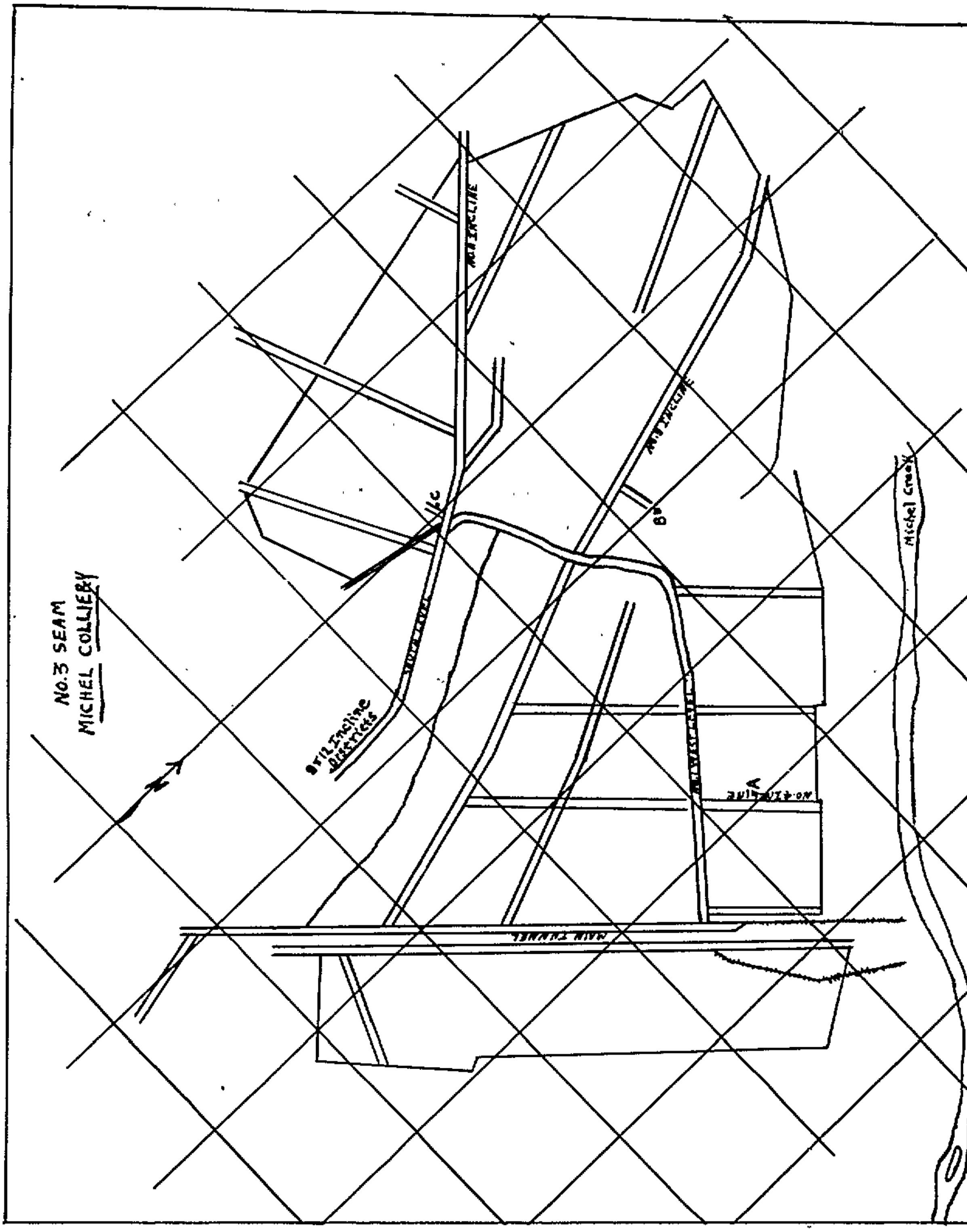


Figure 1

II Analyses

The proximate analyses, sulphur contents and ash fusibilities of the various channel samples are shown in the following tables. All the analyses were calculated for the composites of the sections of each channel sample.

TABLE I

Analysis-Dry basis	A - 4 Incline, Face Top Coal 57 in.	Middle Coal 60 in.	Bottom Coal 15 in.	Composite Total 132 in.
Ash...............%	6.6	6.7	10.6	7.1
Volatile Matter....%	22.8	22.7	23.8	22.9
Fixed Carbon.......%	70.6	70.6	65.6	70.0
Sulphur............%	0.6	0.8	0.9	0.7
Coking Properties..	Good	Good	Good	Good
Ash Fusibility.....				
Initial.......°F	2850+	2800	2850+	2850+
Softening.....°F	2850+	2850+	2850+	2850+
Fluid.........°F	2850+	2850+	2850+	2850+

TABLE II

Analysis-Dry basis	B - 3 Room off 9 Incline Top Coal 19 in	Middle Coal 49 in.	Bottom Coal 48 in.	Composite Total 116 in.
Ash...............%	9.2	9.5	10.5	9.9
Volatile Matter....%	23.7	22.4	21.7	22.3
Fixed Carbon.......%	67.1	68.1	67.8	67.8
Sulphur............%	0.7	0.7	0.6	0.7
Coking Properties..	Good	Good	Good	Good
Ash Fusibility.....				
Initial.......°F	2800	2850+	2700	2800+
Softening.....°F	2850+	2850+	2850+	2850+
Fluid.........°F	2850+	2850+	2850+	2850+

TABLE III

Analysis-Dry basis	C-New Chute-Foot of 12 Incline Top Coal 36 in.	Middle Coal 42 in.	Bottom Coal 39 in.	Composite Total 117 in.
Ash...............%	11.7	9.8	7.7	9.7
Volatile Matter....%	21.0	21.2	21.3	21.2
Fixed Carbon.......%	67.3	69.0	71.0	69.1
Sulphur............%	0.8	0.7	0.9	0.8
Coking Properties..	Good	Good	Good	Good
Ash Fusibility.....				
Initial.......°F	2700	2850+	2600	—
Softening.....°F	2850+	2850+	2850	2850+
Fluid.........°F	2850+	2850+	2850+	2850+

III Discussion of Results

As indicated in Figure 1, the channel samples from No.3 seam, Michel Colliery, have been taken from the mine in the West level district. Samples A and B were taken from the South section, whereas sample C was taken from the Northern section near the new development work.

Each channel sample was divided from roof to floor into three sections depending either upon differences in the coal itself or upon separation by dirt bands. Figure 2 gives a diagramatic representation of the channel samples collected, showing the vertical sections and indicating the ash and volatile matter of these sectional samples.

It should be noted that the seam does not vary appreciably in thickness, the channel samples collected ranging from 116 in. to 132 in. From the samples studied it seems that the coal seam is thicker in the section approaching the eastern district, where sample A shows a thickness of 132 in. in comparison to an average thickness of approximately 117 in. for the samples B and C taken in a more westerly direction.

The disivion of the seam into roof, middle and floor coal does not appear to be very clearly defined in any of the samples collected. Examination of the ash contents of the

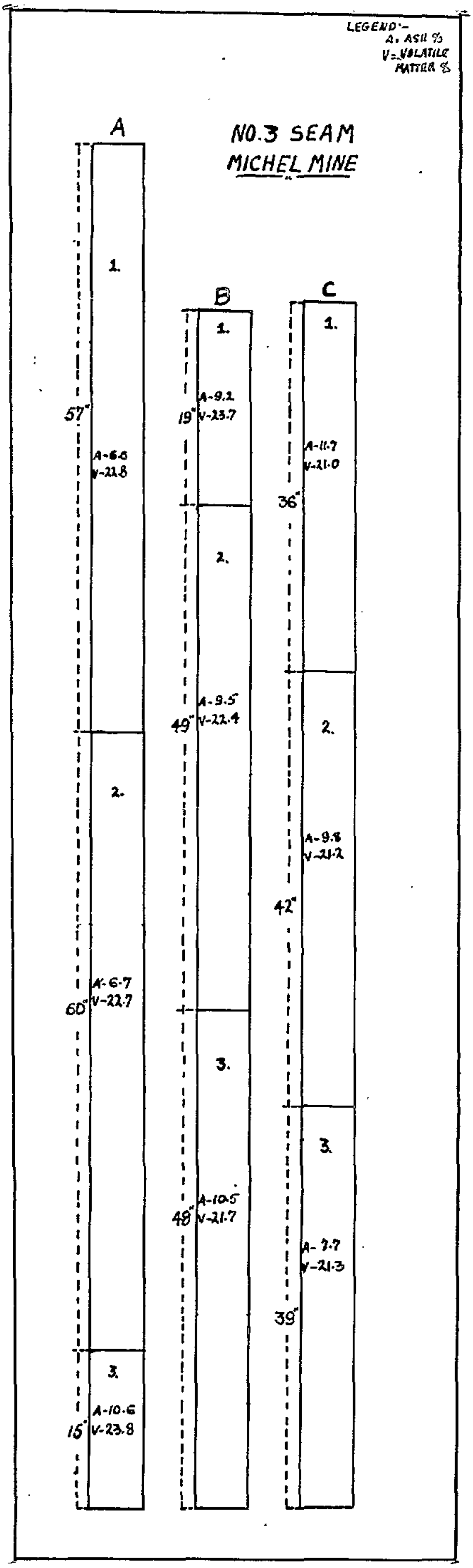

LEGEND:-
A. ASH %
V. VOLATILE MATTER %
NO.3 SEAM
MICHEL MINE
A
B
C
1.
2.
3.
57"
A-6.6
V-21.8
60"
A-6.7
V-22.7
15"
A-10.6
V-23.8
19"
A-9.2
V-23.7
49"
A-9.5
V-22.4
48"
A-10.5
V-21.7
36"
A-11.7
V-21.0
42"
A-9.8
V-21.2
39"
A-7.7
V-21.3

Figure 2

sections, shown in Figure 2 indicates that, there is no appreciable concentration of mineral matter in either the roof or floor coal, the ash contents for all samples varying from 6.6 to 11.7%.

The volatile matter contents of the various sections are fairly uniform throughout the whole portion of the seam sampled, varying from 21.0 to 23.8%. It should be noted that sample C, indicates throughout its vertical height a lower volatile matter content than the other two channel samples, and this decrease in volatile matter cannot be accounted for by an increase in the mineral content of the coal, as samples B and C have practically the same ash contents.

The ash fusibility of the coal is very uniform both vertically and from one location ~~at~~ to the other. In all cases the softening temperature of the ashes was very high, namely 2850+°F.

An examination of the analysis of the composite of each channel sample, shown in Tables I to III, inclusive, indicates the run-of-mine coal should not vary to any great extent in so far as its major chemical and physico-chemical properties are concerned. The ash varies from 7.1% to 9.9%, the volatile matter from 21.2% to 22.9% and the softening temperature of the ash should be uniformly high at 2850+°F. Reduction of the quantity of mineral matter in the coal should have no material influence on the other characteristics of the coal.

4

Report of Investigations--Carbonization Section - 130

Physical and Chemical Survey Report No. 60

Study of Coal From

Michel Mine, No.1 Seam, Crowsnest Area, B.C.

Operated By

The Crow's Nest Pass Coal Co. Ltd., Fernie, B.C.

By

R.A. Strong, E. Swartzman E.J. Burrough
and J.H.H. Nicolls

Fuel Research Laboratories

LBL

November, 1939

Physical and Chemical Survey Report No. 60

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Table of Contents

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I

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Michel Mine, No.1 seam worked in the Crowsnest area in the Michel Creek district 24 miles northwest of Fernie, British Columbia, by the Crow's Nest Pass Coal Co. Ltd., of Fernie, British Columbia. This Study is part of the investigation dealing with the Physical and Chemical characteristics of the mines operating in the Province of British Columbia. Fifty-nine reports have already been issued on the Physical and Chemical survey of Canadian coal seams, and, accordingly, this present in investigation was conducted in the same manner as that adopted for the previous studies. The report is, therefore, presented in sections dealing with the following subjects;

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The run-of-mine coal from the No.1 Seam was sampled by an official from the Fuel Research Laboratories in the presence of a representative from the operating company. The combined sample, which weighed approximately 2,000 pounds, was bagged for shipment to the Fuel Research Laboratories at Ottawa. In addition to the above, channel samples were taken at various locations. These were also shipped to Ottawa for examination, the results of this study appearing as an appendix to this report.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railways for the aid given in connection with the collection of the samples of coal herewith reported.

II

PHYSICAL PROPERTIES

1. Screen Analyses

The sample of coal from the No.1 Seam was collected at the tipple, a representative portion being taken from the various working places at the time of sampling. In this manner, a sample of run-of-mine coal weighing 2,010 pounds and representative of the output of the mine was collected. This sample was used for the screening test, standard round-hole screens made from 1/4" plate being employed. The results of this test are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two - or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by a modification of the method for determining the apparent gravity of coke as outlined in the Gas Chemists' Hand book. The results of the above two tests are also presented in Table I.

TABLE I

Screen Analysis Specific Gravity and Bulk Density

Screen Sizes	As received % By weight	As received % Cumulative	Specific Gravity	Bulk Density (lbs/cu.ft.)	Ash %
Plus - 4 in.	7.5	7.5	1.27	44.75	5.3
2 - 4 in.	12.9	20.4	1.34	45.00	9.3
1-1/2 - 2 in.	2.8	23.2	1.39	42.50	9.3
1 - 1-1/2 in.	5.8	29.0	1.35	44.25	13.0
3/4 - 1 in.	4.2	33.2	1.41	43.50	15.6
1/2 - 3/4 in.	6.7	39.9	1.39	43.25	17.4
1/4 - 1/2 in.	15.3	55.2	1.35	43.25	16.5
1/8 - 1/4 in.	11.9	67.1	1.32	41.25	15.5
No.48 - 1/8 in.	22.3	89.4	1.28	48.75	13.5
0 - No.48 in.	10.6	100.0			11.3
Mine Run		100.0		55.25	12.7
0 - 4 in.		92.5		56.00	13.9
1/8 - 4 in.		59.6		51.25	17.9
3/4 - 4 in.		25.7		47.25	15.5
0 - 3/4 in.		66.8		55.00	15.6
0 - 1-1/2 in.		76.8		56.75	14.1
0 - 1/8 in.		32.9	1.28	48.75	12.5

	As Received
Weight of Sample..................lbs.	2010.0
Average Size of Coal after Shipment from Mine to Ottawa....in.	1.058

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3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials(A.S.T.M.) with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal", has been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls and G.P. Connell, Mines Branch publication No.762. This tentative method was used for testing the relative "size stability" of single sizes. The term "size stability" is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index"1/

The results of ~~his~~ the friability study on the coal from the No.1 Seam are shown in Table II. The samples of the single sizes and the mixed sizes which were tested are as follows: 2" to 3"; 3/4" to 4", and 0 to 4"; in all three samples were tested.

4. Grindability

For the determination of the grindability, or the ease of pulverizability, of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Co. has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coals from the No.1 Seam.

1/ Quoted from the above mentioned publication of the Mines Branch
2/ "Tentative Method of Test for Grindability of Coal By the Hardgrove Machine Method" A.S.T.M. Designation D 409-35T.

TABLE II

Size Stability (Friability)

Sizes tested and number of drops	Screen analysis of coal before and after dropping; percent weight retained on — Round hole screens						Square		Average size of coal before and after test inches	Size stability per cent
	3"	2"	1½"	1"	3/4"	1/2"		-1/2"		
Single Sizes										
2 to 3 " lumps(1)*									2.500	
10 drops		40.0	12.5	9.0	5.0	5.5		28.0	1.480	59.2
Mixed Sizes										
3/4 - 4 in.										
Sample (1)	8.2	42.0	10.9	22.6	16.3				1.954	
2 drops	3.8	19.6	12.1	15.0	12.5	9.6		27.4	1.261	64.5
4 drops	0.0	16.3	9.6	11.2	11.7	10.4		40.8	0.985	50.4
0 - 4 in.	3"	2"	1½"	1"	3/4"	1/2"	1/4"	-1/4"		
Sample(1)	2.3	11.7	3.0	6.3	4.5	7.2	16.5	48.5	0.713	
2 drops	0.0	6.3	3.8	9.2	5.8	8.3	17.9	46.7	0.571	80.1
4 drops	0.0	5.4	3.8	6.3	5.0	7.9	16.7	54.9	0.506	71.0

* This and other bracketed figures in this column are the numbers of fifty-pound tests averaged.

TABLE III

Grindability

Screen Size Tested	Hardgrove Index
0 - 4 in.	107.2
0 -3/4 in.	110.4
0 -1/8 in.	115.2

For comparison, three samples of varying screen-size prepared from the run-of-mine coal, were selected for testing as follows:

0 - 4 in.	Composite
0 -3/4 in.	Slack, and
0 -1/8 in.	Slack

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the No.1 Seam were subjected to certain chemical and physical-chemical analyses as follows:

1. The Proximate Analyses including the sulphur and the calorific value which are shown in Table IV

2. The Ultimate Analyses for the selected size mixture which are presented in Table V.

3. The Sulphur Forms in the coal which were determined according to the accepted Powell method, whereby the sulphite sulphur is determined by extraction with hydrochloric acid; the pyritic sulphur by oxidation with nitric acid, and the organic sulphur by the difference between the inorganic sulphur and the total sulphur, the results being presented in Table VI.

4. The Distribution of Fusain the importance of fusain with respect to its influence on the spontaneous combustion of coal, and its effect on the coking properties of the coal necessitates a study of the quantitative distribution of this petrographic coal constituent. The Carbonization Section of the Fuel Research Laboratories have adopted the Heathcoat method, with certain modifications, for determining fusain. This method takes advantage of the fact that, in bituminous coals, fusain is more resistant to oxidation than the other coal constituents; hence after oxidizing the insoluble humic material to an alkaline-soluble humic substance, the more resistant fusain is collected by filtration. The results of this test, together with the forms of sulphur for the samples examined are shown in Table VI.

5. The Fusibility of the Ash including the Melting Range, and Softening and Fluid Intervals of the Ash, which are given in Table VII; the data on temperature lags being presented because of their bearing on the clinkering properties of the ash.

6. The Chemical Analyses of the Ash which are shown in Table VIII.

TABLE IV

Chemical Analyses of Coal

Proximate, Sulphur, and Calorific Value

Screen Sizes	Moisture (as rec'd)	Dry Basis				
		Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/lb.
Plus - 4 in.	1.0	5.3	24.8	69.9	0.5	---
2 - 4 in.	0.9	9.3	24.0	66.7	0.5	---
1-1/2 - 2 in.	0.9	9.3	23.6	67.1	0.5	---
1 - 1-1/2 in.	0.9	13.0	23.2	63.8	0.5	---
3/4 - 1 in.	0.9	15.6	22.5	61.9	0.5	---
1/2 - 3/4 in.	0.8	17.4	22.4	60.2	0.4	---
1/4 - 1/2 in.	0.9	16.5	22.4	61.1	0.5	---
1/8 - 1/4 in.	1.1	15.5	22.6	61.9	0.5	---
No. 48 - 1/8 in.	1.0	13.5	23.1	63.4	0.6	---
0 - No. 48.	1.1	11.3	23.7	65.0	0.6	---
Mine Run	1.0	12.7	23.3	64.0	0.6	13,425
0 - 4 in.	1.1	13.9	23.0	63.1	0.5	13,405
1/8 - 4 in.	1.0	17.9	22.2	59.9	0.4	12,645
3/4 - 4 in.	1.0	15.5	22.6	61.9	0.5	12,960
0 - 3/4 in.	1.0	15.6	22.9	61.5	0.5	13,100
0 - 1-1/2 in.	1.0	14.1	23.0	62.9	0.5	13,345
0 - 1/8 in.	1.0	12.5	22.3	65.2	0.5	13,545

TABLE V

Ultimate Analyses

Sample	Dry Basis					
	Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
0 4 in.	75.3	4.7	0.5	1.4	4.2	13.9

TABLE VI

Sulphur Forms & Fusain

Sample	Total Sulphur	Sulphate Sulphur		Pyritic Sulphur		Organic Sulphur		Fusain
	% of Coal	% of Coal	% of sulphur	% of coal	% of sulphur	% of coal	% of sulphur	% of Pure Coal
0 - 4 in	0.48	0.0	0.0	0.01	2.1	0.47	97.9	1.71
1/8 - 4 in								2.50
0 - 1½ in								1.81
0 - 1/8 in								2.02

TABLE VII

Fusibility of Ash

Sample	Initial Deformation °F	Softening Temperature °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F	Ash %
Plus - 4 in.	2850+	2850+	+	+	+	+	5.3
2 - 4 in	2760	2850+	+	90+	90+	+	9.3
1-1/2 - 2 in.	2740	2850+	+	110+	110+	+	9.3
1 - 1-1/2 in.	2750	2850+	+	100+	100+	+	13.0
3/4 - 1 in.	2850+	+	+	+	+	+	15.6
1/2 - 3/4 in.	2750	2850+	+	100+	100+	+	17.4
1/4 - 1/2 in.	2750	2850+	+	100+	100+	+	16.5
1/8 - 1/4 in.	2800	2850+	+	50+	50+	+	15.5
No. 48 - 1/8 in.	2850+	+	+	+	+	+	13.5
0 - No. 48	2850+	+	+	+	+	+	11.3
Mine Run	2800	2850+	+	50+	50+	+	12.7
0 - 4 in.	2840	2850+	+	10+	10+	+	13.9
1/8 - 4 in.	2800	2850+	+	50+	50+	+	17.9
3/4 - 4 in.	2740	2850+	+	110+	110+	+	15.5
0 - 3/4 in.	2760	2850+	+	90+	90+	+	15.6
0 - 1-1/2 in.	2770	2850+	+	80+	80+	+	14.1
0 - 1/8 in.	2850+	+	+	+	+	+	12.5

TABLE VIII

Chemical Analysis of Ash

Sample	SiO_2	Fe_2O_3	Al_2O_3	CaO+ MnO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	Total
0 - 4 in.	58.4	3.7	31.7	1.3	1.0	Nil	1.3	1.1	0.5	1.5	100.5

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float and sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1-1/2-in slack and on the 1-1/2-¼ in lumps prepared from the run-of-mine coal, is presented in several tables and has been plotted as shown in the accompanying curves. The method used for plotting the data is patterned after that of J.H. Campbell of the American Rheolaveur Corporation, to which has been added the "Specific Gravity Distribution" curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves representing the following information:

Curve 1, which is the cumulative float ash per cent curve, represents the variation of the ash.

Curve, 2 represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ±.10 specific gravity curve of distribution, represents a measure of the comparative difficulty of separation, according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following tables:

+.10 Curve	Degree of Difficulty	Preparation
Per Cent		
2 - 7	Simple.................	Almost any process; high tonnage
7 - 10	Moderately difficult..	Efficient process; high tonnage
10 - 15	Difficult............	Efficient process; medium tonnage
15 - 20	Very difficult........	Efficient process; low tonnage
20 - 25	Exceedingly difficult.	Very efficient process; low tonnage
Above 25	Formidalbe...........	Limited to a few exceptionally efficient processes

For the ordinary study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. If a horizontal line is drawn from this point on Curve 4 (Specific Gravity Curve) the point at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur, However, as the total sulphur of the coal is low a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction in ash, which is possible under varying conditions of washing the 1½ in. slack are presented in Figure I. Figure II presents the sizing curve and the ash and sulphur contents of the various screen sizes, as well as the data obtained by washing the sized coal fraction at a selected gravity of 1.45. This includes the ash contents of the floats at this gravity, as well as the quantity recovered and the percentage of ash in the sinks. Figure III gives the washability curves for the 1-1/2-4 in lumps.

All of the data used in the construction of the curves are presented in the following tables:

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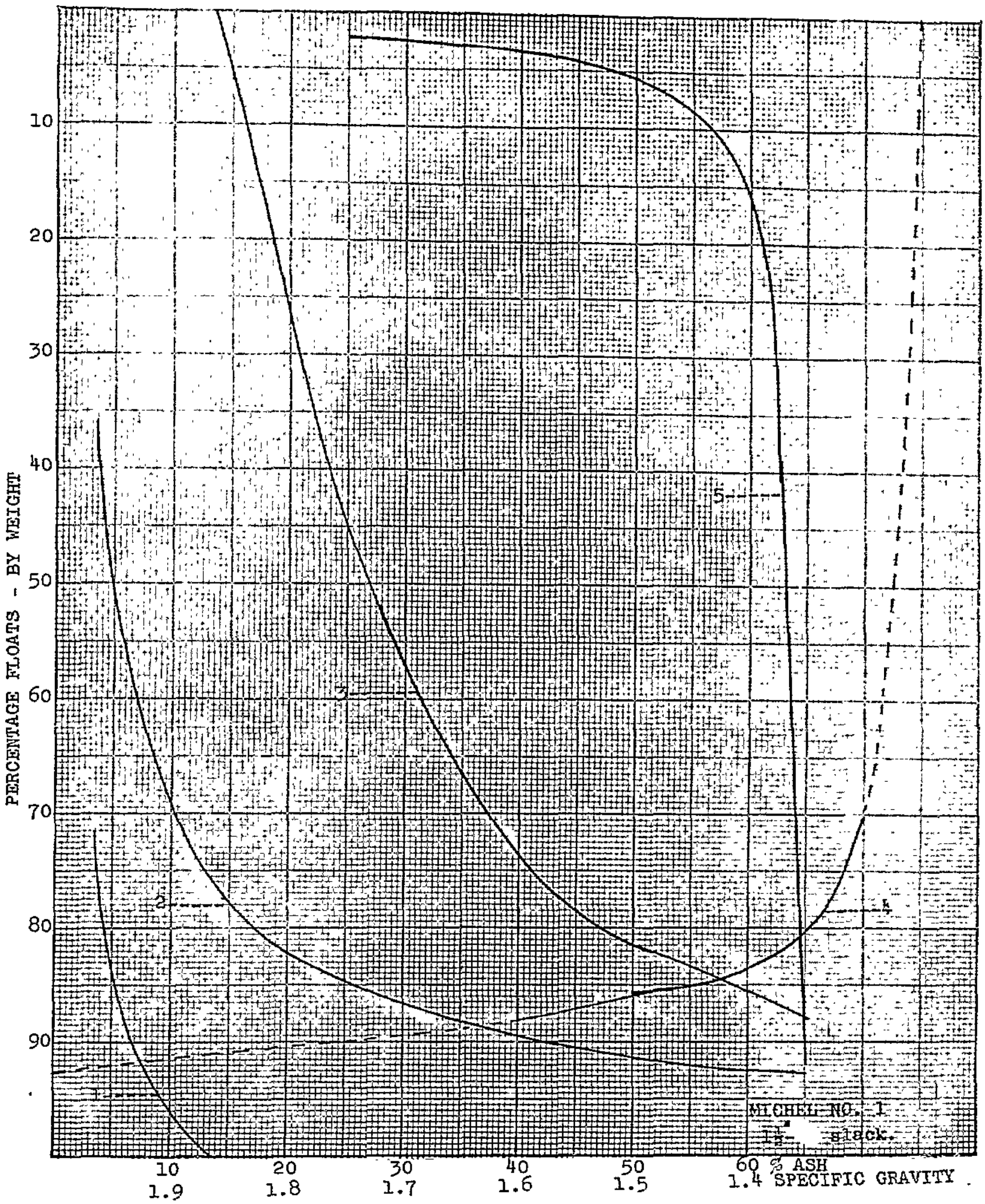

FIG. I - Washability Curves for Michel No.1 Seam Coal - Ash

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution

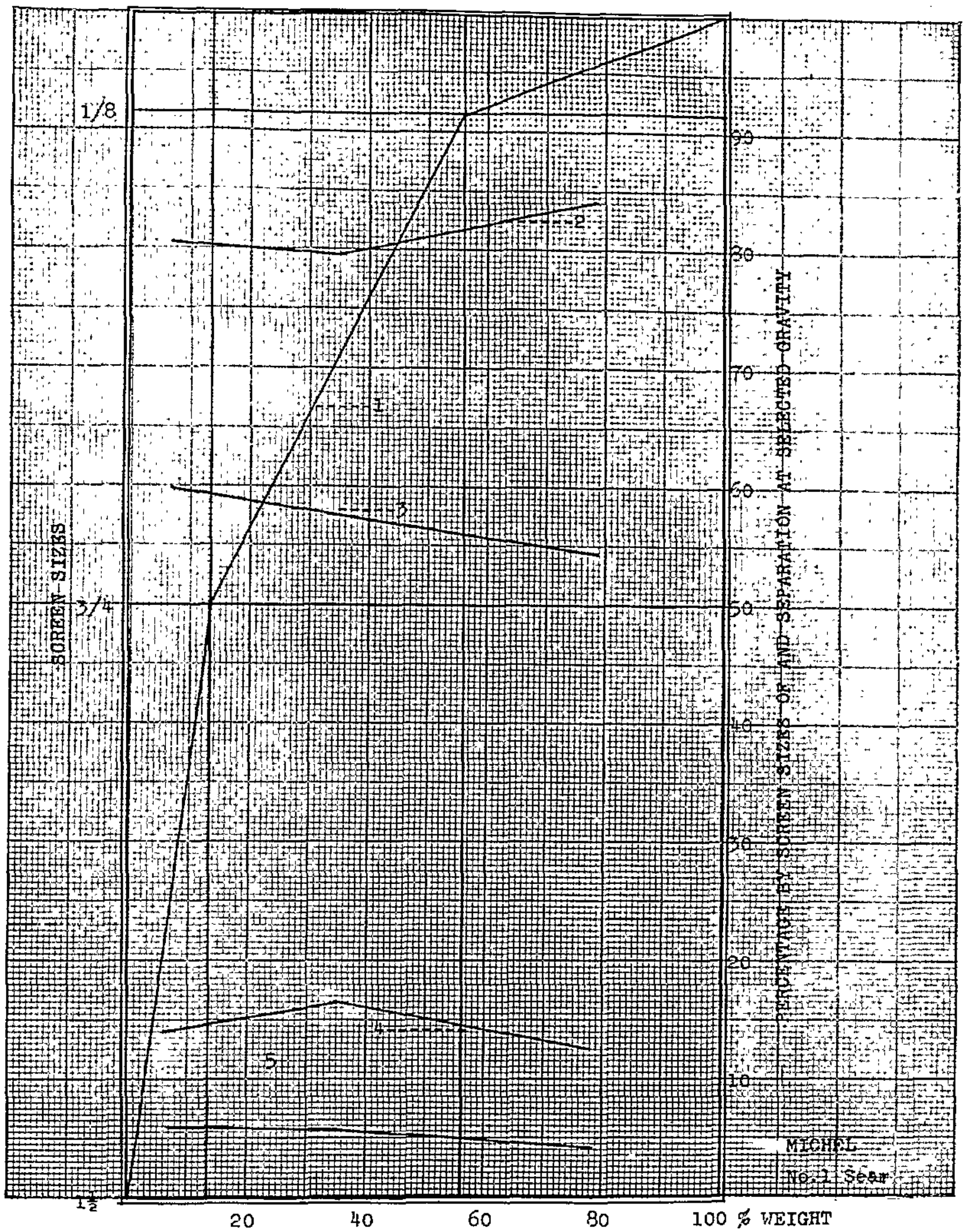

FIG. II - Curves showing screen analysis and Washing Data On Screen Sizes for Michel No. 1 Seam.

Curve 1 - Sizing curve
Curve 2 - Percentage float at 1.45 specific gravity
Curve 3 - Percentage ash in sinks at 1.45 specific gravity
Curve 4 - Percentage ash in screen sizes
Curve 5 - Percentage ash in floats at 1.45 specific gravity

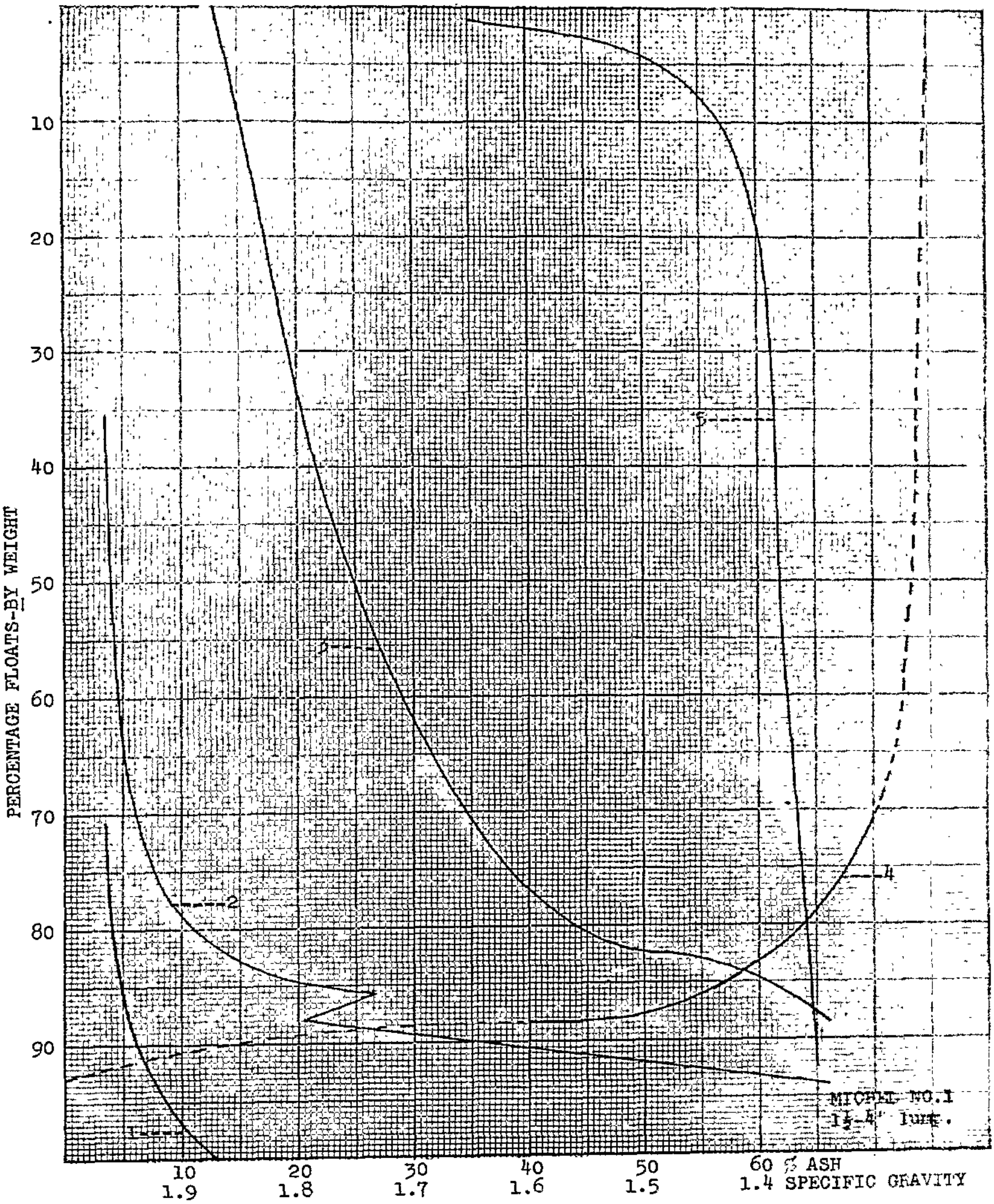

FIG. III - Washability Curves for Michel No.1 Seam Coal - 1½"- 4" Lump

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution

TABLE IX

Float and Sink Data on 1½" Slack

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
								1.35	92.0
	Floats 1.30	71.6	3.4	71.6	3.4	100.0	13.4	1.40	15.6
Sinks 1.30	" 1.40	11.4	14.4	83.0	4.9	28.4	38.6	1.45	7.9
" 1.40	" 1.50	3.0	26.5	86.0	5.7	17.0	55.1	1.55	4.3
" 1.50	" 1.60	1.8	31.7	87.8	6.2	14.0	60.8	1.65	3.2
" 1.60		12.2	65.1	100.0	13.4	12.2	65.1	1.75	1.8
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

(Dry Basis)

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
	Floats 1.30	3.4	24.5	72.1	Good	0.5	2850+	+	+	+	+	+
Sinks 1.30	" 1.40	14.7	22.2	63.1	Good to Fair	0.4	2850+	+	+	+	+	+
" 1.40	" 1.50	26.6	20.4	53.0	Poor	0.5	2850+	+	+	+	+	+
" 1.50	" 1.60	32.1	20.5	47.4	Poor	0.9	2850+	+	+	+	+	+
" 1.60		65.4	14.8	19.8	Agglomerate	0.2	2850+	+	+	+	+	+

TABLE XI

Float and Sink Data on 1½-4 in. Lumps

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats 1.30	70.8	3.5	70.8	3.5	100.0	12.7	1.35	92.4
Sinks 1.30	" 1.40	12.0	8.2	82.8	4.2	29.2	34.9	1.40	18.3
" 1.40	" 1.50	5.0	26.4	87.8	5.4	17.2	53.6	1.45	7.6
" 1.50	" 1.60	0.3	20.3	88.1	5.5	12.2	64.7	1.55	2.7
" 1.60		11.9	65.8	100.0	12.7	11.9	65.8	1.65	0.8
Curve No	4		2	1,2,4	1	3	3	5	5

TABLE XII

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw Coal	Clean Coal Floats 1.45	Refuse Sinks 1.45
Weight....................%	100.0	80.2	19.8
Proximate Analysis (D.B.)			
Ash.......................%	14.1	5.4	53.6
Volatile Matter...........%	23.0	23.8	17.0
Fixed Carbon..............%	62.9	70.8	29.4
Sulphur...................%	0.5	0.5	0.3
Calorific Value BTU/lb..	13,345	14,670	-----
Fusion Point of Ash.....°F	2850+	2850+	2850+
Melting Range of Ash....°F	80+	100+	+
Coking Properties........	Good	Good	Poor.

TABLE XIII

Fusain in Raw Coal, Clean Coal, and Refuse

	Fusain % of Pure Coal
1-1/2" Slack (Raw)......	1.81
Clean Coal:	
Floats.........	2.08
Refuse: Sinks..........	6.01

Table XIV

Screen Analysis and Chemical Analysis of 1½" Slack
(Dry Basis)

Screen Sizes	Weight %	Cum. Weight %	Ash %	Sulphur %	F.P.A. °F
3/4 - 1-1/2 in.	13.0	13.0	14.1	0.5	2850+
1/8 - 3/4 in.	44.1	57.1	16.4	0.5	2850+
0 - 1/8 in.	42.9	100.0	12.5	0.5	2850+

TABLE XV

Float and Sink Data on Screened Sizes

Using a Selected Gravity of 1.45

	Floats				Sinks			
	Weight %	Ash %	Sul-phur %	F.P.A. °F	Weight %	Ash %	Sul-phur %	F.P.A. °F
3/4 - 1-1/2 in.	80.5	6.0	0.5	2850+	19.5	59.7	0.2	2850+
1/8 - 3/4 in.	79.6	5.7	0.5	2850+	20.4	57.3	0.2	2850+
0 - 1/8 in.	84.2	4.2	0.5	2850+	15.8	54.4	0.3	2850+

V

Coking Properties

1. "Swelling Index" Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories, which has been outlined and published by the Mines Branch1/. This test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the "Swelling Index" is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

Samples of the raw and washed 1½ in. slack from the No.1 Seam were subjected to the above test, the results being shown in Table XVI.

2. "Caking Index" Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are more capable of withstanding a higher admixture of inert material, and will yield a carbonized residue of definite crushing strength than are the more inferior coals. This phenomenon has been thoroughly studied and methods have been developed for the determination of the "Caking Index". While these tests are of uncertain value for the purpose of assessing the wide range of coals in their application to the production of by-product coke, a knowledge of the "caking value" is of importance when it is desired to mix inert carbonaceous material or non-coking coals with coking coals.

The method developed by Gray, as modified at the Fuel Research Laboratories, in which 25-gramme mixtures of coal and sand, in varying proportions are carbonized in Illium crucibles

1/ " A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant By-Product Coke" by R.A. Strong E.J. Burrough and E. Swartzman--Mines Branch publication No. 737-2 at 950 C., has been adopted as a standard at the Fuel Research Laboratories. The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designated as the "Caking index". The higher the "caking index", the greater the coking properties. The results of this test, as applied to the run-of-mine coal from the No.1 Seam are shown in Table XVI.

Table XVI

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

As Indicated by a

"SWELLING INDEX" TEST

	1-1/2 in. Slack As received	1-1/2 in. Slack After Washing
Volatile Matter at 600 C. (D.B.).......%	17.3	19.0
Swelling Index..........................	1790	1790
Section--Coke Classification Chart......	II	II
Specific Volatile Index.................	194.4	189.6
Section--Coal Classification Chart......	H - Metabituminous	
Ash per cent in coal (dry)............%	14.1	5.4
PHYSICAL PROPERTIES OF BY-PRODUCT COKE		
Size on wharf (% on 3" screen.........	30.0	40.0
(Breeze: %-1/2".........	2.0	2.0
Shatter test (Index: % on 2" screen..	60.0	60.0
(Breeze: %-1/2".........	2.5	2.5
Abrasion test (Index: % on 1½" screen.	90.0	95.0
(Dust: %-1/16".........	3.0	2.5
Density (App. Specific Gravity..	0.95	0.90
(Lbs. per cubic foot....	26	25
Transverse shrinkage..................	Fair	Fair
Appearance of natural surface.........	steel gray smooth	steel gray smooth
Shape.................................	square	square
Strength..............................	Hard	Hard
Cross fracture........................	Med. to large amt. sq.	Med. to large amt. square
Longitudinal fracture.................	Small to med. amt.	Small to med. amt.
Cell structure........................	Dense	Dense
Sponge................................	Very little	Very little
Pebbly seam...........................	None	None
TYPE OF TEST..........................		
REMARKS...............................	This is unsuitable when used 100% in by-product ovens because of insufficient shrinkage.	Washing slightly improves the contraction properties of this coal, but it all remains a borderline product.

Caking Properties

	Gray Caking Index
Run-of-mine sample.........	55

VI

Summary and Discussion of Results

The run-of-mine sample of coal from the Michel mine operating on the No.1 seam in the Crowsnest Area, Michel Creek district, was collected at the mine by sampling at the tipple. In this way, approximately 2000 pounds of coal, considered to be representative of the output of the coal at this mine, was collected and shipped to the Fuel Research Laboratories for the investigation as to the Physical and Chemical properties.

Physical Properties

The results of the screening test on the coal which was conducted at the Fuel Research Laboratories, are shown in Table I, which contains the percentages of the various screened sizes on the "As received" basis, i.e. as received at Ottawa. On this basis, it will be noted that 32.9% of the coal was below 1/8-in. in size, 7.5% was above 4-in. in size, 12.9% 2 - 4 in. in size, the remaining 46.7% being distributed between the other sizes. The amount of dust, i.e., material passing a 48-mesh screen, was very high in quantity, amounting to 10.6% of the total coal. The average size of the run-of-mine coal "as received" was 1.058 in., yeilding 66.8% of 3/4-in. slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. These results agree very well with those of other coals of similar ash contents, the individual screen sizes above 1/8-in. having uniformly lower bulk density than mixtures of these sizes.

The results of the friability tests on the coal from the No.1 Seam are shown in Table II. One single size and two mixed sizes prepared from the run-of-mine coal were tested according to the method described in publication No. 762 of the Mines Branch. The table contains the results of a two-drop test on the various sizes studied, as well as the results of a four-drop test on the mixed size samples. This latter procedure is preferred for mixed sizes because of the cushioning effect on the fines. In the 0 - 4 in. coal, after four drops, the size stability was 71.0%, whereas, the "size stability" of the 3/4 - 4 in., after only two drops, was 64.5%. It is noteworthy that the single size tested had a relatively low size stability, namely: 59.2% for the 2 - 3 in. lumps.

The grindability indices for three sizes of coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method, which has been described in Mines Branch publication No.737-1. The finer sizes are evidently more easily pulverized than the coarser sizes, but in all cases this test indicates a material which should be very easily pulverized.

Chemical Properties

The Proximate and Ultimate Analyses of the various screen sizes are shown in Table IV and V respectively. It will be noted, referring to Table IV, that the ash content of the various sizes increase with decrease in size, from 5.3% ash for the plus 4 in. lumps to 17.4% ash for the 1/2-3/4 in. coal. With a further decrease in size the ash content decreases, the -48 in. mesh dust showing an ash content of 11.3%. The composites vary in ash content according to the proportion of the sizes included, the run-of-mine coal yielding 12.8% ash, whereas the 1/8 - 4 in. lump yields 17.9% ash. The sulphur content is quite low and uniform for all the sizes, ranging from 0.4% to 0.6% with an average for the run-of-mine amounting to 0.6%.

The volatile matter of the run-of-mine coal is medium in quantity and based on the "Specific Volatile Index"1/ method of classifications, this coal has an index of approximately 192, which places it in section H of the metabituminous coals. According to the A.S.T.M. classification Designation D 388-36T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is medium Volatile Bituminous.

1/ "Classification of Coals Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 725-2

Table V gives the ultimate analyses of the 0 - 4 in. mixture of sizes indicating a high carbon and low oxygen coal.

Table VII shows the results of the ash fusion determinations, including the melting range and the softening and fluid intervals for the various sizes of coal; whereas, Table VIII gives the chemical analyses of the ash of a composite of sizes. It will be noted that the Softening Temperature of the ashes for all the sizes are uniformly high, being 2850+°F.

The forms of sulphur for a composite prepared from the run-of-mine coal are shown in Table VI. The pyritic sulphur is quite low, amounting to 0.01% of the total coal in the 0 - 4 in. size i.e., 2.1% of the total sulphur is due to the presence of pyrite. This is to be expected in a coal which contains less that 1% of total sulphur.

The distribution of fusain in the coal from the No.1 seam is also shown in Table VI. It will be noted that the fusain content of the coal is low in quantity, being 1.71% in the 0 - 4 in. size. It is evidently very uniformly distributed throughout all the sizes, there being some concentration in the coarser sizes, the 1/8-4 in coal having a fusain content of 2.50%. This is an unusual feature as in most coal studied the soft fusain tends to concentrate in the fines.

<u>Laboratory Washing Tests</u>

The washing tests on the coal from the No.1 Seam were conducted in the standard manner on a sample of 1½ inch slack and 1½-4 in. lumps prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and I, it will be noted that the 1½ in. slack contains 3.4% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 71.6% of the coal is recovered. The inherent sulphur is low, amounting to 0.5%. Washing this coal at a specific gravity of 1.45, which according to the ±.10 specific gravity distribution curve represents simple wet washing, resulted in the production of 80.2% of clean coal having 5.4% of ash and 0.5% sulphur. The softening temperature of the ash remained unchanged at 2850+°F. by washing. These results are shown in Table XII which gives the chemical analyses of the raw coal, the clean coal and the refuse. Table XIII gives the fusain content of the above three samples. It will be noted that the refuse snown a decided concentration of fusain which is not accompanied by an increase in sulphur. The clean coal indicates a small decrease in fusain with no change in total sulphur. The relatively low proportion of sulphur remaining in the refuse indicates the absence of finely disseminated pyrite in the fusain. Tables XIV and XV show that the finer sizes of the 1½ in. slack may be washed to a lower ash content and with an attendant lower refuse loss than the larger sizes. The 3/4 - 1½ in. coal is reduced in ash to 6.0% with a refuse loss of 19.5%, the 1/8 - 3/4 in. coal is reduced in ash to 5.7% with a refuse loss of 20.4%, whereas the fines, material through a 1/8 in. screen, may be experimentally washed better than the larger sizes, the ash being reduced to 4.2% with a refuse loss of 15.8%. The sulphur, which is low in all the sizes, is not reduced on washing. The ash fusion temperatures of the various sizes are unchanged by washing, remaining high at 2850+°F.

Referring to Table XI and Figure III, which give the data for the washing of the 1½-4 in. lumps, it should be noted that the lumps contain 3.5% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 70.8% of the coal is recovered. This coal may be washed as easily as the 1½ in. slack, at a specific gravity of 1.45. At this gravity, according to the curves in Figure III, 85% of the coal should be recovered as a clean product containing approximately 5.5% ash.

Coking Properties

The phenomenon of coking, whereby a bituminous coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or "caking". Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value "swelling index" is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the 1½ in. slack before and after washing, are shown in Table XVI. It will be noted that the "swelling index" of the raw coal is 1790, and, on the basis of this test, indicates a coal that would result in the production of a very good coke when processed in by-product ovens. However, its shrinkage properties are poor and result in a product that would give difficulty in discharging. Washing results in material improvement in the shrinkage characteristics. However, the washed product remains a borderline coal in so far as ease in discharge is concerned. This washed coal however, when blended with high volatile coals, should be satisfactory for coke production in standard by-product ovens.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The "caking index" determined by this method, and described in Section V, does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories, but, as yet no definite correlation has been established. The result of the caking index test on a sample of the run-of-mine coal from the No.1 Seam is shown in Table XVI, the index being 55. This value indicates a good caking coal.

APPENDIX

Study of Channel Samples

I Samples Collected

A coal seam usually varies in analyses both vertically through the deposit and also laterally from one location to to another. In view of the importance of this variation in relation to the preparation and use of the coal, it was decided to study channel samples of the No.1 seam in addition to the regular tipple sample of run-of-mine coal collected for the Physical and Chemical Survey.

Channel samples, from three different locations in the mine, were collected as follows:

(A) From the New Entry to the Seam off the Rock Tunnel

(B) From No.3 Level - Face

(C) From No.4 room off No.6 Incline.

Locations B and C are indicated on the Mine plan, Figure I. the exact location of sample A was not noted.

Each channel sample was divided into three sections vertically, depending upon either marked differences in the coal itself, or upon separation by dirt bands. These sections were as follows:

(A) New Entry to Seam off Rock Tunnel

(a) 10 in. "Gumbo" (slickensided shale)
(b) 46 in. Top Coal
(c) 39 in. Middle Coal
(d) 48 in. Bottom Coal
Total thickness(without "Gumbo") 133 in.

(B) No.3 Level - Face

(a) 29 in. Top Coal, excluding 12 in. of soft shale occurring above it.
(b) 36 in. Middle Coal
(c) 39 in. Bottom Coal
Total thickness 104 in.

(C) No.4 Room off No.6 Incline

(a) 36 in. Top Coal
(b) 26.5" Middle Coal
(c) 41 in. Bottom Coal
Total thickness 103.5 in.

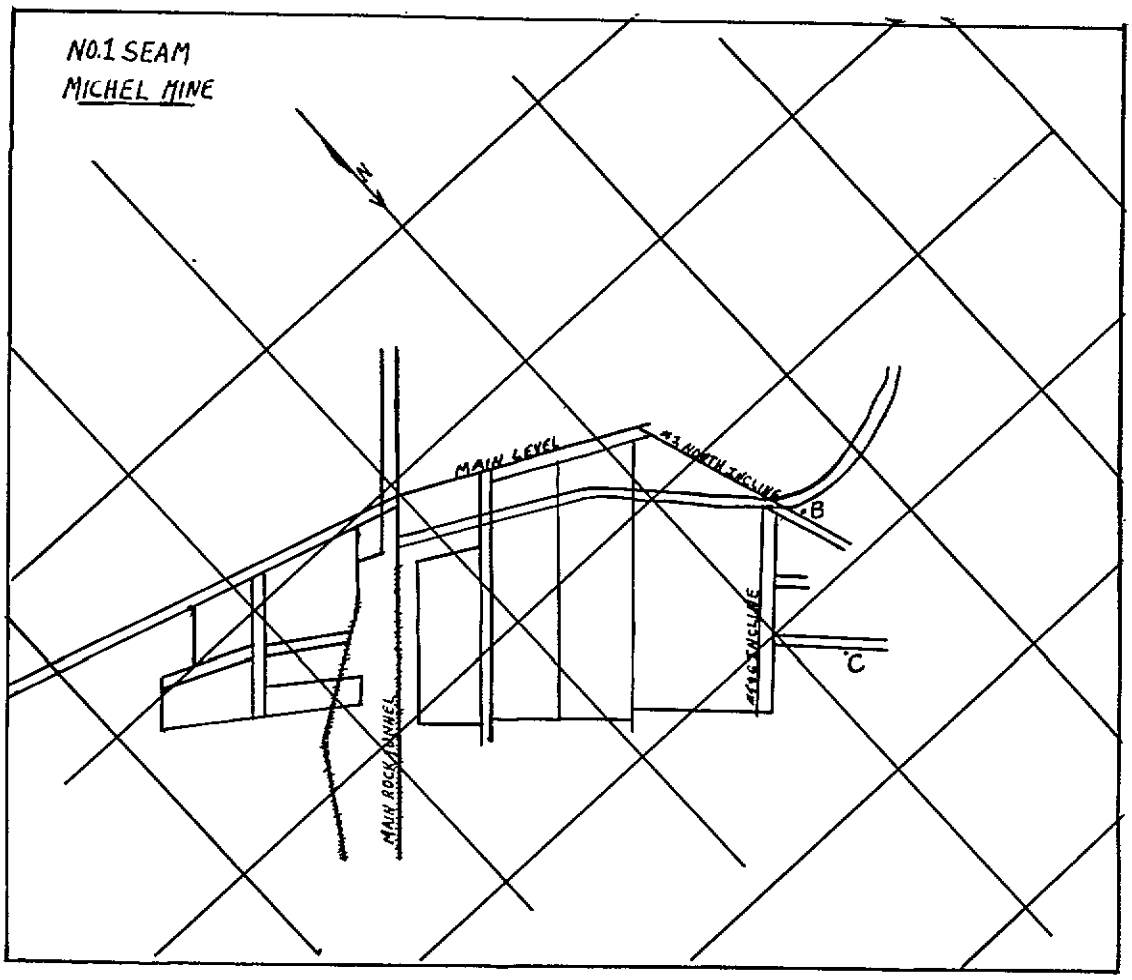
NO.1 SEAM
MICHEL MINE
N
MAIN LEVEL
#3 NORTH INCLINE
B
C
MAIN ROCK TUNNEL

Figure 1

The coal seam shows little visible impurities, with the exception of the shale band at the roof, which varies from a narrow band to as much as 12 inches at some points. The seam is relatively thick, with an average value of approximately 11 feet.

II Analyses

The proximate analyses, sulphur contents and ash fusibilities of the various channel samples are shown in the following series of tables. All the analyses were collected for the composites of the sections of each channel sample

Table I

	A - New Entry to Seam off Rock Tunnel			
Analyses-Dry Basis	Top Coal 46 in.	Middle Coal 39 in.	Bottom Coal 48 in	Composite 133 in.
Ash..................%	11.4	15.2	8.3	11.4
Volatile Matter......%	23.9	23.0	24.3	23.8
Fixed Carbon.........%	64.7	61.8	67.4	64.8
Sulphur..............%	0.9	0.4	0.5	0.6
Coking Properties....%	Good	Good	Good	Good
Ash Fusibility				
Initial.........°F	2500	2850+	2850+	2850+
Softening.......°F	2850+	+	+	+
Fluid...........°F	+	+	+	+

Table II

Analysis-Dry Basis	B - No.3 Level - Face			
	Top Coal 29 in.	Middle Coal 36 in.	Bottom Coal 39 in.	Composite 104 in.
Ash...............%	7.7	11.4	6.4	8.5
Volatile Matter....%	23.6	23.8	24.9	24.1
Fixed Carbon.......%	68.7	64.8	68.7	67.4
Sulphur............%	0.6	0.4	0.4	0.5
Coking Properties..	Good	Good	Good	Good
Ash Fusibility				
Initial.......°F	2850	2850+	2850+	2850+
Softening.....°F	2850+	+	+	+
Fluid.........°F	+	+	+	+

Table III

Analysis-Dry Basis	C - No.4 Room off No.6 Incline			
	Top Coal 36 in.	Middle Coal 26.5 in.	Bottom Coal 41 in.	Composite 103.5 in.
Ash...............%	7.1	14.3	9.4	9.8
Volatile Matter....%	23.1	22.9	24.0	23.4
Fixed Carbon.......%	69.8	62.8	66.6	66.8
Sulphur............%	0.5	0.4	0.3	0.4
Coking Properties..	Good	Good	Good	Good
Ash Fusibility				
Initial.......°F	2850+	2850+	2750	2850+
Softening.....°F	+	+	2850+	+
Fluid.........°F	+	+	+	+

III Discussion of Results

As indicated in Figure I, the channel samples from No.1 Seam, Michel Colliery, have been taken from the Mine in the West district, at various points representing the development at the time.

Each channel sample was divided from roof to floor into three sections depending either upon differences in the coal itself or upon separation by dirt bands. Figure 2, gives a diagramatic representation of the channel samples collected, showing the vertical sections and indicating the ash and volatile matter content of these sectional samples.

It should be noted that seam varies in thickness, the channel samples collected varying from 103.5 to 133 inches. It appears that the coal seam in the West district (B&C) is very iniform in thickness. However as the East and North is approached, and if sample A is an average of what is to be expected, the coal seam tends to become appreciably thicker.

The division of the seam into roof, middle and floor coal is apparently quite well defined in this seam. Examination of the ash contents of the sections, shown in Figure 2, indicates that in all cases the middle coal is higher in ash than either the roof or floor coal. The roof coal varies from 7.1% to 11.4%, the middle coal from 11.4% to 15.2%, and the floor coal from 6.4% to 9.4%.

The volatile matter contents of the various sections of the channel samples are very uniform ranging from 22.9% to 24.9%, and the variation is in accordance with the varying ash contents of the samples.

The ash fusibility of the coal, as indicated by the softening temperature is very uniform and high, namely 2850+°F. The ash fusibility does not vary vertically nor laterally from one location to another.

An examination of the analyses of the composite of each channel sample, shown in Tables I to III, inclusive, indicates

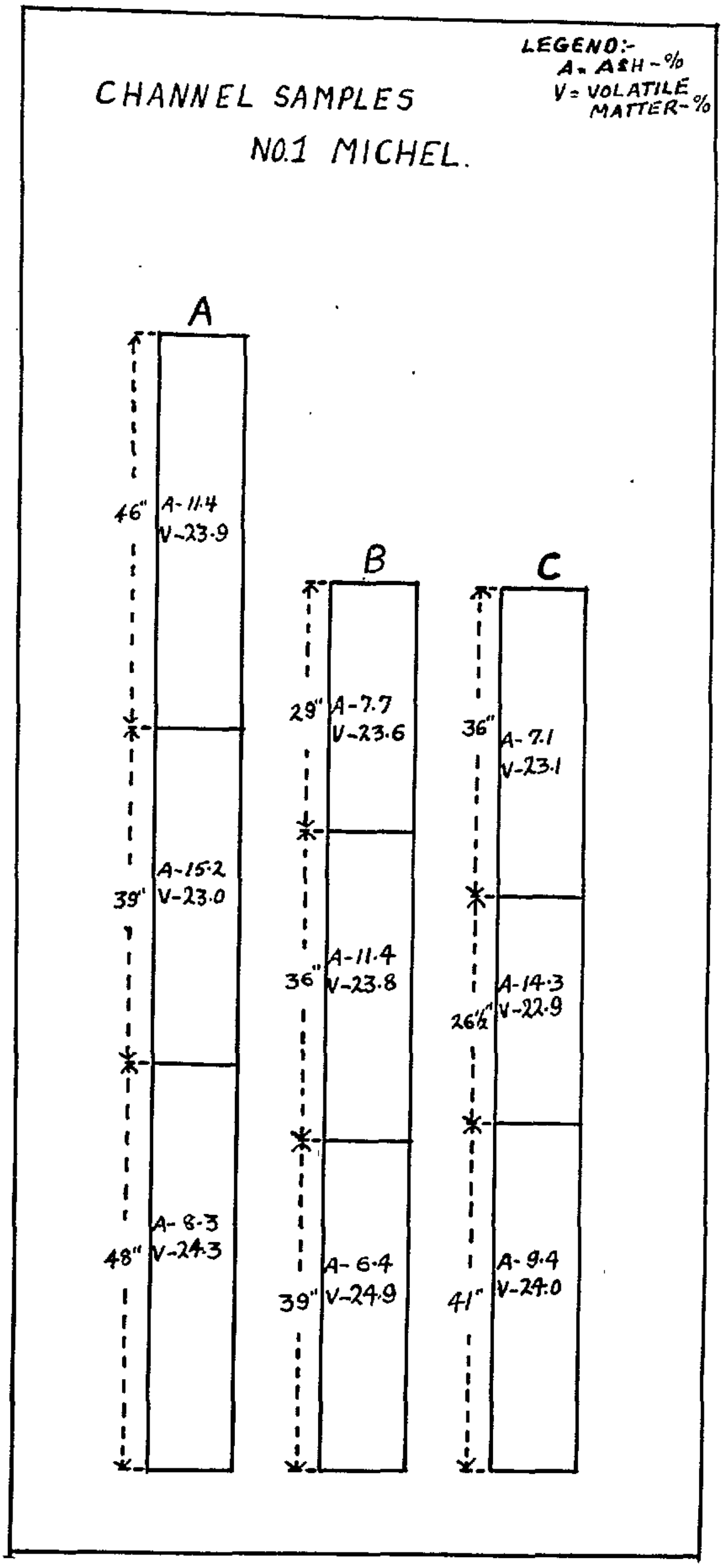
CHANNEL SAMPLES
NO.1 MICHEL.
LEGEND:-
A = ASH - %
V = VOLATILE MATTER - %
A
46"
A-11.4
V-23.9
39"
A-15.2
V-23.0
48"
A-8.3
V-24.3
B
29"
A-7.7
V-23.6
36"
A-11.4
V-23.8
39"
A-6.4
V-24.9
C
36"
A-7.1
V-23.1
26½"
A-14.3
V-22.9
41"
A-9.4
V-24.0

Figure 2

that the run-of-mine coal should not vary to any great extent in so far as chemical and physical-chemical properties are concerned. The ash varies from 8.5% to 11.4% with an average of 9.9%, while the volatile matter ranges from 23.4% to 24.1%, with an average of 23.8%. Reduction of mineral matter in the coal by washing should not affect the ash fusibility of the coal, which should remain high at 2850+°F.

4

Report of Investigations---Carbonization Section - 131

Physical and Chemical Survey Report No. 61

Study of Coal From

Coal Creek No.1 East Mine, Crowsnest Area, B.C.

Operated By

The Crow's Nest Pass Coal Co., Ltd., Fernie, British Columbia

By

R.A. Strong, E. Swartzman, E.J. Burrough
and J.H.H. Nicolls

Fuel Research Laboratories

LBL November, 1939

Physical and Chemical Survey Report No. 61

Study of Coal From

Coal Creek No. 1 East Mine, Crowsnest Area, B.C.

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Table of Contents

I

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Coal Creek No.1 East Mine worked in the Crowsnest area about 5 miles east of the town of Fernie, British Columbia, by The Crow's Nest Pass Coal Co., Ltd., of Fernie. This study is part of the investigation dealing with the Physical and Chemical characteristics of the mines operating in the Province of British Columbia. Sixty reports have already been issued on the Physical and Chemical survey of Canadian coal seams, and, accordingly, this present investigation was conducted in the same manner as that adopted for the previous studies. The report is, therefore, presented in sections dealing with the following subjects;

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The run-of-mine coal from the Coal Creek No.1 Mine was sampled by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 2,100 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railways for the aid given in connection with the collection of the samples of coal herewith reported.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Coal Creek No.1 Mine was collected at the tipple, a representative portion being taken from the various working places at the time of sampling. In this manner, a sample of run-of-mine coal weighing approximately 2,100 pounds and representative of the output of the mine was collected. This sample was used for the screening test, standard round-hole screens made from 1/4" plate being employed. The results of this test are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two - or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by a modification of the method for determining the apparent gravity of coke as outlined in the Gas Chemists' Handbook. The results of the above two tests are presented in Table I.

Table I

Screen Analysis, Specific Gravity and Bulk Density

Screen Sizes	As Received % By weight	As Received % Cumulative	Specific Gravity	Bulk Density (lbs./cu.ft.)	Ash %
Plus - 4 in.	6.8	6.8	1.30	41.25	10.1
2 - 4 in.	13.2	20.0	1.34	42.00	11.2
1-1/2 - 2 in.	4.2	24.2	1.36	41.50	13.6
1 - 1-1/2 in.	7.4	31.6	1.37	44.25	13.0
3/4 - 1 in.	4.5	36.1	1.33	42.75	13.1
1/2 - 3/4 in.	6.4	42.5	1.31	42.00	12.8
1/4 - 1/2 in.	13.7	56.2	1.31	42.75	11.0
1/8 - 1/4 in.	14.4	70.6	1.29	40.50	8.0
No. 48 - 1/8 in.	18.8	89.4	1.22	48.00	5.9
0 - No. 48	10.6	100.0			7.0
Mine Run		100.0		58.00	9.8
0 - 4 in.		93.2		54.75	9.4
1/8 - 4 in.		63.8		50.50	12.4
3/4 - 4 in.		29.3		46.50	16.4
0 - 3/4 in.		63.9		50.25	8.0
0 - 1-1/2 in.		75.8		54.75	8.0
0 - 1/8 in.		29.4	1.22	48.00	6.1

	As Received
Weight of Sample............lbs.	2096.0
Average Size of Coal after Shipment from mine to Ottawa.......................in.	1,068

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.) with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption i.e., the " Drop Shatter Test for Coal" has been published in 1935 by the Department of Mines under the title "Coal Friability Tests by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No.762. This tentative method was used for testing the relative "size stability" of single sizes. The term "Size stability" is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index".1/

The results of the friability study of the run-of-mine coal from the Coal Creek No.1 Mine are shown in Table II. The samples of the single sizes and the mixed sizes which were tested are as follows: 2" - 3"; 3/4 - 4", and 0" - 4"; in all, three samples were tested.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Co. has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coals from the Coal Creek No.1 Mine

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove Machine Method, A.S.T.M. Designation D 409-35T.

Table II

Size Stability (Friability)

Sizes tested and number of drops	Screen analysis of coal before and after dropping; percent weight retained on — Round hole screens 3"	2"	1½"	1"	3/4"	1/2	Square -1/2"		Average size of coal before and after test inches	Size stability per cent
Single Sizes										
2 to 3" lumps(1)*									2.500	
2 drops		44.5	15.5	9.5	5.0	4.0	21.5		1.626	65.0
Mixed Sizes										
3/4 to 4 in.										
Sample(1)	12.0	33.1	14.3	25.2	15.4				1.948	
2 drops	8.8	19.2	12.9	14.6	12.1	9.2	23.2		1.419	72.8
4 drops	5.8	15.8	8.8	14.2	10.8	10.4	34.2		1.176	60.4
0 - 4 in.	3"	2"	1½"	1"	3/4"	1/2"	1/4"	-1/4"		
Sample(1)	3.8	10.4	4.5	7.9	4.8	6.9	14.7	47.0	0.770	
2 drops	3.3	8.8	2.9	4.2	3.3	9.2	19.1	49.2	0.661	85.8
4 drops	2.5	2.9	3.3	3.3	2.5	8.3	18.3	53.9	0.595	77.3

* This and other bracketed figures in this column are the numbers of fifty-pound tests averaged.

Table III

Grindability

Screen Size Tested	Hardgrove Index
0 - 4 in.	98.9
0 - 3/4 in.	96.9
0 - 1/8 in.	99.3

For comparison, three samples of varying screen size prepared from the run-of-mine coal, were selected for testing as follows:

0 - 4 in. Composite

0 - 3/4 in. Slack, and

0 - 1/8 in. Slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the Coal Creek No.1 Mine were subjected to certain chemical analyses as follows:

1. The Proximate Analyses including the sulphur and the calorific value which are shown in Table IV.

2. The Ultimate Analyses for the selected size mixtures which are presented in Table V.

3. The Sulphur Forms in the coal which were determined according to the accepted Powell Method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid, the pyrite sulphur by oxidation with nitric acid, and the organic sulphur by the difference between the inorganic sulphur and the total sulphur, the results being shownin Table VI.

4. The Distribution of Fusain. The importance of fusain with respect to its influence on the spontaneous combustion of coal, and its effect on the coking properties of the coal necessitates a study of the quantitative distribution of this petrographic coal constituent. The Carbonization Section of the Fuel Research Laboratories have adopted the Heathcoat method, with certain modifications, for determining fusain. This method takes advantage of the fact that, in bituminous coals, fusain is more resistant to oxidation than the other coal constituents; hence after oxidizing the insoluble humic material to an alkaline-soluble humic substance, the more resistant fusain is collected by filtration. The results of this test, together with the forms of sulphur for the samples examined are shown in Table VI.

5. The Fusibility of the Ash including the Melting Range and Softening and Fluid Intervals of the Ash, which are given in Table VII; the data on temperature lags being presented because of their bearing on the clinkering properties of the ash.

6. The Chemical Analyses of the Ash which are shown in Table VIII.

Table IV

Chemical Analyses of Coal

Proximate, Sulphur, and Calorific Value

Screen Sizes	Moisture (as rec'd)	Dry Basis Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific BTU/lb. Value
Plus - 4 in.	1.0	10.1	27.3	62.6	0.3	----
2 - 4 in.	1.0	11.2	27.2	61.6	0.3	----
1-1/2 - 2 in.	1.0	13.6	26.5	59.9	0.3	----
1 - 1-1/2 in.	1.0	13.0	26.2	60.8	0.3	----
3/4 - 1 in.	1.0	13.1	26.6	60.3	0.4	----
1/2 - 3/4 in.	1.0	12.8	26.8	60.4	0.3	----
1/4 - 1/2 in.	1.0	11.0	26.7	62.3	0.4	----
1/8 - 1/4 in.	1.0	8.0	27.3	64.7	0.3	----
No. 48 - 1/8 in.	1.2	5.9	27.1	67.0	0.4	----
0 - No. 48	1.3	7.0	27.6	65.4	0.4	----
Mine Run	1.0	9.8	27.1	63.1	0.3	14,130
0 - 4 in.	1.1	9.4	26.9	63.7	0.4	14,185
1/8 - 4 in.	1.0	12.4	26.7	60.9	0.5	13,605
3/4 - 4 in.*	1.0	12.3	26.7	61.0	0.4	13,730
0 - 3/4 in.	1.0	8.0	26.8	65.2	0.4	14,520
0 - 1-1/2 in.	1.1	8.0	27.2	64.8	0.3	14,520
0 - 1/8 in.	1.1	6.1	27.6	66.3	0.4	14,775

* These analyses were calculated

Table V

Ultimate Analyses

Sample	Dry Basis Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
0 - 4 in.	80.3	5.1	0.4	1.2	3.6	9.4

Table VI

Sulphur Forms and Fusain
(as received basis)

	Total Sulphur % of Coal	Sulphate Sulphur % of coal	Sulphate Sulphur % of sulphur	Pyritic Sulphur % of coal	Pyritic Sulphur % of sulphur	Organic Sulphur % of coal	Organic Sulphur % of sulphur	Fusain % of Pure Coal
0 - 4 in.	0.37	0.0	0.0	0.04	10.8	0.33	89.2	1.77
1/8 - 4 in.								2.31
0 - 1½ in.								1.58
0 - 1/8 in.								1.23

Table VII

Fusibility of Ash

Sample	Initial Deformation °F	Softening Temperature °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F	Ash %
Plus - 4 in.	2030	2110	2150	120	80	40	10.1
2 - 4 in.	2050	2150	2170	120	100	20	11.2
1-1/2 - 2 in.	2040	2140	2250	210	100	110	13.6
1 - 1-1/2 in.	2100	2190	2230	130	90	40	13.0
3/4 - 1 in.	2120	2230	2300	180	110	70	13.1
1/2 - 3/4 in.	2130	2230	2350	220	100	120	12.8
1/4 - 1/2 in.	2230	2310	2415	185	80	105	11.0
1/8 - 1/4 in.	2300	2420	2520	220	120	100	8.0
No. 48 - 1/8 in.	2300	2420	2510	210	120	90	5.9
0 - No. 48	2200	2330	2420	220	130	90	7.0
Mine Run	2180	2250	2340	160	70	90	9.8
0 - 4 in.	2200	2260	2355	155	60	95	9.4
1/8 - 4 in.	2060	2180	2300	240	120	120	12.4
3/4 - 4 in.	2100	2190	2260	160	90	70	16.4
0 - 3/4 in.	2250	2340	2415	165	90	75	8.0
0 - 1-1/2 in.	2150	2320	2410	260	170	90	8.0
0 - 1/8 in.	2250	2360	2450	200	110	90	6.1

Table VIII

Chemical Analysis of Ash

Sample	SiO_2	Fe_2O_3	Al_2O_3	CaO+ MnO	MgO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	Total
0 - 4 in.											

IV

Laboratory Washing Tests

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float and sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1-1-2 in. slack prepared from the run-of-mine coal, and the 1-1/2 to 4 in. lumps, which are presented in several tables, have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation, to which has been added the "Specific Gravity Distribution" curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ±.10 specific gravity distributed curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation/

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized as in the following tables:

±.10 Curve	Degree of Difficulty	Preparation
Per Cent		
2 - 7	Simple..................	Almost any process; high tonnage
7 - 10	Moderately difficult...	Efficient process; high tonnage
10 - 15	Difficult...............	Efficient process; Medium tonnage
15 - 20	Very difficult.........	Efficient process; low tonnage
20 - 25	Exceedingly difficult..	Very efficient process; low tonnage
Above 25	Formidable.............	Limited to a few exceptionally efficient processes.

For the ordinary study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. If a horizontal line is drawn from this point on Curve 4 (Specific Gravity Curve) the point at which it cuts the other lines represents the following:

Curve 1 the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However as the total sulphur of the coal is low a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction of ash and sulphur, which is possible under varying conditions of washing the 1-1/2 in. slack, are presented in Figure I. Figure II presents the sizing curve and the ash contents of the various screen sizes, as well as the data obtained by washing the mixed coal fractions at a selected gravity of 1.45. This includes the ash and sulphur contents of the floats at this gravity, as well as the quantity recovered and the percentage of ash in the sinks. Figure III gives the ash washability curves for the 1-1/2 in. to 4-in. lumps. All of the data used in the construction of the curves are presented in the following tables:

****

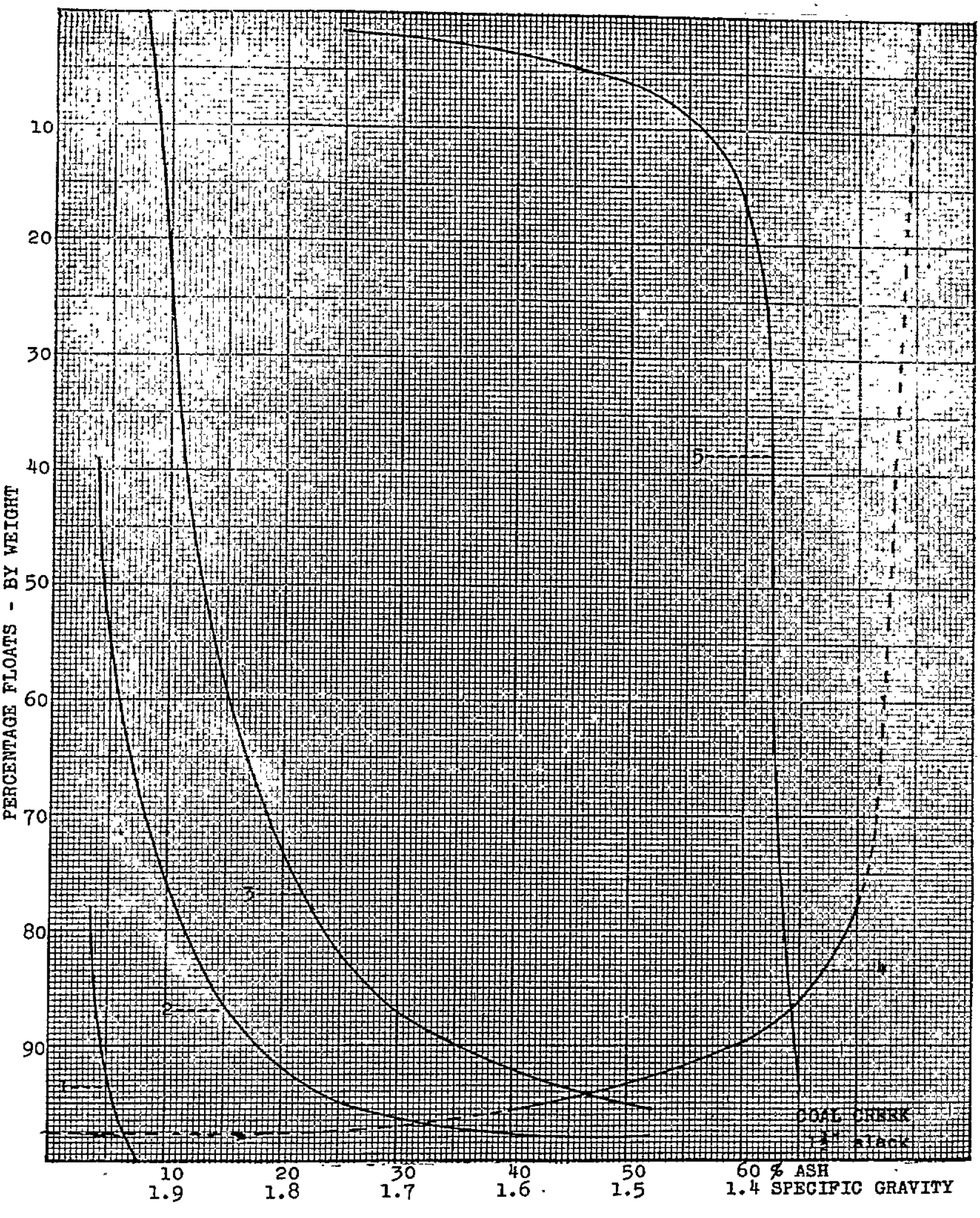

FIG. I - Washability Curves for Coal Creek No. 1 Seam Coal - Ash

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

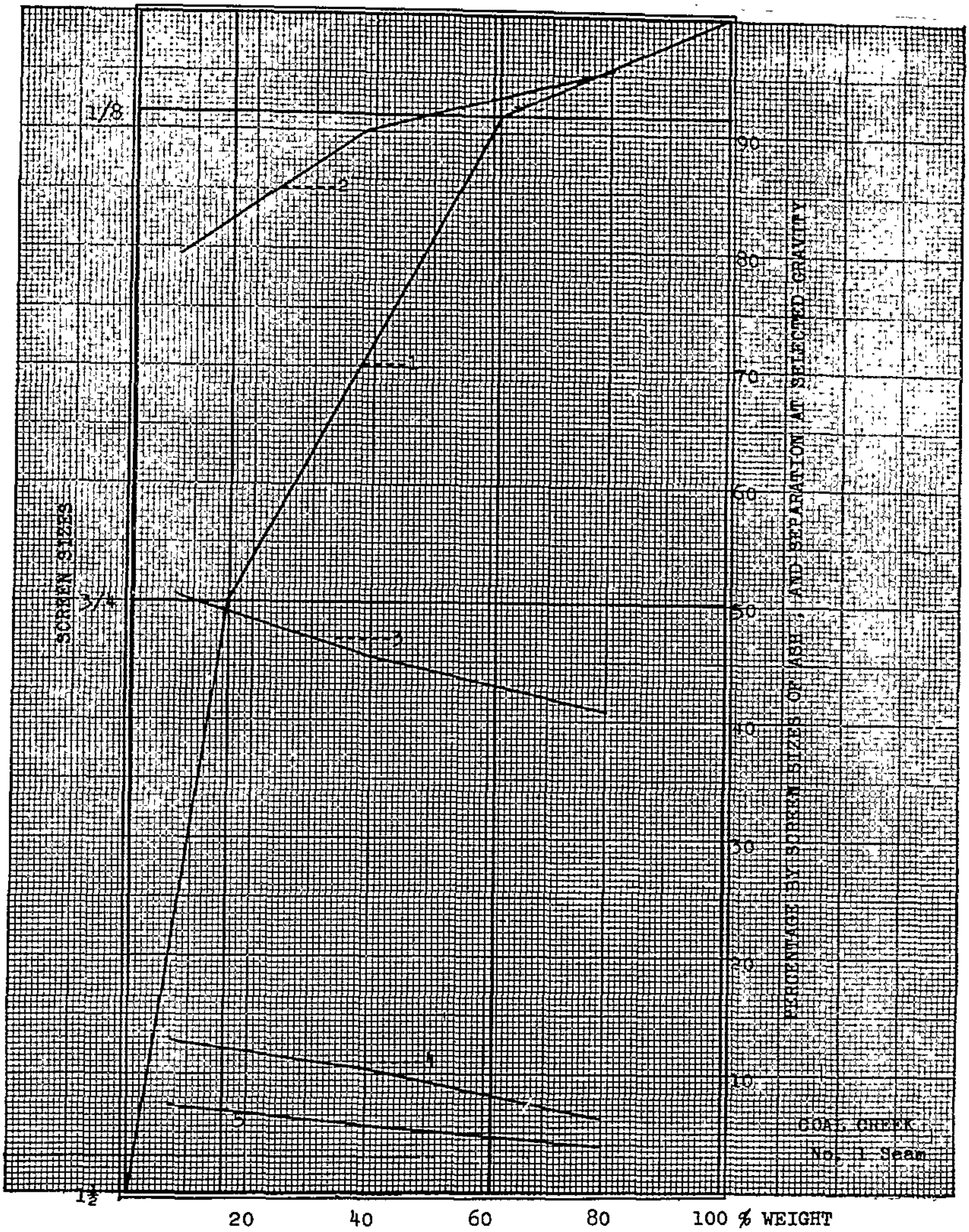

FIG. II - Curves showing screen analysis and Washing Data on Screen Sizes for Coal Creek No. 1 Seam Coal.

Curve 1 - Sizing curve
Curve 2 - Percentage float at 1.45 specific gravity
Curve 3 - Percentage ash in sinks at 1.45 specific gravity
Curve 4 - Percentage ash in screen sizes
Curve 5 - Percentage ash in floats at 1.45 specific gravity

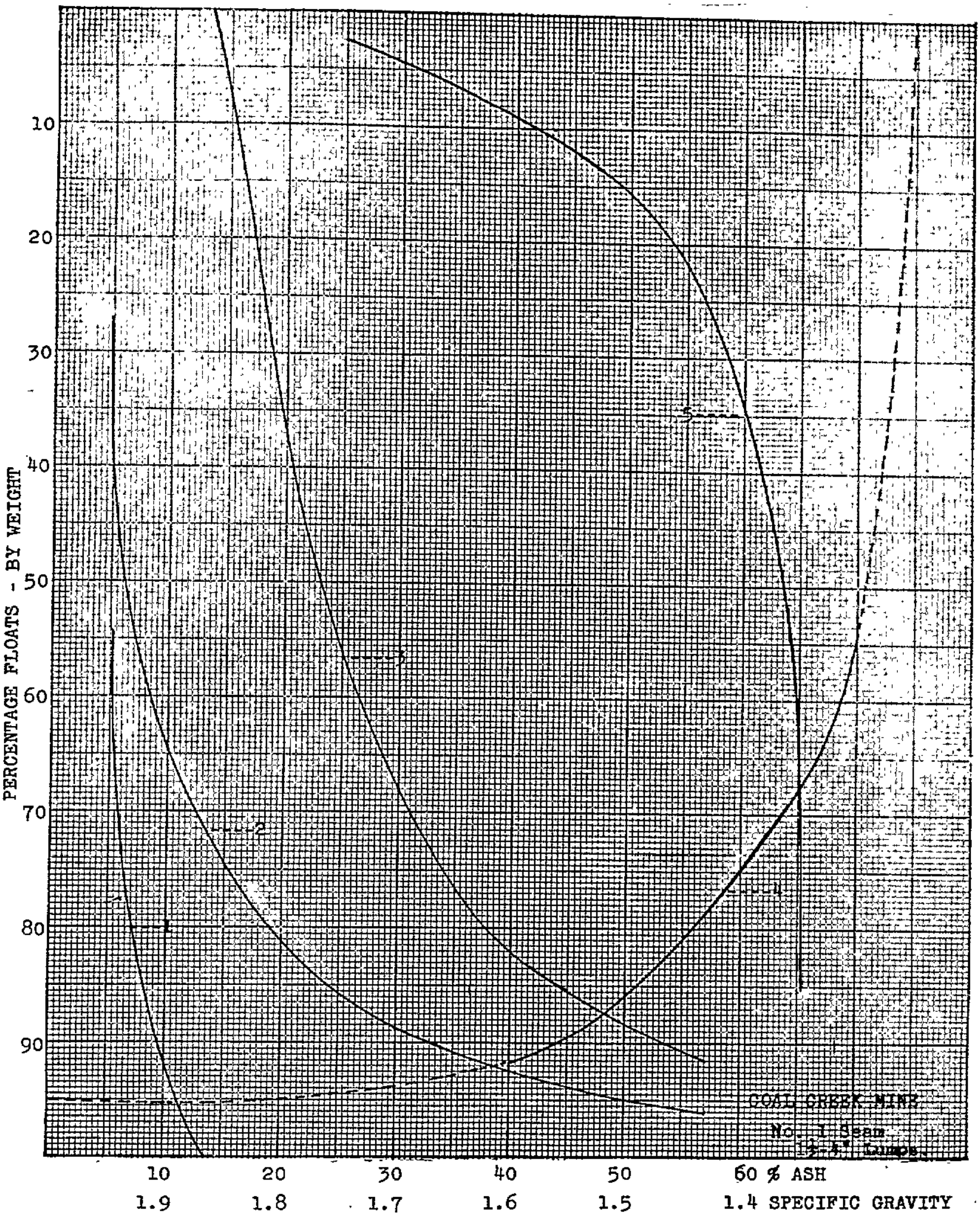

FIG. III - Washability Curves for Coal Creek No. 1 Seam - 1½"- 4" Lump

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

TABLE XI

Float and Sinks Data on 1¼ - 4" Lumps

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
								1.35	85.2
	Floats 1.30	54.2	5.0	54.2	5.0	100.0	13.5	1.40	33.2
Sinks 1.30	" 1.40	19.1	9.3	73.3	6.1	45.8	23.5	1.45	22.6
" 1.40	" 1.50	12.4	20.1	85.7	8.1	26.7	33.7	1.55	12.3
" 1.50	" 1.60	6.0	29.9	91.7	9.6	14.3	45.5	1.65	5.3
" 1.60		8.3	56.7	100.0	13.5	8.3	56.7	1.75	2.4
Curve No.	4		2	1,2,4	1	3	3	5	5

Table IX

Float and Sink Data on 1½" Slack - Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats 1.30	78.1	3.6	78.1	3.6	100.0	7.8	1.35	94.1
Sinks 1.30	" 1.40	11.4	11.7	89.5	4.6	21.9	22.6	1.40	16.6
" 1.40	" 1.50	4.8	20.1	94.3	5.4	10.5	34.5	1.45	8.7
" 1.50	" 1.60	1.2	25.4	95.5	5.7	5.7	46.6	1.55	4.7
" 1.60		4.5	52.2	100.0	7.8	4.5	52.2	1.65	2.9
								1.75	1.3
Curve No.	4		2	1,2,4	1	3	3	5	5

Table X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening interval °F	Flow Interval °F
	Floats 1.30	3.6	27.4	69.0	Good	0.4	2270	2600	2720	450	330	120
Sinks 1.30	" 1.40	12.0	26.1	61.9	Good	0.3	2170	2270	2350	180	100	80
" 1.40	" 1.50	20.6	25.6	53.8	Fair to Good	0.3	2050	2150	2200	150	100	50
" 1.50	" 1.60	26.2	25.0	48.8	Fair	0.5	2020	2150	2270	250	130	120
" 1.60		52.5	20.9	26.6	Agglomerate	0.5	2000	2100	2260	260	100	160

Table XII

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw Coal	Clean Coal Floats 1.45	Refuse Sinks 1.45
Weight..................%	100.0	91.1	8.9
Proximate Analysis (D.B.)			
Ash.....................%	8.0	5.3	45.8
Volatile Matter.........%	27.2	27.5	21.8
Fixed Carbon............%	64.8	67.1	32.4
Sulphur.................%	0.3	0.3	0.4
Calorific Value BTU/lb...	14520	14920	---
Fusion Point of Ash °F	2320	2390	2075
Melting Range of Ash °F	260	200	250
Coking Properties........	Good	Good	Poor

Table XIII

Fusain in Raw Coal, Clean Coal, and Refuse

		Fusain % of Pure Coal
1-1/2" Slack (Raw)		1.58
Clean Coal:		
	Floats	1.21
Refuse:	Sinks	4.86

Table XIV

Screen Analysis and Chemical Analysis (Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. Weight %	Ash %	Sulphur %	F.F.A. °F
3/4 - 1-1/2 in.	15.7	15.7	13.0	0.3	2200
1/8 - 3/4 in.	45.5	61.2	10.4	0.3	2330
0 - 1/8 in.	38.8	100.0	6.1	0.4	2360

Table XV

Float and Sink Data on Screened Sizes Using a Selected Gravity of 1.45

	Floats				Sinks			
	Weight %	Ash %	Sulphur %	F.F.A. °F	Weight %	Ash %	Sulphur %	F.F.A. °F
3/4 - 1-1/2 in.	79.3	7.6	0.3	2310	20.7	50.4	0.2	2100
1/8 - 3/4 in/	90.1	5.9	0.3	2380	9.9	45.9	0.2	2200
0 - 1/8 in.	95.2	3.9	0.4	2680	4.8	40.9	0.8	2160

V

COKING PROPERTIES

1. "Swelling Index" Test

In order to predict the physical properties of by-product coke madefrom any given coal, a laboratory test has been developed at the Fuel Research Laboratories, which has been outlined and published by the Mines Branch.1/ This test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the "Swelling Index" is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

Samples of the raw and washed normal 1½-in. slack from the Coal Creek No.1 Mine were subjected to the above test, the results being shown in Table XVI.

2. "Caking Index" Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. This phenonemon has been thoroughly studied and methods have been developed for the determination of the "caking Index". While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the "caking value" is of importance when it is desired to mix inert carbonaceous material or non-coking coals with coking coals.

The method developed by Gray, and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C., has been adopted as a standard. The ratio

1/ "A Laboratory Test On Coals for Predicting the Physical Properties of the Resultant By-Product Coke" - by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No.737-2.

of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designated as the "caking index". The higher the "Caking Index" the greater the coking properties. The results of this test, as applied to the run-of-mine coal from the Coal Creek No.1 Mine are shown in Table XVI.

Table XVI

PHYSICAL PROPERTIES OF BY-PRODUCT COKE

As indicated by a

"SWELLING INDEX" TEST

	1-1/2 in. Slack As Received	1-1/2 in. Slack After Washing
Volatile Matter at 600 C (D.B.)..........%:	21.5	22.6
Swelling Index......................:	1395	1105
Section--Coke Classification Chart........:	III	III
Specific Volatile Index...................:	193.6	192.2
Section--Coal Classification Chart........:	H - Metabituminous	
Ash per cent in coal (dry)..............%:	8.0	5.3
PHYSICAL PROPERTIES OF BY-PRODUCT COKE--		
Size on wharf (% on 3" screen............:	40.0	35.0
(Breeze: %-1/2"...........:	2.0	2.0
Shatter test (Index: % on 2" screen....:	60.0	60.0
(Breeze: %-1/2"...........:	2.5	2.5
Abrasion test (Index: % on 1½" screen...:	95.0	95.0
(Dust: %-1/16"...........:	2.0	2.0
Density (App. Specific Gravity....:	0.95	0.90
(Lbs. per cubic foot......:	26.0	26.0
Transverse shrinkage......................:	Fair to Good	
Appearance of natural surface...........:	steel grey, smooth	
Shape.....................................:	square	
Strength..................................:	Hard	
Cross fracture............................:	Med. Amt. Square	
Longitudinal fracture.....................:	Small to Med. Amt.	
Cell structure............................:	Dense	
Sponge....................................:	Very little	
Pebbly seam...............................:	None	
REMARKS...................................:	Washing the raw coal should be quite satisfactory when used 100% in by-product ovens. Washing definitely improves the contracting properties of the coal.	

Caking Properties

	Gray Caking Index
Run-of-mine sample.......	68

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Coal Creek No.1 East Mine operated by The Crow's Nest Pass Coal Co., Ltd. in the Crowsnest area, British Columbia, was collected at the mine by sampling at the tipple. In this way, approximately 2,100 lb. of coal, considered to be representative of the output of the coal at this mine, was collected and shipped to the Fuel Research Laboratories for the investigation as to the Physical and Chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories are shown in Table I, which contains the percentages of the various screened sizes on the "as received" basis. On this basis it will be noted that 29.4% of the coal was below 1/8-in. in size, 6.8% was above 4-in. in size, 13.2% 2 - 4 in. in size, the remaining 50.6% being distributed between the other sizes. The amount of dust, i.e., material passing a 48-mesh screen, was very high in quantity amounting to 10.6% of the total coal. The average size of the run-of-mine coal "as received" was 1.068 inches yielding 63.9% of 3/4-in. slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results of the run-of-mine coal agree very well with other coals of similar ash contents, the individual screen sizes above 1/8 in. having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the Coal Creek No.1 Mine are shown in Table II. One single size and two mixed sizes prepared from the run-of-mine coal were tested according to the method described in publication No.762 of the Mines Branch. The table contains the results of a two-drop test on the various sizes studied, as well as the results of a four-drop test on the mixed size samples. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines. In the 0 - 4" coal, after four drops, the "Size stability" was 72.3%, whereas, the "size stability" of the 3/4" to 4", after only two drops, was 72.8%. It is noteworthy that the single size tested had a low size stability, namely 65.0% for the 2" - 3" lumps.

The grindability indices for three sizes of coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method which has been described in Mines Branch publication No.737-1. The various sizes react very similarly to grinding the results of the test indicating a coal that should be quite easily pulverized.

Chemical Properties

The Proximate and Ultimate analyses of the various screen sizes are shown in Tables IV and V respectively. It will be noted, referring to Table IV, that the ash content of the various sizes retained on a 1/4-in. screen is fairly uniform, varying from 10.1% to 13.6%. The sizes passing a 1/4-in. screen indicate a lower ash product ranging from 5.9% to 8.0%, the dust, coal passing a 48-mesh screen, containing 7.0% ash. The composites vary in ash content according to the proportion of the sizes included, the run-of-mine coal yielding 9.8% of ash, whereas the 3/4" to 4 in. lumps yields 12.3% ash. The sulphur content is very low and uniform for all the sizes ranging from 0.3% to 0.4% with an average for the run-of-mine amounting to 0.3%.

The volatile matter of the coal is medium in quantity and, based on the "Specific Gravity Index"1/ method of classification, this coal has an index of approximately 193 which places it in Section H of the metabituminous or "blending" coals. According to the A.S.T.M. classification designation D 388-36T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is Medium Volatile Bituminous-A.

Table V gives the Ultimate Analyses of the 0 - 4 in. composite. The coal is a high carbon and low oxygen material.

Table VII shows the results of the ash fusion determinations

1/ Classification of Coals Using Specific Volatile Index" by R.A. Strong, E.J. Burrough & E. Swartzman--Mines Branch publication No. 725-2.

including the melting range and the softening and fluid intervals for the various sizes and types of coal; whereas Table VII gives the chemical analyses of the ash of a composite of sizes. It will be noted that the Softening Temperature of the ashes for the various sizes tested are fairly uniform showing a tendency to increase with a decrease in size. The values vary from 2110°F to 2420°F, with 2180°F for the 1/8 - 4 in. coal and 2340°F for the 0 - 3/4 in. slack. The flow interval (range from softening to fluid temperature) for the various sizes is medium, varying from 20°F. to 120°F. the value for the run-of-mine amounting to 90°F.

The forms of sulphur for a composite prepared from the run-of-mine coal are shown in Table VI. The pyritic sulphur is low amounting to 0.04% of the total coal in the 0" - 4" size, i.e., 10.8% of the total sulphur is due to the presence of pyrite. This is to be expected of a coal which contains less than 1% of total sulphur.

The distribution of fusain in the coal from the Coal Creek No.1 Mine also shown in Table VI. It will be noted that the fusain content of the coal is low in quantity, being 1.77% in the 0" - 4" size. It is evidently very uniformly distributed throughout all the sizes, there being some concentration in the coarser coal, the 1/8 - 4 in. coal having a fusain content of 2.31%.

Laboratory Washing Test

The washing tests on the coal from the Coal Creek No.1 Mine were conducted in the standard manner on a sample of 1-1/2" slack, prepared from the run-of-mine coal and on the 1-1/2 to 4-in lumps. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be noted that the 1-1/2 in. slack contains 3.6% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 78.1% of the coal is recovered. The inherent sulphur is very low amounting to 0.4%. Washing this coal at a specific gravity of 1.45, which according to the ±.10 specific gravity distribution curve represents simple wet washing. resulted in the production on 91.1% of clean coal having

5.3% of ash and 0.3% sulphur. The softening temperature of the ash was little changed by washing. These results are shown in Table XII which gives the chemical analyses of the raw coal, the clean coal, and the refuse. Table XIII gives the fusain contents of the above three samples. It will be noted that the refuse shows a decided concentration of fusain. However this is not accompanied by an appreciable decrease in the fusain content of the clean coal. The concentration in the refuse is not accompanied by a concentration of sulphur as there is very little pyrite present in the coal. Tables XIV and XV show that the finer sizes of the 1-1/2 inch slack may be washed to a lower ash content with an attendant lower refuse loss than the larger sizes. The 3/4 - 1-1/2 in. coal is reduced in ash to 7.6% with a refuse loss of 20.7%, whereas the 1/8 - 3/4 in. coal is reduced in ash to 5.9% with a refuse loss of 9.9%. The fines, material through an 1/8 inch screen, may be experimentally washed as easily as the larger sizes, the ash being reduced to 3.9% with a refuse loss of 4.8%. The ash fusion temperature of the various sizes are not materially altered by washing.

Referring to Table II and Figure IV, it will be noted that the 1-1/2 - 4 inch lumps prepared from the run-of-mine coal are not as amenable to washing as the 1-1/2 in. slack. The inherent ash is high as indicated by the material floating at a specific gravity of 1.30. There was 54.2% of this faction containing 5.0% ash. From the data and the curves it will be readily seen that this lump coal may be easily washed at an equivalent specific gravity of 1.60 to produce 91.7% of clean coal containing 9.6% ash.

<u>Coking Properties.</u>

The phenomenon of coking, whereby a bituminous coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or "caking". Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detain in Mines Branch publication No.737-2. The calculated value "Swelling Index" is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the 1-1/2 in. slack before and after washing, are shown in Table XVI. It will be noted that the "Swelling Index" of the raw coal is 1395, and, on the basis of this test, indicates a coal that would result in the production of a very good coke when processed in by-product ovens. This coal should have sufficient shrinkage to allow for discharge from the coke ovens without damage. Washing results in substantial improvement in the shrinking properties, the swelling index of the coal decreasing to 1105. This washed coal used either alone or when blended with a high volatile coal, should be satisfactory for coke production in standard by-product ovens.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The "Caking Index" determined by this method, and described in Section V, does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The results of the caking index test on a sample of the run-of-mine coal from the Coal Creek No.1 Mine are shown in Table XVI. The index for the coal is 68 indicating a good caking coal.

Physical and Chemical Survey Report No. 64

Study of Coal From

Michel Mine, A Seam, Crowsnest Area, B.C.

Operated By

The Crow's Nest Pass Coal Co. Ltd., Fernie, B.C.

By

R.A. Strong, E. Swartzman, E.J. Burrough
and J.H.H. Nicolls

Fuel Research Laboratories

February, 1940

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Michel Mine, A seam, Crowsnest Area, B.C.

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I

INTRODUCTION

The following report deals with a Physical and Chemical study of samples of coal from the Michel Mine, A Seam worked in the Crowsnest area in the Michel Creek district 24 miles northwest of Fernie, British Columbia, by the Crow's Nest Pass Coal Co. Ltd., of Fernie, B.C. This study is part of the investigation dealing with the Physical and Chemical characteristics of the coal seams mined in the Province of British Columbia. Sixty-three reports have already been issued on the Physical and Chemical survey of Canadian coal seams, and, accordingly, this present investigation was conducted in the same manner as that adopted for the previous studies. The report is, therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The run-of-mine coal from the mine was sampled by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 1,228 pounds, was boxed and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Crow's Nest Pass Coal Co. Ltd. for the aid given in connection with the collection and shipment of the samples of coal herewith reported.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Michel Mine A Seam was collected at the tipple in such a manner as to be representative of the day's output. In this manner, a sample of run-of-mine coal weighing 1,228 pounds was collected. This sample was used for the screening test, standard round-hole screens made from 1/4" plate being employed. The results of this test are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by a modification of the method for determining the apparent gravity of coke as outlined in the Gas Chemist's Handbook. The results of the above two tests are presented in Table I.

TABLE I

Screen Analysis Specific Gravity and Bulk Density

Screen Sizes°	As Received % By weight	As Received % Cumu-lative	Specific Gravity	Bulk Density (lbs./ cu.ft.)	Ash %
Plus - 4 in.	6.7	6.7	1.29	39.00	5.4
2 - 4 in.	13.5	20.2	1.28	39.50	5.4
1-1/2 - 2 in.	5.5	25.7	1.28	39.75	5.5
1 - 1-1/2in.	8.0	33.7	1.29	40.25	5.3
3/4 - 1 in.	5.4	39.1	1.29	40.50	5.7
1/2 - 3/4 in.	7.3	46.4	1.30	40.25	7.1
1/4 - 1/2 in.	13.3	59.7	1.29	40.75	9.5
1/8 - 1/4 in.	11.7	71.4	1.28	39.50	12.7
No. 48 - 1/8 in.	19.5	90.9	1.27	47.25	12.8
0 - No. 48	9.1	100.0			11.7
Mine Run		100.0		55.00	10.2
0 - 4 in.		93.3		54.75	9.0
1/8 - 4 in.		64.4		48.00	8.7
3/4 - 4 in.		32.4		42.00	6.2
0 - 3/4 in.		60.9		50.50	11.9
0 - 1-1/2 in.		73.3		52.50	9.3
0 - 1/8 in.		28.6		47.25	13.0

°All screens 1/8" and larger are round hole Screen No.48 is Tyler 48 mesh with nominal aperture of 0.295 mm.

	As Received
Weight of Sample..........................lbs	1228.25
Average Size of Run of Mine coal after shipment from mine to Ottawa...........In.	1.153

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.) with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" has been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative "size stability" of single sizes. The term "size stability" is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may be assumed that the complement of a given friability index will be the corresponding size stability index".1/

The results of the friability study on the coal from A Seam are shown in Table II. The samples of the single size and the mixed sizes which were tested are as follows: 2" - 3"; and 3/4" - 4"; in all, two samples were tested.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Co. has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1 was used for evaluating the grindability of the coal from Michel A Seam.

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal By the Hardgrove Machine Method, A.S.T.M. Designation D 409-35T".

TABLE II

Size Stability (Friability)

Sizes tested and number of drops	Screen analysis of coal before and after dropping; percent weight retained on: Round hole screens 3"	2"	$1\frac{1}{2}$"	1"	3/4"	1/2"	Square -1/2"	Average size of coal before and after test inches	Size stability per cent
Single Sizes:									
2 - 3" lumps(1)*								2.500	
2 drops		40.5	15.0	11.0	6.0	8.0	19.5	1.566	62.6
Mixed Sizes									
3/4 - 4 in.									
Sample (1)	15.1	26.5	17.0	24.7	16.7			1.945	
2 drops	9.2	16.7	12.9	17.1	13.3	9.6	21.2	1.409	72.4
4 drops	5.8	7.5	12.5	15.0	12.5	11.7	35.0	1.068	54.9

* This and other bracketed figures in this column are the numbers of fifty-pound tests averaged.

TABLE III

Grindability

Screen Size	Hardgrove Index
0 - 4 in.	124.6
0 - 3/4in.	126.7
0 - 1/8in.	127.7

For comparison, three samples of varying screen-size prepared from the run-of-mine coal, were selected for testing as follows:

0 - 4 in. Composite.

0 - 3/4 in. Slack, and

0 - 1/8 in. Slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

III

Chemical Properties

The various screen sizes obtained from the screening test of coal from the A seam, Michel mine were subjected to certain chemical analyses as follows:

1. <u>The Proximate Analyses</u> including the sulphur and the calorific value which are shown in Table IV.

2. <u>The Ultimate Analyses</u> for a selected size mixture which are presented in Table V.

3. <u>The Sulphur Forms</u> in the coal which were determined according to the accepted Powell method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid, the pyritic sulphur by oxidation with nitric acid, and the organic sulphur by the difference between the inorganic sulphur and the total sulphur, the results being shown in Table VI.

4. <u>The Distribution of Fusain</u> The importance of fusain with respect to its influence on the spontaneous combustion of coal, and its effect on the coking properties of the coal necessitates a study of the quantitive distribution of this petrographic coal constituent. The Carbonization Section of the Fuel Research Laboratories have adopted the Heathcoat method, with certain modifications, for determining fusain. This method takes advantage of the fact that, in bituminous coals, fusain is more resistant to oxidating than the other coal constituents; hence after oxidizing the insoluble humic material to an alkaline--soluble humic substance, the more resistant fusain is collected by filtration. The results of this test for the samples examined are shown in Table VI.

5. <u>The Fusibility of the Ash</u> including the Melting Range and Softening and Fluid intervals of the Ash, which are given in Table VII. This data is given only for the composites because the ash fusibility is uniformly very high.

6. <u>The Chemical Analyses of the Ash</u> which are shown in Table VIII.

TABLE IV

Chemical Analyses of Coal

Proximate, Sulphur, and Calorific Value

Screen Sizes	Moisture (As rec'd)	Dry Basis: Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/lb.
Plus 4 in.	0.8	5.5	24.6	70.0	0.5	......
2 - 4 in.	0.8	5.4	24.7	69.9	0.5	......
1½ - 2 in.	0.6	5.5	24.8	69.7	0.5	......
1 - 1½ in.	0.7	5.3	24.4	70.3	0.5	......
3/4 - 1 in.	0.8	5.7	24.8	69.5	0.5	......
1/2 - 3/4 in.	0.6	7.1	24.4	68.5	0.5	......
1/4 - 1/2 in.	0.6	9.5	24.1	66.4	0.4	......
1/8 - 1/4 in.	0.6	12.7	23.6	63.7	0.5	......
No.48 - 1/8 in.	0.6	12.8	23.6	63.6	0.4	......
0 - No. 48	0.6	11.7	21.4	66.9	0.5	......
Mine Run	0.9	10.2	24.3	65.5	0.5	14,065
0 - 4 in.	0.9	9.0	24.3	66.7	0.5	14,240
1/8 - 4 in.	0.8	8.7	23.9	67.4	0.4	14,260
3/4 - 4 in.	0.7	6.2	24.6	69.2	0.5	14,730
0 - 3/4 in.	0.9	11.9	23.5	64.6	0.4	13,750
0 - 1½ in.	0.9	9.3	24.0	66.7	0.4	14,155
0 - 1/8 in.	0.7	13.0	23.4	63.6	0.5	13,475

TABLE V

Ultimate Analyses

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
0 - 4 in.	79.7	4.8	0.5	1.4	4.6	9.0

TABLE VI

Sulphur Forms and Fusain
(as received basis)

	Total Sulphur % of Coal	Sulphate Sulphur % of coal	Sulphate Sulphur % of sulphur	Pyritic Sulphur % of coal	Pyritic Sulphur % of sulphur	Organic Sulphur % of coal	Organic Sulphur % of sulphur	Fusain % of Pure Coal
0 - 4 in.	0.46	0.0	0.0	0.027	5.9	0.433	94.1	1.85
1/8 - 4 in.								2.58
0 - 1½ in.								1.62
0 - 1/8 in.								1.94

TABLE VII

Fusibility of Ash

	Initial Deformation °F	Softening Temperature °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F	Ash %
Mine Run	2850+	+	+	+	+	+	10.2
0 - 4 in.	2850+	+	+	+	+	+	9.0
1/8 - 4 in.	2850+	+	+	+	+	+	8.7
3/4 - 4 in.	2730	2850+	+	120+	120+	+	6.2
0 - 3/4 in.	2850+	+	+	+	+	+	11.9
0 - 1-1/2 in.	2850+	+	+	+	+	+	9.3
0 - 1/8 in.	2850+	+	+	+	+	+	13.0

TABLE VIII

Chemical Analysis of Ash

Sample	SiO_2	Fe_2O_3	Al_2O_3	$CaO+MnO$	MgO	Na_2O	K_2O	P_2O_5	TiO_2	SO_3	Total
0 - 4 in.	51.3	4.4	35.5	2.4	1.3	Nil	0.8	0.1	1.5	2.5	99.8

IV

LABORATORY WASHING TEST

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float and sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1-1/2 in. slack prepared from the run-of-mine coal, and the lumps retained on an 1-1/2 in. screen, which are presented in several tables have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation, to which has been added the "Specific Gravity Distribution" curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the $\pm$.10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized as in the following table:

±.10 Curve	Degree of Difficulty	Preparation
Per Cent		
2 - 7	Simple................	Almost any process; high tonnage
7 - 10	Moderately difficult	Efficient process; high tonnage
10 - 15	Difficult............	Efficient process; medium tonnage
15 - 20	Very difficult......	Efficient process; low tonnage
20 - 25	Exceedingly difficult......	Very efficient process; low tonnage
Above 25	Formidable..........	Limited to a few exceptionally efficient processes.

For the ordinary study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. If a horizontal line is drawn from this point on Curve 4 (Specific Gravity Curve) the point at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the sulphur in this coal is very low, it was not necessary to study this constituent with respect to washing.

Curves showing the reduction of ash, which is possible under varying conditions of washing the 1-1/2 in. slack, are presented in Figure I. Figure II presents the sizing curve and the ash contents of the various screen sizes, as well as the data obtained by washing the mixed coal fractions at a selected gravity of 1.50. This includes the ash contents of the floats at this gravity, as well as the quantity recovered and the percentage of ash in the sinks. All of the data obtained in the washing study are presented in the following tables:

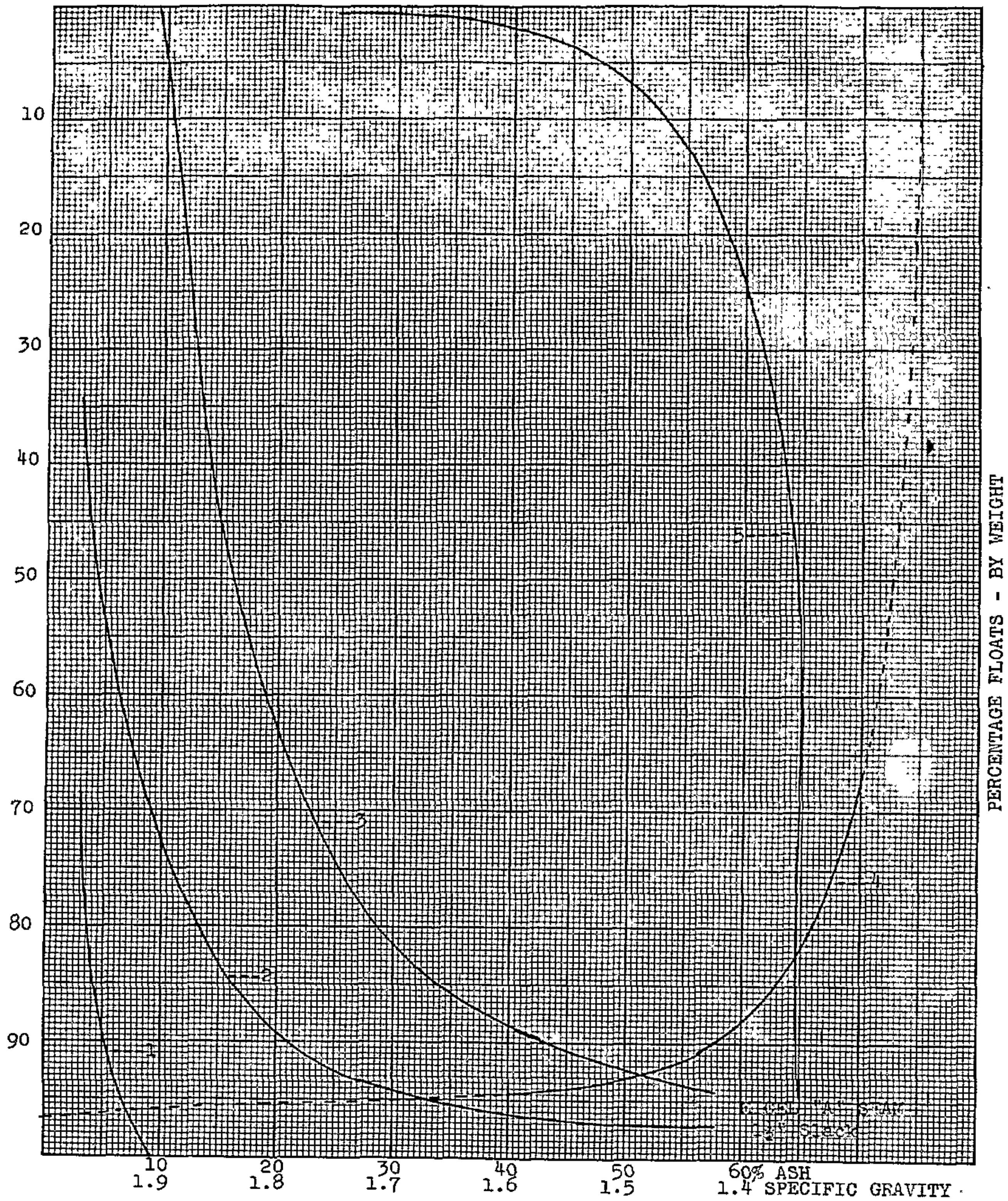

FIG. I - Washability Curves for Michel Mine, "A" Seam - Ash.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

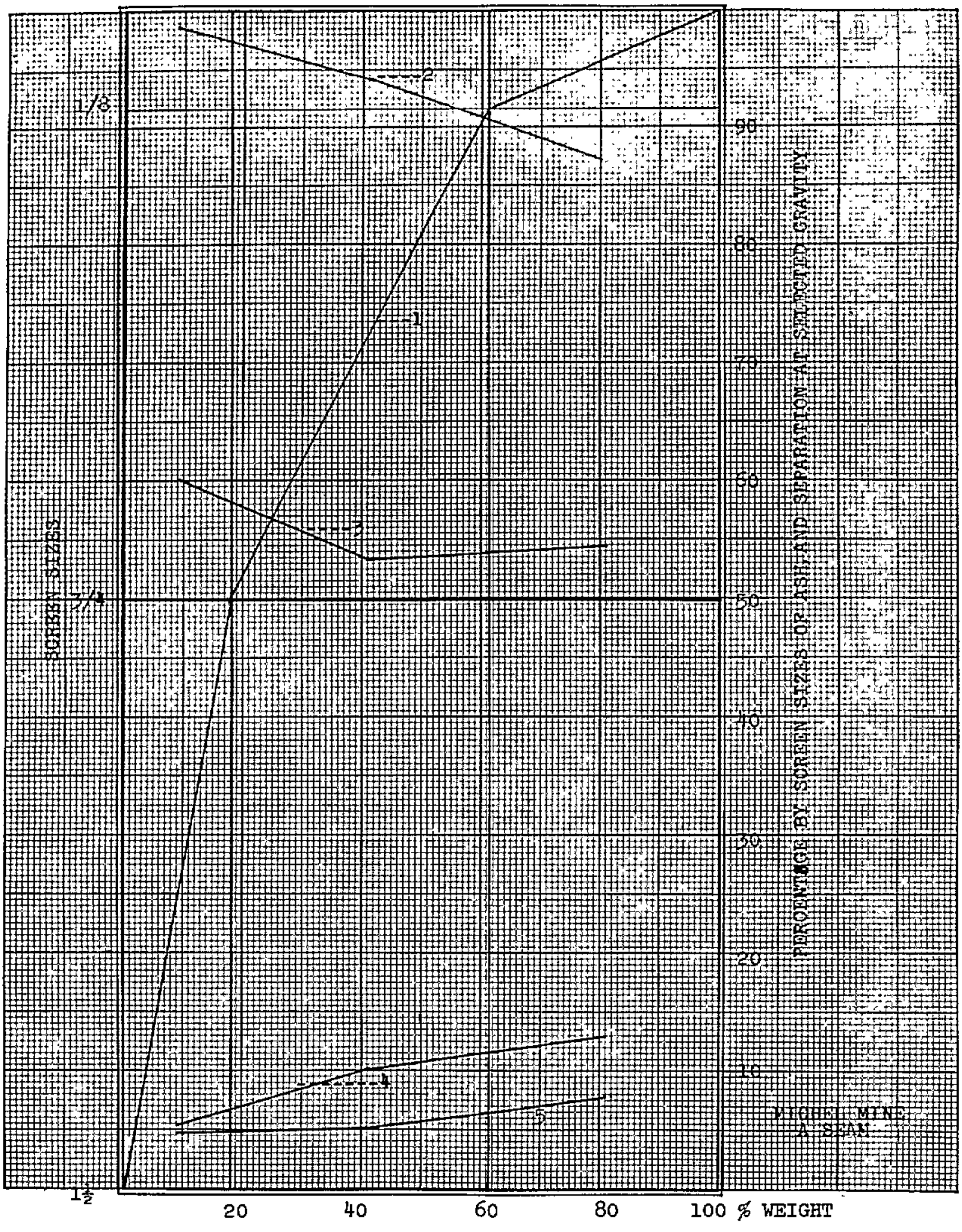

FIG.II - Curves showing screen analysis and Washing Data On Screen Sizes for Michel Mine, "A" Seam.

Curve 1 - Sizing curve
Curve 2 - Percentage float at 1.50 specific gravity.
Curve 3 - Percentage ash in sinks at 1.50 specific gravity.
Curve 4 - Percentage ash in screen sizes.
Curve 5 - Percentage ash in floats at 1.50 specific gravity.

TABLE IX

Float and Sink Data on 1½" Slack

- Ash -

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
Floats 1.30	68.4	3.0	68.4	3.0	100.0	9.2	1.40	25.2
Sinks 1.30 " 1.40	19.4	12.2	87.8	5.0	31.6	22.6	1.45	12.7
" 1.40 " 1.50	5.0	21.1	92.8	5.9	12.2	39.1	1.55	3.3
" 1.50 " 1.60	1.6	30.7	94.4	6.3	7.2	51.6	1.65	1.2
" 1.60	5.6	57.6	100.0	9.2	5.6	57.6	1.75	0.8
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.30	3.0	25.4	71.6	Good	0.5	2850+	+	+	+	+	+
Sinks 1.30 " 1.40	12.3	22.4	65.3	"	0.5	2840	2850+	+	10+	10+	+
" 1.40 " 1.50	21.3	21.7	57.0	Fair	0.5	2780	2850+	+	70+	70+	+
" 1.50 " 1.60	30.9	20.8	48.3	Poor	0.3	2850+	+	+	+	+	+
" 1.60	58.0	18.0	24.0	Agglomerate	0.2	2850+	+	+	+	+	+

TABLE XI

Float and Sink Data on +1-1/2 in. Lump

– Ash –

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats 1.30	50.9	3.0	50.9	3.0	100.0	4.6		
Sinks 1.30	" 1.40	42.6	4.9	93.5	3.9	49.1	6.2		
" 1.40	" 1.50	5.7	13.0	99.2	4.4	6.5	15.0		
" 1.50	" 1.60	0.6	26.0	99.8	4.5	0.8	29.3		
" 1.60		0.2	39.3	100.0	4.6	0.2	39.3		
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XII

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight..........................%	100.0	90.8	9.2
Proximate Analysis (dry basis)			
Ash.............................%	9.3	6.2	51.7
Volatile Matter.................%	24.0	24.1	18.6
Fixed Carbon....................%	66.7	69.7	29.7
Sulphur.........................%	0.4	0.5	0.2
Calorific Value..........BTU/lb.	14,155	14,770	---
Fusion Point of Ash..........°F.	2850+	2850+	---
Melting Range of Ash.........°F.	+	+	---
Coking Properties...............	Good	Good	Poor

TABLE XIII

Fusain in Raw Coal, Clean Coal, and Refuse; 1-1/2 in. Slack

	Fusain % of Pure Coal
1-1/2 in. Slack (Raw)	1.62
Clean Coal: Floats	1.65
Refuse: Sinks	5.04

TABLE XIV

Screen Analysis and Chemical Analysis (Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. Weight %	Ash %	Sulphur %
3/4 - 1½ in.	18.0	18.0	5.5	0.5
1/8 -3/4 in.	43.4	61.4	10.1	0.5
0 -1/8 in.	38.6	100.0	13.0	0.5

TABLE XV

Float and Sink Data on Screened Sizes Using a Selected Gravity of 1.50

	Floats			Sinks		
	Weight %	Ash %	Sulphur %	Weight %	Ash %	Sulphur %
3/4 - 1½ in.	98.8	4.7	0.5	1.2	60.0	0.2
1/8 - 3/4 in.	94.1	5.2	0.4	5.9	53.5	0.2
0 - 1/8 in.	87.2	7.9	0.5	12.8	54.5	0.4

TABLE XVI

Chemical Analyses of Raw Coal, Clean Coal, and Refuse

	Raw* Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight.....................%	100.0	99.4	0.6
Proximate Analysis (dry basis)			
Ash.....................%	5.5	5.2	29.1
Volatile Matter.....................%	24.7	24.2	20.5
Fixed Carbon.....................%	69.8	70.6	50.4
Sulphur.....................%	0.5	0.5	0.4
Calorific Value..........BTU/lb.	14,800	14,845	---
Fusion Point of Ash..........°F.	2850+	2850+	2850+
Melting Range of Ash..........°F.	+	+	+
Coking Properties..............	Good	Good	Fair

* Analysis calculated.

V

COKING PROPERTIES

1. "Swelling Index" Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories, which has been outlined and published by the Mines Branch.1/ This test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the "Swelling Index" is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

Samples of the raw and washed 1-1/2 in. slack from the Michel mine A seam were subjected to the above test, the results being shown in Table XVII.

2. "Caking Index" Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength that are the more inferior coals. This phenomenon has been thoroughly studied and methods have been developed for the determination of the "caking index". While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the "caking value" is of importance when it is desired to mix inert carbonaceous material or non-coking coals with coking coals.

The method developed by Gray, in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C., has been adopted as a standard at the Fuel Research Laboratories. The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to

1/ "A Laboratory Test On Coals for Predicting the Physical Properties of the Resultant By-Product Coke" - by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737-2.

support a weight of 500 grammes, is designated as the "Caking index". The higher the "Caking Index" the greater the coking properties. The results of this test, as applied to the run-of-mine coal from the A seam, are shown in Table XVII.

TABLE XVII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A "SWELLING INDEX" TEST

	1-1/2 In. Slack	
	Raw Coal	Washed Coal
Volatile Matter at 600°C. (Dry Basis)...%	18.8	19.2
Swelling Index.............................	825	1225
Section--Coke Classification Chart........	II near III	II near III
Specific Volatile Index..................	193.7	198.8
Section--Coal Classification Chart........	X Metabituminous	
Ash per cent in coal (dry)...............%	9.3	6.2
PHYSICAL PROPERTIES OF BY-PRODUCT COKE--		
Size on wharf (% on 3" screen...........	30.0	40.0
(Breeze: %-1/2"...........	2.0	1.5
Shatter test (Index: % on 2" screen....	50.0	55.0
(Breeze: %-1/2"...........	2.0	2.0
Abrasion test (Index: % on 1½" screen..	85.0	90.0
(Dust %-1/16"............	3.0	2.5
Density (App. Specific Gravity....	0.90	0.90
(Lbs. per cubic foot.....	25.0	25.0
Transverse shrinkage.....................	Fair	Fair
Appearance of natural surface............	Steel grey and smooth	
Shape....................................	Square	
Strength.................................	Hard	
Cross fracture...........................	Medium amt. square	
Longitudinal fracture....................	Small to Med. Amt.	
Cell structure...........................	Dense.	
Sponge...................................	Very Little	
Pebbly seam..............................	None	
Remarks:	This coal is very suitable when blended with higher volatile coal for the preparation of by-product coke When used alone there would be difficulty in discharging in a standard by-product oven	

Caking Properties

	Gray Caking Index
Run-of-Mine Sample	54

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Michel Mine A seam operated by The Crow's Nest Pass Coal Co., Ltd., in the Crowsnest area, British Columbia, was collected at the mine by sampling at the tipple. In this way, 1,223 lbs. of coal, considered to be representative of the output of the coal from this seam was collected and shipped to the Fuel Research Laboratories for the investigation as to the Physical and Chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories ("as received") are shown in Table I. On the "as received" basis it will be noted that 28.6% of the coal was below 1/8-in in size, 6.7% was above 4-in. in size, 13.5% 2 - 4 in. in size, the remaining 51.2% being distributed between the other sizes. The amount of dust, i.e. material passing a 48-mesh screen, was very high in quantity amounting to 9.1% of the total coal. The average size of the run-of-mine coal "as received" was 1.153 in. yielding 32.4% of 3/4-in. slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar ash contents, the individual screen sizes above 1/8 in/ having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the Michel mine, A seam are shown in Table II. One single size and one mixed size prepared from the run-of-mine coal were tested according to the method described in publication No. 762 of the Mines Branch. The table contains the results of a two-drop test on the two sizes studied, as well as the results of a four-drop test on the mixed size samples. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines. In the 3/4 - 4" coal, after four drops, the "Size stability" was 54.9%, whereas, the "size stability" after only two drops, was

72.4%. It is noteworthy that the single size tested had a relatively low size stability, namely 62.6% for the 2" - 3" lumps.

The grindability indices for three sizes of coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes of the coal appear to be slightly more easily pulverized than the coarser sizes, it is quite evident that the coal as a whole lends itself readily to pulverization.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables IV and V respectively. It will be noted, referring to Table IV, that the ash contents of the various sizes retained on a 3/4 in. screen are fairly uniform, varying from 5.3% to 5.7%. For all sizes passing the 3/4 in. screen the ash increases with a decrease in size to a maximum of 12.8% for the 48 mesh - 1/8 in. material. The dust showed a slightly lower ash with 11.7%. The composites vary in ash content according to the proportions of the sizes included, the 0 - 4 in. coal yielding 9.1% of ash, whereas the 3/4 - 4 in. lumps yield 6.2% ash. The sulphur content is low and uniform for all the sizes ranging from 0.4 to 0.5% with an average for the run-of-mine amounting to 0.5%

The volatile matter of the coal is medium in quantity and, based on the "Specific Volatile Index"1/ method of classification, this coal has an index of approximately 196 which places it in Section H of the meta-bituminous coals. The rank of this coal according to the A.S.T.M. classification Designation D 388-36T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, is medium volatile bituminous.

1/ Classification of Coals Using Specific Volatile Index" by R. A. Strong, E.J. Burrough and E. Swartzman-Mines Branch publication No. 725-2

Table V gives the Ultimate Analyses of the 0 - 4 in. composite. The coal is a high carbon and medium oxygen material.

Table VII shows the results of the ash fusion determinations including the melting range and the softening and fluid intervals for the various composite/of coal; whereas Table VIII gives the chemical analyses of the ash of a composite of sizes. It will be noted that the Softening Temperature of the ashes for the various sizes are very uniformly high, all being 2850+°F. The ash is highly refractory and very low in fluxing agents such as Iron Oxide and Lime.

The forms of sulphur for the 0 - 4 in. composite prepared from the run-of-mine coal are shown in Table VI. The pyritic sulphur is very low, amounting to 0.027% of the total coal; i.e., 5.9% of the total sulphur is due to the presence of pyrite. As the total sulphur is very low, the forms in which the sulphur occur are unimportant.

The distribution of fusain in the coal from the A seam is also shown in Table VI. It will be noted that the fusain content of the coal is low in quantity, being 1.85% in the 0 - 4" size. It is evidently fairly uniformly distributed throughout all the sizes, there being some concentration in the larger sizes, the 1/8 - 4 in. coal showing a fusain content of 2.58% as against 1.94% for the 0 - 1/8 in. fines.

Laboratory Washing Tests

The washing tests on the coal from the Michel mine, A seam were conducted in the standard manner on a sample of 1-1/2 in. slack, prepared from the run-of-mine coal as well as on the plus 1-1/2" lumps. The results are given in a series of tables and curves shown in section IV. Referring to Tables IX and X, it will be noted that the 1-1/2 in. slack contains 30% of inherent ash, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 68.4% of the coal is recovered. The sulphur is low and practically all inherent material. Washing this coal at a specific gravity of 1.50, which according to the

±.10 specific gravity distribution curve represents fairly simple wet washing resulted in the production of 90.8% of clean coal having 6.2% of ash and 0.5% sulphur. The softening temperature of the ash was unchanged remaining high at 2850+°F. These results are shown in Table XII which gives the chemical analyses of the raw coal, the clean coal, and the refuse. Table XIII gives the fusain content of the above three samples. It will be noted that the refuse shows a decided concentration of fusain. The clean coal indicated no change in fusain content. Tables XIV and XV show that the finer sizes of the 1-1/2" slack may be washed almost as readily as the coarser sizes but with an attendant greater loss as refuse. The 3/4 - 1-1/2 in. coal is reduced in ash to 4.7% with a refuse loss of 1.2% whereas, the 1/8 - 3/4 in. coal is reduced in ash to 5.2% with a refuse loss of 5.9%. The fines, material through an 1/8" screen, may be experimentally washed as easily as the larger sizes, the ash being reduced to 7.9% with a refuse loss of 12.8%. The ash fusion temperatures of the sizes would in all probability be unaltered by washing.

Referring to Table XI, it will be noted that the plus 1-1/2 in. lumps prepared from the run-of-mine coal are not very amenable to washing, as the ash is very low. The inherent ash of the coal as indicated by the material floating at a specific gravity of 1.30, was 3.0%, a value not far removed from that of the coal as a whole. Washing the lumps at a specific gravity of 1.50 resulted in the production of 99.4% of clean coal containing 5.2% ash and 0.5% sulphur. Obviously these results indicate the futility of washing the plus 1-1/2 in. lump.

Coking Properties

The phenomenon of coking, whereby a bituminous coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or "caking". Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method leveloped at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value "Swelling Index" is a comparative measure of the swelling properties, and the higher the index the greater the swelling/ This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the 1-1/2 in. slack before and after washing, are shown in Table XVII. It will be noted that the "Swelling Index" of the raw coal is 825 and, on the basis of this test, indicates a coal that would produce a good coke when processed in by-product ovens. However, difficulty would be encountered in operation due to the poor shrinkage. Washing results in improvement in the coking properties, the swelling index of the coal increasing to 1225. However, the shrinkage problem is not overcome by washing the coal.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The "Caking Index" determined by this method, and described in Section V, does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The results of the caking index test on a sample of the run-of-mine coal from the Michel mine, A seam is shown in Table XVII, and the value of 54 indicates a good coking material.

REPORT OF COKING TESTS

ON

COMOX COLLIERY COALS

FOR THE

PRODUCTION OF BLAST FURNACE COKE

by

E.J. Burrough

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Fuel Research Laboratories
Bureau of Mines
Ottawa, Canada

Ottawa, January 24, 1941.

PREFACE

On November 4, 1940, Dr. John F. Walker, Deputy Minister of the Department of Mines of British Columbia, telegraphed to this Department requesting that samples of coal from the Comox mine of the Canadian Collieries (Dunsmuir) Limited be tested in our coke ovens to determine the suitability of this coal for metallurgical purposes in connection with the production of pig iron from British Columbia iron ores.

The accompanying report gives in detail the results of the tests which were conducted in our Laboratories in Ottawa. A comparison is also made of the quality of the coal received for this test and for tests of coals received from the Canadian Collieries (Dunsmuir) Limited in 1930, 1933 and 1938.

It is believed that sufficient data is included in this report to enable a metallurgist to appraise the value of the coke made from the samples of coal submitted for the production of pig iron from British Columbia iron ores either in the standard blast furnace or in an electric smelting furnace.

B.F. Haanel

B.F. Haanel,
Chief, Division of Fuels.

Ottawa, January 25, 1941.

REPORT OF COKING TESTS
ON
COMOX COLLIERY COALS
FOR THE
PRODUCTION OF BLAST FURNACE COKE

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Table of Contents

I

Description Of Coals And Summary Of Previous Tests

The coal samples supplied for the present investigation were forwarded under the direction of the Chief Inspector of Mines for British Columbia. The shipment was made during November 1940, and the samples received were designated as follows:

1) Sample of Comox No. 5 mine washed coal taken from Canadian Collieries (D) Ltd. Union Bay washery. Approximate weight: 1,000 pounds.

2) Sample of Comox No. 5 mine coal taken from picking tables at the mine, unwashed. Approximate weight: 1,000 pounds.

3) Sample of Comox No. 8 mine coal taken from picking tables at the mine, unwashed. Approximate weight: 1,000 pounds.

4) Sample of Comox No. 8 mine washed coal taken from Canadian Collieries (D) Ltd. Union Bay washery. Approximate weight: 1,000 pounds.

Analyses from samples of the above coals were made, and the results obtained are presented in the following table.

TABLE I

Analyses Of Comox Colliery Coals
Sampled November 6, 1940

	No. 5 Mine Washed Slack	No. 5 Mine 3 inch Lump	No. 8 Mine 3 inch Lump	No. 8 Mine Washed Slack
Moisture......................%	3.1	1.3	2.3	3.0
Proximate analysis (dry basis)				
Volatile matter.............%	33.0	34.1	33.5	32.5
Fixed carbon................%	53.9	58.1	55.9	55.9
Ash.........................%	13.1	7.8	10.6	11.6
Sulphur.......................%	2.4	2.0	2.7	2.5
Fusion Point of Ash........°F.	2200	2350	2326	2160
Calorific value.....B.t.u./lb.	13,219	14,260	13,613	13,561

The practice at the colliery is to prepare a +3 inch coal and a -3 inch slack. The slack coal is transported to the Union Bay washery for cleaning, and the 3 inch lump coal is processed on picking tables before loading at the mines. Screen analyses of the samples as received are presented in Table II.

TABLE II

Screen Analyses Of Comox Colliery Coals
Sampled November 6, 1940

Screen Sizes (round hole)	No. 5 Mine Washed Slack	No. 5 Mine 3 inch Lump	No. 8 Mine Washed Slack	No. 8 Mine 3 inch Lump
+4 in...	....	46.1	....	20.1
4 - 3 in...	....	30.4	....	48.8
3 - 2 in...	13.5	12.3	11.5	16.2
2 - 1½ in...	11.3	2.1	12.6	3.5
1½ - 1 in...	12.5	2.1	14.8	2.4
1 - 3/4 in...	7.5	1.3	9.6	1.2
3/4 - 1/2 in...	3.8	1.3	8.9	1.8
1/2 - 1/4 in...	23.3	1.6	12.6	2.4
1/4 - 1/8 in...	12.0	1.3	11.8	1.2
1/8 - 0 in...	16.1	1.5	18.2	2.4

In an investigation undertaken in November 1938 at the Union Bay washery plant, a series of samples was taken which included the -3 inch slack coals as supplied to the washery from the No. 5 and No. 8 mines of the Comox colliery. These samples were analysed, and a series of sink-and-float tests made for the evaluation of the washing characteristics of the coals supplied to the washery. The results of these tests, previously reported, are summarized in the following tables.

TABLE III

Screen Analyses Of Comox Colliery Coals
3 inch Raw Slack To Washery
Sampled November 7, 1938

Screen Sizes	No. 5 Mine	No. 8 Mine
3 - 2 in...	16.0	14.8
2 - 1½ in...	8.1	8.6
1½ - 1 in...	9.2	9.7
1 - 3/4 in...	6.8	7.6
3/4 - 1/2 in...	10.1	10.8
1/2 - 1/4 in...	13.8	14.7
1/4 - 1/8 in...	11.4	10.6
1/8 - 0 in...	24.6	23.2

TABLE IV

Proximate Analyses Of Comox Colliery 3 inch Slack
(Dry Basis)

	No. 5 Mine	No. 8 Mine
Ash.........................%	23.9	28.0
Volatile matter.............%	31.3	29.1
Fixed carbon................%	44.8	42.9
Sulphur.....................%	3.6	3.8
Fusion point of ash........°F.	2210	2240

The following table has been prepared from laboratory tests of the washing characteristics of the coal samples and indicates the theoretical recoveries obtainable for the individual samples tested based on the conditions of simple washing with minimum rejects.

TABLE V

Theoretical Washery Yields For
Comox Colliery Slack Sampled 1938

Screen Sizes	Raw Coal			Clean Coal			Refuse	Data on Raw Coal Basis		
	Per cent	Ash %	Sulphur %	Yield %	Ash %	Sulphur %	Ash %	Yield %	Ash %	Sulphur %
Comox No. 8 mine										
3" - $1\frac{1}{2}$".....	23.4	32.9	3.8	54.0	9.5	2.3	60.0			
$1\frac{1}{2}$" - 20 mesh	63.5	23.0	3.3	77.0	12.0	3.0	60.0	74.6	12.7	2.7
-20 mesh.....	13.1	21.2	2.7	13.1	21.2	2.7	....			
Comox No. 5 mine										
3" - $1\frac{1}{2}$".....	24.1	39.0	4.5	52.0	11.5	3.1	61.0			
$1\frac{1}{2}$" - 20 mesh	62.1	20.7	3.4	78.0	10.5	2.8	58.0	74.8	13.1	3.0
-20 mesh.....	13.8	23.7	2.6	13.8	23.7	2.6	....			

In comparing these results obtained on the 1938 samples with the analyses of the slack coals from the washery forwarded for the present coking tests, an improvement in the washability of the raw coals at present mined is indicated by the reduction in the inherent sulphur content of the cleaned slack coals.

The coal carbonized at the Fuel Research Laboratories in October 1930 included a washed slack from the Union Bay washery plant which, it was presumed, was representative of the slack coals produced at the Comox colliery from the mines in operation during that period. The following analysis was reported for the coal carbonized.

TABLE VI

Comox Washed Slack October 1930

Moisture......................%	3.9
Dry Basis	
Volatile matter...........%	30.9
Fixed carbon..............%	53.7
Ash.......................%	15.4
Sulphur...................%	1.5
Fusion point of ash.....°F.	2516

The carbonization tests made in the coke ovens of the British Columbia Electric Power And Gas Company, located at Vancouver, included several tests on washed Comox slack as supplied from the Union Bay washery during March 1933, and in addition a specially washed slack of low ash content which was included in this series of tests.

TABLE VII

Comox Washed Slack Coal, March 1933

Sample designation.............	Washed 1½ Inch Slack	Washed Slack. (for test)	Double Washed Slack.
Moisture.......................%	5.8	6.5	6.7
Dry Basis:			
Volatile matter............%	31.2	33.4	33.4
Fixed carbon...............%	54.5	55.7	60.0
Ash........................%	14.3	10.9	6.6
Sulphur....................%	1.5	1.7	1.2
Fusion point of ash......°F.	2400	2550	2410
Calorific value...B.t.u./lb.	12879	13330	14410

The standard preparation at the washery produced a washed slack of approximately 14 per cent ash content. However, two other shipments were prepared having lower ash contents, one with an ash content of approximately 10 per cent and the other with an ash content of less than 7 per cent.

From the analyses and washing data presented in the preceding tables, it is indicated that the slack coals produced during 1933 and earlier were much lower in sulphur content than those produced in 1938, and that a slight improvement in the sulphur reduction has been obtained in the present shipment of samples, which may be due to a slight change in the dispersion of the sulphur in the coal seams.

II

Methods of Testing

The carbonizing equipment at the Fuel Research Laboratories includes a test unit of the by-product coke oven type which is designed to carbonize a charge of 500 pounds under conditions as near as possible to those obtaining in the standard commercial by-product coke oven. The coke produced from each test is in sufficient quantity for the requirements of the several tests which have been designed to evaluate the physical properties of coke for metallurgical or domestic uses.

Test Oven

The oven chamber is constructed of silica and fire brick to the following dimensions: width 16 inches, height 48 inches, height of charge 36 inches, length 36 inches. The flues are arranged in series of six in each of the side walls of the chamber and are fitted with gas burners which project vertically downwards in the flues. The burners are supplied with 500 B.t.u. gas and compressed air is used to produce a short flame. The carbonizing chamber is equipped with a single cast iron door and door frame.

Coke Yield

The weighed coal charge for testing is fed into the hot chamber from a hopper bin over the charging hole of the oven chamber and levelled through the levelling door. On completion of carbonization, the coke is drawn from the oven by hand rakes and water-quenched. The entire charge is collected and dried at 110° C. for twelve hours, after which it is weighed to obtain the dry coke yield which is expressed as a percentage of the weight of dry coal charged.

Coke Screen Test

The coke from the test, after drying, is screened on standard square-hole screens, and the percentages obtained for the following screen limits reported: on 3", on 2" on 1½", on

1", on 1/2", and thru 1/2". The distribution of the screen sizes is an indication of the structure and strength of the coke.

Shatter Test

The standard method of conducting a shatter test and the apparatus employed are described in A.S.T.M. Designation 141-23. The method consists of dropping a 50-pound sample of coke--the pieces selected being representative of the width of the oven--four times from a height of 6 feet. The quantity of coke retained on a 2" screen being the 2" index which is reported together with the 1½" index. Duplicate tests are made on each sample.

Apparent Density

The density of the coke is determined by a modification of the method outlined in the Gas Chemists Handbook.

Abradability Test

The abrasion test adopted at the Fuel Research Laboratories is that developed by the Midland Coke Research Committee, which is termed the "Sheffield Coke Abrasion Test". For this test, a drum 18 inches in diameter and 18 inches long is used. Two cubic feet of 3 to 2 inch dry coke is placed in the drum which is rotated at 23 r.p.m. for 30 minutes, or the equivalent of 690 revolutions. A screen test of the coke is then made, and the percentages on the 1½" screen and the dust passing the 1/16" mesh screen are noted. The abrasion index is the percentage on the 1½ inch screen, and the percentage passing the 1/16" mesh screen is reported as dust due to abrasion.

Bulk Density

The bulk density, or weight per cubic foot, is reported in these tests on coke screened through a 3-inch screen and retained on a 2-inch screen.

Chemical Analyses

A proximate analysis of all cokes tested, together with sulphur and ash fusion determinations, is made. These analyses, together with the physical tests as outlined in this section of the report, are presented in section III, which is entitled "Details of Tests".

By-product Yields

The by-product yields are presented in Section IV and are obtained by the tube test method developed by the Koppers Research Department.

III

Details Of Coking Tests

The data obtained from the physical and chemical tests made on the coals received and the cokes produced are tabulated in detail, together with photographs of the natural surface of the specimens and sections cut parallel to the main axis of the specimen pieces, in the following details of tests.

Five tests are reported, four of which are on the individual samples received, and the fifth test was conducted on a blend of the slack coals from the two seams of the Comox colliery and a coking slack coal from Crowsnest Pass area, which were blended in equal quantities.

Details of Coking Tests

Comox Coal

Date charged..... November 26, 1940.

Name of coal..... Comox 3" washed slack.

Mining Company... Canadian Collieries (Dunsmuir) Ltd.

Mine............. Comox No. 5.

Area............. Cumberland, Vancouver Island.

Province......... British Columbia.

Appearance of test coal: Wet slack, mostly dull coal.

Coking time...... 16 hours.

Screen Analysis of Coal (as received)

on 2"	on 1"	on 1/2"	on 1/8"	thru 1/8"
13.5%	23.8%	11.3%	35.3%	16.1%

Coal prepared for charging

on 1/8"	thru 1/8"
10%	90%

Coal weight per cubic foot: 44.5 pounds

Analysis of coal and coke

	Moisture %	Dry Basis V.M. %	F.C. %	Ash %	Sul. %	F.P.A. °F.
Coal................	3.1	33.0	53.9	13.1	2.4	2200
Coke on $1\frac{1}{2}$" screen	...	3.4	78.1	18.5	2.3	2230

Physical tests of Coke

Coke Screen Test (square mesh openings)

on 3"	on 2"	on $1\frac{1}{2}$"	on 1"	on 1/2"	thru 1/2"
69.5%	22.6%	4.4%	1.4%	0.6%	1.5%

Coke Shatter Test

2" index: 73.3%; $1\frac{1}{2}$" index: 86.5%

Abrasion Test

Index: 89.0% on $1\frac{1}{2}$"; dust (-1/16"): 6.0%

Apparent specific gravity: 0.92

Coke weight per cubic foot (3 to 2 in.): 25.0 pounds

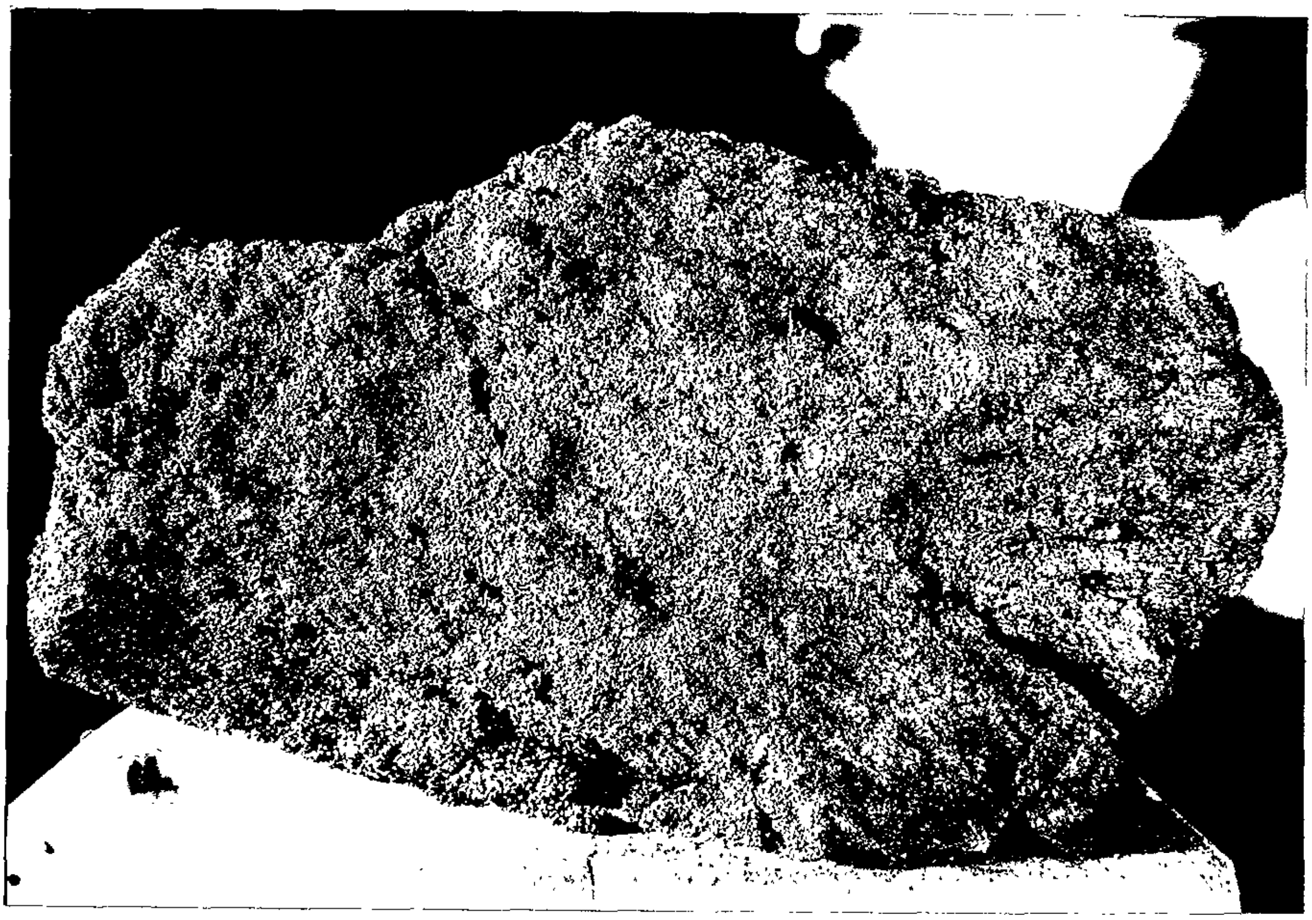
Coke Yield

Weight of coal charged.........lb.	450.0
Moisture..........................%	3.1
Total dry coal..................lb.	436.0
Total dry coke..................lb.	301.0
Yield, dry coal to dry coke.....%	69.1

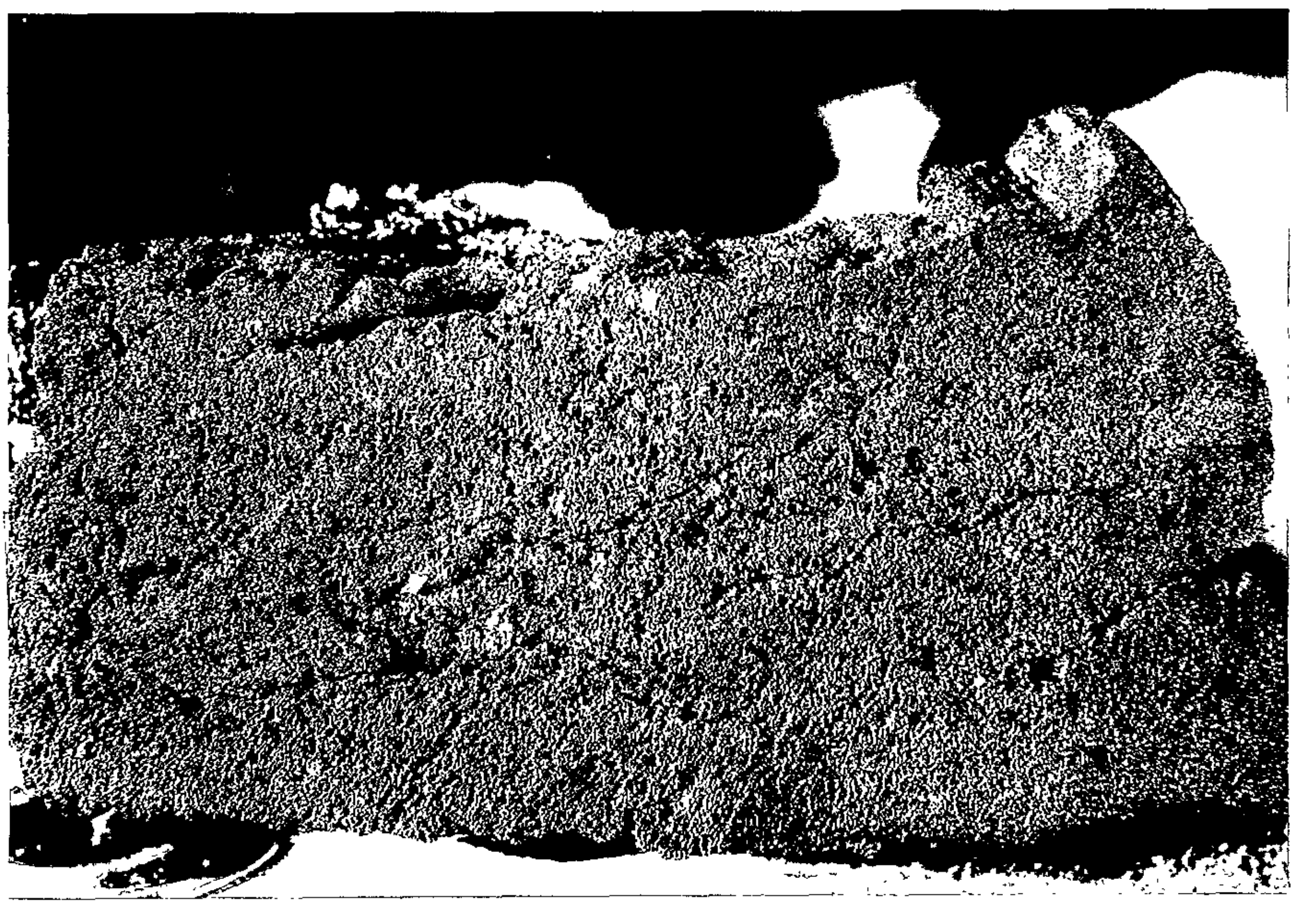
Carbonization data

Width of oven.................	16 inches
Condition of heats...........	Good
Average flue temperature.....	2110°F.
Transverse shrinkage.........	3/4 inch
Carbonization................	Complete
Appearance of natural surface	Silvery, smooth
Size on wharf................	Fairly large
Shape........................	Blocky
Cross fracture...............	Slight amount
Longitudinal fracture........	Slight amount, straight
Type of cross fracture.......	Irregular
Cell structure...............	Regular, small cells
Slaty material...............	Slight amount
Pebbly seam..................	None
Sponge loose.................	None
Sponge ends..................	Very slight amount
Ring when struck.............	Metallic
Strength.....................	Tough

COMOX COAL
No. 5 Mine Washed Slack



Natural Surface



Section

Details of Coking Tests

Comox Coal

Date charged..... November 30, 1940.

Name of coal..... Comox 3" lump hand-picked.

Mining Company... Canadian Collieries (Dunsmuir) Ltd.

Mine............. Comox No. 5.

Area............. Cumberland, Vancouver Island.

Province......... British Columbia.

Appearance of test coal: Screened lump, dull coal, with some banded material.

Coking time...... 16 hours.

Screen analysis of coal (as received)

on 4"	on 2"	on 1"	on 1/2"	on 1/8"	thru 1/8"
46.1%	42.7%	4.2%	2.6%	2.9%	1.5%

Coal prepared for charging

on 1/8"	thru 1/8"
4.4%	95.6%

Coal weight per cubic foot: 46.8 pounds.

Analysis of coal and coke

	Moisture %	Dry basis V.M. %	F.C. %	Ash %	Sul. %	F.P.A. °F.
Coal...............	1.3	34.1	58.1	7.8	2.0	2350
Coke on 1½" screen	...	2.5	86.1	11.4	1.8	2250

Physical tests of coke

Coke Screen test (square mesh openings)

on 3"	on 2"	on 1½"	on 1"	on 1/2"	thru 1/2"
53.3%	29.1%	10.5%	4.0%	0.8%	2.3%

Coke shatter test
2" index: 66.5%; 1½" index: 85.5%

Abrasion test
index: 86.8% on 1½"; dust (-1/16"): 4.8%

Apparent specific gravity: 0.86

Coke weight per cubic foot (3 to 2 in.): 25.0 pounds

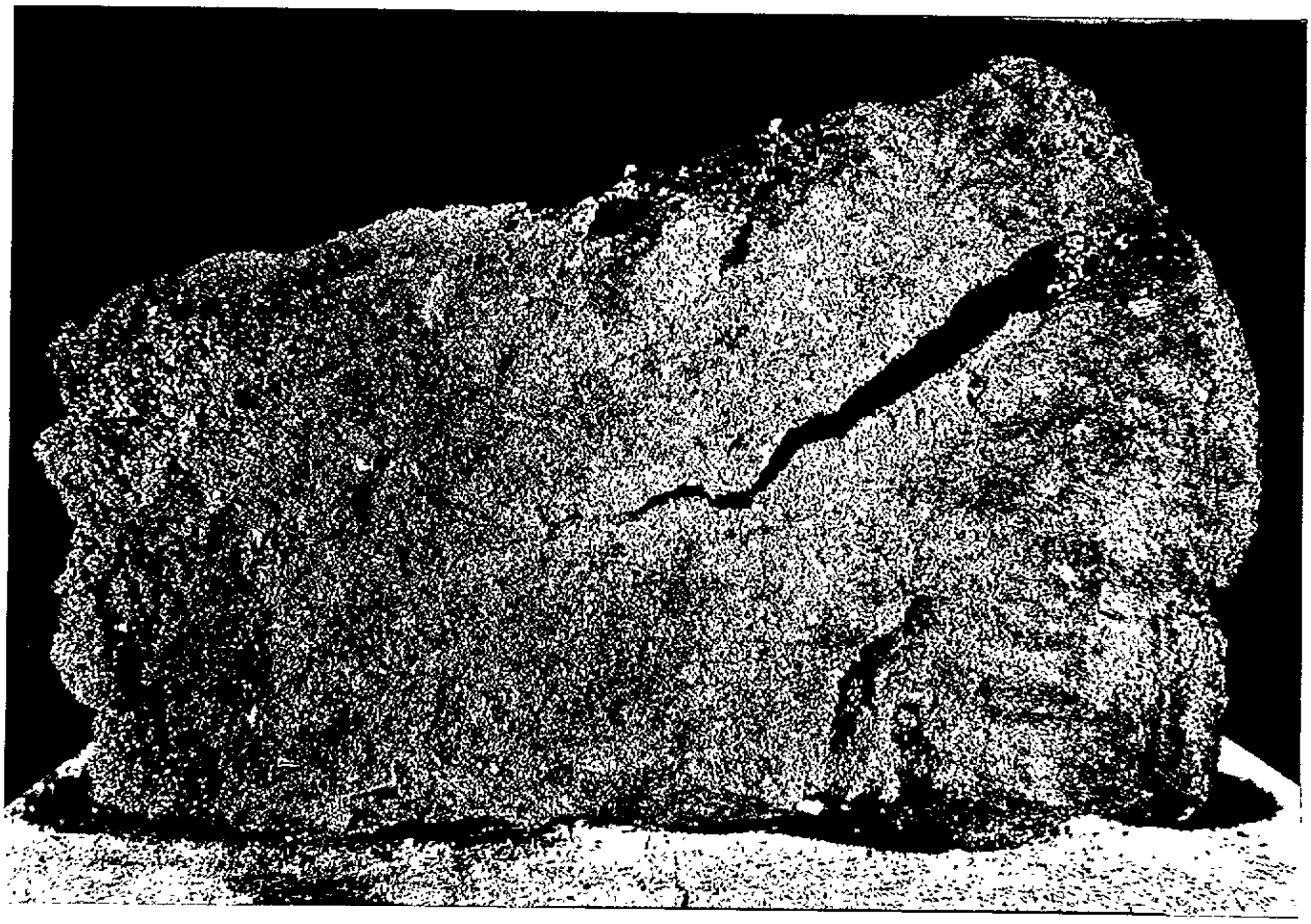
Coke Yield

Weight of coal charged..........lb.	450
Moisture.........................%	1.3
Total dry coal...................lb.	444
Total dry coke...................lb.	305
Yield, dry coal to dry coke.......%	68.7

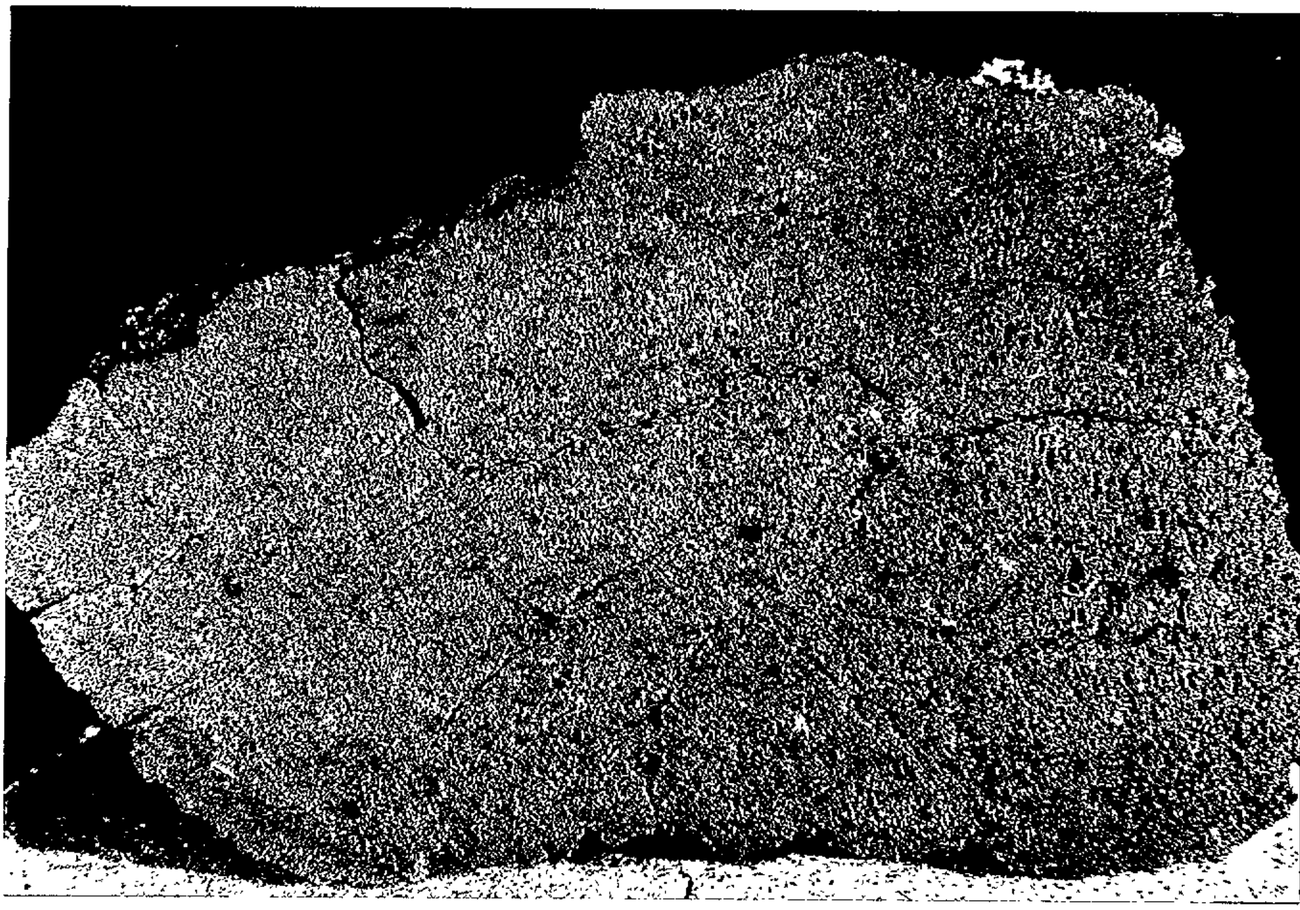
Carbonization data

Width of oven................	16 inches
Condition of heats...........	Good
Average flue temperature.....	2210°F.
Transverse shrinkage.........	3/4 inch
Carbonization................	Complete
Appearance of natural surface	Silvery, fairly smooth
Size on wharf................	Large
Shape........................	Blocky
Cross fracture...............	Slight amount
Longitudinal fracture........	Slight amount, irregular
Type of cross fracture.......	Irregular
Cell structure...............	Regular, small
Slaty material...............	Slight amount
Pebbly seam..................	None
Sponge loose.................	None
Sponge ends..................	Very slight amount
Ring when struck.............	Metallic
Strenght.....................	Tough to brittle

COMOX COAL
No. 5 Mine (Hand-picked Lump)



Natural Surface



Section

Details of Coking Tests

Comox Coal

Date charged..... November 28, 1940.

Name of coal..... Comox 3" lump hand-picked.

Mining company... Canadian Collieries (Dunsmuir) Ltd.

Mine.............. Comox No. 8

Area.............. Cumberland, Vancouver Island.

Province.......... British Columbia.

Appearance of test coal: Lump, banded, mostly dull coal.

Coking time...... 16 hours

Screen analysis of coal (as received)

on 4"	on 2"	on 1"	on 1/2"	on 1/8"	thru 1/8"
20.1%	65.0%	5.9%	3.0%	3.6%	2.4%

Coal prepared for charging

on 1/8"	thru 1/8"
6.8%	93.2%

Coal weight per cubic foot: 47.5 pounds

Analyses of coal and coke

	Moisture %	Dry basis V.M. %	F.C. %	Ash %	Sul. %	F.P.A. °F.
Coal...............	2.3	33.5	55.9	10.6	2.7	2326
Coke on 1½" screen	...	3.0	82.6	14.4	2.2	2370

Physical tests of coke

Coke screen test (square mesh openings)

on 3"	on 2"	on 1½"	on 1"	on 1/2"	thru 1/2"
53.2%	31.4%	8.6%	3.7%	1.0%	2.1%

Coke shatter test

2" index: 70.0%; 1½" index: 88.3%

Abrasion test

index: 89.3%; dust (-1/16"): 5.0%

Apparent specific gravity: 1.01

Coke weight per cubic foot (3 to 2 in.): 25.5 pounds

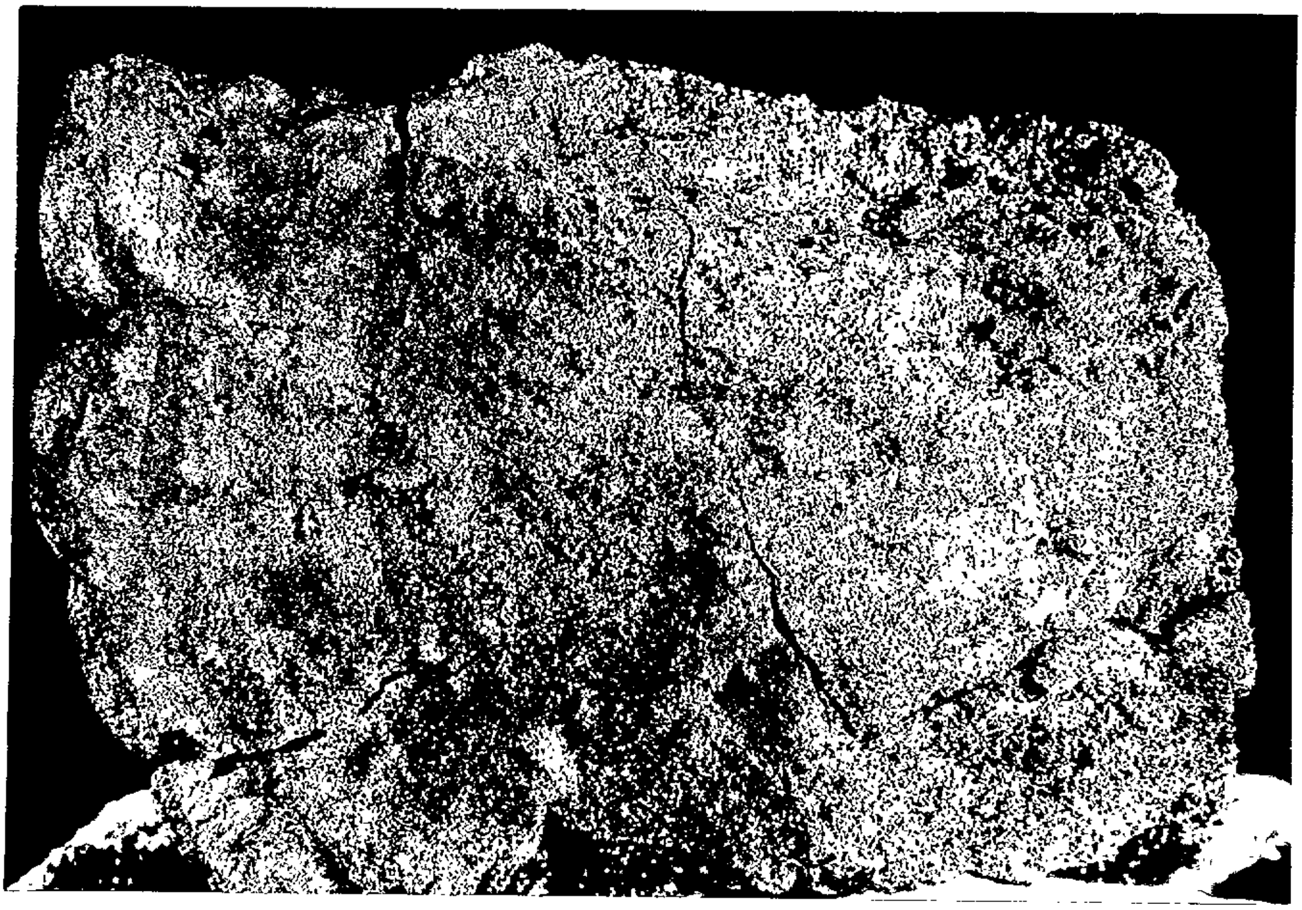
Coke Yield

Weight of coal charged..........	lb.	450
Moisture.........................	%	2.3
Total dry coal...................	lb.	440
Total dry coke...................	lb.	306
Yield, dry coal to dry coke.......	%	69.6

Carbonization data

Width of oven..................	16 inches
Condition of heats............	Good
Average flue temperature.....	2180°F.
Transverse shrinkage..........	3/4 inch
Carbonization.................	Complete
Appearance of natural surface	Silvery, smooth
Size on wharf.................	Large
Shape.........................	Blocky
Cross fracture................	Slight amount
Longitudinal fracture.........	Slight amount, irregular
Type of cross fracture........	Irregular
Cell structure................	Small, regular
Slaty material................	Slight amount
Pebbly seam...................	None
Sponge loose..................	None
Sponge ends...................	Very slight amount
Ring when struck..............	Metallic
Strength......................	Tough

COMOX COAL
No. 8 Mine (Hand-picked Lump)



Natural Surface

Section

Details of Coking Tests

Comox Coal

Date charged..... November 27, 1940.

Name of Coal..... Comox washed slack.

Mining company... Canadian Collieries (Dunsmuir) Ltd.

Mine............. Comox No. 8.

Area............. Cumberland, Vancouver Island.

Province......... British Columbia.

Appearance of test coal: Wet slack, mostly dull coal.

Coking time...... 16 hours.

Screen analysis of coal (as received)

on 2"	on 1"	on 1/2"	on 1/8"	thru 1/8"
11.5%	27.4%	18.5%	24.4%	18.2%

Coal prepared for charging

on 1/8"	thru 1/8"
15.3%	84.7%

Coal weight per cubic foot: 44.0 pounds

Analyses of coal and coke

	Moisture %	V.M. %	F.C. %	Ash %	Sul. %	F.P.A. °F.
		Dry Basis				
Coal................	3.0	32.5	55.9	11.6	2.5	2160
Coke on 1½" screen	...	2.2	80.7	17.1	2.4	2110

Physical tests of coke

Coke Screen test (square mesh openings)

on 3"	on 2"	on 1½"	on 1"	on 1/2"	thru 1/2"
64.3%	23.4%	7.1%	2.4%	1.0%	1.8%

Coke shatter test
2" index: 68.6%; 1½" index: 86.5%

Abrasion test
index: 85.5%; dust (-1/16"): 6.9%

Apparent specific gravity: 0.98

Coke weight per cubic foot (3 to 2 in.): 24.0 pounds

Coke Yield

Weight of coal charged..........lb.	450
Moisture...........................%	3.0
Total dry coal....................lb.	436
Total dry coke........................	306
Yield, dry coal to dry coke.......%	70.4

Carbonization data

Width of oven..................	16 inches
Condition of heats............	Good
Average flue temperature.....	2210°F.
Transverse shrinkage..........	3/4 to 1 inch
Carbonization................	Complete
Appearance of natural surface	Silvery, smooth
Size on wharf................	Large
Shape.......................	Blocky
Cross fracture...............	Slight amount
Longitudinal fracture.........	Slight amount
Type of cross fracture.......	Irregular
Cell structure...............	Small, regular
Slaty material...............	Slight amount
Pebbly seam..................	None
Sponge loose.................	None
Sponge ends..................	Very slight amount
Ring when struck.............	Metallic
Strength.....................	Tough

COMOX COAL
No. 8 Mine Washed Slack

Natural Surface

Section

Details of Coking Tests

1/3 Comox No. 8 Slack
1/3 Comox No. 5 Slack
1/3 Michel B Seam Slack

Date charged..... November 28, 1940.

Name of coal..... Michel B seam slack.

Mining company... Crow's Nest Pass Coal Co., Fernie, B.C.

Mine.............. Michel B mine.

Area.............. Crowsnest Pass area at border of Alberta and British Columbia.

Coking time...... 16 hours.

Coal blend prepared for charging

on 1/4"	on 1/8"	thru 1/8"
3.4%	13.6%	83.0%

Coal weight per cubic foot: 46.0 pounds

Analyses of coal and coke

	Moisture %	Dry Basis V.M. %	F.C. %	Ash %	Sul. %	F.P.A. °F.
Coal blend.........	1.5	29.7	58.8	11.5	1.8	2300
Coke on $1\frac{1}{2}$" screen	...	2.0	82.6	15.4	1.7	2250

Physical tests of coke

Coke screen test (square mesh openings)

on 3"	on 2"	on $1\frac{1}{2}$"	on 1"	on 1/2"	thru 1/2"
58.4%	28.2%	6.5%	3.1%	0.9%	2.9%

Coke shatter test

2" index: 69.9%; $1\frac{1}{2}$" index: 86.4%

Abrasion test

index: 95.4%; dust (-1/16"): 2.0%

Apparent specific gravity: 0.92

Coke weight per cubic foot: 27.0 pounds

Coke yield

Weight of coal charged............	lb.	450
Moisture..........................	%	1.5
Total dry coal....................	lb.	446
Total dry coke....................		323
Yield, dry coal to dry coke.......	%	72.2

Carbonization data

Width of oven................	16 inches
Condition of heats...........	Good
Average flue temperature.....	2160°F.
Transverse shrinkage.........	1/2 to 3/4 inch
Carbonization................	Complete
Appearance of natural surface	Silvery, smooth
Size on wharf................	Medium to large
Shape........................	Blocky
Cross fracture...............	Slight amount
Longitudinal fracture........	Slight amount
Type of cross fracture.......	Fairly square
Cell structure...............	Small, regular
Slaty material...............	Very slight amount
Pebbly seam..................	None
Sponge loose.................	None
Sponge ends..................	Very slight amount
Ring when struck.............	Metallic
Strength.....................	Brittle to tough

COAL BLEND
1/3 Comox No. 8 Slack
1/3 Comox No. 5 Slack
1/3 Michel B Seam Slack

Natural Surface

Section

IV

Laboratory Carbonization Tests

Since it is difficult to obtain accurate by-product yields on single tests from plant or semi-plant scale carbonizing equipment, a number of laboratory methods have been devised for determining by-product yields, but none are directly comparable with commercial operation and, hence, are in many cases misleading.

The equipment in use at the Fuel Research Laboratories for the predicting of by-product and coke yields obtainable from standard by-product coke ovens has been designed by Messrs. Sperr and Rose of the Koppers Company. The equipment has been correlated, by the use of yield factors, to commercial practice from plant operation data, and for this reason is considered very reliable.

The coke yield figures, which are adjusted to commercial practice by factors, check very closely those obtained in the 500-pound test oven which have been included as the last item in the following table of tube test results.

TABLE VIII

Laboratory Carbonization Results
(Tube tests based on dry coal)

Sample Tested	Comox No. 5 Mine Washed Slack	Comox No. 5 Mine Hand-picked Lump	Comox No. 8 Mine Hand-picked Lump	Comox No. 8 Mine Washed Slack	Coal Blend: 1/3 Comox No. 5 1/3 Comox No. 8 1/3 Michel B Seam
Proximate analyses					
Volatile matter.......%	33.0	34.1	33.5	32.5	31.3
Fixed carbon..........%	53.9	58.1	55.9	55.9	58.3
Ash...................%	13.1	7.8	10.6	11.6	10.4
Sulphur...............%	2.4	2.0	2.7	2.5	1.9
Fusion point of ash.°F.	2200	2350	2326	2160	2300
Products of distillation					
Water from dried coal.%	5.694	4.883	5.421	5.273	4.867
Carbon dioxide........%	1.681	1.595	1.749	1.488	1.765
Hydrogen sulphide.....%	0.638	0.535	0.680	0.680	0.475
Grains H_2S per 100 cu.ft. of gas.........	890	704	894	933	654
Composition of gas, calculated free of oxygen, carbon dioxide and Hydrogen sulphide					
Illuminants...........%	6.3	6.8	5.4	5.7	5.1
Carbon monoxide.......%	6.2	6.3	6.1	6.2	6.0
Hydrogen..............%	50.5	50.4	52.0	52.3	52.5
Methane...............%	33.7	33.6	31.9	33.1	33.0
Nitrogen..............%	3.3	2.9	4.6	2.7	3.4
Density (Air = 1)......	0.376	0.377	0.370	0.362	0.366
B.t.u. in gas per pound of coal.........	3133	3295	3128	3086	3065
Practical yields					
Total gas (inclusive of light oils) cu.ft.	12,286	12,920	12,267	12,102	12,016
B.t.u. of gas/cu.ft....	510	510	510	510	510
Tar, Imp. gallons/ton..	8.90	11.30	9.15	9.55	8.75
Ammonium sulphate...lb.	18.9	18.8	18.2	19.1	19.6
Light oils, Imp.gal/ton	2.55	3.02	2.78	2.47	2.44
Total dry coke, per cent of coal.........	69.90	68.47	69.63	70.25	72.21
500-pound oven, coke yields..............%	69.1	68.7	69.6	70.4	72.2

V

Summary and Conclusions

The evaluation of coke for blast furnaces is generally based on the standard of quality of the coking coals available within the area where the furnaces are operated rather than on any rigid specifications set up as minimum standards for the industry.

Certain standardized tests, which have been developed for the estimation of the physical properties of coke, are used together with the chemical analyses for estimating the comparative values of cokes for blast furnace use. These tests include the shatter test and abrasion test, which are used to estimate the hardness of coke. The shatter indices obtained on the cokes produced from the Comox coal range from 73.3 to 66.5 for the 2-inch index, and 88.3 to 85.5 for the 1½-inch index. The abrasion indices range from 89.3 to 85.5, with dust percentages of 6.9 to 4.8. These results indicate that a tough blocky coke may be produced, which tends to be rather friable as shown by the abrasion indices and dust percentages. The abrasion index values for blast furnace cokes are usually over 90 per cent with less than 3 per cent of dust. There is a marked improvement in the resistance to abrasion of the coke prepared from a blend of 2/3 Comox coal and 1/3 of a higher rank bituminous coal, the values being 95.4 for the abrasion index and 2 per cent for the dust.

Either the carbon content or the calorific value of blast furnace coke is a convenient method of assessing the chemical value of the coke and is also an indirect measure of the ash and water contents present. The ash contents in the cokes produced from the Comox coals range from 11.4 per cent to 18.5 per cent, and the sulphur contents from 1.8 per cent in the coke from No. 5 mine lump coal to 2.4 per cent in the cokes from the slack coals. These sulphur values show a considerable increase over values previously obtained in tests made for the investigations of 1930 and 1933, when the washed slack coals processed contained 1.5 per cent sulphur.

The cokes made from the present series of Comox colliery coals show very little deviation in general characteristics. The coke yields are approximately 70 per cent of the coal charged, and the average ash content of the +1½ inch coke samples is 15.4 per cent.

The by-product yields obtainable include approximately 8,000 cubic feet of 500 B.t.u. surplus gas, 9 gallons of tar, 18 pounds of ammonium sulphate and 2.5 gallons of light oil per ton of coal carbonized.

Physical and Chemical Survey Report No. 91

STUDY OF COAL FROM

ELK RIVER COLLIERY, NO.9 SEAM

CROWSNEST AREA

OPERATED BY

THE CROW'S NEST PASS COAL CO., LTD., FERNIE, B.C.

By

E.Swartzman

Fuel Research Laboratories
Bureau of Mines
Ottawa Canada

May, 1944

<u>Physical and Chemical Survey Report No. 91</u>

Study of Coal from

Elk River Colliery, No. 9 Seam

Crow'snest Area

OPERATED BY

The Crow's Nest Pass Coal Co., Ltd., Fernie, B.C.

<u>Table of Contents</u>

I

INTRODUCTION

The following report deal_ with a Physical and Chemical study of a sample of coal from the Elk River Colliery, No. 9 Seam, worked in the Crowsnest area, about 4 miles east of Fernie, British Columbia, by the Crow's Nest Pass Coal Co. Ltd. of Fernie, B.C. The Elk River mines, opened in 1943, are still in the development stage, and all the coal mined in both the No.9 & No.4 seams, at Elk River and the Coal mined at Coal Creek are prepared in a common tipple, situated at the Elk River Mines, and no attempt is made to segregate the coal from the various seams.

This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Ninety reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. Th e report, is therefore, presented in sections dealing with the following subjects:

1. Physical Propebties,
2. Chemical Properties,
3. Washing Charactebistics,
4. Coking and swelling Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the No.9 seam, Elk River mine was sampled at the mine by an official from the Fuels Research Laboratories in the presence of representatives from the operating companies. The combined sample, which weighed approximately 1990 pounds was boxed and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due various members of th Crow's Nest Pass Coal Co. Ltd., for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H.Nicolls of the Fuel Research Laboratories under whose direction, the major portion of the chemical analyses was conducted .

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Elk River mine, No. 9 Seam, was collected at the mine during January 1944. A combined sample of the unprepared run-of-mine coal, weighing approximately 1990 pounds was collected from the conveyor belt and was considered to be representative of the output at that time. This sample was used for the screening test, standard round-hole screens made from ⅛ inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by modification of the method used for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability.

Friability, which is an important proper ty in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.) investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connel, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size Stability' is the antonym of friability and "on the assumption that

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, AND BULK DENSITY

Screen Sizes*	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	8.8	8.8	1.31	--	19.6
2 - 4 in.	11.8	20.6	1.42	43.75	14.2
1½ - 2 in.	3.3	23.9	1.46	43.25	18.8
1 - 1½ in.	8.0	31.9	1.42	43.25	20.5
3/4 - 1 in.	5.3	37.2	1.38	42.25	19.2
1/2 - 3/4 in.	9.1	46.3	1.37	41.25	15.5
1/4 - 1/2 in.	15.0	61.3	1.30	40.00	12.9
1/8 - 1/4 in.	14.2	75.5	1.27	38.50	11.3
#48 - 1/8 in.	16.1	91.6	1.25	47.25	9.8
0 - #48	8.4	100.0			9.3
Mine Run		100.0		56.00	16.2
Plus 1½ in.		23.9		45.00	18.8
0 - 1½ in.		76.1		54.00	13.6
3/4 - 1½ in.		13.3		43.00	19.8
0 - 1/8 in.		24.5	1.25	47.25	9.7

	As Received
Average Size of Run-of-Mine ....in.	1.23

* All screens 1/8 in. and larger are round-hole screens. No.48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test 2 - 3 in. Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	47.5	33.0
1½ - 2 in.		13.0	15.0
1 - 1½ in.		10.5	11.0
3/4 - 1 in.		5.0	6.0
1/2 - 3/4 in.		5.5	7.0
0 - 1/2 in.		18.5	28.0
Av'g Size in.		1.670	1.380
Size Stab'ty %		66.8	55.2

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	93.4
0 - 1½ in.	100.3
0 - 1/8 in.	109.7

friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the Elk River Mine, No.9 Seam are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1, was used for evaluating the grindability of the coal from the No.9 Seam of the Elk River Mine.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite,
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100 .

5. Crushing Test

In washing coal or in preparing special sizes & size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore,

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1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D. 409-35T.

a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England The rols were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Elk River No.9 Seam coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 INCH LUMP
(Crusher set at 1½ inch)

		Screen Analysis	
		Before Crushing %	After Crushing %
8 - 10 in.	%	6.8	
7 - 8 in.	%	21.6	
6 - 7 in.	%	20.5	
5 - 6 in.	%	22.7	
4 - 5 in.	%	28.4	9.1
3 - 4 in.	%		8.7
2 - 3 in.	%		23.8
1½ - 2 in.	%		7.6
1 - 1½ in.	%		8.5
3/4-1 in.	%		5.3
½ - 3/4 in.	%		7.0
¼ - ½ in.	%		9.6
1/8-¼ in.	%		7.2
0 - 1/8 in.	%		13.2
Average Particle Size. in.		6.091	1.700
Size Reduction	%		27.9

III

CHEMICAL PROPERTIES

The various screen sizes obtained frpm the screening tests of the coal from the Elk River Mine, No.9 Seam were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.

2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.

3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, as shown in Table VII. Data on temperature lags are presented because of their bearing on the clinkering properties.

4. The Chemical Analyses of Ash, which are shown in Table VIII.

N.B. The sulphur forms were not determined as this coal is very low in sulphur.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis				
		Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/Lb
Plus 4 in.	1.0	19.6	23.0	57.4	0.6	--
2 - 4 in.	0.9	14.2	25.0	60.8	0.7	13210
1½ - 2 in.	0.8	18.8	23.5	57.7	0.5	--
1 - 1½ in.	0.7	20.5	22.0	57.5	0.6	--
3/4 - 1 in.	0.8	19.2	23.0	57.8	0.5	--
1/2 - 3/4 in.	1.0	15.5	24.2	60.3	0.5	--
1/4 - 1/2 in.	1.0	12.9	25.0	62.1	0.5	--
1/8 - 1/4 in.	1.2	11.3	25.2	63.5	0.5	--
#48 - 1/8 in.	0.6	9.8	23.1	65.1	0.5	--
0 - #48	0.6	9.3	24.9	65.8	0.6	--
Mine Run	1.3	16.2	23.4	60.4	0.5	12965
Plus 1½ in.	0.7	18.8	23.3	57.9	0.6	12560
0 - 1½ in.	1.4	13.6	24.1	62.3	0.5	13345
3/4 - 1½ in.	1.0	19.8	22.0	58.2	0.5	13325
0 - 1/8 in.	1.3	9.7	25.5	64.8	0.6	13995

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis					
	Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	73.9	4.4	0.5	0.6	4.4	16.2

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2150	2390	2580	430	240	190	19.6
2 - 4 in.	2120	2270	2410	290	150	140	14.2
1½ - 2 in.	2150	2300	2540	390	150	240	18.8
1 - 1½ in.	2300	2420	2690	390	120	270	20.5
3/4 - 1 in.	2350	2530	2770	420	180	240	19.2
1/2 - 3/4 in.	2350	2530	2790	440	180	260	15.5
1/4 - 1/2 in.	2300	2530	2800	500	230	270	12.9
1/8 - 1/4 in.	2370	2470	2680	310	100	210	11.3
#48 - 1/8 in.	2400	2520	2660	260	120	140	9.8
0 - #48 in.	2150	2270	2500	350	120	230	9.3
Mine Run	2290	2400	2650	360	110	250	16.2
Plus 1½ in.	2180	2300	2650	470	120	350	18.8
0 - 1½ in.	2270	2470	2830	560	200	360	13.6
3/4 - 1½ in.	2350	2460	2710	360	110	250	19.8
0 - 1/8 in.	2350	2490	2710	360	140	220	9.7

TABLE VIII

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run												

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the $1\frac{1}{2}$ inch slack, $1\frac{1}{2}$ to 4 inch lump, and +4 inch lump crushed to pass a $1\frac{1}{2}$ inch screen, all prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R.Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash .

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the revovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

± .10 Curve Per cent	Degree of Difficulty	Preparation
2 – 7	Simple	Almost any process; high tonnage
7 – 10	Moderately difficult	Efficient process high tonnage
10 – 15	Difficult	Efficient process; medium tonnage
15 – 20	Very difficult	Efficient process low tonnage
20 – 25	Exceedingly difficult	Very efficient process low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following;

Curve 1, the average ash percent of the separated coal.

Curve 2, the actual ash per cent of the heaviest pieces of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II, III. All of the data used in the construction of the curves are presented in Tables IX to XVII inclusive.

TABLE IX

Float and Sink Data on 1½" Slack

-Ash-

Specific Gravity	Weight	Ash	Cumulative Floats Weight	Cumulative Floats Ash	Cumulative Sinks Weight	Cumulative Sinks Ash	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	%	%	%	%	%	%		
Floats 1.30	0.0	-	0.0	--			1.40	93.5
Sinks 1.30 Floats 1.32	68.1	2.9	68.1	2.9	100.0	[illegible]	1.45	11.7
Sinks 1.32 " 1.40	10.7	13.7	78.8	4.4	31.9	42.1	1.55	3.8
" 1.40 " 1.50	4.9	20.1	83.7	5.3	21.2	56.4	1.65	2.2
" 1.50 " 1.60	1.1	26.0	84.8	5.6	16.3	67.3	1.75	1.1
" 1.60	15.2	70.3	100.0	15.4	15.2	70.3		
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.32	2.9	27.0	70.1	Good	0.5	2600	2750	2850	250	150	100
Sinks 1.32 " 1.40	13.8	22.5	63.7	Poor	0.5	2350	2650	2800	450	300	150
" 1.40 " 1.50	20.3	20.1	59.6	Poor	0.6	2350	2450	2550	200	100	100
" 1.50 " 1.60	26.1	21.9	52.0	Poor	0.8	2100	2220	2390	290	120	170
" 1.60	70.8	11.4	17.8	Agglomerate	0.5	2360	2600	2850+	490+	240	250+

TABLE XI

Float and Sink Data on 1½-4in. lump

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± .10 Specific Gravity Distribution Gravity	± .10 Specific Gravity Distribution Calculated Ordinate
								1.35	67.8
	Floats 1.30	9.8	3.2	9.8	3.2	100.0	23.0	1.40	57.2
Sink 1.30	" 1.40	43.1	4.7	52.9	4.4	90.2	25.2	1.45	24.4
" 1.40	" 1.50	6.7	16.5	59.6	5.8	47.1	43.9	1.55	16.4
" 1.50	" 1.60	13.8	26.5	73.4	9.7	40.4	48.5	1.65	15.0
" 1.60		26.6	59.9	100.0	23.0	26.6	59.9	1.75	9.3
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XII

Float and Sink Data on Plus 4" Lump (Crushed)

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± .10 Specific Gravity Distribution Gravity	± .10 Specific Gravity Distribution Calculated Ordinate
								1.35	81.8
	Floats 1.30	57.2	5.4	57.2	5.4	100.0	19.6	1.40	15.6
Sinks 1.30	" 1.40	10.0	6.4	67.2	5.5	42.8	38.6	1.45	12.7
" 1.40	" 1.50	3.3	18.7	70.5	6.2	32.8	48.4	1.55	7.5
" 1.50	" 1.60	4.5	27.0	75.0	7.4	29.5	51.7	1.65	5.4
" 1.60		25.0	56.2	100.0	19.6	26.0	56.2	1.75	5.4
~~CURVE No.~~	4		2	1 2 4.	1	3	3	5	5

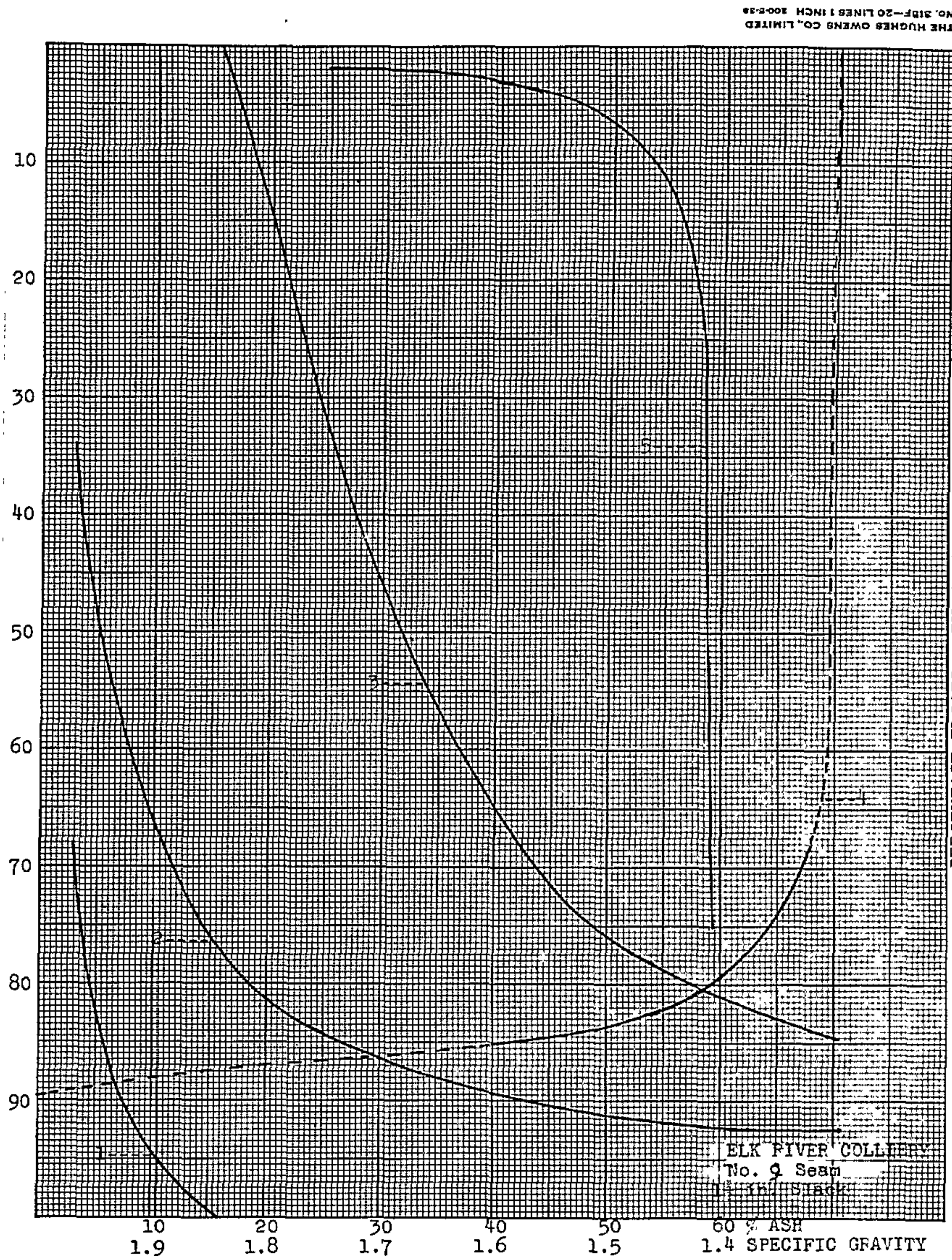

FIG. I - Washability Curves for 1-1/2 in. Slack - Elk River Mine-No. 9 Seam

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific Gravity
Curve 5 - ±.10 specific gravity distribution

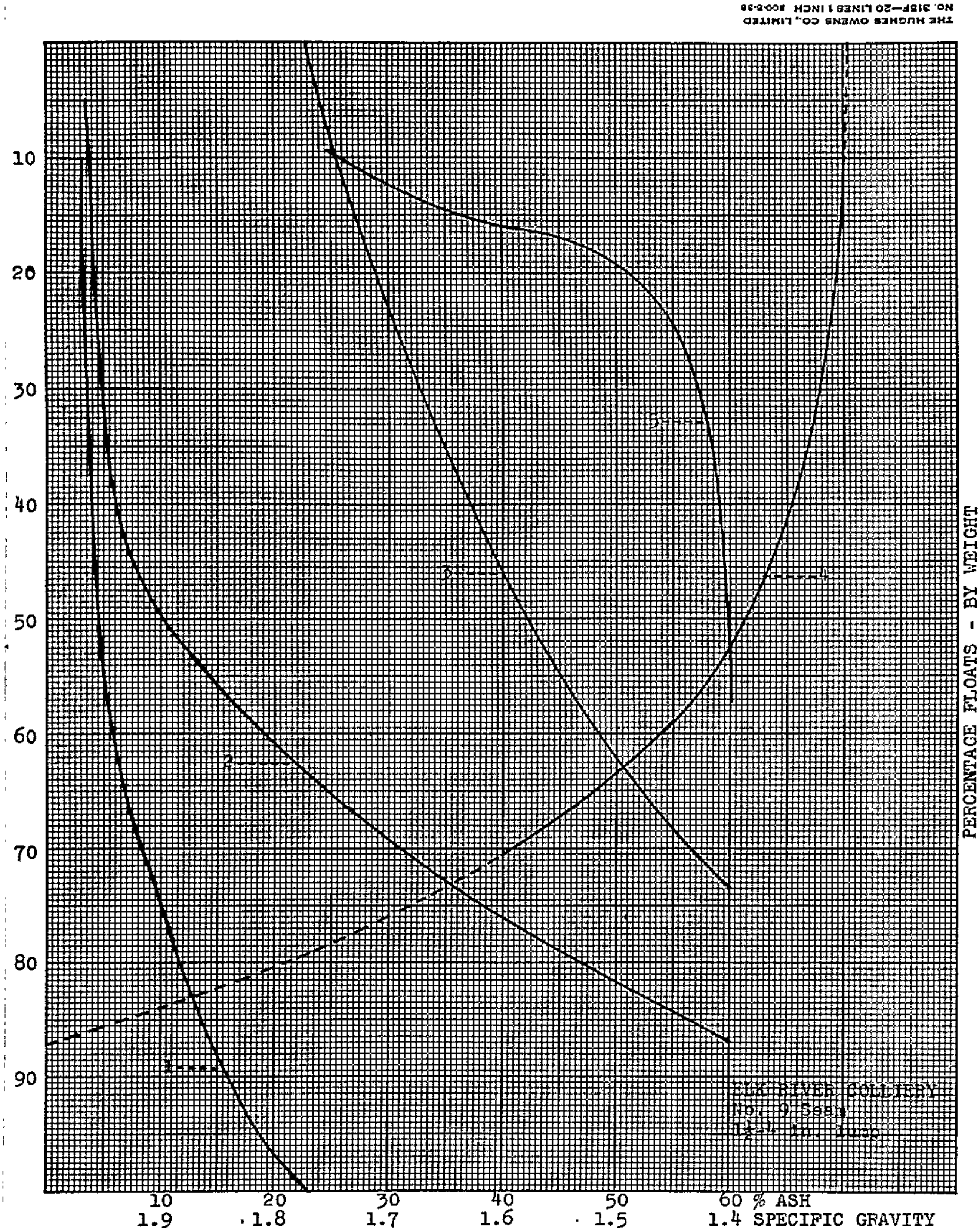

FIG. II - Washability Curves for 1-1/2 to 4 in. Lump - Elk River Mine-No. 9 Seam

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative Slate-ash percentage (sink)
Curve 4 - Specific Gravity
Curve 5 - ±.10 specific gravity distribution.

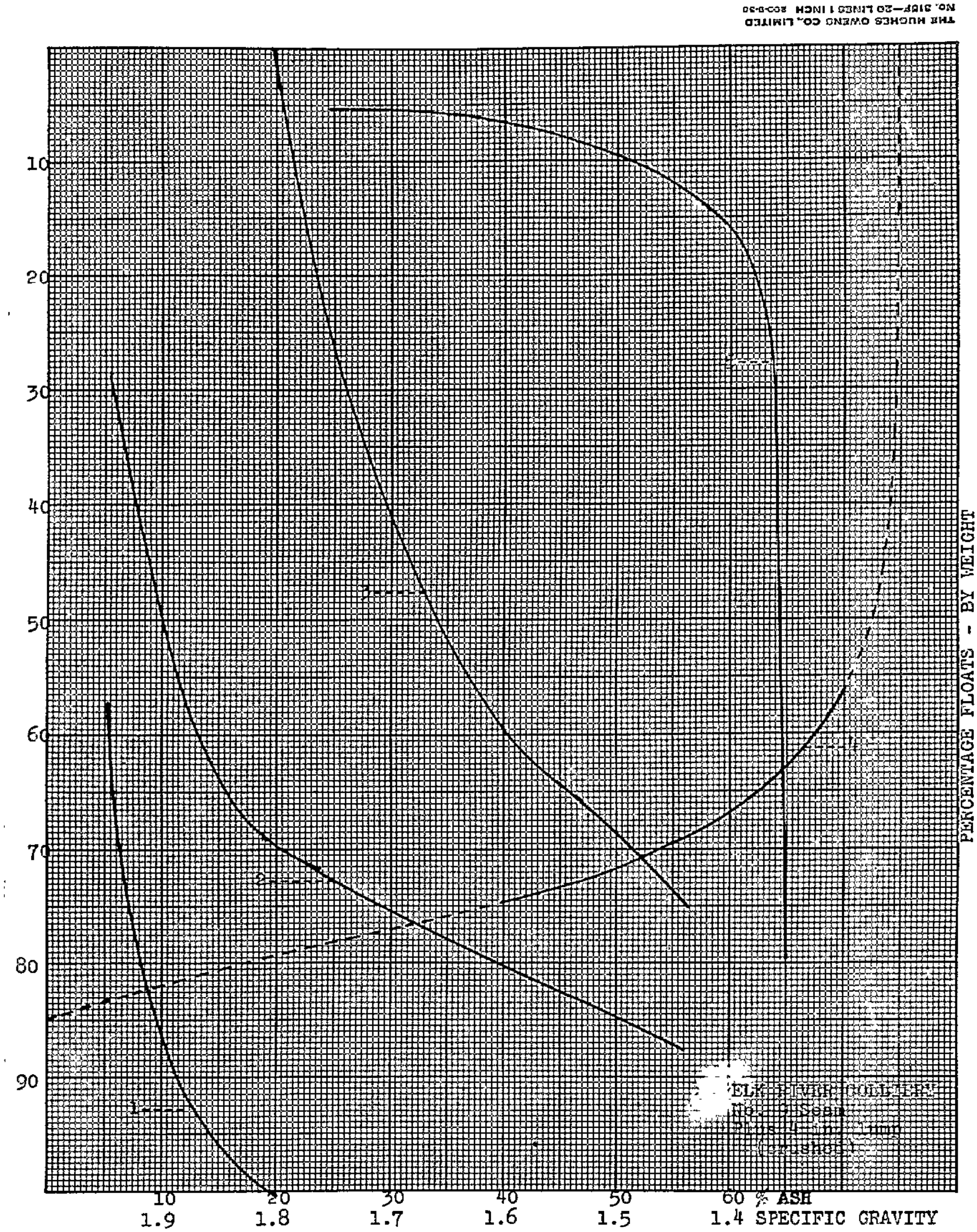

FIG. III - Washability Curves for Plus 4-in. Lump.- Elk River Mine-No. 9 Seam

Curve 1 - Cumulative coal-ash percentage (Float)
Curve 2 - Acutal ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific Gravity
Curve 5 - ±.10 specific gravity distribution.

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE
0 to 1¼ Inch Slack

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight..........................%	100.0	86.2	13.8
Proximate Analysis (dry basis)			
Ash..........................%	13.6	8.5	55.2
Volatile Matter..............%	24.1	25.5	16.4
Fixed carbon.................%	62.3	66.0	28.4
Sulphur......................%	0.5	0.5	0.7
Calorific Value......B.T.U./lb	13345	14245	6270
Fusion Point of Ash.........°F.	2470	2400	2460
Melting Range of Ash........°F.	560	350	540
Coking Properties.............	Good	Good	Agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
1½ to 4 Inch Lump

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight..........................%	100.0	63.8	36.2
Proximate Analysis (dry basis)			
Ash..........................%	15.2	7.0	59.6
Volatile Matter..............%	24.7	25.0	14.6
Fixed carbon.................%	60.1	68.0	25.8
Sulphur......................%	0.6	0.5	0.5
Calorific Value.....B.T.U./lb.	13055	14485	--
Fusion Point of Ash........°F.	2280	2430	2680
Melting Range of Ash.......°F.	340	260	370
Coking Properties.............	Good	Good	Agglomerate

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
Plus 4 Inch Lump (Crushed)

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight.........................%	100.0	88.4	11.6
Proximate Analysis (dry basis)			
Ash..........................%	15.7	11.9	45.0
Volatile Matter.............%	24.1	26.1	18.2
Fixed carbon................%	60.2	62.0	36.8
Sulphur.....................%	0.6	0.5	0.6
Calorific Value....B.T.U./lb.	12980	13355	--
Fusion Point of Ash.......°F.	2390	2170	2340
Melting Range of Ash......°F.	430	240	440
Coking Properties............	Good	Good	Agglomerate

TABLE XVI

SCREEN ANALYSIS AND CHEMICAL ANALYSIS

(Dry Basis of 1½" Slack

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	17.5	17.5	20.0	0.5	2465
1/8 -3/4 inch	50.3	67.8	12.9	0.5	2510
0 -1/8 inch	32.2	100.0	9.7	0.6	2490

TABLE XVII

FLOAT AND SINK DATA ON SCREENED SIZES USING A SELECTED GRAVITY OF 1.60

(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F.	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ in.	68.2	8.5	2300	31.8	64.5	2540
1/8 - 3/4 in.	83.7	10.4	2450	16.3	69.7	2540
0 - 1/8 in.	85.9	6.2	2380	14.1	48.9	2250

V

COKING PROPERTIES

1. Swelling Index Test (F.R.L.)

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Elk River No.9 Seam coal are shown in Table XVIII.

2. Free-Swelling Index of Coal

The Free-Swelling Index of coal as determined by the A.S.T.M. Tentative Method D720-43T, and patterned after the B.S.I. Crucible Swelling Test is very similar to the F.R.L. Swelling Index test, in that the method is a "small-scale laboratory test for obtaining information regarding the free-swelling properties of a coal". The coke buttons produced under regidly standardized conditions are compared to a series of Standard Profiles with Swelling Index numbers frpm 1 to 9, the larger the number the greater the swelling. According to the A.S.T.M. "the results may be used as an indication of the coking characteristics of the coal when burned as a fuel".

The results obtained by means of this test in comparison to those obtained by the F.R.L. Swelling Index test on various siz-mixtures of Elk River, No.9 Seam coal are shown in Table XIX

1/"A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant by-Product Coke", by R.A.Strong, E.J. Burrough and E. Swartzman -Mines Branch piblication No, 737 -2.

TABLE XVIII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A
"SWELLING INDEX" TEST

	1½ in. Slack Unwashed	1½ in. Slack Washed at 1.60 Sp.Gr.
Volatile Matter at 600°C. (D.B.) . . . %	18.9	20.1
Swelling Index	503	572
Section--Coke Classification Chart . . .	IX	IX
Specific Volatile Index	190	
Section--Coal Classification Chart . . .	G-H:Border of Ortho- and Metabituminous.	
Ash per cent in coal (dry) . . . . %	13.6	8.5
PHYSICAL PROPERTIES OF BY-PRODUCT COKE--		
Size on wharf (% on 3" screen	70.0	70.0
(Breeze: %-1/2"	2.0	2.0
Shatter test (Index: % on 2" screen .	60.0	60.0
(Breeze: %-1/2"	4.0	4.0
Abrasion test (Index: % on 1½" screen.	90.0	90.0
(Dust: %-1/16"	2.5	2.5
Density (App. Specific Gravity .	1.0	0.95
(Lbs. per cubic foot . .	30.0	27.0
Transverse shrinkage	Good	
Appearance of natural surface	Steelgrey, slightly irregular.	
Shape	Blocky, slightly triangular.	
Strength	Tough to Hard.	
Cross fracture	Small to medium, slightly steppy.	
Longitudinal fracture	Small to medium amount.	
Cell structure	Small to medium.	
Sponge	Small amount.	
Pebbly seam	None.	
REMARKS	Although washing does not appear to change the coking characteristics of this coal, it is inherently a fair coking coal and may be used by itself for the preparation of reasonably good coke in standard by-product ovens. The swelling index seems to indicate a coal that should give no expansion difficulties.	

Caking Properties	Gray Caking Index
[illegible]	[illegible]

3. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with caking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard. The results of the test are also given in Table XVIII.

TABLE XIX

SWELLING PROPERTIES

	F.R.L. Swelling Index Test		A.S.T.M. Free-Swelling Index
	Volatile Matter at 600°C. (D.B.)	Swelling Index	Swelling Number
Mine Run - unwashed	17.9	810	7.5
Plus 1½" lump. - unwashed.	17.6	255	6
0-1½" slack-unwashed.	18.9	503	7.75
0-1½" slack-washed.	20.1	572	8½
1½-4" lump-washed.	20.0	320	6½
Plus 4" lump-washed	19.6	295	6½

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Elk River No. 9 Seam operated by The Crow's Nest Pass Coal Co. Ltd. in the Crowsnest Area, British Columbia, was collected at the mine by sampling from freshly mined coal. In this way approximately 1,990 pounds of coal, representative of the seam at this mine at the time of sampling during January 1944, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 24.5% of the coal was below 1/8 inch in size , 8.8% was above 4 inch in size, and 11.8% was 2 to 4 inch in size, the remaining 54.9% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 1.23 inch yielding 76.10% of 1½ inch slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability tests on the coal from the Elk River No,9 Seam coal. are shown in Table II. One single size prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushionong effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was very friable, the size stability being 66.8% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-Machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be very easy to grind in comparison to the general run of coal used for powdered fuel firing. Reduction in ash content will somewhat improve the grinding characteristics of the coal, as the 0-1/8 with 9.7% showed a grindability index of 109.7 whereas the mine run coal with 16.2% ash had a grindability index of 93.4.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. The test indicated that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 27.9% of that of the uncrushed lumps, that is from an average particle size of 6.09 inches to an average particle size of 1.70 inches. This crushing resulted in the production of 39.9% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 12.3% of ½ to 1 inch 'stoker' coal, and 17.8% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 30.0% of 0 to ½ inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes range widely in ash content. As the size decreased from the +4 inch lump to the 0-48 mesh dust the ash decreased more or less regularly from 19.6% to 9.3%. The composites although fairly uniform vary in ash content according to the properties of the sizes included, the run-of-mine yielding 16.20% ash, the +1½ inch lump 18.8% ash, and the 0 to 1½ inch slack 13.6% ash. The sulphur content of this coal is low and uniform for all the sizes examined, being about 0.5%.

The volatile matter of the coal is medium in quantity and based on the Specific Volatile Index 1/method of classification this coal has an index of approximately 190 which places it on the border of the ortho and metabituminous coals, the so-called "blending coals" for by product use. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a medium volatile bituminous coal.

Table VI gives the ultimate analyses of the mine run composite. The coal is a medium carbon and low oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table VIII gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is low to medium ranging from 2270°F to 2530°F. The fusibility of the ash seems to vary somewhat with the size of the coal, the smalls below 1½ inch showing a higher ash fusion temperature than the plus 1½ in. lump, It is important to note that the 0-48 mesh dust, reverted back to a low ash fusion temperature. Examination of the float-and-sink data for the 1½" slack indicates that the mineral matter of both the very low & very high ash materials are of such a nature as to have a relatively higher softening temperature, 2600°F- 2700°F., than the intermediate fractions.

Laboratory Washing Tests

The washing tests on the coal from the Elk River No.9 Seam coal were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X,

1/"Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E.Swartzman- Mines Branch publication No.752-2 it will be noted that the $1\frac{1}{2}$ inch slack has a medium inherent ash content of 2.9% and a relatively low sulphur content of 0.5% as indicated by the fraction floating at a specific gravity of 1.32. At this gravity 68.10% of the coal is recovered. Washing this coal at specific gravity of 1.60, which according to the $\pm$ .10 specific gravity distribution curve represents simple wet washing would result in the production of approximately 86.0% clean coal having between 6.0 and 8.5% ash and 0.5% sulphur; these data are shown in Tables ~~IX~~ and XIII. It should be noted that the sulphur reduction is negligible as is to be expected with a coal initially containing less than 1% sulphur. The washing data for the $1\frac{1}{2}$ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The inherent ash is somewhat higher, the $1\frac{1}{2}$ to 4 inch lump showing 3.2% ash in 9.8% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 5.4% ash in 57.2% of the coal floating at a gravity of 1.30. Washing the $1\frac{1}{2}$ to 4 inch lump at a selected gravity of 1.60 would result in a substantial reduction in the ash content, the reduction varying to some extent with the the original ash content, a clean product containing 7.0% to 10.0% ash being possible. Washing the crushed +4 inch lump, yields results similar to the washing to the $1\frac{1}{2}$-4 in. lump, and it is possible to reduce the ash content to about 8.0% to 12.0%. It is thus concluded that the sample of No.9 seam coal, as obtained from the Elk River No.9 seam is quite amenable to cleaning by either wet or dry processes, in so far as the various sizes are concerned, but a little more difficulty, and less uniformity may be experienced with lump coal retained on an $1\frac{1}{2}$ inch screen .

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research

Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The resutls of this test, as applied to the raw and washed 1½ inch slack coal from the Elk River No.9 seam coal indicated that the coal had fairly good coking characteristics, in so far as use in standard by-product ovens is conerned. The Swelling Index was 572 for the washed slack, and according to the coke classification chart, should result in a reasonably good domestic coke as indicated in Table XVIII. Washing the slack only improves the chemical characteristics of the coal. There is quite a variation in coking properties as between the lump and slack, as indicated by the results of the F.R.L. Swelling test and the A.S.T.M. Free-Swelling Test, shown in Table XIX. The plus 1½ inch lump sizes show a lower swelling and the extent is indicated to a greater degree by the F.R.L test, which shows that the lump has half the swelling index of that of the slack. Washing does not appreciably increase the swelling characteristics of the lump sizes.

The method developed by Gray is used at the Fuel Research Laboratories for deteminiing the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Elk River No.9 seam coal gave a caking index of 54 which represents good caking. This characteristic in combination with the low swelling of the lump sizes appears to be indicative of a coal that might be highly suited for underfeed stokers.

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Physical and Chemical Survey Report No. 82

STUDY OF COAL FROM

MIDDLESBORO NO. 2 NORTH MINE, NO. 2 SEAM, NICOLA VALLEY AREA,

OPERATED BY

MIDDLESBORO COLLIERIES LTD., MERRITT, B. C.

BY

E. SWARTZMAN

Fuel Research Laboratories,
Bureau of Mines
Ottawa Canada

VHJ

December, 1941

Physical and Chemical Survey Report No. 82

Study of Coal From

Middlesboro No. 2 North Mine, No. 2 Seam, Nicola Valley Area,

Operated by

Middlesboro Collieries Ltd., Merritt, B.C.

Table of Contents

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Middlesboro No. 2 Mine; No. 2 Seam, worked in the Nicola Valley area at a point about one mile west of Merritt, British Columbia, by the Middlesboro Collieries Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-one reports have already been issued on the Physical and Chemical Survey of Canadian coal seams, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the No.2 Seam was sampled at the tipple by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 2,185 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railway Company for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H. Nicolls of the Fuel Research Laboratories under whose direction the major portion of the chemical analyses was conducted.

Physical Properties

1. Screen Analysis

The sample of coal from the Middlesboro No. 2 Mine, No. 2 Seam, was collected at the tipple during August 1941 from mine cars representing the average output of the seam. In this manner, a sample of unprepared run-of-mine coal, weighing approximately 2,185 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity.

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two-or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.), with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, and BULK DENSITY

Screen Sizes+	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	16.9	16.9	1.30	46.50	10.3
2 - 4 in.	18.9	35.8	1.33	43.50	12.8
1½ - 2 in.	7.8	43.6	1.34	44.50	14.1
1 - 1½ in.	11.3	54.9	1.29	45.00	16.0
3/4 - 1 in.	7.8	62.7	1.27	44.50	14.0
1/2 - 3/4in.	9.1	71.8	1.24	43.50	13.5
1/4 - 1/2In.	11.0	82.8	1.28	43.25	15.2
1/8 - 1/4in.	7.0	89.8	1.29	42.00	16.4
#48 - 1/8in.	7.5	97.3	----	-----	18.4
0 - #48in.	2.7	100.0	----	-----	26.7
Mine Run		100.0	----	-----	14.3
Plus 1½ in.		43.6	----	-----	11.4
0 - 1½ in.		56.4	----	54.50	15.9
3/4 - 1½ in.		19.1	----	-----	13.8
0 - 1/8in.		10.2	1.32	49.50	20.3

	As Received
Average Size of run-of-mine coal ....in.	2.14

+ All screens 1/8 in. and larger are round-hole screens. No.48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

"Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index".1/

The results of the friability study of the coal from the Middlesboro No. 2 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability.

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1, was used for evaluating the grindability of the coal from the No. 2 Seam of the Middlesboro No. 2 Mine.

For comparison, three samples of varying screen size were selected for testing, as follows:

Mine-run composite;
0 to $1\frac{1}{2}$ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

1/ Quoted from the above mentioned publication of the Mines Branch.

2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test. 2 - 3 in.		
	Before Test %	After 2 drops %	After 4 drops %
2 - 3 in.	100.0	54.0	38.0
$1\frac{1}{2}$ - 2 in.		15.5	18.2
1 - $1\frac{1}{2}$ in.		10.8	12.5
3/4 - 1 in.		4.7	6.5
1/2 - 3/4in.		5.0	7.0
0 - 1/2in.		10.0	17.8
Av'ge Size in.	2.500	1.853	1.568
Size Stab'ty %		74.1	62.7

TABLE III

GRINDABILITY

Screen Size of Coal Tested.	Hardgrove Index.
Mine Run	55.6
0 - $1\frac{1}{2}$ in.	56.7
0 - 1/8in.	69.1

5. Crushing Test.

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch. Middlesboro No. 2 Mine coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 Inch LUMP
(Crusher set at 1½ Inch)

	Screen Analysis	
	Before Crushing %	After Crushing %
10 to 14 in.	13.0	
8 - 10 in.	10.0	
7 - 8 in.	1.8	
6 - 7 in.	23.7	
5 - 6 in.	20.1	
4 - 5 in.	31.4	2.5
3 - 4 in.		4.8
2 - 3 in.		28.4
1½ - 2 in.		15.2
1 - 1½ in.		15.8
3/4 - 1 in.		7.6
1/2 - 3/4in.		8.1
1/4 - 1/2in.		8.6
1/8 - 1/4in.		4.5
0 - 1/8in.		4.5
Average Size in.	6.654	1.616
Size Reduction %		74.3

III

Chemical Properties

The various screen sizes obtained from the screening tests of the coal from the Middlesboro No. 2 Mine, No. 2 Seam, were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.

2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.

3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, which is given in Table VII. Data on temperature lags are presented because of their bearing on the clinkering properties.

4. The Chemical Analyses of Ash, which are shown in Table VIII.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, and CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis: Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/Lb.
Plus 4 in.	6.9	10.3	38.2	51.5	0.6	-----
2 - 4 in.	7.1	12.8	38.1	49.1	0.6	12337
1½ - 2 in.	6.7	14.1	37.6	48.3	0.5	-----
1 - 1½ in.	6.8	16.0	37.2	46.8	0.5	-----
3/4 - 1 in.	7.1	14.0	37.4	48.6	0.5	-----
1/2 - 3/4 in.	7.3	13.5	37.4	49.1	0.5	-----
1/4 - 1/2 in.	7.3	15.2	37.1	47.7	0.5	-----
1/8 - 1/4 in.	6.8	16.4	36.6	47.0	0.5	-----
#48 - 1/8 in.	5.8	18.4	35.1	46.5	0.6	-----
0 - #48	3.2	26.7	32.4	40.9	0.6	-----
Mine Run	7.4	14.8	36.9	48.3	0.5	11977
Plus 1½ in.	7.0	11.4	38.4	50.2	0.5	12517
0 - 1½ in.	7.5	15.9	37.1	47.0	0.5	11826
3/4 - 1½ in.	7.2	13.8	37.8	48.4	0.5	12127
0 - 1/8 in.	6.6	20.3	35.0	44.7	0.6	11011

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
Mine Run	68.3	4.8	0.5	1.5	10.1	14.8

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F	Softening Temperature °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F	Ash %
Plus 4 in.	2520	2830	2850+	330+	310	20+	10.3
2 - 4 in.	2620	2750	2810	190	130	60	12.8
1½ - 2 in.	2670	2850+	2850+	180+	180+	+	14.1
1 - 1½ in.	2600	2700	2750	150	100	50	16.0
3/4 - 1 in.	2620	2750	2800	180	130	50	14.0
1/2 -3/4 in.	2630	2720	2820	190	90	100	13.5
1/4 -1/2 in.	2550	2790	2840	290	240	50	15.2
1/8 -1/4 in.	2600	2800	2830	230	200	30	16.4
#48 -1/8 in.	2610	2850	2850+	240+	240	+	18.4
0 - #48	2630	2850+	2850+	220+	220+	+	26.7
Mine Run	2550	2800	2850	300	250	50	14.8
Plus 1½ in.	2660	2850+	2850+	190+	190+	+	11.4
0 - 1½ in.	2650	2850	2850+	200+	200	+	15.9
3/4 - 1½ in.	2480	2600	2730	250	120	130	13.8
0 -1/8 in.	2750	2850+	2850+	100+	100+	+	20.3

TABLE VIII

CHEMICAL ANALYSIS OF ASH

Sample	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run	54.3	6.3	29.5	2.8	1.2	Trace	2.0	1.2	0.6	1.0	1.4	100.3

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4-inch screen prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ±.10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of

wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the total sulphur of this coal is very low, a detailed study of the washing characteristics with reference to this material in unnecessary.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in the following tables:

TABLE IX

FLOAT AND SINK DATA ON $1\frac{1}{2}$" SLACK. ASH

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
								1.35	88.0
	Floats 1.30	22.6	4.9	22.6	4.9	100.0	13.3	1.40	69.1
Sinks 1.30	" 1.40	54.3	8.2	76.9	7.2	77.4	15.7	1.45	29.7
" 1.40	" 1.50	12.0	21.6	88.9	9.2	23.1	33.4	1.55	10.5
" 1.50	" 1.60	4.5	27.7	93.4	10.1	11.1	46.1	1.65	3.1
" 1.60		6.6	58.7	100.0	13.3	6.6	58.7	1.75	1.0
Curve No.		4	2	1.2.4	1	3	3	5	5

TABLE X

CHEMICAL ANALYSIS AND FUSIBILITY OF ASH ON FLOAT AND SINK PORTIONS OF $1\frac{1}{2}$" SLACK.

Dry Basis

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
	Floats 1.30	5.3	40.7	54.0	Poor-Fair	0.5	2850+	+	+	*	*	+
Sinks 1.30	" 1.40	8.8	39.2	52.0	Poor	0.6	2850+	+	+	+	+	+
" 1.40	" 1.50	23.0	33.7	43.3	Agglomerate	0.5	2620	2740	2790	170	120	50
" 1.50	" 1.60	29.3	30.9	39.8	Non-agglomerate	0.4	2500	2800	2840	340	300	40
" 1.60		60.7	28.0	11.3	" "	0.4	1800	2130	2270	470	330	140

TABLE XI

FLOAT AND SINK DATA ON $1\frac{1}{2}$ - 4 Inch LUMP

ASH

Specific Gravity		Weight	Ash	Cumulative				±.10 Specific Gravity Distribution	
				Floats		Sinks			
		%	%	Weight %	Ash %	Weight %	Ash %	Gravity	Calculated Ordinate
								1.35	91.8
	Floats 1.30	26.6	5.4	26.6	5.4	100.0	13.9	1.40	68.0
Sinks 1.30	" 1.40	55.3	9.8	81.9	8.4	73.4	17.0	1.45	26.0
" 1.40	" 1.50	9.9	26.6	91.8	10.3	18.1	38.8	1.55	6.2
" 1.50	" 1.60	1.3	31.5	93.1	10.6	8.2	52.5	1.65	1.6
" 1.60		6.9	57.7	100.0	13.9	6.9	57.7	1.75	1.0
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XII

FLOAT AND SINK DATA ON PLUS 4 INCH LUMP (CRUSHED)

ASH

Specific Gravity		Weight	Ash	Cumulative				±.10 Specific Gravity Distribution	
				Floats		Sinks			
		%	%	Weight %	Ash %	Weight %	Ash %	Gravity	Calculated Ordinate
								1.35	93.3
	Floats 1.30	29.4	4.7	29.4	4.7	100.0	12.3	1.40	64.6
Sinks 1.30	" 1.40	54.0	8.4	83.4	7.1	70.6	15.5	1.45	30.2
" 1.40	" 1.50	8.0	19.1	91.4	8.1	16.6	38.7	1.55	4.6
" 1.50	" 1.60	1.8	33.8	93.2	8.6	8.4	58.3	1.65	2.1
" 1.60		6.8	63.1	100.0	12.3	6.8	63.1	1.75	1.6
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE

0 to 1½ Inch Slack

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	91.4	8.6
Proximate Analysis (dry basis)			
Ash .... %	15.9	9.9	62.8
Volatile Matter .... %	37.1	38.3	21.6
Fixed Carbon .... %	47.0	51.8	15.6
Sulphur .... %	0.5	0.5	0.3
Calorific Value ......B.T.U./lb.	11826	12631	-----
Fusion Point of Ash ....°F.	2850	2850+	2570
Melting Range of Ash ....°F.	200+	90+	520
Coking Properties	Poor	Poor	Non-Agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
1½ to 4 Inch Lump

	Raw+ Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight .... %	100.0	95.7	4.3
Proximate Analysis (dry basis)			
Ash .... %	13.2	10.5	38.9
Volatile Matter .... %	37.9	38.4	30.1
Fixed Carbon .... %	48.9	51.1	31.0
Sulphur .... %	0.6	0.5	0.4
Calorific Value ......B.T.U./lb.	12280	12661	-----
Fusion Point of Ash ....°F.	2850+	2850+	2350
Melting Range of Ash ....°F.	215+	110+	350
Coking Properties	Poor	Poor	Non-agglomerate

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
Plus 4 Inch Lump (Crushed)

	Raw+ Coal	Clean Coal Floats 1.50	Refuse Sinks 1.50
Weight .... %	100.0	96.5	3.5
Proximate Analysis (dry basis)			
Ash .... %	10.3	7.6	47.5
Volatile Matter .... %	38.2	39.0	28.1
Fixed Carbon .... %	51.5	53.4	24.4
Sulphur .... %	0.6	0.6	0.5
Calorific Value ......B.T.U./lb.	12691	13104	----
Fusion Point of Ash ....°F.	2830	2850+	2150
Melting Range of Ash ....°F.	330+	+	220
Coking Properties	Poor	Poor	Non-Agglomerate

+ Calculated Analyses

TABLE XVI

SCREEN ANALYSIS AND CHEMICAL ANALYSIS

(Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	33.9	33.9	15.2	0.5	2720
1/8 - 3/4 inch	48.0	81.9	14.9	0.5	2770
0 - 1/8 inch	18.1	100.0	20.3	0.6	2850+

TABLE XVII

FLOAT AND SINK DATA ON SCREENED SIZES
USING A SELECTED GRAVITY OF 1.60
(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ inch	92.8	10.7	2850+	7.2	59.3	2170
1/8 - 3/4 inch	91.6	9.7	2850+	8.4	62.5	2300
0 - 1/8 inch	77.2	10.4	2850+	22.8	52.4	2710

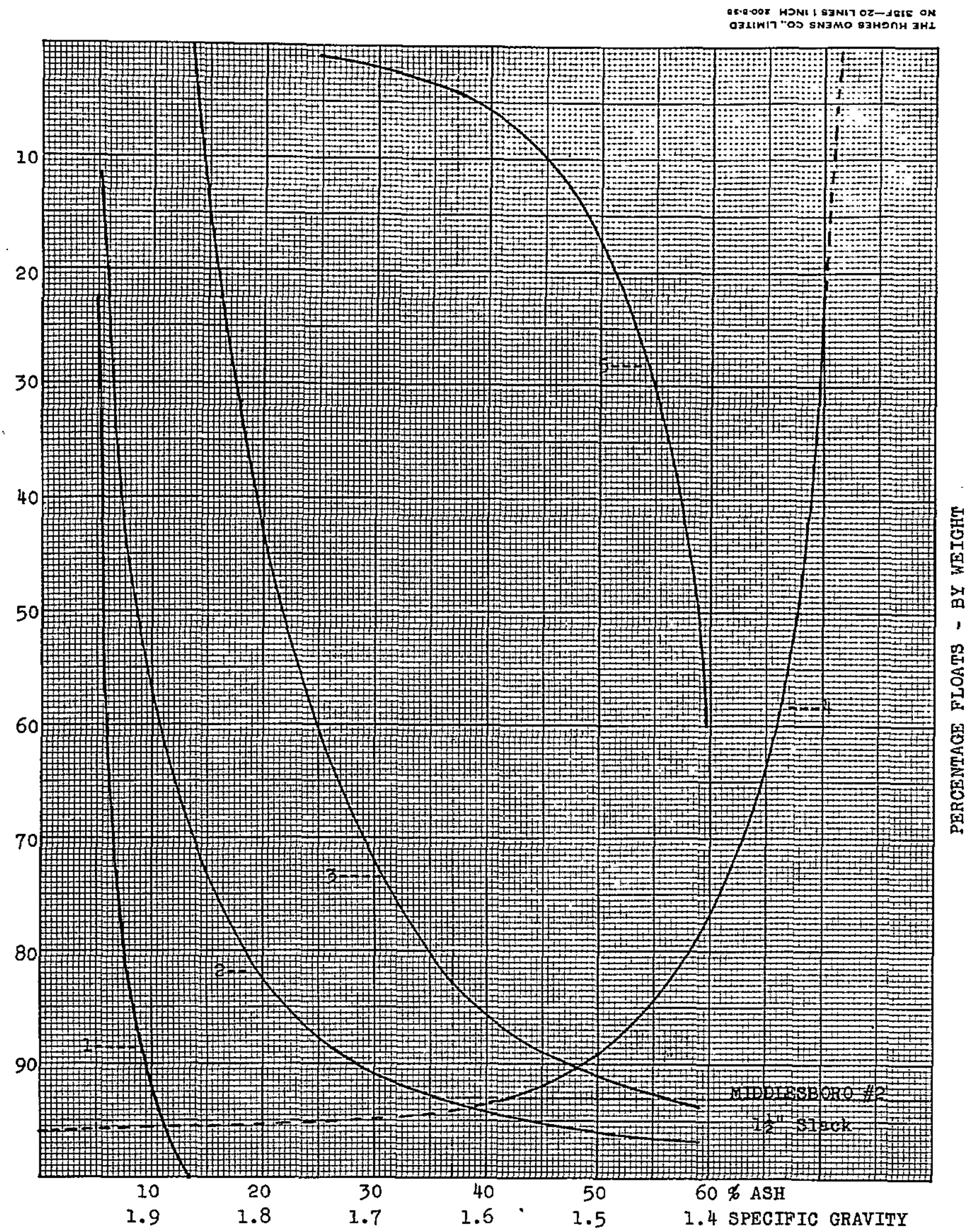

FIG. 1 - Washability Curves for 1½" Slack Middlesboro No. 2 Mine

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

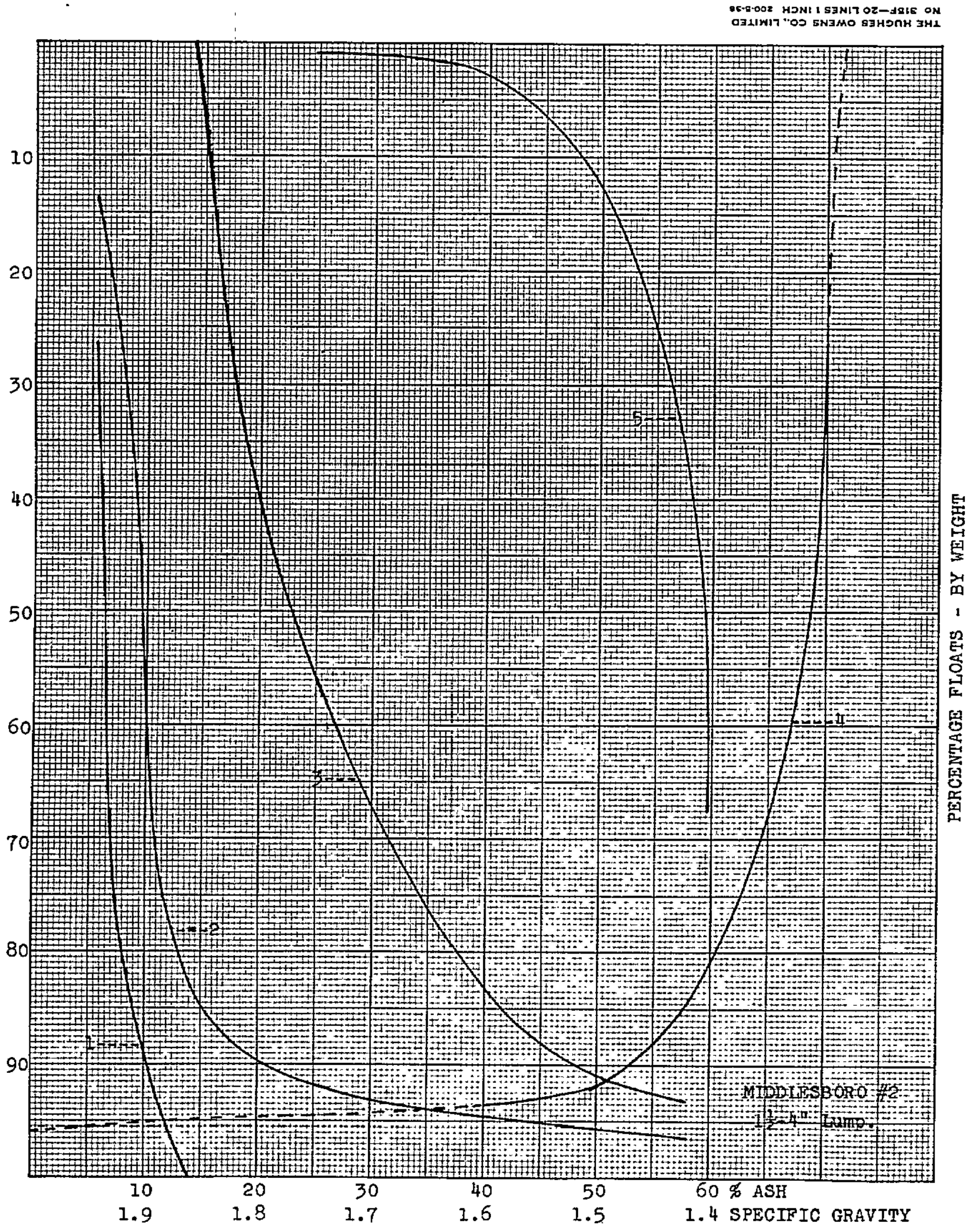

FIG. II - Washability Curves for 1½" - 4" Lump - Middlesboro No.2 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

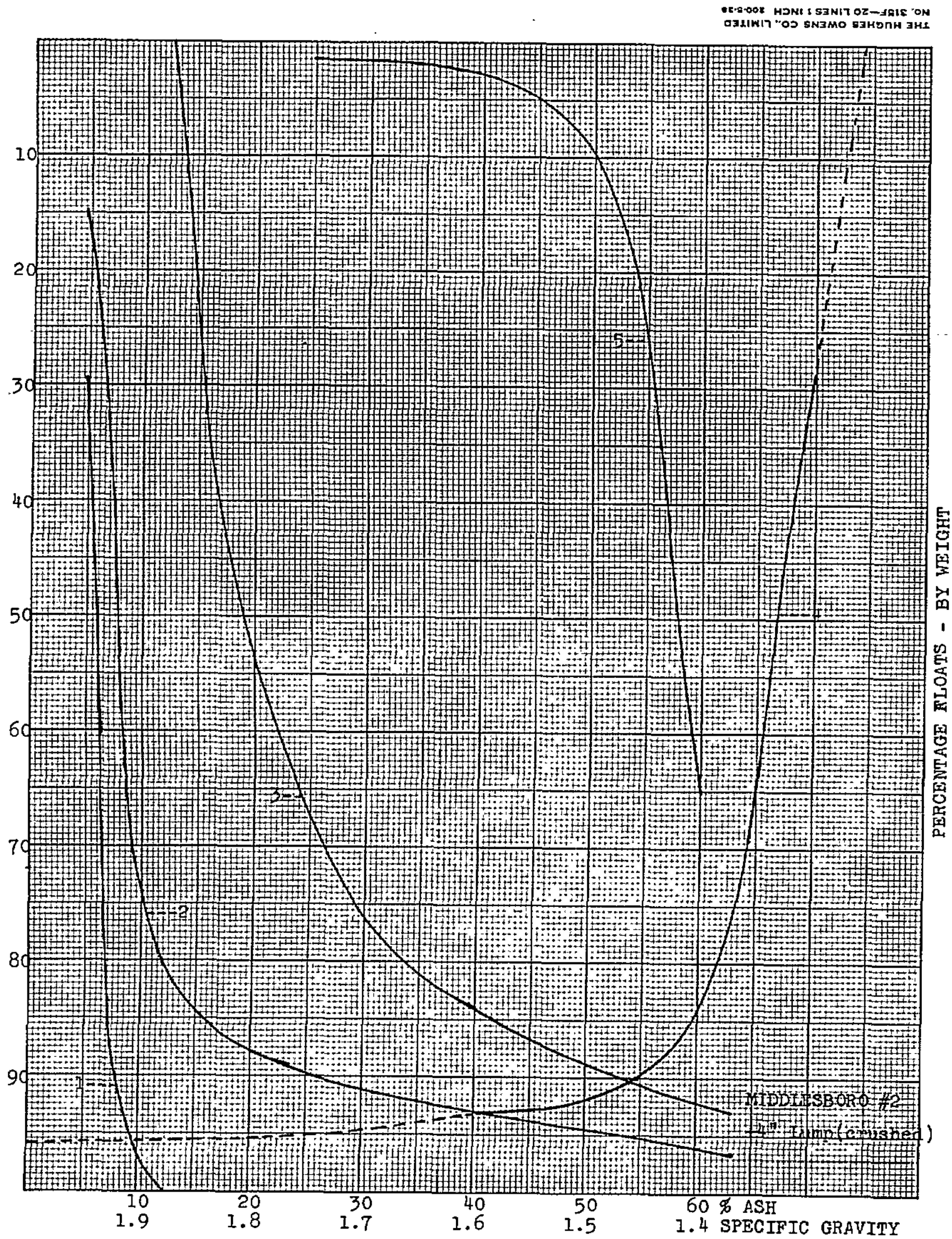

FIG.III - Washability Curves for Plus 4-in. Lump - Middlesboro No.2 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

V

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Middlesboro No.2 mine coal are shown in Table XVIII.

2. Caking Index Test.

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C, has been adopted as a standard.

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant By-Product Coke", by R.A.Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No.737-2.

The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designated as the 'caking index'. The higher the 'caking index' the greater are the coking properties. The results of this test conducted on the Middlesboro No.2 Seam coal are shown in Table XVIII.

TABLE XVIII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A
"SWELLING INDEX" TEST

	0-1½ Inch Slack Washed at 1.60 sp.gr.
Volatile Matter at 600°C. (D.B.) %	30.6
Swelling Index	negative
Section--Coke Classification Chart	XIII
Specific Volatile Index	139.6
Section--Coal Classification Chart	B - Subbituminous
Ash per cent in coal (dry) ....%	9.9
Remarks	This coal does not coke.

CAKING PROPERTIES

	Gray Caking Index
Run-of-Mine Sample	1

VI

SUMMARY and DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Middlesboro No.2 Mine, No.2 Seam, operated by the Middlesboro Collieries Ltd. in the Nicola Valley area, British Columbia, was collected at the mine by sampling from the mine cars at the tipple. In this way approximately 2,185 pounds of coal, representative of the output of the seam at this mine at the time of sampling during August 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 10.2% of the coal was below 1/8 inch in size, 16.9% was above 4 inch in size, and 18.9% was 2 to 4 inch in size, the remaining 54.0% being distributed between the other sizes. The average size of the run-of-mine coal "as received" was 2.14 inch, yielding 56.4% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the Middlesboro No.2 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample.

This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 74.1% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing. This conforms with the results obtained in most other low rank coals.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 24.3% of that of the uncrushed lumps, that is, from an average particle size of 6.654 inches to an average particle size of 1.616 inches. This crushing resulted in the production of 59.4% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 15.9% of 1/2 to 1 inch 'stoker' coal, and 7.3% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 17.6% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes are medium high in ash, with the fines passing a 1/8 inch screen, indicating an appreciable increase in ash content with a decrease in size. The coal lumps retained on a 1/8 inch screen and passing the 4 inch screen are more or less uniform, varying in ash from 12.8% to 16.4%, whereas the fines have an average ash content of 20.3%. It is of interest to note that the +4 inch lumps are lower in ash than all the other sizes, namely, 10.3%. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 14.8% ash, the +1½ inch lump 11.8% ash, and the 0 to 1½ inch slack 15.9% ash. The sulphur content of this coal is very low and uniform for all the sizes examined, and hence will occur mainly in the organic form. Visual examination of the coal indicated that there was no or very little pyrite present. The moisture content for all the sizes, with the exception of the dust (0-48 mesh), was uniform on the 'as received' basis, with an average of 7.4% for the mine-run coal.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index[1]/ method of classification this coal has an index of approximately 140 which places it in the subbituminous class of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile B bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a medium carbon and high oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table VIII

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2.

gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is uniformly high ranging from 2600°F. to 2850°F. The fusibility of the ash does not vary with the ash content of the coal. Examination of the float-and-sink data indicates that the mineral matter of the very high ash material is of such a nature as to have a low softening temperature, yet when mixed with the lower ash fractions it seems to have very little or no effect in lowering the ash fusion temperatures.

Laboratory Washing Tests

The washing tests on the coal from the Middlesboro No.2 Mine, No.2 Seam, were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be noted that the 1½ inch slack has a medium inherent ash content of 4.9%, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 22.6% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 91.4% clean coal having 9.9% ash; these data are shown in Table XIII. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The results of the tests on these sizes are somewhat similar to that obtained with the 1½ inch slack. The inherent ash is medium to high in amount, the 1½ to 4 inch lump showing 5.4% ash in 26.6% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 4.7% ash in 29.4% of the coal floating at the same gravity. Washing the 1½ to 4 inch lump at a selected gravity of 1.50 would result in the recovery of about 95.7% clean coal containing 10.5% ash (see Table XIV), while washing the crushed +4 inch lump in a similar manner would yield about 96.5% clean coal containing about 7.6% ash (see Table XV). It is thus concluded that the sample of No. 2 seam coal, as obtained it the Middlesboro mine, is amenable to a degree to cleaning by either wet or dry processes. It should be noted that crushing the +4 inch lump materially aided in improving the washing characteristics of this size, it being feasible to produce a medium to low ash coal with a small loss as rejects. The screen analysis of the crushed coal was as is shown in Table IV.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the Middlesboro No.2 mine, indicated that the coal was non-coking, in so far as use in standard by-product ovens is concerned.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Middlesboro No.2 Mine coal indicated a coal that is almost non-coking, the caking index being 1.

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Physical and Chemical Survey Report No. 83

STUDY OF COAL FROM

MIDDLESBORO NO. 3 MINE, NO. 3 SEAM, NICOLA VALLEY AREA,

OPERATED BY

MIDDLESBORO COLLIERIES LTD., MERRITT, B. C.

BY

E. SWARTZMAN

Fuel Research Laboratories,
Bureau of Mines
Ottawa Canada

VHJ January, 1942

Physical and Chemical Survey Report No. 83

Study of Coal from

Middlesboro No. 3 Mine, No. 3 Seam, Nicola Valley Area,

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Table of Contents

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Middlesboro No.3 Mine; No.3 Seam, worked in the Nicola Valley area at a point about one mile west of Merritt, British Columbia, by the Middlesboro Collieries Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-two reports have already been issued on the Physical and Chemical Survey of Canadian coal seams, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results,

The unprepared run-of-mine coal from the No. 3 Seam was sampled at the tipple by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 1677 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railway Company for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H. NICOLLS of the Fuel Research Laboratories under whose direction the major portion of the chemical analyses was conducted.

Physical Properties

1. Screen Analysis

The sample of coal from the Middlesboro No. 3 Mine, No. 3 Seam, was collected at the tipple during August 1941 from mine cars representing the average output of the seam. In this manner, a sample of unprepared run-of-mine coal, weighing approximately 1677 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity.

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table 1.

3. Friability.

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M), with R.E. Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, AND BULK DENSITY

Screen Sizes[*]	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	12.5	12.5	1.35	48.50	24.5
2 - 4 in.	20.5	33.0	1.39	46.50	21.5
1½ - 2 in.	7.4	40.4	1.39	45.50	23.0
1 - 1½ in.	11.4	51.8	1.37	45.50	21.8
3/4 - 1 in.	7.9	59.7	1.31	45.00	21.3
1/2 - 3/4 in.	8.8	68.5	1.30	45.00	22.3
1/4 - 1/2 in.	11.1	79.6	1.36	43.00	23.8
1/8 - 1/4 in.	7.5	87.1	1.37	42.25	22.4
#48 - 1/8 in.	9.1	96.2	----	-----	24.1
0 - #48	3.8	100.0	----	-----	29.8
Mine Run		100.0	----	-----	23.2
Plus 1½ in.		40.4	----	-----	22.0
0 - 1½ in.		59.6	----	56.75	23.5
3/4 - 1½ in.		29.3	----	-----	22.9
0 - 1/8 in.		12.9	1.37	53.25	24.4

	As Received
Average Size of run-of-mine coal	1.803

[*] All screens 1/8 in. and larger are round-hole screens.
No. 48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

"Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index".1/

The results of the friability study of the coal from the Middlesboro No. 3 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability.

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1, was used for evaluating the grindability of the coal from the No. 3 Seam of the Middlesboro No. 3 Mine.

For comparison, three samples of varying screen size were selected for testing, as follows:

Mine-run composite;
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

1/ Quoted from the above mentioned publication of the Mines Branch.

2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

TABLE LI

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test. 2 - 3 in.		
	Before Test %	After 2 drops %	After 4 drops %
2 - 3 in.	100.0	56.5	41.5
1½ - 2 in.		15.3	17.5
1 - 1½ in.		10.7	14.0
3/4 - 1 in.		5.0	7.2
1/2 - 3/4 in.		4.3	5.8
0 - 1/2 in.		8.2	14.0
Av'ge Size in.	2.500	1.907	1.651
Size Stab'ty %		76.3	66.0

TABLE LII

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	59.4
0 - 1½ in.	58.7
0 - 1/8 in.	67.8

5. Crushing Test.

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at $1\frac{1}{2}$ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Middlesboro No. 3 Mine coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 Inch LUMP
(Crusher set at $1\frac{1}{2}$ Inch)

		Screen Analysis	
		Before Crushing %	After Crushing %
10 - 14 in.		11.2	
8 - 10 in.		3.2	
7 - 8 in.		2.4	
6 - 7 in.		8.8	
5 - 6 in.		28.8	
4 - 5 in.		45.6	4.1
3 - 4 in.			9.4
2 - 3 in.			32.6
$1\frac{1}{2}$ - 2 in.			14.6
1 - $1\frac{1}{2}$ in.			15.2
3/4 - 1 in.			7.2
1/2 - 3/4 in.			5.9
1/4 - 1/2 in.			5.6
1/8 - 1/4 in.			2.6
0 - 1/8 in.			2.8
Average Particle Size	in.	6.020	1.902
Size Reduction	%		31.6

III

Chemical Properties

The various screen sizes obtained from the screening tests of the coal from the Middlesboro No. 3 Mine, No. 3 Seam, were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.

2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.

3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, which is given in Table VII. Data on temperature lags are presented because of their bearing on the clinkering properties.

4. The Chemical Analyses of Ash, which are shown in Table VIII.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE.

Screen Sizes	Moisture (as rec'd) %	Dry Basis Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/lb.
Plus 4 in.	4.9	24.5	33.9	41.6	0.9	-----
2 - 4 in.	4.5	21.5	35.6	42.9	0.7	11010
1½ - 2 in.	4.1	23.0	34.8	42.2	0.6	-----
1 - 1½ in.	4.3	21.8	34.9	43.3	0.7	-----
3/4 - 1 in.	4.4	21.3	34.6	44.1	0.6	-----
1/2 - 3/4 in.	4.8	22.3	34.1	43.6	0.6	-----
1/4 - 1/2 in.	5.3	23.8	33.1	43.1	0.6	-----
1/8 - 1/4 in.	4.6	22.4	33.8	43.8	0.6	-----
#48 - 1/8 in.	5.8	24.1	32.8	43.1	0.6	-----
0 - #48 in.	4.6	29.8	31.1	39.1	0.8	-----
Mine Run	5.4	23.2	34.1	42.7	0.6	10815
Plus 1½ in.	5.4	22.0@	35.5	42.5	0.7	10950@
0 - 1½ in.	5.7	23.5	33.9	42.6	0.6	10760
3/4 - 1½ in.	4.9	22.9	34.7	42.4	0.6	10850
0 - 1/8 in.	4.7	24.4	32.7	42.9	0.7	10550

@ Corrected according to analyses of individual sizes.

TABLE VI

ULTIMATE ANALYSIS

Sample	Dry Basis Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
Mine Run	61.5	4.6	0.6	1.4	8.7	23.2

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2350	2530	2750	400	180	220	24.5
2 - 4 in.	2600	2700	2790	190	100	90	21.5
1½ - 2 in.	2700	2770	2820	120	70	50	23.0
1 - 1½ in.	2670	2770	2850+	180+	100	80+	21.8
3/4 - 1 in.	2800	2850+	2850+	50+	50+	+	21.3
1/2 - 3/4 in.	2850+	+	+	+	+	+	22.3
1/4 - 1/2 in.	2850+	+	+	+	+	+	23.8
1/8 - 1/4 in.	2850+	+	+	+	+	+	22.4
#48 - 1/8 in.	2850+	+	+	+	+	+	24.1
0 - #48	2770	2850+	+	80+	80+	+	29.8
Mine Run	2780	2850+	+	70+	70+	+	23.2
Plus 1½ in.	2750	2840	2850+	100+	90	10+	22.0
0 - 1½ in.	2790	2850+	+	60+	60+	+	23.5
3/4 - 1½ in.	2710	2810	2850+	140+	100	40+	22.9
0 - 1/8 in.	2850+	+	+	+	+	+	24.4

TABLE VIII

CHEMICAL ANALYSIS OF ASH

Sample	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run	54.0	5.5	34.0	1.9	1.2	0.1	0.3	1.3	0.4	0.8	0.8	100.3

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4-inch screen prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the $\pm$ .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of

wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the total sulphur of this coal is very low, a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in the following tables:

TABLE IX

FLOAT AND SINK DATA ON 1½" SLACK. ASH

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
							1.35	80.1
Floats 1.30	17.2	5.7	17.2	5.7	100.0	21.7	1.40	69.1
Sinks 1.30 " 1.40	46.6	14.2	63.8	11.9	82.8	25.1	1.45	41.1
" 1.40 " 1.50	17.7	25.7	81.5	14.9	36.2	39.1	1.55	16.6
" 1.50 " 1.60	7.0	36.8	88.5	16.6	18.5	51.9	1.65	5.7
" 1.60	11.5	61.1	100.0	21.7	11.5	61.1	1.75	2.5
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE X

CHEMICAL ANALYSIS AND FUSIBILITY OF ASH ON FLOAT AND SINK PORTIONS OF 1½" SLACK

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softeening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.30	6.0	39.2	54.8	Poor	0.6	2700	2780	2830	130	80	50
Sinks 1.30 " 1.40	14.9	37.1	48.0	Poor	0.6	2850+	+	+	+	+	+
" 1.40 " 1.50	26.7	33.0	40.2	Agglomerate	0.6	2850+	+	+	+	+	+
" 1.50 " 1.60	38.3	27.8	33.9	Non-Aggl'ate	0.5	2850+	+	+	+	+	+
" 1.60	63.0	21.2	15.8	" "	0.9	2150	2300	2500	350	150	200

TABLE XI

FLOAT AND SINK DATA ON $1\frac{1}{2}$ - 4 Inch LUMPS

ASH

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats 1.30	0.9	8.1	0.9	8.1	100.0	25.5	1.40	84.9
Sinks 1.30	" 1.40	41.9	13.9	42.8	13.8	99.1	25.7	1.45	71.2
" 1.40	" 1.50	36.6	26.3	79.4	19.6	57.2	34.3	1.55	23.1
" 1.50	" 1.60	7.4	30.2	86.8	20.5	20.6	48.5	1.65	5.3
" 1.60		13.2	58.8	100.0	25.5	13.2	58.8	1.75	2.8
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XII

FLOAT AND SINK DATA ON PLUS 4 Inch LUMPS (CRUSHED)

ASH

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats 1.30	1.9	8.4	1.9	8.4	100.0	25.1	1.40	76.6
Sinks 1.30	" 1.40	29.9	15.1	31.8	14.7	98.1	25.4	1.45	75.6
" 1.40	" 1.50	42.8	25.2	74.6	20.7	68.2	29.9	1.55	44.3
" 1.50	" 1.60	17.5	35.6	92.1	23.6	25.4	37.8	1.65	7.9
" 1.60		7.9	42.6	100.0	25.1	7.9	42.6	1.75	1.3
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE
0 to $1\frac{1}{4}$ Inch Slack

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	87.4	12.6
Proximate Analysis (dry basis)			
Ash .... %	23.5	17.5	59.5
Volatile Matter .... %	33.9	35.8	22.1
Fixed Carbon .... %	42.6	46.7	18.4
Sulphur .... %	0.6	0.5	0.6
Calorific Value ... B.T.U./lb.	10760	11730	----
Fusion Point of Ash ....°F.	2850+	2850+	2620
Melting Range of Ash ......°F.	60+	+	230
Coking Properties	Poor	Poor	Non-Agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
$1\frac{1}{4}$ to 4 Inch Lump

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	92.8	7.2
Proximate Analysis (dry basis)			
Ash .... %	21.9*	16.5	51.6
Volatile Matter .... %	35.4	36.7	25.6
Fixed Carbon .... %	42.7	46.8	22.8
Sulphur .... %	0.7	0.5	1.0
Calorific Value ... B.T.U./lb.	10955	11725	----
Fusion Point of Ash ....°F.	2725	2850+	2130
Melting Range of Ash ......°F.	150	+	180
Coking Properties	Poor	Poor	Non-Agglomerate

* Calculated.

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
Plus 4 Inch Lump (Crushed)

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	91.8	8.2
Proximate Analysis (dry basis)			
Ash .... %	24.5	17.5	49.6
Volatile Matter .... %	33.9	36.7	35.2
Fixed Carbon .... %	41.6	45.8	15.2
Sulphur .... %	0.9	0.6	1.2
Calorific Value ... B.T.U./lb.	10590+	11780	----
Fusion Point of Ash ....°F.	2530	2850+	2000
Melting Range of Ash ....°F.	400	+	80
Coking Properties	Poor	Poor	Non-Agglomerate

TABLE XVI

SCREEN ANALYSIS AND CHEMICAL ANALYSIS
(Dry Basis) of 1½" Slack

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	32.4	32.4	21.6	0.7	2850+
1/8 - 3/4 inch	46.0	78.4	22.9	0.6	2850+
0 - 1/8 inch	21.6	100.0	24.4	0.7	2850+

TABLE XVII

FLOAT AND SINK DATA ON SCREENED SIZES
USING A SELECTED GRAVITY OF 1.60
(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F+	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ inch	89.1	21.3	2850+	10.9	64.4	2100
1/8 - 3/4 inch	86.5	16.3	2850+	13.5	64.3	2660
0 - 1/8 inch	75.5	17.1	2850+	24.5	50.9	2850

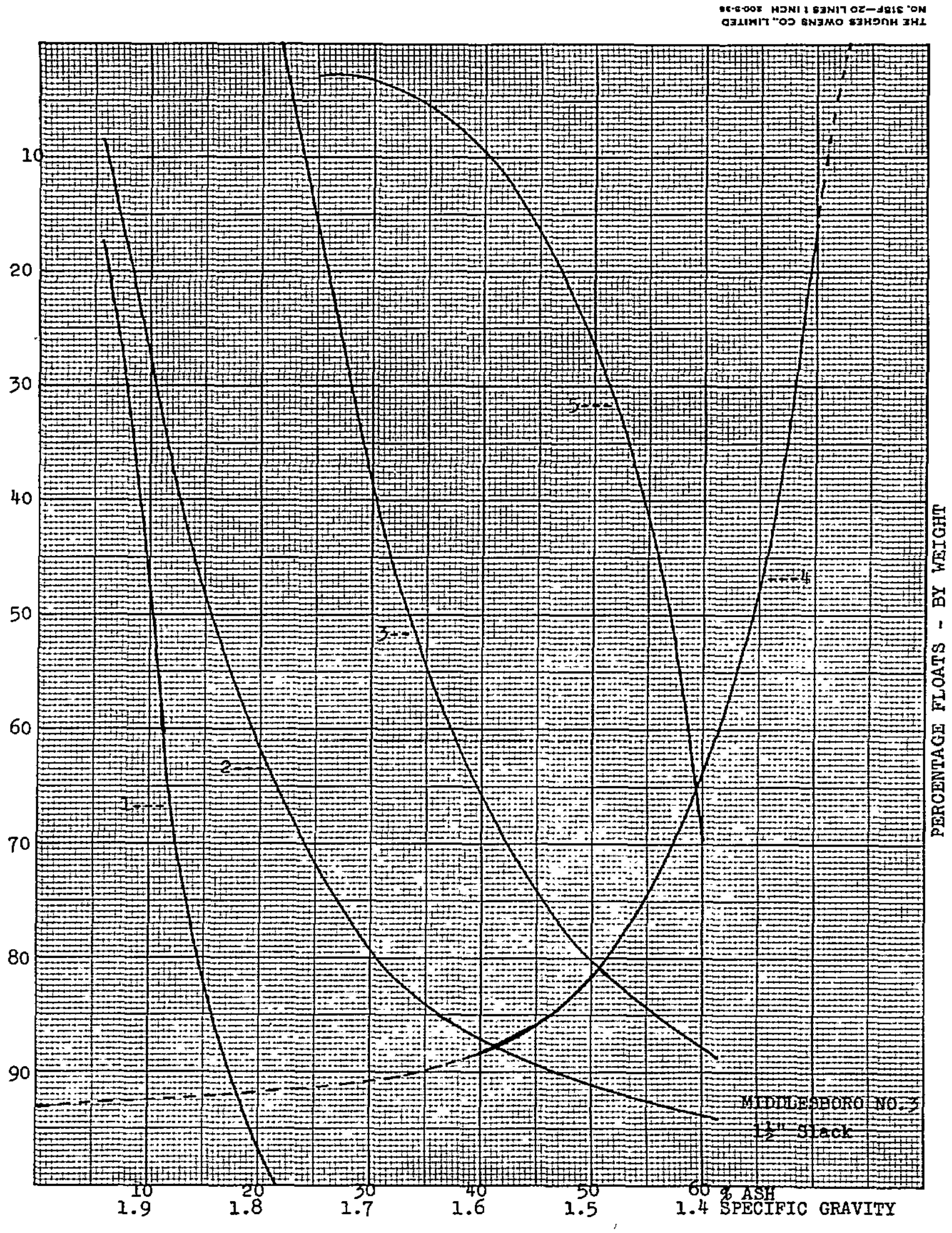

FIG. 1 - Washability Curves for 1½" Slack Middlesboro No. 3 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

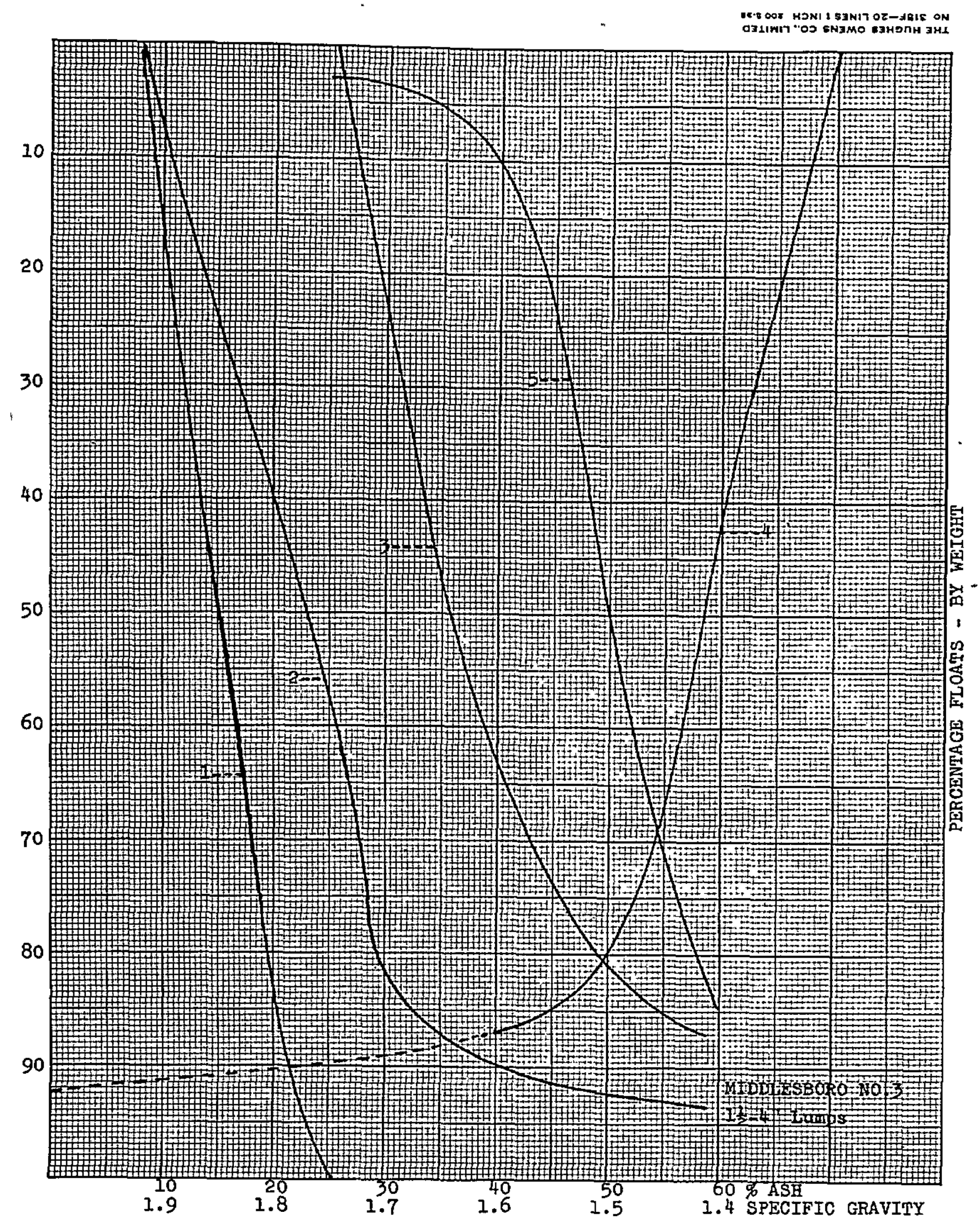

FIG. 11 - Washability Curves for 1½" - 4" Lump - Middlesboro No.3 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

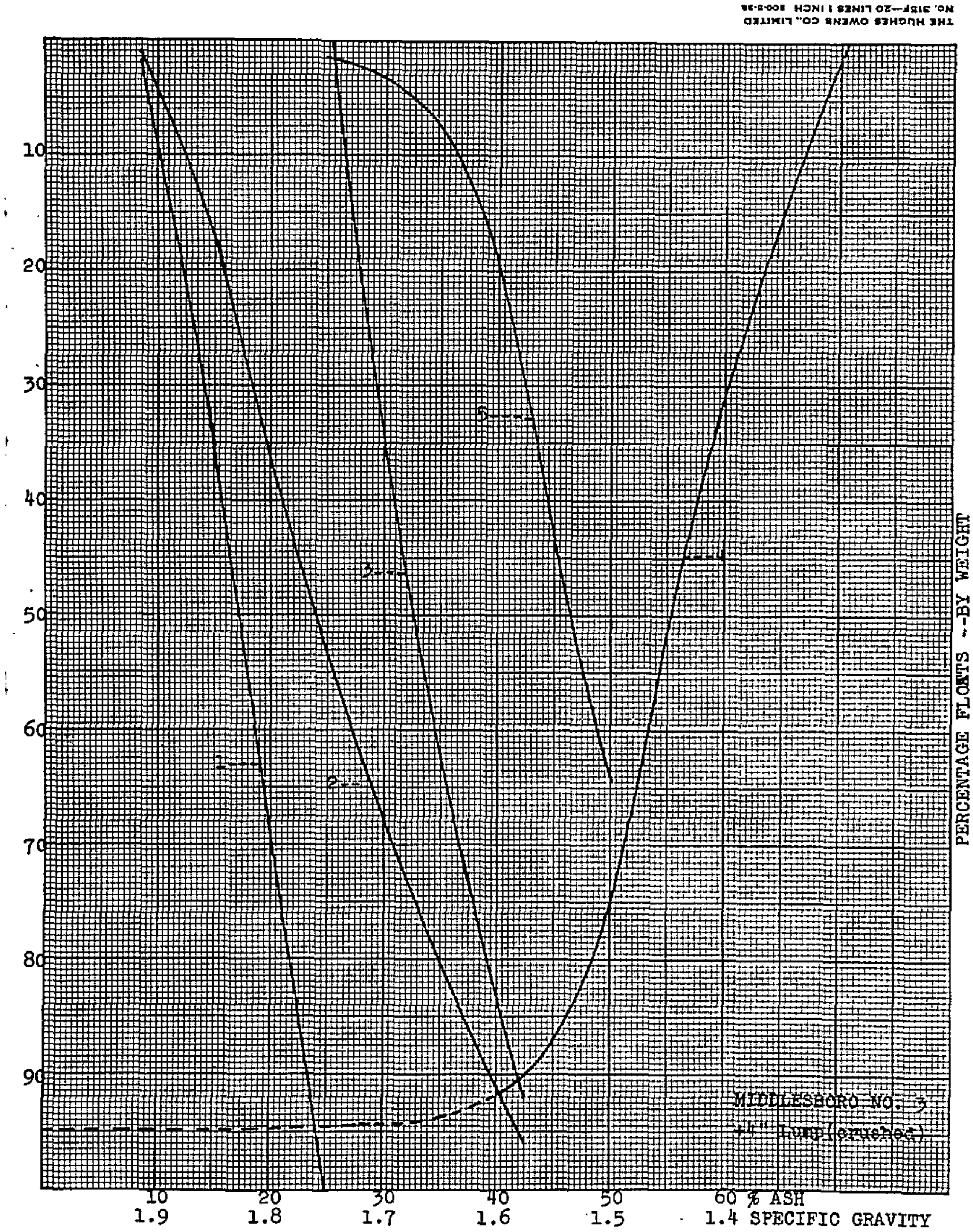

FIG.111 - Washability Curves for Plus 4-in. Lump - Middlesboro No.3 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Middlesboro No. 3 mine coal are shown in Table XVIII.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard.

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant By-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737-2.

The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designed as the 'caking index'. The higher the 'caking index' the greater are the coking properties. The results of this test conducted on the Middlesboro No. 3 Seam coal are shown in Table XVIII.

TABLE XVIII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A
"SWELLING INDEX" TEST

	0 - $1\frac{1}{2}$ inch Slack Washed at 1.60 Sp. Gr.
Volatile Matter at 600 °C. (D.B.) ... %	28.4
Swelling Index	negative
Section--Coke Classification Chart	XIII
Specific Volatile Index	143.6
Section--Coal Classification Chart	B - Subbituminous
Ash per cent in coal (dry) ....%	17.6
REMARKS	This coal does not coke.

CAKING PROPERTIES

	Gray Caking Index
Mine Run Sample	3

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Middlesboro No. 3 Mine coal indicated a coal that is almost non-coking, the caking index being 3.

VI

SUMMARY and DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Middlesboro No. 3 Mine, No. 3 Seam, operated by the Middlesboro Collieries Ltd. in the Nicola Valley area, British Columbia, was collected at the mine by sampling from the mine cars at the tipple. In this way approximately 1,677 pounds of coal, representative of the output of the seam at this mine at the time of sampling during August 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 12.9% of the coal was below 1/8 inch in size, 12.5% was above 4 inch in size, and 20.5% was 2 to 4 inch in size, the remaining 54.1% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 1.80 inch, yielding 59.6% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the Middlesboro No. 3 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 76.3% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing. This conforms with the results obtained in most other low rank coals.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 31.6% of that of the uncrushed lumps, that is, from an average particle size of 6.020 inches to an average particle size of 1.902 inches. This crushing resulted in the production of 62.4% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 13.1% of 1/2 to 1 inch 'stoker' coal, and 13.5% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 11.0% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively.

It will be noted, referring to Table V, that the various sizes are uniformly high in ash, with the fines passing a 1/8 inch screen, indicating a slight increase in ash content with a decrease in size. The coal lumps retained on a 48 mesh screen are more or less uniform, varying in ash from 21.3% to 24.5%, whereas the dust (0-48 mesh) has an ash content of 29.8%. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 23.2% ash, the +1½ inch lump 22.0% ash, and the 0 to 1½ inch slack 23.5% ash. The sulphur content of this coal is very low and uniform for all the sizes examined, and hence will occur mainly in the organic form. Visual examination of the coal indicated that there was no or very little pyrite present. The moisture content for all the sizes, was uniform on the 'as received' basis, with an average of 5.4% for the mine-run coal.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 144 which places it in the subbituminous class of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile B bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a medium carbon and high oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2.

Table VIII gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is uniformly high ranging from 2530 °F. to 2850+ °F. The fusibility of the ash does not vary with the ash content of the coal. Examination of the float-and-sink data indicates that the mineral matter of the very high ash material is of such a nature in the 0 - 1½" slack sizes as to have a relatively high softening temperature, which when mixed with the lower ash fractions seems to have very little or no effect in lowering the ash fusion temperatures. However, in the cases of the lumps retained on a 1½ inch screen the high ash fractions have a low softening temperature which appears to affect the softening temperature as a whole by lowering it.

Laboratory Washing Tests.

The washing tests on the coal from the Middlesboro No. 3 Mine, No. 3 Seam, were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be noted that the 1½ inch slack has a medium to high i nherent ash content of 5.7%, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 17.2% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 87.4% clean coal having 17.5% ash; these data are shown in Table XIII. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The results of the tests on these sizes are somewhat similar to that obtained with the 1½ inch slack. The inherent ash is high in amount, the 1½ to 4 inch lump showing 8.1% ash in 0.9% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 8.4% ash in 1.9% of the coal floating at the same gravity. Washing the 1½ to 4 inch lump at a selected gravity of 1.60 would result in the recovery of about 92.8% clean coal containing 16.5% ash (see Table XIV), while washing the crushed +4 inch lump in a similar manner would yield about 91.8% clean coal containing about 17.5% ash (see Table XV). It is thus concluded that the sample of No. 3 seam coal, as obtained at the Middlesboro mine, is not very amenable to cleaning by either wet or dry processes. It should be noted that crushing the +4 inch lump did not materially aid in improving the washimg characteristics of this size.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed $1\frac{1}{2}$ inch slack coal from the Middlesboro No. 3 mine, indicated that the coal was non-coking, in so far as use in standard by-product ovens is concerned.

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Report of Investigation - Carbonization Section - No. 183

Report of Field Investigations, July - August 1941

by

E. Swartzman

Part I

The Occurrence, Mining, Preparation and Distribution
of Coals from Vancouver Island and Mainland
British Columbia.

Part II

The Preparation and Distribution of Coals from
Alberta and Crowsnest B.C. With
Special Reference to the Winnipeg Domestic Market.

Fuel Research Laboratories
Bureau of Mines
Ottawa, Canada.

October 1941

Report of Field Investigations, July-August 1941

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Part II

The Preparation and Distribution of Coals from Alberta, Crowsnest B.C. and Saskatchewan, with Special Reference to the Winnipeg Domestic Market.

PART I

THE OCCURRENCE, MINING, PREPARATION AND DISTRIBUTION OF COALS FROM VANCOUVER ISLAND AND MAINLAND OF BRITISH COLUMBIA

1. Introduction

The following report is a record of the information obtained in the field during the months of July and August, 1941 when coal samples were collected from various operating properties and distributing centres in the province of British Columbia.

The purpose of the work in collecting the samples and obtaining information with respect to mining, preparation and distribution was to complete the current programme of the Physical and Chemical Survey of Canadian coals as mined, and to continue the Survey of the commercial coals as prepared at the mines and as delivered to various Canadian centres of distribution. The areas visited in British Columbia included districts producing subbituminous as well as bituminous coals on Vancouver Island, and in the Princeton, Nicola and Crowsnest areas of the mainland. The study of the commercial coals on the Canadian market is of particular significance at this time in view of the fact that the Fuel Research Laboratories is being consulted continuously with respect to the selection of fuels and with respect to problems arising from the use of fuels by the various government departments.

Insofar as the collection of coal samples on Vancouver Island and in the Princeton and Nicola areas is concerned the wholehearted cooperation of the British Columbia Department of Mines was obtained, and Dr. J.F. Walker, Deputy Minister of that Department arranged for the shipment of the Island samples to Ottawa. Arrangements were also made by the Fuel Research Laboratories with the Canadian Pacific Railway Company for the free shipment of the coal samples from the B.C. mainland to Ottawa. This facilitated the collection of sufficiently large quantities of coal for a thorough physical and chemical study.

The author spent about four and a half weeks in the province of British Columbia, visiting seven mining operations and collecting seven different samples representing the run-of-mine product from the mines. Ninety-seven commercial samples of the various sizes prepared were collected at each of the mines as well as at the Cities of Vancouver, North Vancouver and New Westminster. Of these 55 were collected at the mines and 42 at the distribution points mentioned above. These latter samples included eighteen(18) Alberta coals and one sample of American briquettes.

The mining properties and distribution centres visited and the samples taken are as follows:-

A. Vancouver Island.

1. Canadian Collieries (Dunsmuir) Ltd. - 5 P.& C. survey mine run samples and 25 commercial samples.

B. British Columbia Mainland

1. Cities of Vancouver, North Vancouver and New Westminster. Forty-two commercial samples, 18 of which were from Alberta mines and one from United States.

2. Middlesboro Collieries Ltd., Merritt, B.C. - 2 P.& C. survey mine-run samples and 5 commercial samples.

3. Granby Consol. Mining, Smelting & Power Co. Ltd. - 6 commercial samples.

4. Princeton-Tulameen Coal Co. Ltd. - 5 commercial samples.

5. Crows'Nest Pass Coal Co. Ltd. - 2 commercial samples from Coal Creek mine and 12 commercial samples from the Michel mine.

2.

Geological Description of the Vancouver Island, Princeton and Nicola Coal Areas.

A. Vancouver Island

According to a report on the "Coal Resources of Southern Vancouver Island" by J.D. MacKenzie, issued in June 1923 at Ottawa by the Geological Survey of the Department of Mines, the coal bearing strata of Vancouver Island are those of the Nanaimo series of Upper Cretaceous age, and consist of an accumulation of conglomerates, sandstones and shales with some coal. "There are four main areas on Vancouver Island in which the series occurs. These are the Comox area, extending from Campbell lake to Nanoose bay; the Nanaimo area, in the vicinity of the city of Nanaimo, extending from Nanoose bay to Ladysmith and including the Gulf islands; the Cowichan area, underlying the Cowichan valley; and the Alberni area, in the middle of the island. Coal of workable thickness has been found in parts of the Comox and Nanaimo area, but no workable seams are known in either the Cowichan or the Alberni areas".

In the Nanaimo area the coal occurs mainly in the lower part of the series in three seams, the Wellington, the Newcastle and the Douglas. The lowest seam, the Wellington, rests on the East Wellington sandstone and is about 700 feet above the base of the Nanaimo series. The Newcastle seam overlies the Wellington seam by about 800 to 1000 feet. The Douglas seam is from 25 to 100 feet above the Newcastle seam. The associated measures are moderately disturbed and have a general monoclinal structure with a low dip to the northeast. There are a few large open folds and many smaller ones.

The three seams vary greatly in thickness and quality. In places a variation as great as from 2 or 3 feet of dirty, slickensided coal to 30 feet of clean coal, occurs within a lateral distance of 100 feet.

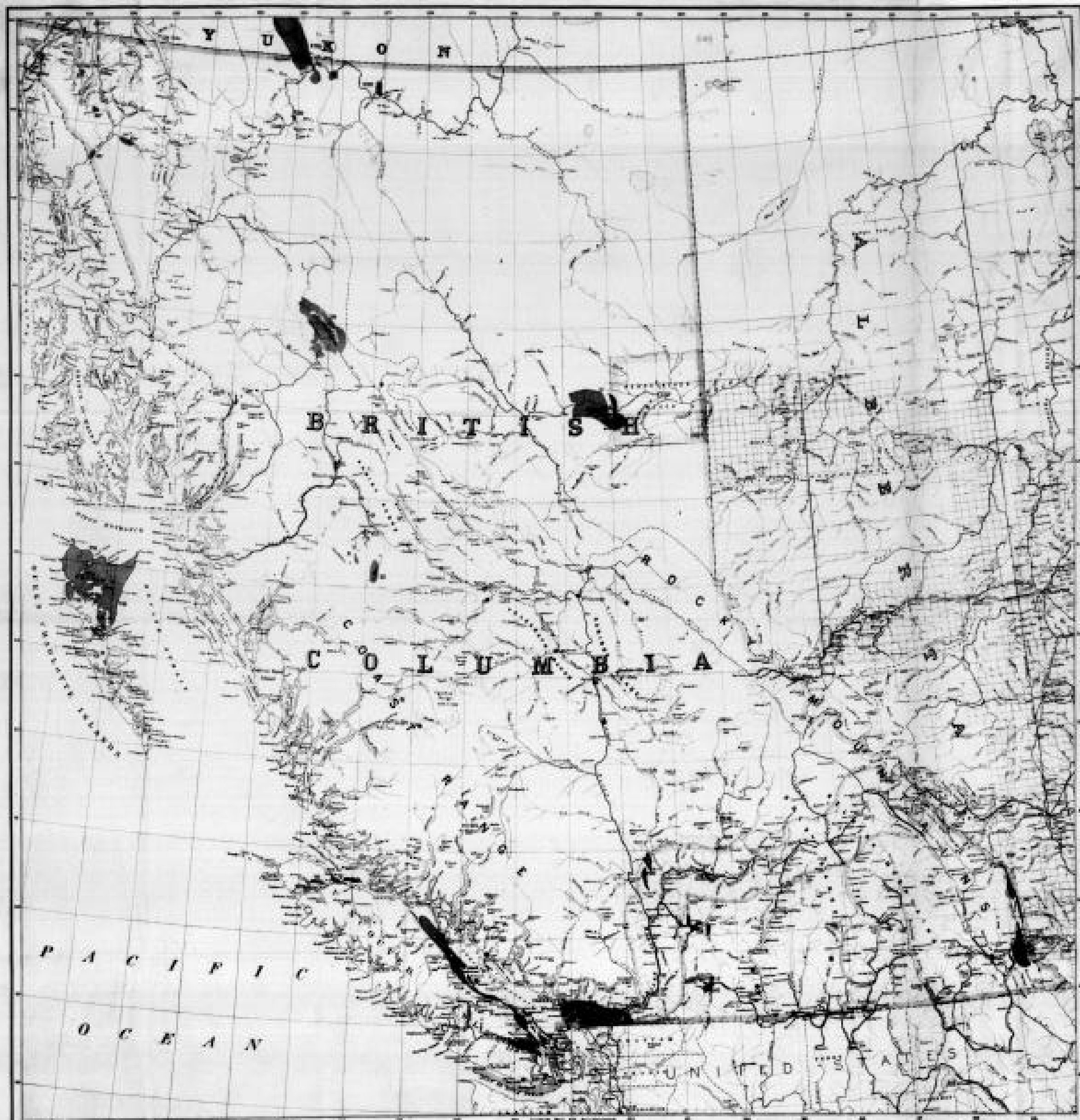
The most conspicuous feature of the Wellington seam which outcrops along the western border of the field is its variability in thickness caused chiefly by minor faults, folds or bends, usually in the roof, while the floor is fairly regular and even. The thickness of the seam varies, where mined, from practically nothing to 30 feet and has an average thickness of from 4 to 7 feet. The quality of the seam varies greatly from a rather clean, bright not greatly fractured material containing some calcite and pyrite to a dirty dull, slickensided product containing carbonaceous shale, bone, pyrite, calcite and bands of rock. At the thin places or "pinches" the coal is dirty and slickensided, while in the thick places it is clean and broken by only a few irregular joints. Coal from this seam is being mined by several small independent operators near the Old Extension, and the old No. 8 Wellington mine is being reopened by the Canadian Collieries (D) Ltd.

Canada
Department of Mines

GEOLOGICAL SURVEY

LEGEND

DIAGRAMS



Coal-fields
of
BRITISH COLUMBIA

The Newcastle coal seam extends from the northern part of Newcastle Island to south of Nanaimo river with a general N.20° W. trend. The average thickness of the seam where mined was from 30 to 40 inches with extremes of 20 inches and 6 or 8 feet. It was thinner but much more regular than either the Wellington or Douglas seams. The floor of the seam was usually a dark green shaly sandstone whereas the roof varied from shaly rock to sandstone, grit and conglomerate. The seam is not worked at present but was mined by the Western Fuel Company, operations ceasing some years ago because of the inferior nature of the product.

The Douglas coal seam, referred to as the upper seam, extends from northern Newcastle Island to south of Nanaimo river, perhaps as far as Ladysmith. The seam, varying from 0 to 30 feet, averages about 5 feet in thickness and was worked from the No.1 mine at Nanaimo and extends in depth below Newcastle Island. At present it is being worked through No. 10 mine. The floor and roof of the Douglas seam vary from grit or fine conglomerate to sandy shale, and the "pinches" and"swells" are caused chiefly by irregularities in the floor. At the "pinches" the coal is dirty and at the "swells" fairly clean and compact. There are no regular or persistent partings, but there are, in places, thick partings of coaly shale. The Douglas coal is fairly brilliant, hard and massive, being broken by irregular joints producing irregularly shaped pieces.

In the <u>Comox Area</u> mining at present is confined to the Cumberland district, centering around the city of Cumberland. This area, of which about 25 square miles are coal bearing, has been producing coal for nearly 53 years, and at present there are two mines working, Comox No. 5 and Comox No. 8. In this field the coal is found in several seams that occur in a sandstone formation, the Comox. This formation, which is analagous to the Protection formation of the Nanaimo area, below which are found the three seams of this latter area, rests directly on the pre-Upper Cretaceous volcanic rocks. Because of this the coal-bearing horizons of the Nanaimo Area are not represented in the Comox Area. Of the four seams known, only three have been mined. The seams are numbered in descending order from 1 to 4. No. 3 seam was never mined, although it is persistent throughout the field, because it only runs from 1 - 15 inches in thickness. The workable coal seams in the Comox Area are more regular than those of the Nanaimo Area, and to a lesser degree, show the "pinching" and "swelling" so characteristic of the Nanaimo coal seams. They are on the thin side varying from 3 - 4 feet in thickness.

Neither the <u>Cowichan</u> nor the <u>Alberni</u> area are considered as possible sources of commercial coal.

B. <u>Princeton Coal Area</u>

The Princeton district lies in a part of what has been called the great Interior plateau of British Columbia, and the town of Princeton which is practically in the centre of the field is situated at the junction of the Similkameen and Tulameen rivers. The principal rocks of the Tertiary coal basin are flat lying sediments of Oligocene age, resting on a basement of tilted Palaeozoic rocks. They include sandstones, clays, shales, conglomerate, and coal seams, and cover an area of nearly fifty square miles, the basin being fourteen miles long with a variable width of from three to five and a half miles.

According to Dr. C. Camsell's[1] report on the area "it would appear that most, though not all, of the workable seams are within 300 feet of the surface. Drill holes in the area have indicated that the thickest seams are in the vicinity of the town of Princeton where a bed over eighteen feet in thickness was struck at a depth of 49 feet below the surface".

(1) "Coal Fields of British Columbia" - compiled by D.B. Dowling. Canadian Geological Survey Memorandum 69 - 1915.

It is apparent from subsequent data obtained through mining that this seam varies to a great degree in thickness, one of the mines at present operating on a seam about 6-1/2 feet thick.

Two companies are at present operating in the Princeton Area. The Granby Consolidated Mining, Smelting & Power Co. Ltd. have two mines about 6 miles west of Princeton, and the Princeton Tulameen Coal Co. Ltd. operates one mine about 1 mile west of Princeton.

C. Nicola Coal Area

According to Camsell[1] this "district lies in the Interior Plateau region into which the Nicola river has cut one of those deep, wide valleys, characteristic of the region". The town of Merritt, the centre of coal mining operations, is situated in the Nicola valley at the junction of the Coldwater and Nicola rivers.

This Tertiary coal basin consists of Oligocene rocks including sandstone, conglomerate, shale and coal, dipping at angles varying from 10 to 40 degrees. The basin covers an area of about 40 square miles all of which, however, does not appear to be underlaid by coal. A block of the Oligocene rocks is preserved to the west of Coldwater river near the Nicola in which mining has been carried on for some years. Here a series of four seams dipping towards the basin are found. These have been numbered in ascending order from 1 to 4, and vary from 3 feet to about 18 feet in thickness. In some places the strata have been folded into anticlines, and in others faulted and considerably displaced.

At present one company, the Middlesboro Collieries Ltd., is operating two mines in the area.

3.

Description of The Coal Mines.

The following is a description of each of the mining operations visited on Vancouver Island and in the Princeton and Nicola areas, with special attention being given to the preparation plants.

A. VANCOUVER ISLAND

Nanaimo Area

1. Canadian Collieries (Dunsmuir) Ltd.

Mine ------------------	No. 10, South Wellington
Seam ------------------	Douglas
Location --------------	Cranberry district, about 7 miles south of the City of Nanaimo, Vancouver Island.
Mine Officials --------	H. Baird, General Superintendent. William Frew, Manager.
Output ----------------	About 1100 tons per 24 hours. Before closing down of the Northfield mine on July 12/41 output was approximately 900 tons per day.

Details of Mine and Seam:

Beginning as a prospect in May, 1937, it joined the producing list of mines in August 1938, and now ranks as the chief producer in the Nanaimo area, operating 251 days during 1940 with a total production of 183,162 tons. It operates on the Douglas seam sometimes referred to as the Upper seam, in the Nanaimo area. The seam varies considerably in thickness, the average being 5 - 7 feet.

The mine is entered by a slope running southeast, which in July 1941 was about 7100 feet long. Coming off this main slope are three diagonal slopes running in a southeasterly direction from which several levels and headings have been driven. The seam is worked by the pillar and stall method, and all the haulage to the main slope is effected by means of compressed air. From here the cars of coal are brought to the surface by means of an electric hoist.

The mine is dry, dusty and gassy, and during 1940 196,000lbs. of rock dust was used in treating 30,000 feet of roadways.

The Tipple or Bankhead.

The tipple is situated about 1/2 mile north of the mine entrance, the mine cars with a capacity of about 27cwt. of coal being brought in trips of 6 to 12 to the tipple by means of a small locomotive. The coal is dumped, at ground level, by means of an end dump tippler into a feed hopper from where it is carried by means of an inclined scraper conveyor, about 35 feet in length, to the top of the preparation house. Here the coal drops onto a double decked reciprocating shaker screen, the top deck being fitted with 2-1/2 in. round hole screens and the bottom deck with 1-1/2 in. round hole screens. The screening surface is 4ft. wide and 18 ft. long.

Normally the coal is separated on the 2-1/2 inch screen. The +2-1/2 in. lump known as "steam lump" goes over a steel belt conveyor picking table, with one man picking, and then direct to open cars for shipment or for delivery to the Nanaimo docks. The 0 - 2-1/2 in. slack passes to open cars which are delivered to the washery at Nanaimo. When coal is being prepared for the employees all the lump retained on the 1-1/2 in. screen, referred to above, is supplied to them at $3.00 per ton.

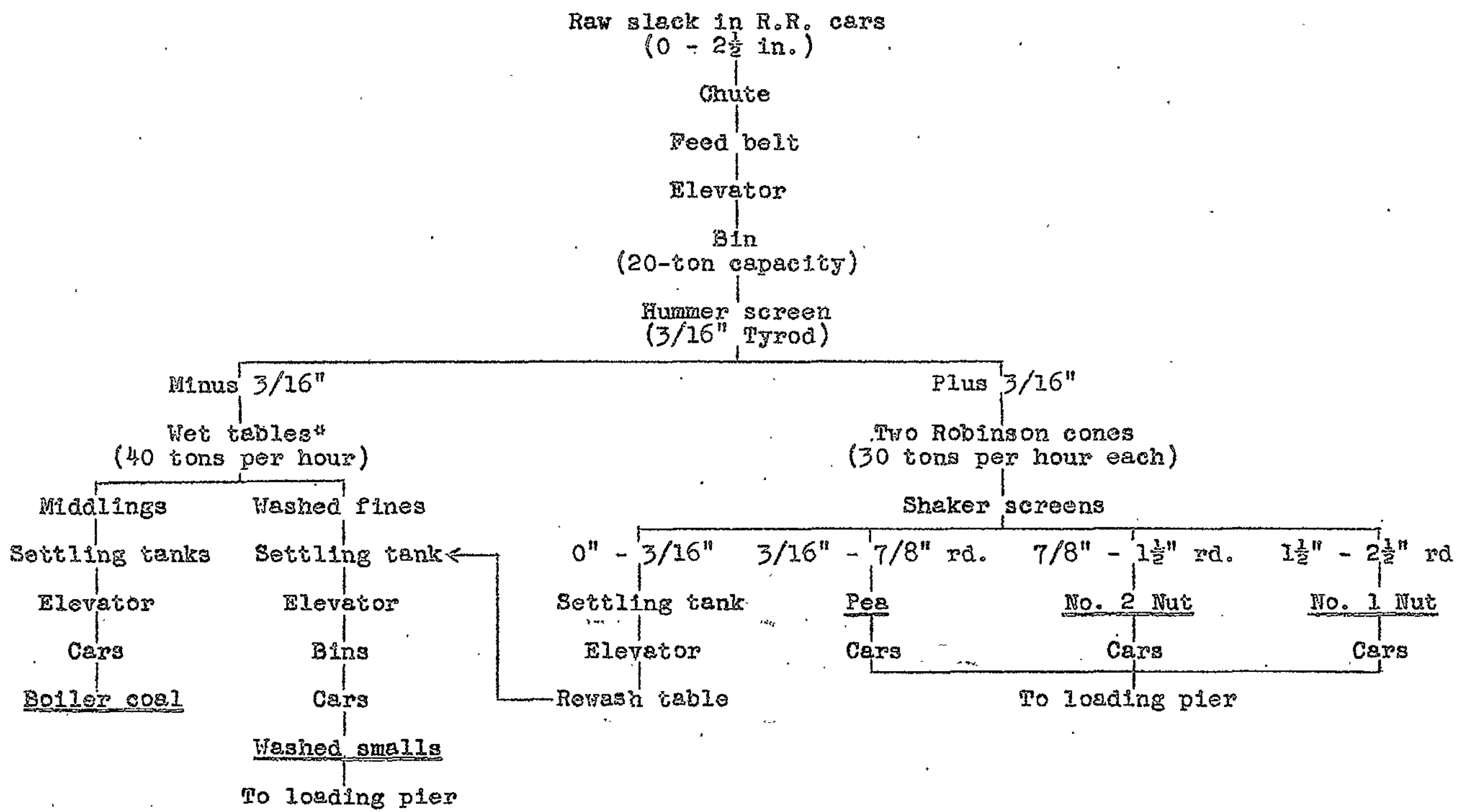
According to estimates made at the mine only about 12% of the total coal passing through the tipple is +2-1/2 in. lump.

The Nanaimo washery has been described in R.I.C.S.115, (March 1939), and accordingly the washed sizes prepared for commercial shipment from the 0 - 2-1/2 in. slack are as follows:

1. No.1 Nut ---------- 1-1/2 - 2-1/2 in. rd. hole screen.
2. No.2 Nut ---------- 7/8 - 1-1/2 in. rd. hole screen.
3. Pea -------------- 3/16 Tyrod - 7/8 in. rd. Hole screen.
4. Washed Smalls ----- 0 - 3/16 in. Tyrod.

In addition to the above, rewashed 0 - 3/16 in. middlings is used as boiler coal at the plant. A flow sheet of the washery is shown in Figure 1.

It should be noted that since the last visit of an official of the Fuel Research Laboratories to the washery in 1939, no great changes have been made in the plant, with the exception that the screen openings for the pea and No.2 nut have been slightly altered. It should also be noted that a Jefferey single roll crusher is available for crushing +2-1/2 in. lump for the preparation of additional quantities of the nut and pea sizes when required.



* Four Diester-Overstrom and Five Plato tables; eight for raw coal and one for middlings.

Fig. 1 -- NANAIMO WASHERY

The production by grades of coal from No. 10 mine for the Fiscal year ending June 30th, 1941, is shown in Table I, below.

Table I

Production by Grade of No. 10 Mine (Douglas Seam) Coal.
Fiscal Year Ending June 30th, 1941.

	Tons	% of Total
Steam Lump	25,445	13.23
No.1 Nut	8,197	4.26
No.2 Nut	9,896	5.14
Pea	41,710	21.68
Washed Smalls	54,040	28.09
Boiler Smalls	9,367	4.87
Total Commercial	148,655	77.27
Loss in Washery	43,718	22.73
Tipple Output	192,373	100.00

To indicate the degree of washing effected at this plant the data in Table II are presented. This shows the ash content on the as received basis, of the raw 0 - 2-1/2 in. slack separated on the 3/16 in. Tyrod as well as the average ash content of three of the sizes prepared. This data was obtained at the Nanaimo washery.

Table II

Ash Contents of Raw & Washed Coal
from No. 10 Mine (Douglas Seam).

		Raw Coal % Ash	Washed Coal % Ash
No. 1 Nut	3/16 to 2-1/2"	20.7	9.8
No. 2 Nut			--
Pea			13.0
Washed Smalls	0 - 3/16"	28.6	16.2

It should be mentioned that the Nanaimo washery in addition to the No. 10 coal handles the coal from several small independent operators, mining in the Wellington seam.

2. Independent Operators Supplying Coal to the Canadian Collieries (Dunsmuir) Ltd.

Mine	(a) No.3 - Operated by R.H. Chambers (b) Hamilton Mine
Seam	Wellington
Location	These mines are located in the Extension district and are operated in a small portion of the Wellington seam.
Output	During July 1941, Chambers mine was producing about 46 long tons per day (expected to increase to 60), and Hamilton was mining about 16 tons per day (may increase to 48 tons).

These mines are working on a sublease from the Canadian Collieries (Dunsmuir) Ltd. on isolated left over sections of the Wellington seam. The life of these mines is thus relatively short even with such a small output as indicated above. It is expected that the Chambers mine may have sufficient coal for 2 years operation, but the life of the Hamilton mine is unknown.

The coal is all handpick mined and delivered from the mines by Diesel trucks in 12-20 ton loads to a small tipple, known as the Beban tipple, and operated by the Canadian Collieries (Dunsmuir) Ltd. a short distance from the Nanaimo washery. The mine run coal is dumped into a large hopper from which it is fed directly onto a single decked shaking screen, 4 ft. wide and about 10 ft. long, equipped with 2-1/2 in. rd. hole screen. The 0 to 2-1/2 in. screenings drop to cars for delivery to the Nanaimo washery, whereas the +2-1/2 in. lump is handpicked before dropping to cars for delivery to the shipping pier.

On the average the mine-run coal yields 16 tons of lump for 55 tons of run-of-mine.

3. Canadian Collieries (Dunsmuir) Ltd.

Mine --------------------	No. 8 Wellington (Timberlands)
Seam --------------------	Wellington.
Location ----------------	Range 1, Section 1, Cranberry district, and in close proximity to McKay's lake and Nanaimo river.

Details of Mine and Seam:

This mine is one of the old group of the Extension colliery and has been closed down since October 1928 due to trade depression. Before it was closed down all the work was concentrated on No. 2 slope, and apparently this is the slope through which the mine is being reopened, work having started during the latter part of June, 1941.

The Wellington seam which underlies this area was accidentally discovered in 1895. The seam averages about 5 feet in thickness and is in two benches, the top bench averaging 15 inches of coal, then about 6 to 8 inches of dirt; the bottom bench is good hard coal. As the mine is favoured with good roof conditions it stood up fairly well during the idle period.

When ready for operation the coal will be machine mined by longwall method. After being brought to the surface it will be loaded into trucks and taken direct to the Nanaimo washery. Only a very simple tipple will be constructed to roughly separate the lump from the slack.

As the seam in this mine is located in a small basin between two ridges, it is anticipated that the mine will have a life of only from 1-1/2 to 2-1/2 years.

The sample of coal for the Physical and Chemical Survey was obtained on the 1st right level at a point about 200 feet in from the main slope where some coal had already been removed for use around the mine. The coal was handpick mined.

Northfield Mine - This mine which was situated four miles north of Nanaimo and yielded coal from the Wellington seam was abandoned during the early part of July 1941. The mine had only been reopened a few years ago with company officials anticipating a fairly long operation. However, due to faulty records and miscalculations, when work progressed it was found that the coal that should have been left as pillars had been mined out, and for the rest, the seam was thin and split into three thin benches which soon became unworkable.

Comox Area

1. Canadian Collieries (Dunsmuir)Ltd.

Mine --------------------	Comox No. 5
Seam --------------------	No. 2
Location ----------------	About 1-1/4 miles N.W. of Cumberland in the Comox district.
Mine Officials ----------	H. Baird, Gen. Superintendent. No mine manager had as yet been appointed since the resignation of R.B. Bonar who is now a mine inspector.
Output ------------------	About 1000 tons per 2 shift day is the capacity of the mine, but the average output has been about 800 tons per 2 shift day.

Details of Mine and Seam:

During the long life of this mine three of the four available seams have been worked; the No. 3 seam being unworkable as it varies from only 1 to 15 inches in thickness. The No. 4 seam was worked until 1910, and the No. 1 seam was exhausted in 1931. Thus all operation since that time has been conducted in No. 2 seam. This seam has an average height of about 3-1/2 feet and contains irregular bands of bone and shale varying from 2 to 30 inches in thickness.

The mine is entered by a shaft 280 feet in depth, which is the level of No. 1 seam. All the workings lie to the dip of the shaft and are accessible by four slopes which are driven from the level of the No. 1 seam. Where the rock tunnels meet No. 2 seam there is about 380 feet of cover. The main slope in No. 2 seam had, by July 1941, been driven a distance of 8500 feet N 70 E to the face of the coal (about 1000 feet of cover). Diagonal slopes, on the dip, are struck off to the east and west. In July 1941 work was conducted on No. 4 West Diagonal and on the main slope. On No. 4 west there was one double wall, 600 feet long, and one single wall, about 300 feet long. On the main slope there was one double wall, 550 feet long, and two single walls each 300 feet long. As indicated then, all of the output is produced from long-wall faces, and their accompanying development places.

All cutting is done in the rock-bands, either in the centre of the seam or underneath, by means of Anderson-Boyes coal-cutting machines which mine the coal to a depth of 6 feet. The long-wall faces are equipped with Meco-type compressed air operated pan-conveyors which carry the coal from the face to loading points on the levels. In addition to the pan-conveyors, two 20 inch gate-end belt-conveyors are used to carry the coal from the pan-conveyors to mine cars (1800 lb. capacity) in loading roads where roof brushing is done.

Horse and compressed air haulage is used on the levels, and an electric hoist hauls the trips up the main slope to the rock tunnel. From here the cars are brought by means of a battery type locomotive to the bottom of the shaft, where a balanced cage elevator is employed in bringing the cars of coal to the surface.

Due to the gassy nature of the mine the closest attention is at all times required in maintaining efficient ventilation; two Sirocco exhaust fans passing 208,000 cu.ft. of air per min. being employed.

The mine is quite dusty, and to combat the dust hazard rock-dust is regularly applied to the roadway and face-lines. In addition the coal coming off the conveyors at the bottom of walls is sprayed with water and all main slope trips are sprayed with water as they leave the different partings.

The Tipple or Bankhead.

In the tipple, the cars of coal, after being weighed are dumped by a rotary dump onto a double-decked shaker screen which is about 45 feet long and 4'6" wide. The top deck is fitted with a 6 in. lip screen and a screen with 6x10 in. staggered openings. The lower deck is equipped with 3 in. round hole screens. The plus 6 in. lump is handpicked on a steel conveyor type picking table and loaded into cars immediately below for shipment. The 3 - 6 in. lump is also handpicked and loaded to cars for shipment. The 0 - 3in. slack or screenings are loaded into cars for delivery to the washery at Union Bay (18 miles from the mine).

A single-roll crusher is available for preparing additional 0 - 3 in. screenings from the big lump, when additional quantities of small sizes are required.

Thus the sizes prepared at the mine are as follows:-

A. Commercial Coals.
1. Big Lump ---------------- +6 in.
2. Cobble or 6 in. Lump --- 3 in. rd.- 6 in.
B. Raw Screenings ----------------- 0-3 in. rd. hole.

2. Canadian Collieries (Dunsmuir) Ltd.

Mine --------------------	Comox No.8
Seams --------------------	No.2 & No.4
Location ----------------	About 3 miles N W of Cumberland in the Comox district, in the vicinity of the Lake Trail road, 2 miles east of the mine camp at Bevan.
Mine Officials ----------	H. Baird, General Superintendent. J.A. Quinn, Manager.
Output ------------------	About 900 tons per 2 shift day, but may be increased to approximately 1100 tons.

Details of Mine and Seam:

The mine at one time operated on both No. 2 and No. 4 seams, but since 1914 production has been entirely confined to No. 2 seam. Recent developments* have indicated the possibility of mining No. 4 seam in the not distant future. In anticipation of this and to comply with a request from Dr. J.F. Walker, B.C. Deputy Minister of Mines, for a suitable sample of coal from the seam, levels have been struck off at about 500 ft. north and south of the shaft and preparations are being made to start operation by the longwall method sometime late this year. The No. 2 seam averages about 40 inches in thickness, and contains a long band in the middle varying from 2 - 8 inches in thickness and averaging about 6 inches.

The seams in this mine are reached by two shafts each about 1000 feet in depth, the No. 2 seam being encountered at a depth of 700 feet.

* The B.C. Dept. of Mines has employed a firm of American Consulting Engineers to study and report on the feasability of a steel industry for B.C. If this develops a low sulphur coking coal will be required for the preparation of suitable coke. The No.4 seam Comox coal in the past was lower in sulphur than the other seams, and accounts for the interest shown in this coal at present.

In this seam the main (south level) goes in a distance of 3000 feet. No. 1 Incline comes off 500 feet from the shaft in a southeast direction and goes in a distance of 2100 feet. No. 1 dip breaks off 600 feet from the shaft and goes in 600 feet in a northeast direction.

Mining is all advance longwall, with one double unit (600 feet long) and six single units (each 300 feet long) in operation during July 1941. The cutting is done in the shale band by means of Anderson-Boyes long-wall machines, Hardiax post-type punching machines being used to cut the development places. Meco-type conveyors are used on the walls, and compressed air is used to operate the coal-cutters and the conveyors. The coal is loaded on the levels into 2400 lb. capacity cars and hauled by horse to the inclines and dips, where compressed air operated rope haulage brings the cars to the main level. On the main level horses were being used, but they are to be replaced by storage battery locomotives. The coal is brought to the head of the tipple up the shaft by means of a balanced cage.

The mine is dry and gassy being ventilated by one Sullivan fan passing 200,000 cu.ft. of air per min. The dust hazard is quite serious and in addition to rock-dusting in the roadways and at the face-lines, the coal is water-sprayed as it is discharged from the conveyor-pans.

The Tipple or Bankhead.

The cars of coal are weighed and then emptied by means of a rotary dump, the coal falling onto a shaker pan conveyor which conducts the coal to the screening table. This is a single decked shaker about 60 ft. long and 4 ft. 6 in. wide, equipped from feed to discharge end as follows:-
(a) 3 in. rd. hole screens, (b) 6 in. lipped screens, and
(c) 6 x 10 in. rectangular staggered screen.

The plus 6 in. lump is handpicked and delivered to cars for shipment as commercial lump (big lump). The 3-6 in. lump, known as 6 in. lump or cobble is also handpicked and delivered to cars for commercial shipment. The 0-3 in. screenings are discharged to cars for delivery to the Union Bay Washery for further processing.

UNION BAY WASHERY

This washery was visited in 1939 by a member of the Fuel Reserrch Laboratories and is described in R.I.C.S. 115. However, since that time, certain changes have been incorporated with a view to improving the resultant products, as well as increasing the overall efficiency of the plant. (see Fig.2)

The Howe cones which had been employed in the past are being replaced by Vissac Jigs, the first one (a 4'6" jig with a 100 ton per hr. capacity) being put into operation in June 1941. Eventually there are to be two of these jigs. The raw 0-3 in. slack, coming from the Comox mines, is screened on a Hummer equipped with a 3/16 in. Tyrod screen. The 3/16 - 3 in. coal is washed in the Vissac jig, whereas the 0 -3/16 in. is processed on the Plato wet washing tables. The cleaned 3/16 - 3in. coal is separated on a shaker dewatering and sizing screen into the following sizes.

(a) 1-1/4 or 1-1/2 - 3 in. rd.hole ---------- No.1 nut.
(b) 7/8 - 1-1/4 or 1-1/2 in. rd. hole -------- No.2 nut.
(c) 3/16 in. Tyrod - 7/8 in. rd .hole -------- Pea.

The 0 - 3/16 in. Tyrod cleaned coal coming from the tables results in the production of the fourth commercial product, namely Washed Smalls. This is the material of which a portion is to be

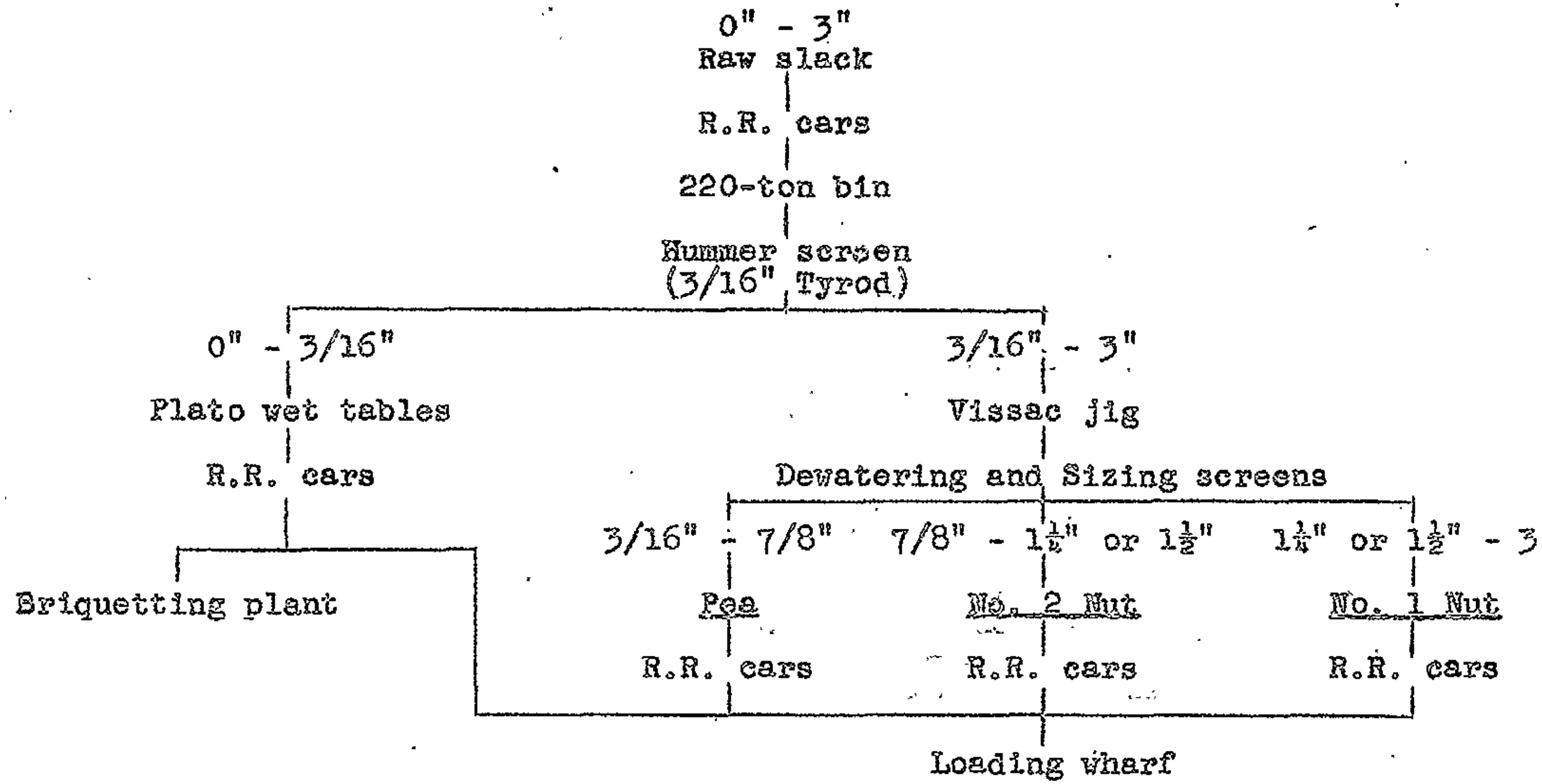


Fig. 2 -- UNION BAY WASHERY FOR COMOX COAL

employed in the preparation of briquettes in the new briquetting plant constructed during the spring and summer of 1941.

All of the above sizes are delivered by railroad car to the loading wharf where they are stored in bins prior to shipment. Although only the above four sizes leave the washery various mixtures of them together with the lump sizes delivered direct from the mines are prepared for shipment, as for example -

1.	Railway Coal -----------	65% ---------	3-6 in. Cobble
		10% ---------	No.2 Nut
		25% ---------	Washed Smalls
2.	Government Mix. --------- (For boats etc.)	80% ---------	3-6 in. Cobble
		10% ---------	No.1 Nut
		10% ---------	Washed Smalls
3.	B.C. Pulp & Paper ------	Pea Coal mix. as follows:-	
		50% ---------	No.2 Nut
		50% ---------	Pea
4.	Domestic Nut for Seattle (Shipped as Pea Slack for customs purposes)	50% ---------	No.1 Nut
		50% ---------	No.2 Nut

The production by grades of coal from the two Comox mines for the Fiscal year ending June 30/41, are shown below in Table III.

Table III

Production by Grade of Comox Coals
Fiscal Year Ending June 30/41.

	Comox No.5		Comox No.8	
	Tons	% of Total	Tons	% of Total
House & Steam Lump	65,477	39.47	40,570	34.55
No. 1 Nut	13,182	7.95	10,695	9.11
No. 2 Nut	14,341	8.65	11,485	9.78
Pea	13,760	8.29	11,178	9.52
Washed Smalls	37,132	22.39	30,471	25.95
Total Commercial	143,892	86.75	104,399	88.91
Loss in Washing	21,971	13.25	13,025	11.09
Tipple Output	165,863	100.00	117,424	100.00

To indicate the degree of washing effected at this plant the data in Table IV are presented. This shows the ash content, on the as received basis, of the raw 0-3 in. slack separated on the 3/16 in. Tyrod screen, as well as the average ash contents of the four sizes prepared. This data was obtained at the Union Bay Washery.

Table IV

Ash Contents of Raw & Washed Coal
from Nos. 5 & 8 Comox Collieries - Av. March, May & June 1941.

	Comox No. 5 Raw Coal % Ash	Comox No. 5 Washed Coal % Ash	Comox No. 8 Raw Coal % Ash	Comox No. 8 Washed Coal % Ash
No. 1 Nut)		10.8	(	11.1
No. 2 Nut) 3/16-3 in.	27.5	12.5	(25.6	12.6
Pea)		12.9	(	13.2
Washed Smalls- 0-3/16"	20.8	14.3	19.0	13.7

In comparing this data to that on the No. 10 Wellington coal, Table II, it is of interest to note that in the raw state the +3/16 in. coal of the No. 10 is lower in ash than the -3/16, whereas in the case of the Comox coals the situation is reversed. It is also important to note that the +3/16 in. Wellington coal in the raw state is lower in ash than the Comox +3/16 in. coal, whereas the Comox -3/16 in. is lower in ash than the No. 10 -3/16 in. fines.

Briquetting Plant at Union Bay.

Late in June 1941, the briquetting plant, which is to be used for briquetting Comox washed smalls, was completed and ready for experimental operation. The plant, which is situated several hundred yards from the Washery, was designed by and apparently constructed under the supervision of Mr. G. Vissac, Consulting engineer resident in Vancouver, B.C. The plant costing about $50,000 consists of both new and old equipment; the Komarek 30 ton per hour roll press, two horizontal pre-drier paddle mixers and some subsidiary equipment being obtained second hand in Seattle, Washington. The vertical drier and main paddle mixers were designed by G. Vissac and constructed by the Riverside Iron Works, Ltd., Calgary, Alberta.

The plant is designed to produce 20 tons of briquettes per hour and is as shown in the following flow sheet.

Cars of wet fines from washery

Track hopper

Elevator

Two horizontal paddle mixers
(steam heated preheaters)

Vissac vertical gravity drier

Dust | Dried dedusted fines

Cone collector

Binder tank

Pump ⟶ Preheating paddle mixer (horizontal)

Fluxing paddle mixer (horizontal)

Tempering paddle mixer (horizontal)

Komarek roll press

Cooling conveyor

Loading boom

R.R. cars

The wet washed smalls (0-3/16) coming from the washery are dumped into a Track hopper at ground level from where they are taken to the top of the Briquetting plant by means of a bucket elevator for delivery to the drying system. This is composed of two horizontal steam jacketed paddle mixers followed by the main flue gas gravity drier designed by G. Vissac. This is a vertical rectangular tube about 31 feet in height equipped with nine arresting plates or baffles. These baffles are free to move, like a flap, being balanced on the outside by a counterpoise. When an arresting plate accumulates sufficient coal it will swing down until the coal slides off, being caught on the next baffle lower down. The tube or drier is supposed to be designed of such length and with sufficient baffles to allow for the fines to be retained on the drier long enough to bring the moisture content down from about 8 - 10% to approximately 2%. Hot flue gases, from a furnace situated in the briquetting building, pass into the lower end of the drier, the cooled, moist and dust laden gases being drawn off into a cone dust collector. The dust is remixed with the dried fines.

To date this drier has not operated very satisfactorily. Various test runs indicated that the reduction in moisture content was very small, only about 2%. In addition it was found that the coal coming out at the bottom of the drier had only attained a temperature of approximately 115°F. With a view to improving this condition superheated steam at about 750°F. was introduced into the horizontal mixers preceding the flue gas drier. This resulted in only a slightly improved reduction in moisture content, and raised the temperature of the coal leaving the vertical drier to about 150°F. In addition to this, difficulty was experienced in maintaining a uniform flow of coal through the vertical drier, the wet coal hanging up on the baffles. Thus, when the plant was visited by the author, the baffles were tied down in a vertical position, the drier acting mainly as a chute, and any drying that was done was apparently effected mainly in the two steamjacketed horizontal mixers preceding the vertical drier.

The coal from the vertical drier passes directly into a short horizontal steamjacketed paddle mixer, known as the preheater. Here the asphalt binder is introduced in the form of a so-called emulsion, really a frothy mixture of asphalt and steam. As originally designed and constructed, the asphalt emulsion was introduced at a point very close to the entry of the coal from the drier. This was unsatisfactory because when the pitch at about 275 - 300°F. came in contact with the relatively cooler coal which was at 115 - 150°F., it congealed and formed balls with some of the coal.
To overcome this difficulty superheated steam was introduced into the jacket of the preheater mixer, and the pitch entry was moved to the centre of the mixer. These changes allowed for the coal to be heated to a higher temperature prior to the introduction of the pitch, and at the time of the author's visit it was noted that "balling" was practically overcome. It was suggested that the pitch entry be moved to the end of this mixer, and allow the main mixing to take place in the horizontal steamjacketed fluxing mixer situated immediatelt below the so-called preheater; thus retaining it as such, and ensuringthe production of a sufficiently hot coal prior to the introduction of the asphalt binder.

After leaving the fluxer which is heated by means of superheated steam, the coal-pitch mixture then drops into a very long horizontal cooling or tempering mixer situated immediately below the fluxer. From here the coal drops into the Komarek roll press, which has been geared down from 30 to 20 tons per hour. The press makes a fairly large cushion-shaped briquette weighing about 4-1/2 ounces. The briquettes drop onto an inclined cooling conveyor which allows for about 20 minutes cooling and hardening before the briquettes are discharged, by means of a loading boom, into railroad cars. During the author's visit some test runs were made and a certain amount of difficulty was encountered in maintaining a uniform feed to the press.

This resulted in the production of a product which consisted of a mixture of so-called "raspberries", "oystered"briquettes and some good briquettes. This condition will be overcome in time when more experience is gained and when some provision is made for rapid and accurate alteration in the feed to the mixers from the vertical drier. In addition it was noted that the coal was too coarse, and it was suggested that either the oversize should be screened out, or the product crushed. However, crushing introduces a difficulty insofar as the Union Bay plant is concerned. The washed smalls delivered to the briquetting plant are very wet and would be extremely difficult to crush in that state. On the other hand to attempt to crush the dried products presents a problem because there is no room for the introduction of a crusher between the drier and the mixers; which would be the logical place for this equipment. Thus it seems that in order to produce a more suitably sized coal for briquetting screening out the oversize would have to be considered, unless a radical change is made in the construction of the plant, whereby a crusher could be introduced between the drying and mixing systems.

It should be noted that the author visited the plant with the object of indicating how the Komarek starch-asphalt process could be employed. However, after examing the plant it was concluded that, as designed, it would be practically impossible, without effecting a great many changes, to use the dual binder according to the Komarek method. This process to be successful in producing a briquette which requires no subsequent drying, is absolutely dependent on the production of a finely crushed coal preheated to a temperature of at least 350°F. prior to the introduction of the starch-asphalt binder.

B. BRITISH COLUMBIA MAINLAND

Princeton Coal Area

1. Princeton Tulameen Coal Co. Ltd.

Mine ----------------	Tulameen Valley - Princeton
Location -------------	About one mile west of the town of Princeton on the Tulameen river.
Mine Officials -------	J. Taylor, Mine Manager. W.D. Seaman, Sec'y Treasurer. Head Offices at Princeton.
Output ---------------	24,731 tons for the year ending May 31st, 1941.

Details of Mine and Seam:

The mine was opened in the fall of 1936, the present company being incorporated in July 1937, with Guy F. Atkinson Co., San Francisco, Cal. as the main financial interests.

The mine is entered by means of a slope at 17° in the coal seam to a depth of 1200 feet in a southerly direction, the workings being to the west of the slope. The seam is approximately 11 feet in thickness and contains several bands of shale, stone and carbonaceous material. The mine is worked by the room and pillar method with 14 ft. rooms and 60 ft. pillars. The coal is machine mined, by percussive air driven machines with the cut being made about 4 ft. from the pavement. The bottom 6 ft. is being mined whereas the top four or five feet is left behind to drain and will be mined at a later date. At the time of the author's visit to the mine all the coal was being loaded by hand. Haulage on the levels was by hand, whereas a small electric hoist brings the coal up the slope to the head of the tipple in trips of two cars, each having a capacity of about 2500 pounds. There is as yet, apparently no trouble with gas, but the mine is rather wet. Power for the operation of this mine is provided by two Diesel units.

The Tipple or Bankhead (See Fig. 3)

In the tipple the coal is dumped by means of an end dump tippler, without weighing, onto a single-decked shaker screen fitted with 1-1/2 in. round hole screens. The 0 - 1-1/2 in. slack falls onto a double-decked vibratory screen immediately below. This vibrator is fitted with a 1 in. square mesh screen on the top deck, and with a 5/8 in. square mesh screen on the bottom deck. The 0 - 5/8 in. slack and the 5/8 - 1 in. square mesh pea are collected in bins. The 1 in. square to 1-1/2 in. round coal passes with the +1-1/2 in. oversize onto a belt conveyor used as a picking table. The picked +1 in. square hole screened and picked coal then passes over a single-decked shaker screen equipped from feed to discharge end as follows:- (a) 2-1/2 in. round hole screens and (b) 4-1/2 in. round hole screens.

The various sizes that can be prepared are as follows:-

(1) +4-1/2 in. rd. hole : Lump
(2) 2-1/2 to 4-1/2 in. rd. hole : Egg
(3) 1 in. sq. to 2-1/2 in. rd. hole : Nut
(4) 5/8 - 1 in. sq. hole: Pea
(5) 0 - 5/8 in. sq. hole: Slack

No railway spur is available at the mine so that for shipping the coal is trucked approximately one mile to the C.P.R. yards. Here the coal is dumped into a ten ton hopper from which it is fed by means of a steel plate conveyor over a shaker screen. When nut or egg is being loaded the coal is rescreened on a 1 in. rd. hole screen, and when lump is loaded rescreening is done on a 2 in. rd. hole screen. Pea coal is delivered direct to the railroad cars from the hopper without screening. All shipments are by box car. The slack is difficult to market. During 1940 a large proportion of it was taken by the power plant of the Granby Consolidated Mining, Smelting & Power Co. Ltd., but this year (1941) apparently this market is not available, and the slack is being dumped on the property.

Although the plant and mine have been designed to handle an output of 200 tons per eight hour shift, to date, the maximum output has been about 150 tons per day. This, of course, is conditioned by sale, and at times the output has been down to approximately 30 or 40 tons per day.

The output of coal at this mine for the year ending May 31st 1941, by sales and production was as follows:-

Production Record
June 1st 1940 - May 31st 1941.

	By Sales		As Produced	
	Tons	%	Tons	%
Lump	4507	21.1	4507	18.2
Egg	5261	24.6	5261	21.3
Nut	4302	20.1	4652	18.8
Pea	3390	15.8	4840	19.6
Pea Slack*	467	2.2	467	1.9
Slack	3464	16.2	5004	20.2
Total	21,391		24,731	

* Pea Slack = 45% Pea + 55% slack.

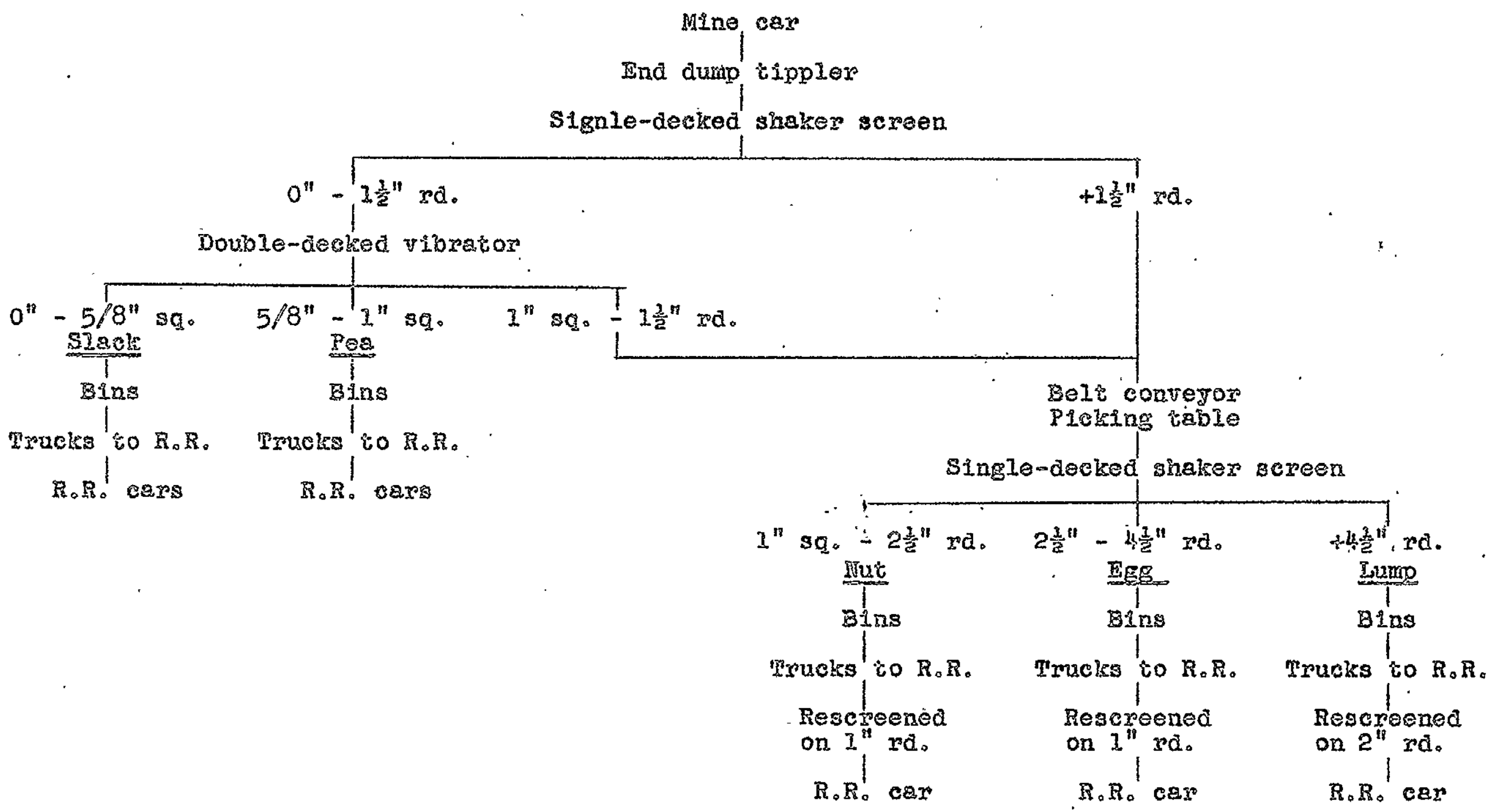


Fig. 3 - PREPARATION OF COAL AT PRINCETON TULAMEEN COAL CO. LTD.

A typical analysis of this coal, from an assay report of the British Columbia Dept. of Mines, dated May 23/41, was as follows:-

Moisture ------------	11.0%
Ash ----------------	4.6%
Volatile Matter -----	31.6%
Fixed Carbon --------	52.8%
Calorific Value -----	11,098 B.T.U./lb.

--- --- --- ---

2. The Granby Consolidated Mining, Smelting and Power Co., Ltd.

Mine -------------------	Granby Tulameen, No. 1 & No.2 Mines
Location ---------------	About 6 miles west of Princeton off the Hope-Princeton Highway in the Bromley Creek Area.
Mine Officials ---------	T.M. Wilson, Manager (Princeton). W.R. Lindsay, Supt. (Allenby, B.C.)
Output -----------------	During 1940 the output was 94,029 tons, for 254 days operation, i.e. about 370 tons per day.

Details of Mine & Seam:

Of the two mines, the No. 1 is in operation whereas No. 2 is in the development stage. The No. 1 mine operates on a seam which has an average thickness of from 5 to 6-1/2 feet and a general pitch east of 25 degrees. The mine workings are developed from two slopes known as the North and South diagonals. There were four levels in operation on the north side of the mine and three levels on the south side. The coal is mined in the usual pillar-and-stall method using the "post-puncher" type of machines. The use of explosives is avoided as much as possible, with a view to producing a large percentage of the larger size coal. Owing to the high inclination of the seam, chutes are in general use to transport the coal from the working faces to the main levels. With the exception of the main underground electric hoist, all the underground power is from compressed air.

Tipple or Bankhead

The coal coming up from the mine in 1-1/3 ton capacity cars is dumped, without weighing, by means of an end dump tippler into a chute feeding a single-decked shaker screen which is 3 ft. 6 in. wide by 27 feet in length. During the summer months this shaker screen is equipped as follows from feed to discharge end.

(a) 5/8 in. rd. hole screen
(b) 1- 1/4 in. rd. hole screen
(c) 3 in. square hole screen and
(d) 5 in. round hole screen.

During the winter months the 5 in. screen is replaced by a 6 in. rd. hole screen, and a 4 in. rd. hole screen is interposed between this and the 3 in. screen. Thus the various sizes that can be prepared at this mine are as follows:-

1. Lump: Plus 5 in. rd. in summer, and Plus 6 in. during winter.
2. Small lump: (a) 4-6 in. rd. (during winter)
   (b) 3 in.Sq. - 5 in. rd. (during summer).
3. Egg: 3 in. sq.-4 in.rd. (during winter)
4. Stove: 1-1/4 in. rd. - 3 in. sq. (all year)
5. Boiler Pea: 5/8 - 1-1/4 in. rd. (all year)
6. Slack: (a) Ordinary,- 0 - 5/8 in. rd. hole
   (b) Pea Slack,- 0 - 5/8 in. with some fines removed.

All the various sizes are collected in bins from which they are loaded into trucks.

When commercial shipments are to be made the coal is taken by truck to the C.P.R. siding 5 miles southeast of the mine, where a loading chute has been erected. However, most of the coal is used for the operation of the large central steam-driven electric power plant located in Princeton at the side of the Similkameen river, the electric power being transmitted to the mine at Copper Mountain and the concentrator at Allenby. Thus most of the coal is transported from the tipple by ten ton trucks and dumped into large coal bins situated on the north bank of the Similkameen river, 2 miles west of Princeton (4-1/2 miles southeast of the coal mine) where it is loaded into buckets and transported across the river by an aerial tramway to the large coal-bunkers at the central power plant.

In view of this, for the present at least, the Granby Consolidated are apparently not very interested in a commercial market, and although the above noted sizes can be prepared, most of them are remixed for the power plant. In addition, coal of various sizes is supplied to Allenby and Copper Mountain for the heating plants, bunkhouses, mess houses and for domestic use.

According to information received at the mine the production by sales for 1940 was as follows:-

Production by Sales Jan. 1 - Dec. 31, 1940

	Tons	%
Big & Small Lump	14,541	15.7
Egg, Stove & Boiler Pea	42,054	45.6
Slack and Pea	34,990	37.9
Sales to Employees & Commercial	695)	0.8
Domestic Sales	21)	
Total	92,301	100.0
Bone	2423	

Nicola Coal Area

1. Middlesboro Collieries Ltd.

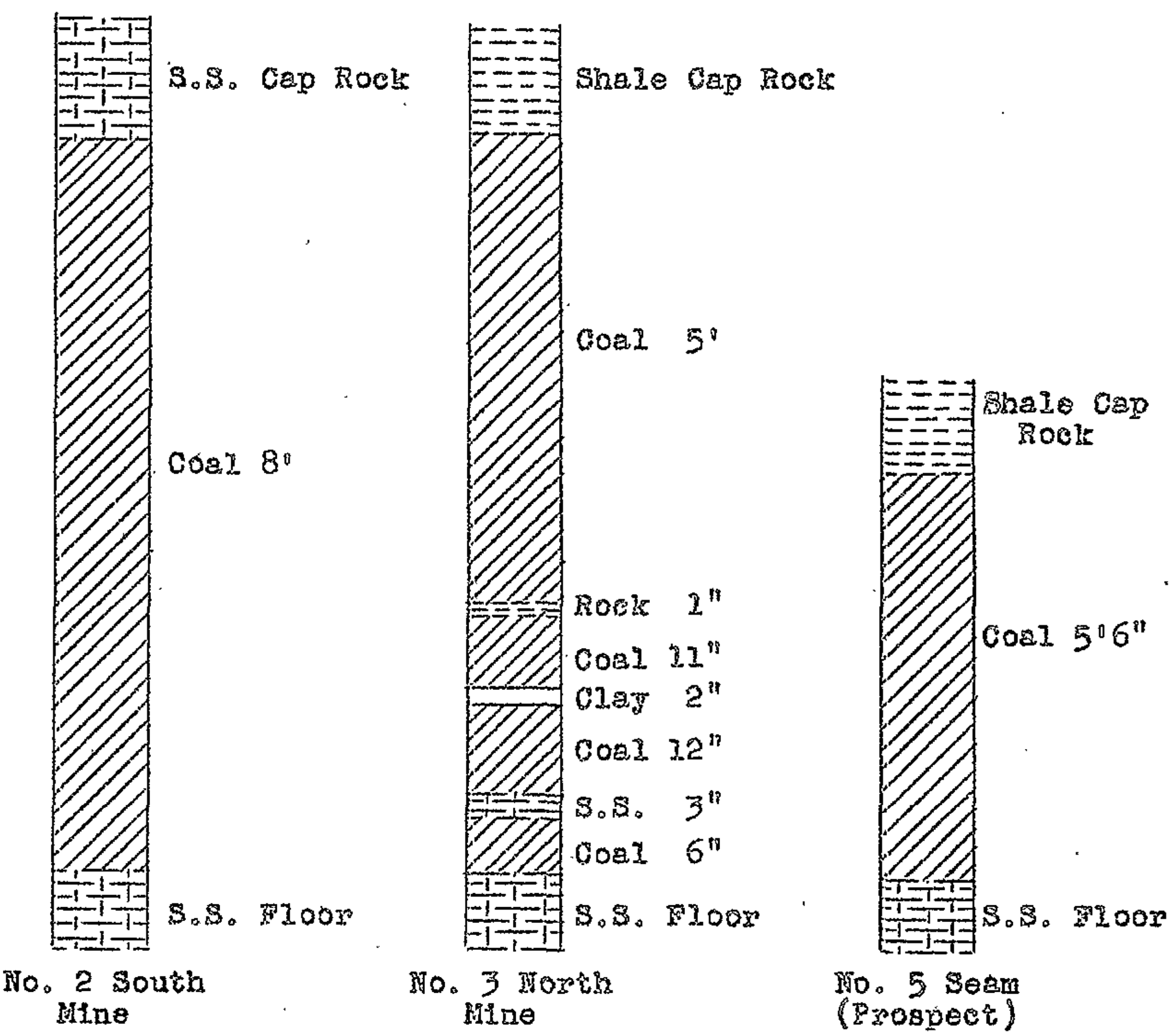
Mines	No. 2 South on No. 2 seam. No. 3 North on No. 3 seam.
Location	About 1 mile south of Merritt in the Nicola valley on a branch line from the Kettle Valley Railway (C.P.R.)
Mine Officials	R. Fairfoull, Manager
Output	Approximately 120 tons per day - 90 tons from No.2 mine and about 30 tons from No. 3 mine.

Details of Mine and Seam:

While the whole of the surface plant is situated in the valley at the foot of the hill south of Merritt, the underground workings are in the side of the hill at a higher elevation. The openings to the mines now in operation are reached by a surface inclined tramway 3000 feet long. The coal measures have a general pitch south-east towards the valley which forms the centre of the coal basin. The strata lie at a high angle of inclination with most of the coal seams coming to the surface on the side of the hill. There are several seams in the area, numbered progressively from the uppermost ones, and at present work is being done in No. 2 and No. 3 seams, while prospecting is being conducted in No. 5 seam. An average section of these seams is shown in the following sketch.

MIDDLESBORO COLLIERIES, LTD.
MERRITT, B.C.

Coal Sections In Mines And Prospect



The No. 2 South mine operating on No. 2 seam is the largest operation and has been developed (since 1928)by a main haulage-level driven from the surface for a distance of some 5000 feet The seam varies from 5 to 10 feet in thickness with an average of about 8 feet.

The No. 3 North mine operating on No. 3 seam is situated a short distance east of the entry of No. 2 mine and has been developed from the surface outcrop by a main slope that follows the inclination of the seam for a distance of 700 feet. The mine is small and the seam averages from 5 to 6 feet in thickness.

The coal in both seams is mined by the room and pillar method, with about 12 ft. rooms and 60 foot pillars. "Post-puncher" type compressed-air operated machines are used for undercutting and shearing; and owing to its pitch the coal is transported from the headings to the main levels by chutes, where it is loaded into 30 cwt. capacity mine cars. Haulage is both by horse and rope to surface, and similarly from mine portal to tipple.

The mines are relatively free from gas, and are ventilated without the aid of fans. The mines are fairly dry and free from excessive quantities of coal dust.

Tipple or Bankhead

The cars of coal after being brought down the 3000 foot tramway to the tipple are weighed and then emptied by means of an end dump tippler. The coal drops onto a short pan conveyor and is carried to a Marcus double-decked shaker screen. The top deck is fitted with 2-1/2 in. rd. hole screens, whereas the lower deck is equipped with 1-1/2 in. rd. hole screens, this latter being employed to lighten the load for the slack and improve the nut. The 0to2-1/2in. coal drops into a small bin and is conveyed by means of an inclined elevator to a rotary screen, 30 feet long, and 8 feet in diameter at the feed end. This screen is fitted as follows from feed to discharge end:-

(a) A round hole screen equivalent to approx. 1/2 in.
(b(A round hole screen, with holes varying from about 3/4 to 1 in.

This screening results in the production of

(1) 1 to 2-1/2 in. nut
(2) 1/2 - 1 in. pea, and
(3) 0 - 1/2 in. slack.

The pea size is rescreened on a stationary inclined chikken wire screen with about 1/2 in. openings.

The +2-1/2 in. lump is carried by a steel conveyor belt, used as a picking table, up an incline to an incline bar screen, with openings which may be varied from 1-1/2 to about 8 in. This results in the production of two sizes (a) Lump, usually over 8 in., and (b) 2-1/2 - 8 in. The latter size is usually remixed with all the smaller sizes retained on a 1/2 in. screen for the preparation of Railway coal.

The various sizes are stored in wooden bunkers from which they may be discharged to cars, or remixed by means of a conveyor belt running along the full length of the bunkers, an elevator being used to redistribute the sizes to other bins when desired.

A Stewart jig (Roberts & Sheaffer) is present but has not been used for several years because the washed coal was too wet, and during the winter was a constant source of difficulty on account of freezing. Washing apparently reduced the ash in the coal by only about 2 or 3%.

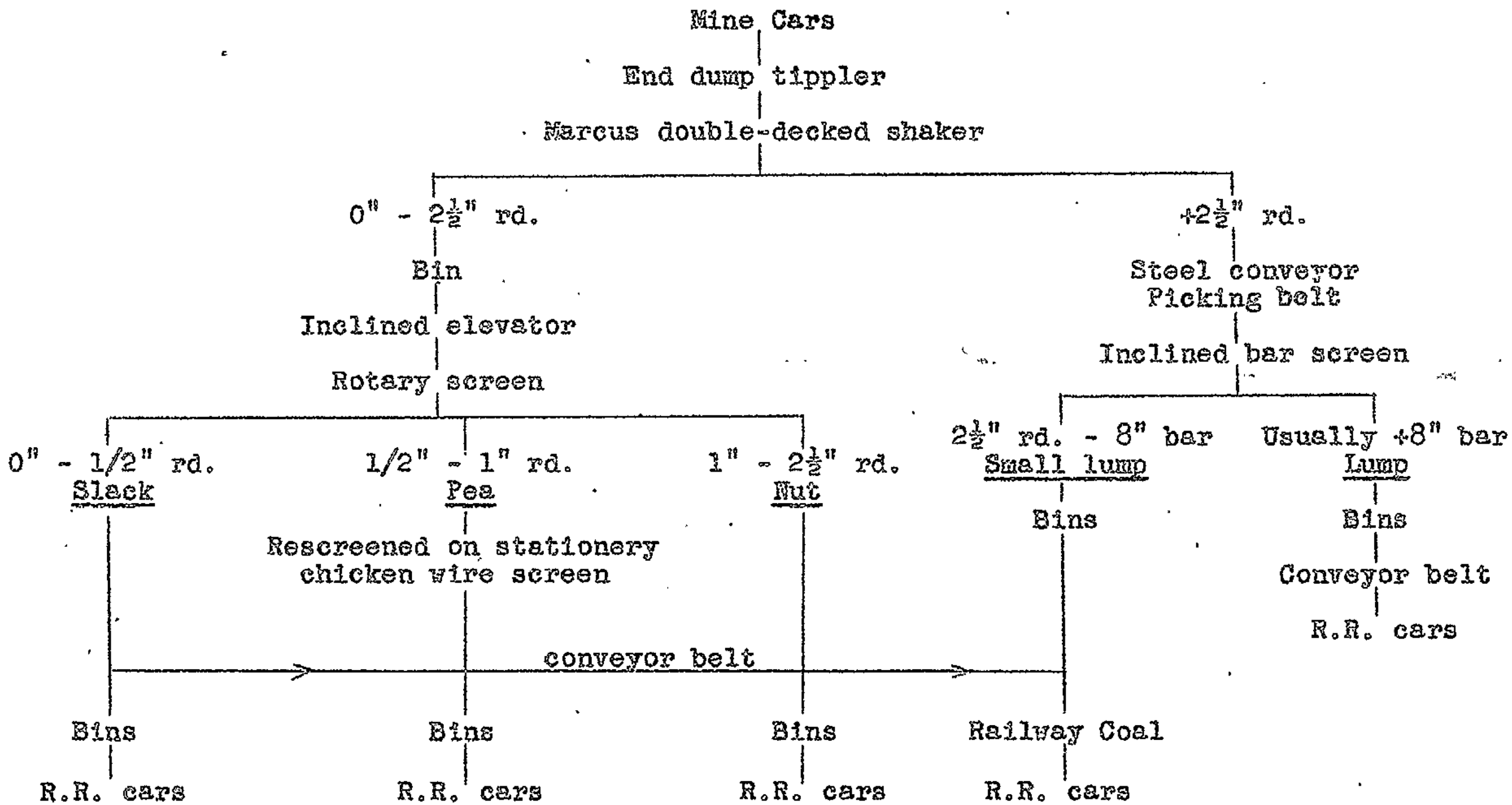


Fig. 4 -- PREPARATION AT MIDDLESBORO COLLIERIES LTD.

Thus the various sizes that may be produced at this mine are as follows:-

1. Lump: + 8 in. bar screen.
2. Small Lump: 2-1/2 in. - 8 in. bar.
3. Nut: 1 in. - 2-1/2 in. rd. hole.
4. Pea: 1/2 - 1 in. rd. hole.
5. Slack: 0 - 1/2 in. rd. hole.
6. Railway Coal: 1/2 in. rd. hole. - 8 in. bar.

A large proportion of the slack produced is used at the power plant near the tipple, which is equipped with hand fired shaker grate boilers. Power is supplied at 2200 volts to the city of Merritt who in turn distribute it throughout the district.

According to Dr. J.F. Walker, Deputy Minister of Mines, B.C., there is not much prospect for the Middlesboro collieries continuing for very long. They have practically lost the whole of their best market, the Kamloops district, to the Canadian Collieries (D) ltd.

In addition to the above areas the collieries in the Crowsnest district were also visited. The only coal mining operations active in this district were those of the Crows' Nest Pass Coal Company Ltd., at Coal Creek and Michel. At Coal Creek only the one mine, No. 1 East was in operation, although there is discussion of extending work to another seam. At Michel three seams are being worked, "A" seam, "B" seam and No. 3 seam. These mines are fully described in R.I.C.S. No. 111.(1938)

3.

The Domestic Distribution of Coals In British Columbia.

A. Vancouver Island Coals.

During 1940 of a total production of 1,867,846 tons of coal for the province of British Columbia, 821,051 tons, or 44.0% was from the Island collieries. Of this approximately 98.5% was produced by the Canadian Collieries (Dunsmuir) Ltd. at Nanaimo and Comox.

According to data obtained from this company, of the total production of 624,593 tons for the fiscal year ending June 30th, 1940, 523,751 tons was available for sales, whereas 100,842 tons or 16.1% was lost in washing. Of the tonnage available for sales, 104,425 tons or 19.9% was distributed in and around Vancouver to domestic consumers. The remaining 81.1% was sold direct to industrial consumers, to railways and for bunkering, and about 34,000 tons was exported to the United States.

An analysis of the sales based on an average annual sale of 650,000 tons indicates the following distribution.

	Tons	% of Total
Domestic	200,000	30.8
Offshore Bunkers	165,000	25.4
Coastwise Bunkers	35,000	5.4
Railways	45,000	6.9
Manufacturing	70,000	10.8
Gas Companies	75,000	11.5
Miscellaneous	60,000	9.2
	650,000	100.0

Distribution of Island and Other Coals in Vancouver

(a) ISLAND COALS

In and around Vancouver the Canadian Collieries (Dunsmuir) Ltd. distribute their domestic coal through seven distribution centres. These plants are operated by the coal company in cooperation with several coal dealers, the plants being established at the dealers' yards. These plants are as follows:-

Distribution Plant		Dealer	Location
No.1	- -----	Evans, Coleman & Evans Ltd.	Foot of Columbia St,
No.2	---------	Diethers Ltd	Granville Is.
No.3	---------	McCleery & Weston Ltd.	9242 Hudson Ave.
No.4	---------	ArrowKirk Coal Co. Ltd.	15 E. 1st Ave.
No.5	---------	Marpole Coal Co. Ltd.	1001 Main St.
No.6	---------	Gilley Bros. Ltd.	New Westminister
No.7	---------	Evans, Coleman & Evans Ltd.	North Vancouver

All the above coal yards are so situated that Island coal can be delivered to them direct by scow. The grades or sizes handled for domestic distribution are as follows:-

A. Wellington Coal
1. Lump (Large Lump and Egg)
2. No. 1 Nut
3. No. 2 Nut - Douglas (This size is called Douglas but is mixed with Wellington Seam coal)
4. Pea

B. Comox Coal
1. Lump
2. Cobble or Egg
3. No.1 Nut
4. No.2 Nut (Handled only at No. 6 plant for special industrial sales).
5. Pea (Only handled at Plants 1,2,5 and 6.)

No washed smalls as prepared at the mines are sold for domestic consumption. However, it should be noted that an appreciable quantity of fines are sold. These are the breakdown screenings from the lump coal as delivered.

The handling and preparation as conducted at the various distribution plants is as follows:-

Plant NO. 1

(a) Lump and Cobble or Egg - These sizes are unloaded by Clamshell and placed into chutes equipped with bar screens set at 1-1/2 inches. The oversize is hand-picked to make up Lump and Egg, without any definite screen limits. Usually this coal is rescreened on a stationary inclined 7/8 in. sq. mesh screen. The undersize from the 1-1/2 in. bar screen is re-screened on the 7/8 in. sq. mesh screen, resulting in an oversize which is mixed with the No. 1 Nut, and screenings. The 0 - 7/8 in. screenings are sold for stoker use. All the coal is kept under cover in shed.

(b) Nut and Pea - These are unloaded by clamshell and placed in bins. However, when insufficient space is available this coal is placed in a covered storage shed. The No.1 and No.2 Nut are rescreened on a 7/8 in. sq. mesh screen before sale, whereas the pea size is not rescreened. All the coal is bagged in 100 lb. lots for distribution.

Plant NO. 2

All the sizes delivered to this plant are placed in a covered storage shed. About half of it is unloaded from the scows by clamshell into truck which delivers it to the shed, and half is unloaded by wheelbarrow. The Lump, Cobble and Nut sizes are rescreened on a 7/8 in. sq. mesh screen and bagged in 100 lb. lots for distribution. The Pea is not rescreened and is stored in bins.

Plant NO. 3

At this plant the lump sizes are unloaded from scows by means of wheelbarrow and placed in covered storage sheds. The nut and pea sizes are moved by clamshell. The Comox nut and Nanaimo pea are placed in bins, whereas the Nanaimo nut is dumped on the ground for storage. The lump and nut sizes are rescreened on a 7/8 in sq. mesh stationary screen.

Plant NO. 4

All the coal at this distribution centre is discharged from the scows by wheelbarrow and placed in covered storage sheds. No bins are available for the smaller sizes. The Lump and nut sizes are rescreened on a 7/8 in. sq. mesh screen.

Plant NO. 5

All the lump and nut sizes are discharged by clamshell onto a 7/8 in. sq. mesh stationary screen. The lump may be either immediately separated into Lump and Egg and bagged, or may be placed in storage for subsequent preparation. The nut coal may also be treated as above. The pea coal does not go over the screens but is either placed into bins (two with 100 ton capacity), or onto the wharf for storage.

Plant NO. 6

At this plant the Lump coal is wheeled off the scows to covered storage sheds. The nut and pea are clammed off and stored in bunkers. The lump and nut are rescreened on a 7/8 in. sq. mesh inclined screen before bagging.

Plant NO. 7

This plant was not quite complete. All the coal will be handled by clam. The lump will be placed in covered storage sheds and then screened on a 7/8 in. Sq. Mesh prior to bagging. The Nut will be handled in the same manner. The pea coal will, in all probability, be placed in bins.

An analysis of the preparation and distribution of the Vancouver Island coals in Vancouver and environs is shown in tabular form in Table V.

The quantity of the various sizes distributed in Vancouver during the company's fiscal years of 1940 and '41 are shown below in Table VI.

Table V — Preparation & Distribution of Vancouver Island Coals in Vancouver.

Wellington (Nanaimo) Coal

Size Designation	Screen Limits as prepared at mine	Method of Transportation to Vancouver	Method of Unloading	Preparation at Distribution Plants in Vancouver	Screen Limits as delivered in Vancouver	Method of Delivery in Vancouver
Lump	+2-1/2" rd. hole	Scow	Clamshell &/or Wheelbarrow	Screened on 7/8" sq.mesh screen & separated into Large Lump & Egg by hand.	Lump=+6"(approx) Egg=7/8 sq.-6"(approx)	100 lb.bags
No. 1 Nut	1-1/2 to 2-1/2" rd.hole	"	"	Screened on 7/8"sq.mesh	7/8"sq. to 2-1/2" rd.	" " "
No.2Nut(Douglas)	7/8" to 1-1/2" rd. hole	"	"	" " " " "	7/8"sq. to 1-1/2" rd.	" " "
Pea	3/16"Tyrod - 7/8" rd.hole	"	"	Not rescreened	3/16"Tyrod -7/8" rd.	" " "
Screenings	———	———	———	Screenings from lump sizes	0 - 7/8 " sq.	Bags or Bulk
			Comox (Union Bay) Coal			
Lump	+ 6 in.	Scow	Clamshell & Wheelbarrow	Screened on 7/8" sq.mesh & separated into Large Lump & Egg.	Lump= +6" (approx.) Egg = 7/8"sq.-6"(approx)	100 lb.bags
Cobble or Egg	3" rd. - 6".	"	"	Screened on 7/8"sq.mesh	7/8"sq. - 6"	" " "
No. 1 Nut	1-1/2" to 3" rd.	"	"	" " " " "	7/8"sq. - 3" rd.	" " "
No. 2 Nut	7/8" to 1-1/2" rd.	"	"	" " " " "	7/8"sq. to 1-1/2"rd.	" " "
Pea	3/16"Tyrod - 7/8" rd.	"	"	Not rescreened	3/16"Tyrod - 7/8" rd.	" " "
Screenings	———	———	———	Screenings fron lump sizes	0 - 7/8" sq.	Bags or Bulk

Remarks:- No egg or cobble sizes available from the Island, in so far as wellington coal is concerned.

Table VI

Vancouver Distribution Plant Sales

Grade of Coal	Year Ended June 30th. 1940 Tons	1941 Tons
Nanaimo-Wellington		
Lump (Including Egg) --------	19,695	19,490
No. 1 Nut -------------------	7,631	9,128
No. 2 Nut (Nanaimo-Douglas) -	2,969	2,928
Pea ------- ----------------	42,990	45,165
Screenings -----------------	7,074	8,964
Comox		
Lump and Egg (Cobble) -------	5,322	5,628
No. 1 Nut -------------------	4,049	4,012
No. 2 Nut -------------------	1,642	1,573
Pea & Screenings -----------	6,456	7,537
Total - --------------------	97,828	104,425

The trend in the distribution of the various sizes during the last ten years is shown in Table VII and Figure 5. (Information supplied by the sales department of Canadian Collieries (D) Ltd. at Vancouver.

Table VII

Vancouver Distribution Plant Sales: 1932 - 1941
(Year ending June 30th)

Years	Lump		No.1&No.2 Nut		Pea		Screenings		Total
	Tons	%	Tons	%	Tons	%	Tons	%	Tons
1932	68,670	62.8	14,399	13.2	13,600	12.4	12,718	11.6	109,387
1933	55,188	54.7	14,187	14.1	20,528	20.3	11,002	10.9	100,905
1934	36,366	45.5	12,980	16.2	22,513	28.2	8,048	10.1	79,907
1935	45,348	45.5	18,519	18.6	26,532	26.4	9,510	9.5	99,729
1936	43,307	40.8	21,714	20.4	31,918	30.1	9,201	8.7	106,140
1937	39,110	38.1	21,164	20.6	30,446	29.6	12,154	11.7	102,874
1938	33,380	31.8	17,292	16.5	41,265	39.4	12,873	12.3	104,810
1939	29,772	30.3	15,030	15.3	40,132	40.8	13,166	13.6	98,100
1940	25,017	25.6	16,291	16.6	42,990	43.9	13,530	13.9	97,828
1941	25,119	24.0	17,626	16.9	50,394	48.3	11,286	10.8	104,425

It is of importance to note that as the proportion of lump coal sold decreased during the last ten years from 62.8% to 24.0% of the total coal marketed, the pea size increased from 12.4% to 48.3% of the total. This latter size of coal selling at $8.00 per ton, or a mixture of it with screenings and marketed as stoker pea at $7.50 per ton, is used mainly in stoker equipped furnaces. The increasing trend toward the use of such equipment in the Vancouver area has been due, to a large degree, to the increased competition of oil and sawdust for domestic heating. These latter two fuels have experienced a tremendous increase in popularity as domestic fuels because of their relative cleanliness, ease in handling, and because of the automatic to semi-automatic system of burning used for them.

In the case of sawdust low cost has been an important if not deciding factor insofar as its use is concerned. Whereas in 1931 there were only 1986 customers using 11,057,901 gals. of fuel oil for domestic and building heating in British Columbia, in 1939 there were 15,008 customers using 27,800,598 gals. of fuel oil. This fuel sold for 8 cents per gallon delivered to the customer. The increase in the use of specially prepared sawdust has been even more pronounced. From a very small and practically neglibible consumption in the late twenties, in 1938 there were some 20,000 residences in Vancouver using sawdust, and by the end of 1940, out of a total of 75,206 residences, apartment houses, churches, etc., over 37,900 were employing sawdust burners. It should be noted that about 10,000 of these had dual burners, i.e. one for the furnace and one for the kitchen range. Specially prepared sawdust for domestic consumption retails in Vancouver at approximately $3.00 per unit of 200 cu.ft.

A comparison of the value of the three competitive fuels can best be indicated by their cost per million B.T.U. A Nanaimo-Comox pea coal mixture with an average calorific value of 12,150 B.T.U./lb., and selling for $8.00 per ton yields 1000,000 B.T.U.at .32.9 cents; and based on an average efficiency of 55% the cost per effective million B.T.U. is 59.8 cents. Sawdust from Douglas Fir with 37% moisture as delivered, having a calorific value of 5800 B.T.U./lb., and weighing 3510 lbs. per unit of 200 cu.ft. sells for $3.00 per unit. The cost for such a fuel per million B.T.U. is 14.7 cents, and based on an average efficiency of 50%, the cost per effective million B.T.U. is 29.4 cents. Fuel Oil weighing about 9.33 lbs. per gallon, and having a calorific value of 19,000 B.T.U./lb. sells for 8 cents per gallon. At this price the cost per million B.T.U. is 45.13 cents, and based on an average efficiency of 70% the cost per effective million B.T.U. is 64.5 cents. It is obvious from the above that insofar as price is concerned there is little to choose between coal and oil, but due to such factors as cleanliness and ease of handling and operation oil replaced coal in a certain proportion of homes. However, sawdust is so much cheaper than either of the above, that on this basis alone it has become one of the most popular fuels in Vancouver.

The degredation of coal, especially of the larger lump sizes, is a very important factor in its economic distribution. The Canadian Collieries (D) Ltd. have made a rather extensive study of this physical property as it affects their coal during handling at Vancouver. The table below (Table VIII) presents information, obtained through the courtesy of Mr. E. Smart, assistant superintendent of the company, on the relative proportions of lump coal recovered for sales at their various distribution plants in Vancouver over a period of ten years. The table also shows the difference in relative degradation as between unloading the scows by crane and by wheelbarrow.

Table VIII

Degradation of Vancouver Island Lump Coal

Vancouver Distribution Plants Lump Yield
Percentage of Total Shipped.

Coal Handled by Wheel-barrow (underlined).

Years	Plant #1	Plant #2	Plant #3	Plant #4	Plant #5	Plant #6	Plant #7
			Nanaimo Coal				
1940	64.8	68.2	74.8	81.5	75.3	88.7	89.5
1939	72.1	71.6	75.3	79.7	80.2	92.5	88.1
1938	72.6	76.2	87.9	87.6	76.6	93.1	92.7
1937	74.0	80.6	77.7	81.0	80.3	91.6	91.1
1936	77.8	77.6	84.9	82.8	82.5	90.6	96.2
1935	79.4	82.6	86.9	87.6	84.0	91.7	97.0
1934	77.1	76.7	86.7	87.7	89.8	91.1	95.7
1933	76.3	80.6	82.2	87.5	92.7	94.4	95.9
1932	72.4	79.3	86.7	88.1	84.6	93.1	92.5
			Comox Coal				
1940	65.8	69.8	71.9	76.9	59.8	75.9	--
1939	62.9	59.0	69.0	76.3	56.7	72.4	--
1938	62.5	67.2	96.8	84.8	63.2	85.1	--
1937	71.8	82.8	77.6	74.2	63.9	78.4	--
1936	73.4	81.2	79.5	83.5	68.6	74.7	--
1935	74.0	79.4	89.9	82.3	72.3	73.6	--
1934	79.8	74.9	83.0	82.6	71.9	74.7	--
1933	73.6	72.8	89.0	62.0	78.4	79.8	--
1932	74.4	73.8	88.0	87.0	82.5	89.4	--

From the above table it is quite apparent that handling the coal by wheelbarrow results in much less degradation of the lump coal than by moving the coal with a clamshell. A rather interesting fact, but one that cannot be easily explained, is that at all their distribution plants and with both the Nanaimo and Comox coals, there has been a steady decrease, during the last ten years, in the quantity of lump reclaimed from shipments; and this seems to be the case irrespective of the method of unloading.

A further study of the degradation of the lump coal showing the size reduction was made and an analysis of this is given in Table IX.

Table IX

Sizes Resulting from Degradation of Island Lump Coal

	Handled by Wheelbarrow	Handled by Caane
	Nanaimo Coal	
Lump	86%	69%
Nut	3%	8%
Screenings	11%	23%
	Comox Coal	
Lump	77%	67%
Nut	6%	5%
Screenings	17%	28%

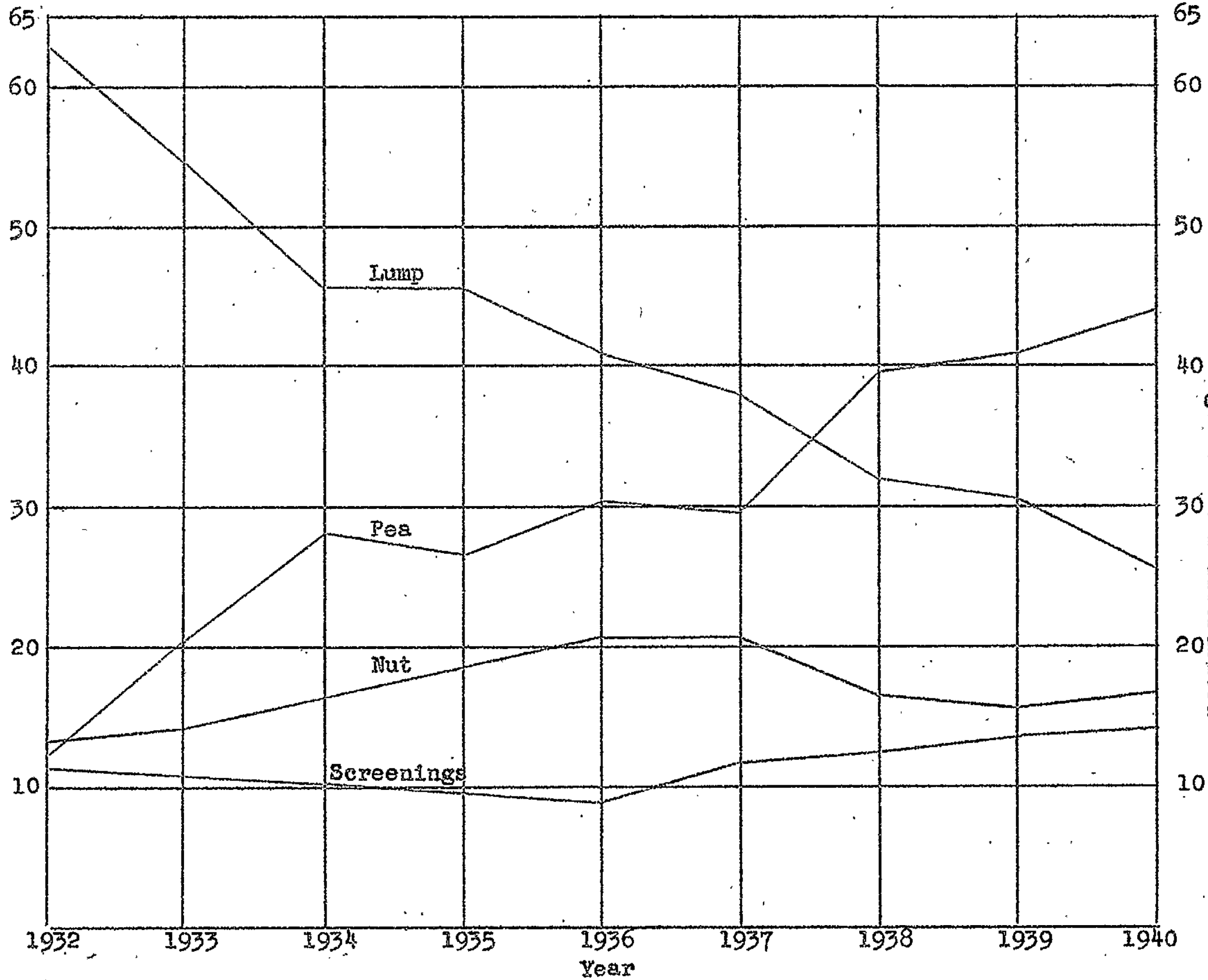


Fig. 5 -- VANCOUVER DISTRIBUTION PLANT SALES, 1932-1940

In the ordinary handling of coal it has been observed that degradation is due more to abrasion than to shattering, and this is borne out by the above data, which shows that the proportion of screenings (-7/8 in. sq. mesh coal) is far higher than the quantity of intermediate sizes produced during the handling.

(b) B.C. MAINLAND, ALBERTA & OTHER COALS.

Although the Vancouver market for coal is practically monopolized by Island coals a certain amount of B.C. mainland and Alberta coal is being sold. According to information obtained, the trend during the last few years has been towards a gradual decrease in the demand for these coals. Of the B.C. Mainland and Alberta coals finding a market in Vancouver, the non-caking bituminous and subbituminous coals of Alberta and B.C. are the most prevalent. The bituminous steam coals are marketed to a very limited extent, and come mainly from the B.C. Crowsnest area. However a small amount of coal from the Alberta Cascade area (Canmore), mostly in the form of briquettes, is also being sold. In addition a very small quantity of U.S. coal and briquettes are sold.

Although specific statistics for Vancouver were not available a resume of the statistics for British Columbia as a whole indicates that a relatively small quantity of Alberta coal is sold in Vancouver. According to the 1940 Annual Report of the British Columbia Minister of Mines "Alberta coal and fuel sold in British Columbia amounted to 311,232 tons. This consisted of 134,840tons of bituminous coal, 41,055 tons of subbituminous (non-caking bituminous), 61,747 tons of domestic coal (subbituminous) and 2885 tons of briquettes". It should be noted that most Alberta non-caking bituminous and subbituminous coals are marketed for domestic use in the eastern parts of British Columbia.

Below is given a list of most of the above mentioned coals found on the market in Vancouver for domestic consumption during the author's field visit in July 1941.

Origin of Coal: Province or Country	Area	Type of Coal	Trade Name of Coal	Sizes Marketed
B.C.	Princeton	Subbituminous	Granby Tulameen	Lump, Egg, Stove, Nut & Pea
	"	"	Tulameen Val.Prin.	Lump, Egg, Stove, Nut & Pea
	Telkwa	Bituminous	Aveling	Lump, Stoker, Blacksmith
	Crowsnest	Bituminous	Michel	Cobble & Stoker
Alberta	Drumheller	Subbituminous	Midland	Lump, Egg, Stove and Nut
	"	"	Monarch	Lump, Egg, Nut and Pea
	Coalspur	Non-caking Bitum's	Minehead	Lump, Egg, Nut.
	"	" "	McLeod River Hard	Lump, Egg, Nut
	"	" "	Foothills	Lump, Egg, Nut
	Cascade	Semi-Anthracite	Canmore	Briquettes
U. States	Washington	Gas Carbon	Casco Briquettes.(1)	
	Pennsylv'a	Anthracite	------	Stove, Nut.

(1) Casco briquettes, which are sold in Vancouver mainly for use in chick brooders, but are recommended for furnaces, fireplaces or heaters, are manufactured from Petroleum Carbon by the Portland Gas & Power Co. in Portland, Oregon, and by the Seattle Gas Company, at Seattle, Washington. The fuel is a by-product in the manufacture of gas from oil, where fuel oil is sprayed on checker brick heated to approximately 1800°F. The lampblack formed is filtered, dried and compressed into briquettes without the addition of binder. According to advertised information the chemical analysis of these briquettes, on the dried basis, is as follows:- Ash ----- 0.25%; Volatile Matter ----- 14.50%; Fixed Carbon ----- 85.25%; Calorific Value ----- 15,100 B.T.U./lb.

A large number of the fuel dealers in Vancouver handle Alberta and British Columbia Mainland coals, but most of it is apparently distributed through those dealers, mentioned above, who also handle the Island coals. The Alberta and Mainland coals are all brought in by rail and are usually sacked in 100 pound lots in the cars prior to storage under cover. In this case where lump is being handled screening out of the fines is not the usual practice. However in those cases where the coal is stored prior to sacking rescreening is usually part of the procedure. For example, at Plant No.4, (Arrow Kirk Coal Co. Ltd.) where the coals are placed in storage prior to bagging, the coal is regraded by hand into say Egg, Stove and Nut, and screened on a 7/8 in. sq. mesh screen The screenings are often mixed with coking coal screenings for stoker use.

The limiting screens for the various sizes marketed is indefinite, preparation being effected by hand insofar as lump sizes are concerned, and sizing being left mainly to the judgment of the laborers employed.

Due to degradation on handling during and subsequent to shipping the screen limits used in preparation at the mines serve only as a rough guide to the size of the coal as marketed.

In the case of the Monarch (Drumheller) coal, however, distributed by the City Coal Co. Ltd., 415 Terminal Ave., some attempt is made to define the screen limits of the sizes sold. This dealer, who apparently is the sole agent for Monarch coal in the district prepares the coal for the market as follows:-

1. Lump - The large lump is rescreened by hand and visually separated into <u>large lump</u> and <u>large egg.</u>

2. Egg - This is forked for removal of slack using a fork with tines about 1 in. apart. (About 1/4 to 1/2 ton of screenings results from a car of egg coal.) Tee coal as sold is roughly 1 - 5 in.

3. Nut & Pea - This comes from the mine as a nut pea mixture which is about 5/8 - 2 in. coal. This is first screened on a 7/8 in. rd. hole stationary screen making <u>7/8 - 2 in. nut.</u> The 0 -7/8" coal is rescreened on a stationary 1/2 in. sq. mesh screen resulting in <u>1/2 - 7/8 in. pea.</u> The balance is 0 -1/2 in. slack.

(c) DELIVERED PRICES OF COAL IN VANCOUVER.

According to information obtained from several leading coal dealers in Vancouver the prices of the various coals marketed in July, 1941 were as listed below:-

<u>Island Coals</u>

Nanaimo Wellington

Lump & Egg	$ 11.50	per ton.
No.1 Nut	$ 10.00	" "
No.2 Nut (Douglas)	$ 9.00	" "
Pea	$ 8.00	" "
Stoker Pea	$ 7.50	" "
Slack (Screenings)	$ 7.00	" "

Comox

Lump & Egg	$ 10.50	" "
Nut	$ 10.00	" "
Pea or Pea Slack	$ 8.00	" "
Slack (Screenings)	$ 7.00	" "

Mainland Coals

Tulameen Valley & Granby (Sometimes called Princeton Sootless)

Lump & Egg	$ 9.75	per ton
Nut	$ 8.50	" "
Pea	$ 6.50	" "

Telkwa (Aveling)

Lump	$12.50	" "
Blacksmith	$24.00	" "

(This is apparently a popular blacksmith coal at present and is marketed by the Arrow Kirk Coal Co. Ltd. under the trade name of Arrow Blacksmith Coal.)

Alberta Coals

McLeod River Hard (Coalspur Area, sold also under trade name of Jasper Hard)

Lump & Egg	$12.00	per ton
Stove	$11.25	" "
Nut	$10.50	" "
Pea	$ 8.50	" "
Slack	$ 7.50	" "

Minehead and Foothills (Coalspur Area)

Lump & Egg	$12.00	per ton
Nut	$10.50	" "

Midland (Drumheller Area)

Lump	$12.00	per ton
Stove	$11.00 - 11.25	per ton.

Monarch (Drumheller Area)

Large Lump	$12.00	per ton
Large Egg	$11.50	" "
Egg (As received)	$11.00	" "

All the above Alberta coals are often referred to as "Alberta Sootless".

Canmore (Cascade Area)

Lump	$11.50	per ton
Nut	$10.00	" "

This coal sometimes referred to as Anthracite in Vancouver is apparently not being advertised for the winter of 1941-42.

Briquettes

Canmore	$12.75	per ton
Gasco (Washington & Oregon, U.S.A.	$19.00	" "

Anthracite

Pennsylvania

Nut	$21.00	per ton

(very little marketed)

B. British Columbia Mainland

The coals of the British Columbia Mainland, according to the Bureau of Statistics reports, come from two districts known as Inland and Crow's Nest Pass. The Inland district includes the Princeton and Nicola areas in the south as well as the Telkwa area in the north, whereas the Crow's Nest Pass district is confined to the Crowsnest area in the East Kootenay district.

Of the 1,367,339 tons of British Columbia coal sold in 1940, 143,202 tons (10.5%) came from the Nicola (High Volatile Bituminous B.& C.) and Princeton (subbituminous) areas, 5,627 tons (0.4%) from the Telkwa area (High Volatile Bituminous) and 623,102 tons (45.6%) from the Crowsnest area (Medium Volatile Bituminous).

NICOLA-PRINCETON AREAS

Of the five operations in these two areas (producing subbituminous and High Volatile Bituminous B. & C. coals) operating in 1940, only four are left, the Coalmont Collieries Ltd. having closed down. Of the remaining four, the Hat Creek Colliery situated 34 miles north of Ashcroft is a very small operation producing only 344 tons of coal during the year under review.

In the Princeton area the Granby Consolidated Mining, Smelting and Power Co. Ltd. with sales of 81,792 tons, and the Princeton-Tulameen Coal Co. with sales of 21,540 tons during 1940, were the only operations. Reference to the description of the Granby Consolidated mine, given in Chapter 3 of this report, indicates that although this company is equipped to produce various sizes for the commercial market, ranging from Lump, Egg, Stove and Pea to Slack, most of their coal is mined for use in their associated power plants and metal mining and concentrating operations. The coal from the Princeton Tulameen Coal Co. is available wholly for commercial sales being prepared as Lump (+4-1/2 rd.); Egg (2-1/2 - 4-1/2 in.rd.); Nut (1"sq. - 2-1/2" rd.); Pea (5/8 - 1 in.sq.); and Slack (0-5/8in.sq.). Most of the coal from this mine is sold in the districts surrounding Princeton, a small amount finding its way into the Vancouver market. This coal is handled at the distribution centres in the same manner as Alberta subbituminous coals. They must be kept in a covered storage shed, and the lump sizes are either forked or passed over a stationary screen to eliminate the slack which has been produced during shipment and handling. As is the case with Alberta subbituminous coals the Princeton coals, especially the lump sizes, cannot be stored for any length of time, even under cover, without serious size degradation.

Coal from the Nicola area is mined by one company, the Middlesboro Collieries Ltd., selling in 1940 a total of 20,442 tons. The commercial market for this coal is practically negligible, the bulk of the output being taken by the railway, and the power plant at Merritt. At one time an appreciable amount of the coal was sold for domestic purposes in the Kamloops and neighboring districts, a small amount finding its way as far as Vancouver. Today, however, Island coal and sawdust have apparently replaced Middlesboro coal, and the prospects for regaining the market, according to information received, are not very good.

TELKWA AREA

In this small area situated on the Prince Rupert branch of the Canadian National Railways there are two small operations, the Bulkley Valley Collieries and the Aveling Coal Co. Ltd. Of the total 5,627 tons of coal sold during 1940, only 324 tons came from the Aveling Coal Co. Ltd.

The Bulkley Valley mine is situated on Goat Creek, a tributary of the Telkwa river, about 7 miles from Telkwa, to which point the coal is hauled by truck. The market for the coal from this mine is mainly domestic and is confined, due to transportation costs, to the small area beteeen Prince Rupert and McBride.

The Aveling Coal Co. Ltd. operate a mine about 6.5 miles from Telkwa, on what is locally known as the "Betty" seam. This coal seam which has a total thickness of about 15 feet 6 inches, has a top section of about 3'4" that is claimed to be very high grade and seems to make an excellent blacksmith coal. This is mined separately and sold as blacksmith coal, several carloads having been distributed in Vancouver during the last year and a half. The other parts of the seam are mined for domestic sales which are restricted to a small local area.

CROWSNEST AREA

In this district there is one company, the Crow's Nest Pass Coal Co. Ltd., operating two mines, one at Coal Creek and the other at Michel. Of the total 623,102 tons of coal sold during 1940, 120,585 tons was from Coal Creek, and the other 502,517 tons came from the Michel colliery. Information received from the company indicates the following combined production for the year 1940 for the various main sizes prepared:

	Tons	% of Total
Lump	12,756	1.5
Mine Run	436,263	53.6
Slack	327,835	40.3
Blacksmith	1,387	0.3
Stoker	35,369	4.3
	813,610	100.0

At the Coal Creek colliery only two sizes are prepared, +1/2 in. rd.hole lump, which is sold as run-of-mine to the railway, and 0 -1/2 in. slack, which is sold for industrial use. When nut or pea or larger slack is required, the railway coal will be +1" or +1-1/2 in lump. This does not occur very often.

At the Michel colliery coal is obtained from three seams, namely "A", "B" and No. 3, each having different characteristics both physical and chemical, which necessitates a certain amount of segregation for the production of fuels suitable for varying purposes. The proportional production from the three seams is as indicated below by the production figures for February - July 1941 inclusive.

	Tons Raw Coal	%
No. 3 Seam	47,083	10.1
A Seam	255,208	55.0
B Seam	162,138	34.9
	464,429	100.0

The sizes produced at the Michel Colliery are as follows:-

1. Lump: +7 in. Lip screen --------- "A","B" & No.3 seams.
2. Cobble: 1-5/8sq. - 7 in. Lip ----- "A","B" & No.3 seams.
3. Stoker: 3/16 Tyrod to 1-5/8 sq. --- " " " "
4. Slack: 0 to 1-5/8 in. sq. --------- " " " "
5. Fines: 0 - 3/16 in. Tyrod -------- " " " "
6. Mine Run: (slack screened out) ---- " " " "
   Mainly Railway Coal.

According to information received at the mine the distribution of Michel coal for commercial sales was approximately as follows during 1940.

7 in. Lump - About 10 cars per year, all the seamsmixed, were sold East and West of Fernie, the largest portion being distributed in Regina, Saskatchewan.

Cobble - (a) The B.C. shipments (west of Michel) amounted to about 80 cars, this being about 50% of the total domestic shipments of this size. It consisted mainly of No. 3 seam coal, with a small proportion of A and B seams. (b) The Eastern shipments, going as far as Timmins, Ontario, accounted for the other 50% of the domestic cobble sold. For the Winnipeg market mainly B seam cobble is prepared, whereas for Ontario all the seams were mixed.

Stoker - (a) The B.C. shipments amounted to about 40 cars. To Vancouver about 10 cars of B seam stoker was shipped, whereas throughout the rest of the Province about 30 cars of mixed No. 3 and A seam was distributed. (b) Eastern shipments are more extensive and amounted to about 460 cars during 1940. This was distributed approximately as follows:- 10 cars "A" seam stoker to Regina; 6 or 7 cars No. 3 seam stoker to Regina and Moosejaw; 40 cars of "B" seam stoker to the Brandon Gas plant; 30 cars (about 1 car per week during the heating season) of "B" seam to Eaton's at Winnipeg; 280 cars (about 10 cars per week during the heating season) of "B" and "A" seam mixed, with "B" predominating for the general Winnipeg market; and about 90 cars of "B" and "A" seams mixed to Selkirk, Manitoba (Manitoba Rolling Mills). (c) About 500 tons per year of No. 3 seam mixed with some "A" seam is exported to United States.

Slack - (a) West of Michel about 20 cars of "A" and No.3 seams mixed, with No. 3 predominating are shipped. (b) Eastern shipments - Manitoba and Ontario apparently are the big industrial markets for Michel slack. During 1940 the bulk of this size shipped to Manitoba was distributed as follows:- Selkirk, Man. (Manitoba Rolling Mills), about 90 cars of "B" and "A" seams mixed; Winnipeg General Hospital - about 85 cars (3 cars per week during heating season) of "A" seam coal; Winnipeg schools - about 115 cars (4 cars per week during heating season) of "B" seam; Deer Lodge Hospital - about 16 cars (800 tons) of No. 3 seam slack; Defence Industries Ltd., Winnipeg - about 4 cars per day (200 tons) of "A" seam coal mixed with some No. 3. In Ontario the major portion of the slack was distributed as follows:- Kenora Paper Mills - about 312 cars per year of No. 3 and "A" seams mixed; Fort Frances Paper Mills - about 624 cars per year of No. 3 and "A" seams mixed; and the Dryden Paper Co. - about 104 cars per year of "B" seam slack.
(c) A certain amount of slack was exported to United States. At the Spokane, Wash., coal yards about 600 tons per annum of No. 3 and "A" seams mixed are distributed. The Spokane Portland Cement Co. takes about 208 cars per year of No. 3 and "A" seams mixed; and the Northwest Magnesite Co. (Washington) handles about 900 tons per week about 935 cars per year of No. 3 and "A" seams mixed.

Fines - (a) In the West in British Columbia the Sentinel Power Plant buys about 1000 tons per year of fines from the "A" seam. (b) In the East, the Winnipeg Electric Co. takes about 6000 tons per year of "B" seam fines. (c) Exports to the United States include about 500 tons per year of No. 3 fines distributed in Spokane.

An indication as to the ash content of the various sizes produced from the three different seams mined at Michel is given in the table below. The data were taken from company records and represent the average, maximum and minimum ash contents of the different sizes for two months during 1941.

	March 1941			June 1941		
		Ash %			Ash %	
	Average	Maximum	Minimum	Average	Maximum	Minimum
			B Seam			
Cobble (1-5/8 - 7 in.)	5.8	7.2	4.4	5.2	7.0	4.4
Stoker (1/8 - 1-5/8 in.)	5.3	6.3	5.0	5.4	6.3	5.1
Fines (0 - 1/8 in.)	7.1	8.0	6.2	7.0	8.0	6.2
Slack (0 - 1-5/8 in.)	6.5	-	-	7.0	-	-
			A Seam			
Cobble	8.8	12.9	6.1	9.3	11.3	8.3
Stoker	9.0	12.7	6.9	8.6	9.5	7.3
Fines	9.5	11.2	7.2	10.0	11.8	8.0
Slack	8.9	11.8	7.1	9.4	11.8	7.5
			No. 3 Seam			
Cobble	9.6	10.9	8.5	9.0	11.4	7.2
Stoker	9.8	10.5	8.9	9.8	10.9	8.7
Fines	8.8	9.2	7.9	9.4	10.5	8.2
Slack	10.0	10.8	9.4	9.8	10.2	9.5

Part II

THE PREPARATION AND DISTRIBUTION OF COALS FROM ALBERTA AND CROWSNEST, B. C. WITH SPECIAL REFERENCE TO THE WINNIPEG DOMESTIC MARKET

1. Introduction

The following section of this report is a record of the information and data obtained in the field during the month of August, 1941, at which time coal samples were collected at various mines and centres of distribution in the Provinces of Alberta and Manitoba.

The main purpose of this work was to continue the survey of commercial coals as prepared at the mines and as delivered to the consumer. The mining areas visited in Alberta included both bituminous and subbituminous coal districts in the Crowsnest, Cascade and Lethbridge areas. The survey of coal as delivered for distribution to the consumer was carried on in Winnipeg, Manitoba, which is the main outlet, especially for domestic use, of all these coals. In this connection it should be noted that the B.C. Crowsnest mines, whose coals are distributed in the Prairie Provinces, was also visited, a complete report on these operations appearing in Part I of this report.

With regard to the collection of the coal samples in Alberta arrangements were made by the Fuel Research Laboratories, with the Canadian Pacific Railway Company for the free shipment of the samples to Ottawa. The collection of delivered coal samples in Winnipeg was facilitated by a similar arrangement with the Fuel Department of the Canadian National Railways. Special acknowledgment is due to Mr. T. Marshal, resident officer in Winnipeg of The Wartime Prices and Trade Board who, due to his intimate knowledge of the Winnipeg coal trade, was able to simplify and expedite carrying on the survey.

The author spent about two weeks in the Province of Alberta, during which time twelve (12) mining operations were visited. Fifty-eight (58) samples of commercial coal were collected at these mines as listed below. During the two weeks spent in Winnipeg twenty-three coal dealers, both wholesale and retail, were visited, and 107 samples of commercial coal were collected as listed below.

The mining properties and distribution centres visited and the samples taken are as follows:-

A. Province of Alberta Mining Operations.

Crowsnest Area

1. International Coal & Coke Co. Ltd., Coleman, Alta.
   One (1) commerfial sample.

2. McGillivray Creek Coal & Coke Co.,Ltd., Coleman, Alta.
   Six (6) commercial samples.

3. West Canadian Collieries Ltd. - Greenhill mine, Blairmore, Alta.
   Six (6) commercial samples.

4. West Canadian Collieries Ltd. - Bellevue mine, Bellevue, Alta.
   Four (4) commercial samples.

5. Hillcrest-Mohawk Collieries Ltd., Bellevue, Alta.
   Eleven (11) commercial samples.

Lethbridge Area

6. Lethbridge Collieries Ltd. - Galt mine, Lethbridge, Alta.
Five (5) commercial samples.

7. Lethbridge Collieries Ltd. - Cadillac mine, Shaughnessy, Alta.
Five (5) commercial samples.

8. J.C. Chester - Royal (Chester) mine - Lethbridge, Alta.
Four (4) commercial samples.

9. Lethbridge Co-operative Mines Association Ltd. - Parkoal mine
Five (5) commercial samples. Lethbridge, Alta.

10. Lund, Nelson, et al, Royalview mine , Lethbridge, Alta.
Five (5) commercial samples.

Cascade Area

11. Canmore Mines Ltd., Canmore, Alta.
Six (6) commercial samples.

Highwood Area

12. Flat Creek Coals Ltd., 40 miles west of High River, Alta.
Arrangements made for collection of P.& C. Survey sample in new seam.

B. Winnipeg, Manitoba

The Canadian coals collected in Winnipeg may be divided up into seven groups as follows:-

1.	Saskatchewan Lignites -	19	commercial samples
2.	Drumheller, Edmonton and Lethbridge coals -	15	commercial samples
3.	Coalspur and Saunder Creek Areas -	20	" "
4.	Alberta & B.C. Crowsnest Pass Coals -	14	" "
5.	Mountain Park & Nordegg Area Coals -	13	" "
6.	Cascade Area Coals -	4	" "
7.	Briquettes -	6	samples

In addition American coals and coke as well as British coal was sampled as shown below:-

8.	American Coals	9	samples
9.	British Coal	1	"
10.	American Coke	3	"

2

Preparation of Commercial Coal Grades at the Mines.

A series of reports* issued during the last three years cover the details with respect to mining and preparation for a large number of collieries operating in the various coal mining districts of Alberta. For the purpose of this report a summary of the sizes prepared at the mines visited and other relavent data collected this year is given below.

* R.I.C.S. #152
R.I.C.S. #126

Crowsnest Area, Alta.

1. International Coal & Coke Co. Ltd., Coleman, Alta.
Denison Mine; No.2 and No.4 Seams.

Sizes that could be prepared in 1940
- (a) Mine Run (Railway Coal)
- (b) House Coal lump; 1-1/4 to 6 in. sq.
- (c) Stoker: 1/4 to 1-1/4 in. sq.
- (d) Slack: 0 to 1-1/4 in. sq.
- (e) Stove & Egg: 2-6 in.

It should be noted that at present (1941) practically no commercial coal was being prepared, the output of the mine being limited to Railway coal, and slack for their beehives. The preparation plant was completely disorganized and there was no indication as to how long it would be before commercial grades could be prepared. During 1940 the production from the International Mine was as follows:-

No. 2 Seam -------------- 309,400 tons
No. 4 Seam -------------- 71,900 tons

The production was about 1550 tons per day, but if staff were available, it was intimated that this could be stepped up to 1700 tons per day. The distribution of their coal during the last year was as follows:-

Shipments
Mine Run --- ------------ 243,000 tons
Slack(0-1/4 in.) -------- 27,900 tons

Used in Coke Ovens
Slack(0-1/4 in.) ------- 105,900 tons. (It should be noted that in order to improve the coke a certain amount of the larger cleaner sizes of coal were crushed to produce coking slack.)

2. McGillivray Creek Coal & Coke Co. Ltd., Coleman, Alta.
Carbondale Mine; No. 2 and No. 4 Seams

At this mine the following commercial sizes are being produced:
- (a) Mine Run
- (b) Screened Lump or "Coarse Coal":- +1-3/4 in.sq.hole screen.
- (c) Stoker: 1/2" rd to 1-3/4 sq. hole.
- (d) 1-3/4 in. Slack: 0 to 1-3/4 in. sq.
- (3) 1/2 in. Slack: 0 to 1/2 in. sq.

The production during 1940 was as follows:-

No. 2 Seam ------------ - 310,900 tons
No. 4 Seam -------------- 1700 tons

that is, about 1300 tons total per day. The distribution of the coal from this mine by size, for 1940, was as follows:-

	Commercial	Railway
Run of Mine	6,708 tons	239,675 tons
Lump (Coarse Coal)	265 "	----
Stoker (Nut Pea)	2,032 "	----
Slack	44,606 "	27,534 "
	53,611 tons	267,209 tons

3 West Canadian Collieries Ltd., Blairmore, Alta.
Greenhill Mine: No. 1 and No. 4 Seams

The sizes normally prepared for the commercial market are as follows:-

(a) Mine Run (Mainly Railway Coal)

(b) Washed Furnace:- 2-5 in. rd. This is prepared from the +1-1/4 in.(sq.) coal, the large lump of which has been reduced in a crusher set at 4 in. by washing in a Vissac Jig and rescreening over a 2 in. rd. hole screen. The undersize goes to smaller sizes except the Wescan stoker.

(c) Ordinary Stoker (Nut-pea or screened steam):- 1/4 to 1-5/8 in. sq. hole screen. When requested a 1/4 to 1-1/4 in. stoker size is produced by crushing the 1/4 to 1-5/8 in. coal and screening out the 0-1/4 fines thus produced. This ordinary or regular stoker coal contains about 11% ash.

(d) Wescan Stoker:- 1/4 to 1-1/4 in. sq. hole screen. This is a specially prepared coal washed in a float-and-sink washer to about 7% ash. This coal has been on the market since November 1940, especially in Northern Ontario. During the summer it is prepared by rewashing the middlings from the tables, but during the heating season it is prepared mainly from the raw coal.

(e) Blacksmith Coal:- 0-1/2 in. This is prepared from the 1/4 to 1-1/4 in. Wescan stoker by washing down to 5% ash and crushing to pass 1/2 in., no fines being removed. An average analysis of this coal obtained from Mr. W. Bird, the Agent in Winnipeg, is as follows:-

Moisture ----------------	1.0%
Volatile Matter ----------	23.5%
Fixed Carbon -------------	70.5%
Ash ----------------------	5.0%
Sulphur ------------------	0.5%
Calorific Value ----------	14,556 B.T.U./lb.
F.P.A. ------------------	3000°F.
Caking ------------------	Good Coking

(f) Steam Slack:- 0 to 1-5/8 in. sq.mesh screen.

(g) 1/4 in. Slack:- 0-1/4 in. sq.mesh screen.

The total shipments from the Greenhill mine during 1940 amounted to 342,297 tons, of which 201,125 tons was commercial coal as follows:-

Washed Furnace --------------------	18,847	tons
Stoker (Nut-Pea) & Wescan ---------	50,588	"
Steam Slack -----------------------	44,000	"
1/4 in. Slack ---------------------	87,690	"

The remainder of the shipments was Mine run to the Railway. During 1941 the output of the Greenhill mine was increased to about 2100 tons per day, the bulk of coal coming from No.1 seam. (Approx. 40 tons per day from #4 seam).

4. West Canadian Collieries Ltd., Blairmore, Alta.
Bellevue Mine No. 1 Seam

The grades of coal normally prepared for shipment during 1941 were as follows:-

(a) Lump: Over 6 in. rd. hole
(b) Washed Furnace: 2-6 in. rd. hole
(c) Steam Slack: 0 to 1-5/8 in. sq.
(d) Slack: 0 to 1/4 in. sq.
(e) Mine Run.

During 1940 311,029 tons of coal were shipped from this mine. Out of this 36,120 tons was for commercial distribution, the bulk of the coal being Mine run and Slack for the railway. The commercial shipments were as follows:-

Lump ----------------	570 tons
Washed Furnace -------	438 "
Steam Slack ----------	28,202 "
Slack (0-1/4in.) ------	6,910 "

During 1941 the production was increased mainly due to increased railway demand, and in July the average was about 1810 tons per day.

5. Hillcrest-Mohawk Collieries Ltd., Bellevue, Alta.
Mohawk (Maple Leaf) Mine No. 2 Seam

The various sizes of coal prepared at this mine are as shown below:-

(a) Screened Lump: +1-1/4 in.rd. hole
(b) Furnace Lump: 1. +1-5/8 in. rd.
2. 1-5/8 to 4 in.rd. (also called stove).
(c) Nut: 1 to 1-5/8 in. rd.
(d) Pea: 1/4 to 1-5/8 in. rd.
(e) Stoker: 1/4 to 1 in. rd.
(f) Mine Run
(g) Slack: 1. Nut Slack:- 0 - 2 in.
2. Steam Slack:- 0 to 1-5/8 or 1 in.
3. 1/4 in. Slack:- 0 to 1/4 in.
(h) Buckwheat: 1/8 - 1 in.

During the year April 1st 1940 to March 31st 1941, the following was the production at this mine by size.

	Tons	%
Mine Run -----------	156,375	82.1
Nut Slack -----------	20,928	11.0
Steam Slack ----------	313	0.2
1/4 in.Slack --------	5,068	2.7
Stoker --------------	605	0.3
Pea ----------------	198	0.1
Nut ----------------	797	0.4
Buckwheat -----------	5,584	2.9
Lump (Screened Furnace & Stove) -----	495	0.3
	190,363	100.0

From the above it is obvious that the bulk of the coal mined, i.e. 96% of it, was shipped as Mine run and Slack, the major portion of it going to the railway. Thus, at present, only a relatively small tonnage is available for commercial distribution.

Cascade Area, Alta.

1. The Canmore Mines Ltd., Canmore, Alta.
New Mine (No.4 Seam)   Old Mine (Morris Seam)

The various grades of coal produced at this mine during 1941 are as follows:-

(a) Lump: +2-3/8 rd. hole.
(b) Stove: 1-1/2 to 2-3/8 rd. hole.
(c) Stoker: 1/4 sq. to 1-1/2in. rd. (also referred to as blower size and Pea.)
(d) Slack: 0 to 1/4 in. sq.
(e) Commercial Mine Run: +1/4 in.sq. -- all #4 Seam.
(f) Railway Mine Run: +1/4 in.sq., sometimes mixed with very little Slack. However at times approximately one-half of the 0-1/4 in. Slack normally produced (about 17% of the coal) is introduced in the form of special briquettes made with about 3 to 3-1/2% of petroleum asphalt binder.

In addition to the above, Commercial briquettes are prepared from the 0-1/4 in. slack using about 6-1/2 to 7% petroleum asphalt binder.

The above coal sizes, with the exception of the slack and railway coal, are usually dustproofed using the Viking hot oil treatment. The lump is treated with about 1/2 gallon of oil per ton; the stove coal with 3/4 gallon per ton; the stoker with 1 gallon per ton, and the Commercial Mine Run with 1/2 gallon per ton.

According to information received most of the commercial coal comes from No. 4 seam and is trade named "Nuseam". During the first two hours of operation at the mine, i.e. till 10 A.M., only No. 4 seam coal comes through the tipple and an attempt is made to prepare all the commercial coal during this period. However, it should be noted that, for example, when it is necessary to prepare stoker coal after 10 A.M. it consists of No. 2 seam as well as No. 4 seam coal; but they are not mixed or blended in the true sense. The coal from each seam goes over the tipple at different times and a car of stoker or any other size will, after 10 A.M., be partially No. 4 and partially No.2, and there is no attempt made to govern the amount of each. During the last few months the relative output of the two seams was as follows:-

No. 4 seam ---------- approx. 900 tons per day,
No. 2 seam ----------   "   300 tons per day.

The distribution of the various sizes perpared is indicated by the following typical screen analyses of the coal going over the tipple and as tested by the company.

	Lump %	Stove %	Stoker %	Slack (0-1/4) %
May 1940	15.4	57.5		27.1
Dec. 1940	15.0	15.5	32.5	37.0
April 1941	18.0	15.5	31.5	35.0

The No. 4 seam is being mined by handpick in addition to short and long wall which are machine mined. The longwall is about 180 ft. long and is equipped with a pan conveyor, whereas the shortwall is 30 ft. long and equipped with a Duckbill loader. This latter method is preferred and it is the intention of the company to extend the shortwall system.

The company has been considering the advisability of introducing a washery especially for the stove size which is dirtier than the other sizes due to the presence of a 1-1/2 in. band of rock in the #4 seam.

Lethbridge Area, Alta.

1. Lethbridge Collieries Ltd., Lethbridge, Alta.
Galt No. 8 Mine   Galt Seam

The various sizes produced at this mine are as follows:-

(a) Lump: +4 in. rd. hole (Handpicked)
(b) Cobble: 4-8 in. rd. hole (Handpicked)
(c) Stove: 1-1/8 to 4 in. rd. hole (Spiral cleaners)
(d) Stoker: 5/8(slot) to 1-1/8 in. rd. hole (Spiral cleaners)
(e) Pea Slack: 0 to 1-1/8 in. rd. hole (Partially spiral cleaned)
(f) Slack: 0-5/8(slot) in. (not cleaned)

Certain changes in the cleaning equipment are to be introduced in the near future. The spiral cleaners will be supplemented with air cleaning tables. According to Mr. B. Coon, General Manager, Mr. G. Vissac has been called upon to design an air cleaning plant for their stove and stoker sizes. Apparently the plan is to install two American Coal Cleaning tables to take a refuse relatively high in clean coal from the spiralizers and reclean it.

2. Lethbridge Collieries Ltd., Shaughnessy, Alta.
Cadillac Mine   Galt Seam.

At this mine the following commercial sizes of coal are produced.

(a) Lump: +4 in. rd. hole. (Handpicked) and some +8 in.
(b) Cobble: 4-8 in. (approx.) (Handpicked)
(c) Stove: 2-4 in. rd. hole or 2-5 in. (Mechanically picked)
(d) Stoker or Pea: 5/8 to 2 in. rd. hole (Spiral cleaned)
(e) Slack: 0 to 5/8 in. or 0-1 in. or 0-2 in. (Uncleaned)
(f) Single Screened Lump: +3/4 in. rd. hole (Handpicked)

The production of the various sizes at this mine during 1940 was as follows:-

	Tons	%
Lump: (a) + 4 in.	24,137	35.5
(b) + 8 in.	1,305	1.9
Single Screened Lump:	5,593	8.2
Cobble:	6,498	9.5
Stove:	9,820	14.4
Pea (Stoker)	3,830	5.6
Slack:	12,594	18.5
Bone:*	4,230	6.4
	68,007	100.0

With a view to decreasing the breakdown of the coal at this mine, the loader for the lump and cobble was altered. The scraper conveyor used in the past tended to scrape particles of coal off the lumps, producing from 1-1/4 to 3 tons of slack per car loaded. To overcome this the scraper was replaced by a belt conveyor with satisfactory results.

* Bone coal with about 18% ash is obtained irregularly from a section in the centre of the seam about 4-5 in. thick; also from bottom of seam. Sold locally at $2.00 per ton.

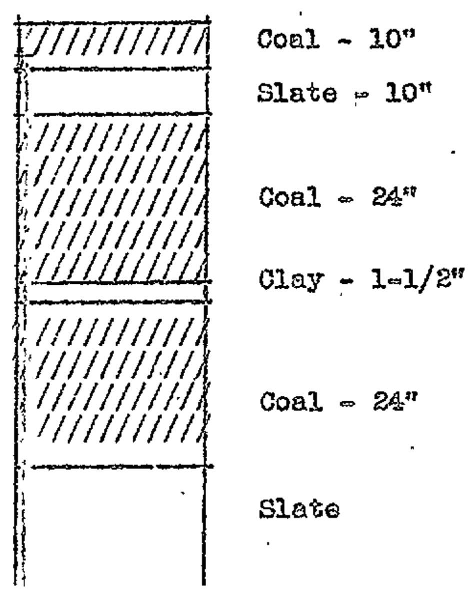
The following three small mines which were visited during this field investigation are described in greater detail as there is no other record of them in our files.

3. J. C. Chester

Mine: ------------------ Chester   Trade Name of Coal: -- Royal
Seam: ------------------ Galt
Location: -------------- About 4-1/2 miles North of Lethbridge in Township 9, Range 21, West of the 4th. meridian.
Mine Officials: -------- J.C. Chester, Proprietor.
Output: - -------------- About 125 tons per day (8 hr. shift).

Details of Mine and Seam:

This mine was started in 1925, and has been operated by Mr. Chester since 1937. The mine is entered by a rock slope at 30°, which runs for a distance of 257 feet to the coal seam. The mine entry is in the coulee from which an incline, 1100 feet long at 12° to 20° is constructed to the prairie level where the tipple is situated. The seam is about four (4) feet in thickness and the average section of the seam is as shown below:



In mining, the top 10 inches of coal with the indicated 10 inches of slate is left in the roof.

From the bottom of the rock slope there is a main haulage entry running in a Northwest direction for a distance of 500 feet. From this are struck off the "butt" entries which are about 300-350 feet in length. The coal is worked by the room and pillar system with 24 foot rooms and 9 to 10 foot pillars at 35 foot centres. All the coal is machine mined using a Sullivan undercutter.

Haulage throughout the mine is by horse. The one ton capacity cars are brought to the prairie level in trips of three by means of an electric hoist.

The Tipple or Bankhead

Each car of coal is hoisted separately from the ground level to the top of the tipple by an elevator and discharged by an end dump onto a stationary 3/4 in. bar screen. The oversize (+3/4 lump) is weighed in a weigh pan, and is then passed over a stationary bar screen with 4 in. openings. The +4 in. lump drops into a bifurcated chute for delivery to trucks. The 3/4 to 4 in. coal is screened on a 1-1/4 in. bar screen situated immediately below the 4 in. bar screen, to make 1-1/4 to 4 in. stove coal which is re-screened before loading into trucks to remove fines. The - 1-1/4 in. coal passes over a 1/2 in. bar screen to produce 1/2 to 1-1/4 in nut.

The 0-3/4 in. slack drops onto a 1/2 in. bar screen to produce 1/2 to 3/4 in. pea or stoker, which is often remixed with the nut coal.

The 0-1/2 in. slack drops into a bin.

All the above sizes are collected in bins from where they are discharged to trucks for delivery, either for local distribution or for shipment. In this latter case the coal is trucked to the C.P.R. freight yards at Lethbridge.

It should be noted that Mr. Chester is planning on introducing a shaker screen as well as a rotary screen to take the place of the stationary screens used at present.

There is no cleaning and very little handpicking, this latter procedure taking place to some extent while the large sizes of coal are delivered to trucks.

The various sizes produced at this mine are as follows:-

(a) Lump: +4 in. bar screen
(b) Stove: 1-1/4 to 4 in. bar
(c) Nut-Pea: 1/2 to 1-1/4 in. bar
(d) Slack: 0 - 1/2 in. bar.

During the year 1940 the production from this mine by size was as below:-

	Tons
Lump & Stove	10,435
Nut-Pea	3,001
Slack	2,879
Total	16,315

The distribution of the sizes, excluding slack, by destination was as follows:-

		Lump & Stove	Nut-Pea
Manitoba	Tons	190	--
Saskatchewan	Tons	2918	33
Alberta	Tons	6293	2968
British Columbia	Tons	226	--
United States	Tons	570	--
		10197	3001

According to a report, issued by the Research Council of Alberta in June 1938, the analysis of a Channel sample taken from the mine was as follows:-

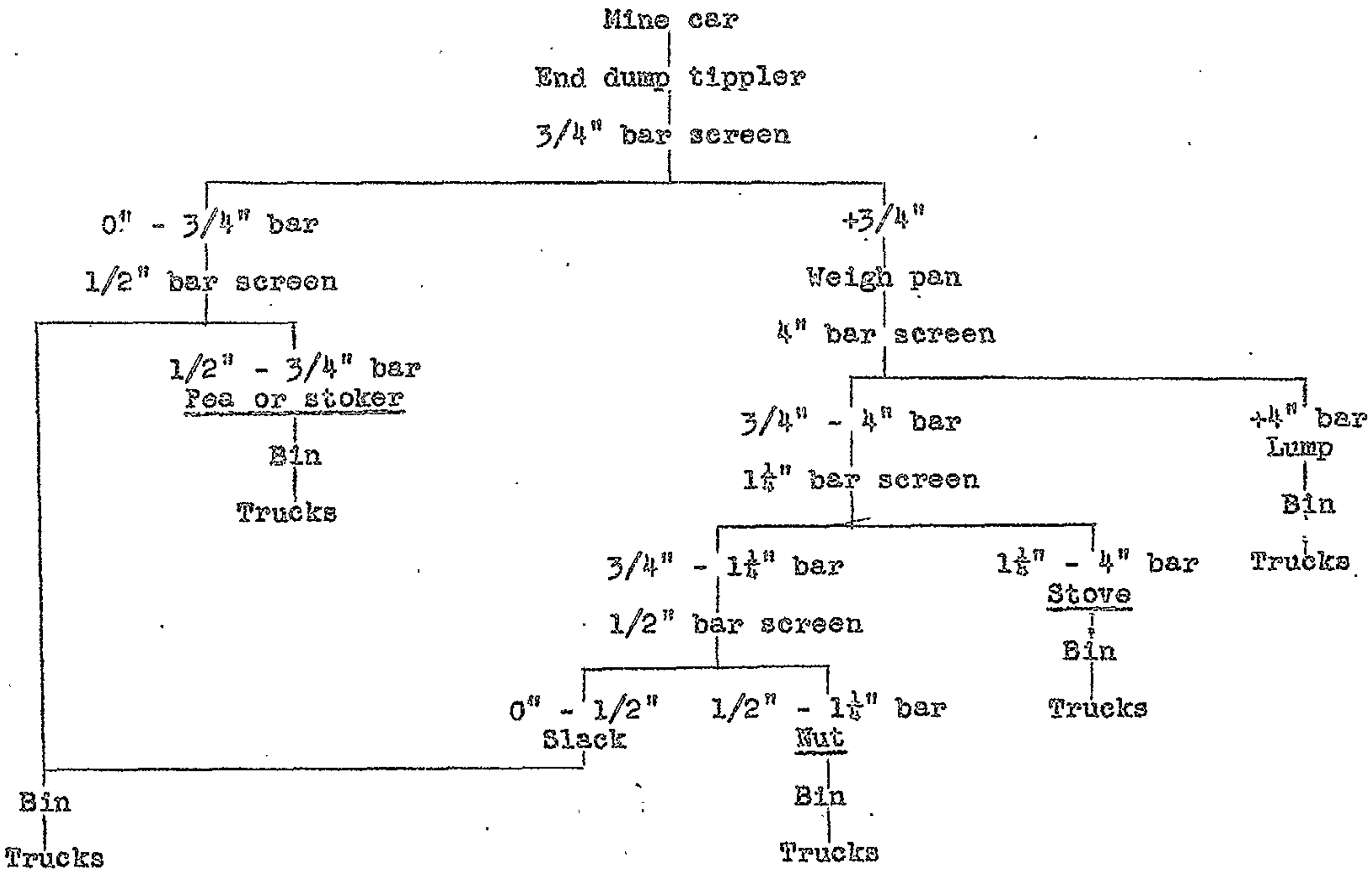


Fig. 6 -- PREPARATION AT CHESTER MINE

	As Received Basis
Moisture ----------- %	11.8
Ash ---------------%	6.8
Volatile Matter------ %	33.2
Fixed Carbon -------- %	48.2
Calorific Value --- B.T.U./lb.	11,220
Caking Properties	non-caking

During the summer the prices of the various sizes per ton F.O.B. mine, for local sales were as follows:-

Lump:	$ 3.75	Nut-Pea:	$1.85
Stove:	$ 3.25	Slack:	$0.75

4. Lethbridge Co-Operative Mines Association Ltd.

Mine: -------------------- Parkoal
Seam: -------------------- Galt
Location: ---------------- About 5 miles North of Lethbridge, and about 1/2 mile East of the Chester mine, in Township 9, Range 21, West of the 4th meridian.
Mine Officials: ---------- John Garrett, Mine Manager
This mine is operated on a co-operative basis.
Output: ------------------ About 125 tons per day.

Details of Mine and Seam:

The Galt seam worked at this mine is similar to that mined at the Chester mine, that is, there is about 4 feet of coal separated by a thin band of clay. The mine entry is in the coulee, and the coal seam is entered by means of a rock slope about 401 feet in length. The coal is mined by the room and pillar method with 24 foot rooms and 10 foot pillars, and is machine mined using a Sullivan undercutter. All haulage underground is by horse, and the 1 ton cars of coal are brought to the top of the tipple, situated at prairie level, from the bottom of the slope by means of an electric hoist.

The Tipple or Bankhead

The coal is discharged in the tipple by means of an end dump onto a stationary 3/4 in. bar screen. The +3/4 in. coal, without being weighed, is passed over a stationary 4 inl bar screen, the +4 in. lump going to a bin. The 3/4 to 4 in. undersize passes over a 2-1/2 in. bar screen situated below the 4 in. screen, resulting in the production of 2-1/2 to 4 in. stove coal. The minus 2-1/2 in. coal passes over a 1-1/2 in. bar screen making 1-1/2 to 2-1/2 in. nut, and the minus 1-1/2 in. coal goes over a 1/2 in. bar screen resulting in 1/2 to 1-1/2 in. pea and 0 to 1/2 in. slack.

The 0-3/4 in. slack from the initial screening passes over the 1/2 in. bar screen, the 1/2-3/4 in. coal going to the pea, and the 0-1/2 in. to the slack bin.

All the sizes produced are stored in bins below the screens, and are delivered by truck for local sales, and to the railway at Lethbridge for shipment.

The sizes normally produced then are as follows:-

(a) Lump: +4 in. Bar screen
(b) Stove: 2-1/2 to 4 in. bar screen
(c) Nut: 1-1/2 to 2-1/2 in. bar screen
(d) Pea: 1/2 to 1-1/2 in. bar screen
(3) Slack: 0 to 1/2 in. bar screen

5. Lund, Nelson, et al

Mine: ----------------------	Royalview
Seam: ---------------------	Galt
Location: ------------------	About 6-1/2 miles North of Lethbridge in Township 9, Range 21, West of the 4th meridian.
Mine Officials: -----------	Fred Lund, Manager
Output: -------------------	About 125 tons per day.

Details of Mine and Seam:

The Galt seam worked at this mine is similar to that mined at the Chester mine being about 4 feet in thickness. The mine situated in the coulee is entered by a shaft which is 90 feet deep to the coal. The seam is mined by undercutting, and is operated by the room and pillar system. All the coal is loaded by hand into the one ton capacity cars which are brought by electric hoist up the shaft to the top of the tipple.

The Tipple or Bankhead

The tipple is situated in the coulee. The coal is discharged from the mine cars at the head of the tipple by means of an end dump onto a 3/4 in. bar screen. The +3/4 in. lump, after being weighed in a weigh pan, passes over a 4 in. bar screen to make +4 in. lump which is rescreened on a 2 in. rd. hole screen prior to delivery to trucks. The undersize goes over a 1-1/4 in. bar screen to make 1-1/4 to 4 in. stove coal. The 0 to 1-1/4 in. coal joins the 0 to 3/4 in. slack from the primary separation, the mixture being screened by means of a rotary screen to give 7/8 in.(sq.) to 1-1/4 in. bar nut coal; 1/2 to 7/8 in. sq.mesh pea coal; and 0-1/2 in. slack.

All the various sizes are held in bins or chutes, and are delivered to trucks either for local sales or for delivery to the railway in Lethbridge for shipment.

The various sizes prepared are as follows:-

(a)	Lump:	+4 in. bar screen
(b)	Stove:	1-1/4 to 4 in. bar screen
(c)	Nut:	7/8" sq. to 1-1/4 in. bar screen
(d)	Pea:	1/2 to 7/8 in. sq. hole screen
(e)	Slack:	0 to 1/2 in. sq. hole screen.

Saunders Area, Alta.

1. Bighorn & Saunders Creek Collieries Ltd.

Although this mine was not visited by the author a certain amount of information was obtained in Winnipeg from Mr. W. Bird, Sales Agent for the company.

Mine: ---------- -----------	Saunders Creek, Bighorn (Also trade name of coal)
Location: ------------------	At Saunders, Alta. in Township 40, Range 13, West of the 5th meridian on the C.N.R. branch line from Rocky Mountain House to Nordegg.
Mine Officials: -----------	J. Charbonnier, President.

Preparation at the Mine:

The following sizes are prepared for shipment,

(a) Double Screened Lump: Over 10"x 18" bar screen.
(b) Junior Lump*: 4"x 8" bar - 10"x 18" bar
(c) Ostrich Egg: 2"x 10" slot screen - 4"x 8" bar.
The Junior Lump and Ostrich Egg are specially prepared for the Ontario market.
(d) Stove: 1-1/4" slot - 2"x 10" slot. (This is not prepared regularly.)
(e) Nut: 3/4" slot to 1-1/4" slot.
(f) Stoker: 0 to 1-1/4" slot.
(g) Slack: 0 - 3/4" slot.

*This lump is called 4-8 in. Cobble when distributed because of degredation.

Although the potential output of this mine is about 60,000 tons per year, during 1940-41 the total shipments for the year amounted to 21,323 tons.

The distribution of the various sizes was as follows:-

Double Screened Lump ------	26%
Junior Lump --------------	26%
Ostrich Egg --------------	22%
Nut ---------------------	12%
Slack -------------------	14%

The stoker coal mentioned above is a mixture of nut and slack.

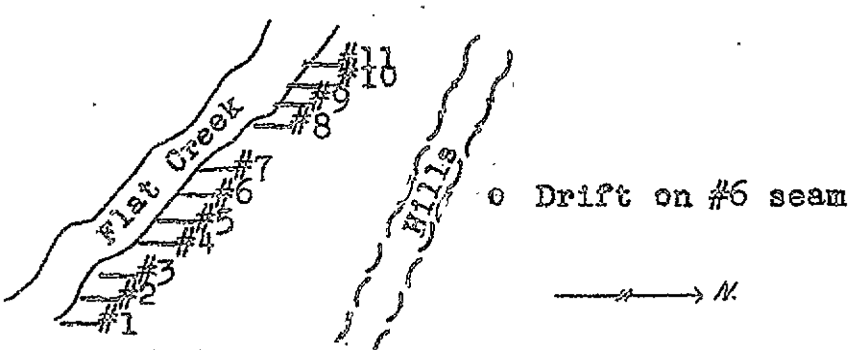
Highwood Area, Alta.

1. Flat Creek Coals Ltd.

Mine: ----------------------	Flat Creek
Seams: ---------------------	No. 6 Seam (8 ft.); No. 7 Seam (35 ft.)
Location: ------------------	East half of Section 34, Township 17, Range 5, West of the 5th meridian, at a point about 40 miles southwest of High River, Alta. (68 miles southwest of Calgary,)
Mine Officials: ------------	R.W. Wallace, Managing Director, 211 - 7th Ave., E., Calgary, Alta.

Details of Mine and Seam:

Work at this mine which is operating on a Freehold lease held by a Mr. W.J. Walker, began in August 1939, in one of the seams (#6) which outcrops on the North bank of Flat Creek. At this point there are apparently eleven seams outcropping as indicated in the following sketch.



The seams vary to a great degree in their thickness and general constitution. The first work was done in No. 6 seam, which is on the average about 8 feet thick. The entry to the mine is about 1200 feet north of the Creek, and consists of a drift passing through about 100 feet of gravel before the seam is struck. Development in the seam which pitches at 52° has proceeded for a distance of some 300 feet, using the room and pillar method of mining, all coal being won by handpick. During 1940 ten men were working at the mine, raising 1500 tons of coal. Examination of this seam, at the face, indicated that it was quite dirty, there being several bands of bone intermingled irregularly with the coal. In addition it is broken up and crumbles very easily with the resultant production of a large quantity of fines.

No. 7 seam, which is separated from No. 6 seam by about 29 feet of strata, is a 35 foot seam and samples taken near the outcrop indicated that it was cleaner than No. 6 seam. Reports of Analyses by the Alberta Research Council showed that No. 6 seam coal contained 13.5% ash whereas No.7 seam coal contained 11.5% ash. This fact, in addition to the thickness of the seam prompted officials of the company to break into No. 7 seam. This was effected by means of a crossout from No. 6 seam, and on Aug. 14/41, during the author's visit to the mine, the coal seam was struck. Examination of a section of this seam near the outcrop at the top of the hill indicated that this coal is probably cleaner and more uniform than No. 6, but it seemed to be softer and more seriously broken up. This, no doubt, will result in the production of a larger quantity of fines during mining.

The Tipple or Bankhead

The coal brought out of the mine, now operating on No. 6 seam, is dumped by an end dump tippler over a 2-1/4 in. bar screen. The +2-1/4 in. lump is retained in a chute or bin. The minus 2-1/4 in. lump is separated on a 1/2 in. screen, the 0 - 1/2 in. slack being at present discarded, while the 1/2 to 2-1/4 in. is separated on a 7/8 in. sq. mesh stationary screen to produce 7/8 to 2-1/4 in. stove coal and 1/2 to 7/8 in. Pea (or Chestnut as they sometimes call it).

As there are no rail facilities, the closest railroad connection being at High River, 40 miles distant, all the coal is moved by truck either to High River or to Calgary, at which latter point they operate a coal yard. Haulage to High River costs $1.50 per ton, whereas haulage to Calgary costs $2.00 per ton.

Thus the sizes at present (1941) available at this mine, and the sale price of these at the mine and at Calgary are as follows:-

	Selling Price per ton	
	At Mine	At Calgary
Lump: +2-1/4 in. Bar screen	$ 4.00	$ 7.00
Stove: 7/8 sq. t 2-1/4in. Bar	3.50	7.00
Pea: 1/2 to 7/8 in. sq.	2.50	6.00

General.

It should be noted that the coals available in this area are somewhat similar to the Canmore coals of the Cascade area in that they are low volatile bituminous non-caking or weakly caking and very friable. This physical characteristic results in the production, during mining and preparation, of an excessive quantity of fines; and according to Mr. Wallace, Managing Director of the company, presents a briquetting problem if mining is to be conducted economically and on a greatly increased scale in the future. As indicated above, the 35 foot No. 7 seam is considered superior to the No. 6 seam because of the lower mineral matter content, and thus it is this seam which mainly interests the operator insofar as the future is concerned. The company has had some preliminary work done by the Alberta Research Council. A sample of 0-1/4 in. coal, was tested at these laboratories for its amenability to briquetting, and the report indicated that the fines tested contained 17% ash. The Volatile Matter was 15-16.5%. The author, in discussions with Mr. Wallace, pointed out the difficulty that would be encountered in marketing a fuel so high in ash in competition with briquettes already being sold. However Mr. Wallace indicated his desire to have his coal thoroughly investigated at the Fuel Research Laboratories by the methods established for studying the physical and chemical characteristics of run-of-mine coal. Such a study will, no doubt, definitely indicate whether or not this coal is or can be made suitable for additional beneficiation by briquetting.

As mining in the No. 7 seam had not yet begun it was tentatively arranged that a suitable sample should be collected at some future date by the company officials. It was suggested that after sufficient work had been conductedto prove the seam, a sample should be collected daily for a week, and the aggregate shipped to Ottawa for investigation.

It is important to note, in connection with the subject of briquetting Flat Creek Coal, that even if the coal were found suitable, certain economic factors may prevent the establishment of such a process. For example, due to the fact that the mine is situated so far from a railway the cost of pitch binder, if this were used, would be very high. The pitch would have to be brought in drums to the mine, and under such conditions of transportation would cost about $36.00 per ton at the minimum. Thus if 6% pitch were used the binder would cost about $2.16 per ton of briquettes. It was alternatively suggested that the establishment of a briquetting plant in Calgary and the use of a starch-asphalt binder may result in a more economical operation.

<u>Drumheller and Edmonton Areas, Alta.</u>

See R.I.C.S. 147 (1939)

<u>The Saskatchewan Lignite Coal Field.</u>

See R.I.C.S. 141 (1939)

3

<u>Distribution</u> of <u>Commercial Coal</u> in <u>Winnipeg</u>.

A thorough survey of the commercial coal market in Winnipeg, especially with regard to domestic consumption, indicated that a great variety of coals were available. The list below shows according to origin the coals which have been marketed in Winnipeg during 1940.

A. <u>Saskatchewan</u> - <u>Lignites</u> from the Bienfait, Estevan and Roche Percee districts in the Souris area are prevalent on the Winnipeg market. These coals coming from several operators are sold in various sizes from lump to slack, the stoker sizes being in increasing demand.

B. Alberta - Subbituminous (Domestic) coals from the Drumheller area are popular in Winnipeg, especially in the lump sizes. Indications are that the consumer is gradually swinging towards the use of smaller lump in preference to the double screened lump so much in demand in the past. A limited amount of subbituminous coals from the Pembina and Edmonton areas are sold in Winnipeg, as well as some from the Carbon area, but little or no coal from the following areas appears on the market; Ardley, Big Valley, Brooks, Camrose, Castor, Champion, Gleichen, Milk River, Pakovki, Redcliff, Sheerness, Taber and Tofield.

Bituminous coals of the non-caking domestic variety find a ready market in Winnipeg especially in the lump and stoker sizes. These include the Coalspur, Saunders and Lethbridge area coals. Apparently these coals are divided into two classes, those most suited for domestic use in lump form, and those regarded more suitable in smaller sizes for stoker use. The Lethbridge coals and the Coalspur area coals from the Val d'Or seam, e.e. the McLeod River Hard, Minehead and Foothills coals, by reason of their tougher and lumpier characteristics are preferred where lump coal is required. On the other hand the Saunders area coals and to a lesser degree those in the Coalspur area mined in the Mynheer seam, that is Sterling and Cova coals, are, by reason of their physical and chemical properties deemed to be more suited for stoker use.

Bituminous coals of the caking variery are not extensively used for domestic purposes by small householders. The greatest market for these coals is in the heating of apartment buildings, stores, office buildings, churches, etc., either by handfiring or mechanical methods. For this purpose the mine run stoker and slack sizes, as well as the lump sizes of the coals from the Mountain Park and Crowsnest areas are the most prevalent. Some Cascade area coal, but practically no Nordegg coal is sold in Winnipeg for domestic use. It should be noted that specially prepared stoker sizes from some of the mines in the above areas are finding an increasing market especially in mixtures with Saskatchewan lignite.

C. British Columbia - The only coals from British Columbia which are sold in Winnipeg are those from the Crowsnest area. These are medium volatile strongly caking coals which are used in various sizes mainly in apartment buildings, stores, office buildings, etc. Insofar as the small householder is concerned mainly the stoker sizes, usually mixed with Saskatchewan lignite, are sold. A decrease in the available American bituminous stoker coals due to war conditions has already and will continue to react favourably insofar as the demand for such Canadian coals is concerned.

D. American Coals - Bituminous caking coals of American origin are imported mainly for blending with Canadian coals for various purposes, but especially for the preparation of suitable blends of stoker coal. For this purpose Elkhorn coal is apparently the most popular, but low volatile coals of the Pocahontas type are also being used. According to information received from the Empire-Hannah Coal Co. at Winnipeg, during 1940 between 15,000 to 18,000 tons of Elkhorn stoker coal was sold mainly blended with Saskatchewan lignite. This is an oil treated product. Of the additional 7,000 tons of American coal sold in Winnipeg most of it was Pocahontas slack and nut, although there was some lump and run of mine.

E. British Coals - Welsh coal in the buckwheat size has apparently been on the market for some time in Winnipeg. It is sold for blower equipped furnaces and is usually mixed with Winneco pea coke in 50 - 50 mixtures. It was intimated that if suitable coal at a reasonable price was available the market for blower coal could be materially increased.

F. Coke - Winneco Coke, manufactured by the Winnipeg Electric Co., has during the last year been practically the only coke on the market. Some "Zenith" coke from Duluth is still available, but due to exchange conditions very little or no American coke will be imported during 1941-42 for domestic consumption. Some MichelCoke, manufactured by the Curran-Knowles process at Michel, B.C. is also sold in Winnipeg.

G. Briquettes - Briquettes, during the last two or three years, have become increasingly popular on the Winnipeg market, due mainly to the success of the Heatglo briquettes manufactured from Saskatchewan lignite char by the Dominion Briquettes and Chemicals Ltd. Other briquettes sold in Winnipeg are the Canmore and Brazeau. The former is prepared from Canmore semi-anthracite and the latter from Brazeau low-volatile bituminous coal. This year an attempt is being made to introduce a binderless briquette manufactured from Greenhill coal. Its success on the Winnipeg market for domestic use will depend mainly upon the physical characteristics of the product. To date the briquettes have been very weak, resulting in an excessive amount of fines on handling. Mixed with stoker coal the briquettes, as they are at present, are apparently satisfactory.

A list of most of the coals sold on the Winnipeg market and the various sizes of these coals is shown in Table X. In some cases the size designation is not shown. It should be noted that in these cases the mines had not been visited, and the dealers were not acquainted, except in a general way, with the size designation of the various coals.

Although practically all the mining companies whose coals are marketed in Winnipeg and in the surrounding district are represented by direct or indirect agents, very few, if any, operate distribution yards. Both the wholesale and retail sales of coal in the district is effected through coal dealers, who in the main, operate independently. In the city of Winnipeg there are a large number of such dealers, but the bulk of the coal is handled retail by the following:-

1. Winnipeg Supply & Fuel Co. Ltd.
2. Thos. Jackson & Son Ltd.
3. Fort Rouge Coal Co. Ltd. - 2 yards
4. D.E. Adams Coal Co. Ltd.
5. Harstone Coal Co. Ltd.
6. Arctic Ice Co. Ltd.
7. Northland Coal Co. Ltd.
8. Hudson Bay Company Ltd.
9. Windatt Coal Co. Ltd.
10. Jubilee Coal Co. Ltd.
11. Capital Coal Co.

Of the above the Winnipeg Supply & Fuel Co. Ltd. are also wholesale dealers. Other wholesale distributors and sales agents in Winnipeg are as follows:- Coal Sellers Co. Ltd.; Great West Coal Co. Ltd.; Manitoba and Saskatchewan Coal Co. Ltd.; Osler, Hammond & Nanton Ltd.; Wildfire Coal Sales; and Empire-Hannah Coal Co. This latter company are the distributors of certain American coals including Elkhorn and Pocahontas.

Table [illegible]

COALS AVAILABLE ON THE [illegible] MARKET

Type of Coal	Province or State	Area	Mining Company	Trade Name of Coal	Mine Run	Double Screened Lump	Single Screened Lump	Cobble	Egg	Stove	Nut (Large)	Pea (Small)	Nut or Slack	Fine	
Lignite	Saskatchewan	Estevan	Western Dominion Coal Mines Ltd.	Climax (dirty pit)		+5" rd.	+4" rd.	4" - 2" rd.		2" - 3" or 4" rd.	1/2" - 2"	1/2" - 1"	0" - 2", 3" or 4"	0" - 1/4" or 1/2"	
				[illegible]		+6" rd.	+4" rd.	4" - 5", 2" or 4" rd.		2" - 4½" rd.	1/2" - 2"		0" - 2", 3" or 4"	0" - 1/2"	
			Manitoba & Saskatchewan Coal Co. Ltd. (Hudson Bay Co. mine)	[illegible] (M. & S.)		+5" rd.	+4" rd.	4" - 5" rd.		2" - 3" or 4" rd.	1/4" or 1/2" - 2"	1/4" - 1½"	0" - 2", 3" or 4"	0" - 1/4" or 1/2"	a/
			Eastern Collieries of Bienfait Ltd.	Eastern		+6" rd.	+4" rd.	4" - 2" rd.		2" - 1" rd.	1/4" or 1/2" - 2"	1/4" - 1½"	0" - 2", 3" or 4"	0" - 1/4" or 1/2"	
			Lignite Coal Mines Ltd.	Pinto High Test		+6" rd.	+4" rd.	4" - 6" rd.		2" - 4" rd.	1/4" or 1/2" - 2"	1/4" - 1½"	0" - 2", 3" or 4"	0" - 1/4" or 1/2"	
			High Test Lignite Coal Co. Ltd.	High Test Lignite		+6" rd.	+4" rd.	4" - 5" rd.		2" - 5" rd.	1/4" or 1/2" - 2"	1/4" - 1½"	0" - 2", 3" or 4"	0" - 1/4" or 1/2"	
			Paulson Bros. Ltd.			Yes		Yes		Yes		Yes			
		Taylorton	Jordan Bros.	Valley Lad		Yes		Yes		Yes		Yes			
		Roche Percee	Roche Percee Coal Mining Co. Ltd.	Green (strip pit)		Yes		Yes		Yes		Yes			
Subbituminous	Alberta	Drumheller	Midland Coal Mining Co. Ltd.	Midland (Jerrary)	Yes	+6" or 5" rd.		[illegible]	3" - 4" rd.	1½" sq. - 5" rd.	3/4" or 2" - 4"	1/4" - 2" sq.	0" - 1½"	0" - 1/4" sq.	
			Murray Collieries Ltd.	Murray Gladstone		+5½" rd.	[illegible]	[illegible] - 6" rd.	2" - 3½" rd.	2" - 1" rd.	3/4" - 2"	5/16" - 3/4"	0" - 2" rd.	0" - 5/16" or 3/4"	
			Atlas Coal Co. Ltd. (Regal Coal Co.)	Wildfire		+5½" rd.	[illegible]	[illegible] - 6" rd.	2" - 3½" rd.	2" - 1" rd.	3/4" - 2"	5/16" - 3/4"	0" - 2" rd.	0" - 5/16" or 3/4"	
			Red Deer Valley Coal Co. Ltd.	Scocoal (10-5)		+5" rd.				2" - 5" rd.	Yes	Yes		0" - 1/4" sq.	
			Rosedale Collieries Ltd.	Rosedale, Star, [illegible]		Yes			Yes	Yes	Yes				
			Hy-Grade Coal Mining Co. Ltd.	Hy-Grade Fireside		+6", 5" or 5" rd.	1½"/7" (lp)			1-3/8" [illegible] - 4" rd.	3/4" - 1-1/4" [illegible]	1/4" sq. - 3/4" lp		0" - 1/4" sq.	
			Brilliant Coal Co.	Brilliant		+5½" lp	[illegible]			1½" sq. - 3½" lp	[illegible] - 2" rd. or 3/4"	1½" sq.	0" - 1" rd. or	0" - 3/8" sq.	
			Newcastle Collieries Ltd.	Newcastle (R.S.C.)		+5" rd.	+5" lp			2" - 3" [illegible]	1-3/8" sq. - 2" rd.	3/4" - 1-1/2"	0" - 1½" bar	0" - 5/8" sq.	
			Maple Leaf Minerals Ltd.	Our National		+5" rd.	+5" rd.	Yes		2" - 3" rd.	[illegible] 1/2" - 2" rd.		0" - 2" rd.	0" - 5/8" sq.	b/
			Western Gem & Jewel Collieries Ltd.	(Gem Jewel) Western Gem		Yes				Yes	1½" - 1"		Yes	Yes	c/
			Empire Collieries Ltd.	Empire, Purity Hero		+5" lp	+2½" rd			2" - 1" 1½p	4½" - 2" sq.	2/8" - 1½" sq.		0" - 5/8" sq.	
			Monarch Coal Mining Co. Ltd.	Premium Monarch		+6" rd.				Yes	[illegible] - 2" rd.		0" - 1" rd.	0" - 5/8" sq.	
			Commander Coal Co. Ltd.	Commander		+5½" rd				1½" sq. - 4½" rd.	Yes		0" - 1½" sq.		
			Elgin Coal Co. Ltd.	Elgin		+5" rd.				1" - 4" rd.	Yes				
			Wayne Coal Products Assn. Ltd.	Mehta		+4½" rd.				2" - 4½" rd.	Yes		0" - 2" rd.	0" - 3" rd.	
		Carbon	Carbon Black Coals	Special		Yes			Yes						
			Fairview-Carbon Collieries Ltd.	Fairview Carbon		Yes			Yes						
		Champion	The Great West Coal Co. Ltd.	Black Diamond		+6" or 5" rd.	+2" rd.		2" - 4" or 2" - 5" rd.		1½" - 2" rd.	3/8" - 1" sq.	0" - 1-1/4" sq.	0" - 3/8" sq.	
		Pembina	Lakeside Coals Ltd.	Victory	Yes	+5"									
Bituminous (High volatile noncoking)	Alberta	Coalspur	The Foothills Collieries Ltd.	Foothills		+5" to +6"			3" sq. - 5" rd.		1" - 2" sq.	3/8" - 1" sq.	0" - 1" sq.	0" - 3/8" sq.	
			Leyland Coals Ltd.	Blackbird Leyland		Yes				Yes	Yes	Yes	Yes	Yes	
			McLeod River Hard Coal Co. Ltd.	McLeod River Hard		Yes			Yes		Yes		Yes	Yes	
			Sterling Collieries Ltd.	Sterling [illegible]	+1/15"			2½" sq. - 6" rd.		1½" - 2½" sq.	3/8" - 1½" sq.	5/16" - 5/8" sq.			d/
			Coal Valley Mining Co. Ltd.	Coal					1" - 4" rd.		1/16" sq. - 1" rd.	1/8" - 5/16" sq.			
		Lethbridge	Lethbridge Collieries Ltd.	Galt		+6" rd		4" - 5" rd.		[illegible] - 4" rd.	5/8" - 1-1/2" rd.		1½" - 1-1/2" rd.	0" - 5/8" sq.	
				Coalfield		+6" rd. (some +8" [illegible])	+3/4" rd.	4" - 5" rd.		2" - 4" or 3" rd.	5/8" - 3" rd.		1½" - 3" or 4" rd.	1½" - 5/8" rd.	
			J.C. Gassler	Royal		+6" bar				1½" - 4" bar					
		Magrath	Alsip Coal Co. Ltd.	Alsip (Alsip)		Yes	Yes	Yes				Yes	Yes	Yes	
			Bighorn & Saunders Creek Coll. Ltd.	Bighorn, Saunders Creek		Over 10" x 3½" bar		Junior lump	Outrial [illegible]	1½" - 2" x [illegible]	3/4" - [illegible]	Stove = 0 - 1½" [illegible]	[illegible]	0" - 3/4" [illegible]	e/
Bituminous (Medium volatile coking)	Alberta	Mountain Park	Mountain Park Coals Ltd.	Mountain Park	Yes		+3" rd.		1½" or 1-1/2" - 5" rd.		3" sq. - 1-3/8" rd.	1/4" sq. - 1/8" rd.	0" - 1-1/2" rd.	0" - 5/8" rd.	
			Cascade Coals Ltd.	Cadomin	(1/16" - 7")		(2" x 7")						0" - 2½"	0" - 1/16"	
			R.C. Collieries Ltd.	R.C.	Yes									Yes	
			Cadomin Coal Co. Ltd.	Cadomin	Yes	Yes	Yes					Yes		0" - 1/8"	
		Crowsnest	Hillcrest Mohawk Collieries Ltd.	New Mohawk	Yes		(+1½" rd.)		(Furnace lump)		1" - 1-1/2" rd.	1/2" - 1-1/2" rd.	0" - 1-1/2" or 2" rd.	0" - 1/4" sq.	f/
			International Coal & Coke Co. Ltd.	International	Yes								Yes	1½" - 1½"	
			McGillivray Creek Coal & Coke Co.	McGillivray Creek	Yes		+1½" sq.					3/8" - 1½" sq.	0" - 1½" sq.	0" - 3/8" sq.	
			West Canadian Collieries Ltd.	Greenhill	Yes				3" - 3" rd. Washed furnace			1/4" - 1-3/4" sq.	0" - 1-3/8" sq.	0" - 3/8" sq.	g/
				Bellevue	Yes	(+6" rd.)			2" - 6" rd. Washed furnace				0" - 1-3/8" sq.	0" - 3/8" sq.	
	British Columbia	Crowsnest	The Crow's Nest Pass Coal Co. Ltd.	Michel (A, B and No. 3)	Without slack	(+4" lp)		1-3/8" sq. - 3"			[illegible] (3/16" [illegible] - 1-1/2" sq.)		0" - 1-1/2" sq.	0" - 1/2"	h/
				Coal Creek	Without 2" slack										i/
Bituminous (Low volatile coking)	Alberta	Nordegg	Brazeau Collieries Ltd.	Brazeau Steam	Yes										i/
Semi-anthracite (Non-coking)	Alberta	Canmore	Canmore Mines Ltd.	(Canmore Smithing) (Canmore Furnace)	+1/4" sq.		+2-1/2" rd.	+5"		1½" - 2½" rd.		1/4" sq. - 1½" rd.	0" - 1"	0" - 1/4" sq.	j/

AMERICAN COALS

Type of Coal	Province or State	Area	Mining Company	Trade Name of Coal	Mine Run	Double Screened Lump	Single Screened Lump	Cobble	Egg	Stove	Nut (Large)	Pea (Small)	Nut or Slack	Fine	
Bituminous (High volatile)	Kentucky	Elkhorn seam	Elkhorn Coal Cor. [illegible]	[illegible], Excelsior	Yes		+4"					Yes		Yes	k/
	Pennsylvania	Pittsburgh seam	Consolidation Coal Co.	[illegible]	Yes		Yes							Yes	
Bituminous (Low volatile)	West Virginia	Sign Nos. 1 & 2 seam; Pocahontas seam	Carter Coal Co.	Pocahontas	Yes		Yes	Yes	Yes		Yes			Yes	
		Pers Nos. [illegible] seams	New River & Poca. Cons. Coal Co.	[illegible]								Buckwheat			

a/ "Heat Glow" briquettes manufactured by Dominion Briquettes & Chemicals, Ltd.
b/ Domestic lump: 5" x 3½" (lp).
c/ Summer lump.
d/ Buckwheat 1/16" - 5/16" sq.
e/ Lumps for Ontario. Junior lump = [illegible] x 5" bar = 10" x 3½" bar. Outrial [illegible] = 2" x 10" [illegible] - 4" x [illegible] bar.
f/ Furnace lump = 1-3/8" - 4" rd.; Stoker = 1/4" - 1" rd.; Buckwheat = 1/8" - 1".
g/ Ordinary stoker = nut pea or screened slack (11.2% ash); Washed stoker = 1/4" - 1½" sq. (7.0% ash). Buckwheat = 1" - 1/8" sq. (9% ash).
h/ Very little to Winnipeg.
i/ Briquettes.
j/ Erroneously referred to in Winnipeg as "Douglas Coal".

Although in the past some of the larger dealers operated as many as eight coal yards, to-day most of them have only two main yards, one in the vicinity of the Canadian Pacific railway yards and the other at a point near the Canadian National Railway yards. This allocation of dealers' coal yards in Winnipeg serves a double purpose; in the first place it allows them to receive coals direct from the mines served by each of the railways; and secondly because the C.P.R. yards are in the North End of the city and the C.N.R. yards in the South End of the city, it gives them two distribution centres from which the whole city can be handled with ease. This reduction in the number of coal yards required by a dealer is due mainly to the replacement of horsedrawn vehicles by motor trucks. However a few of the dealers still operate yards in the more outlying suburban districts such as Elmwood in the North End and St. James in the South Central End of the city.

The method of handling the various kinds and grades of coal at the yards of the larger dealers is fairly uniform. All the lower rank coals which are subject to degradation on weathering are kept in covered storage sheds. These coals include the Saskatchewan lignites, the subbituminous coals from the Drumheller, Edmonton, Carbon and other Alberta areas, and to a lesser degree the non-caking high volatile bituminous coals from the Coalspur, Saunders, and Lethbridge areas. It should be noted that in many cases some, if not all, of the smaller sizes such as stoker, nut, pea and slack, are stored in bins which may be either closed or open at the top. This method is used to facilitate the loading of trucks when delivery is made in bulk.

The higher rank coals and cokes which do not readily break up on weathering are usually stored outside, but it should be noted that where space is available covered storage is preferred because of the difficulties encountered during the severe winter weather.

The lump sizes of Canadian coal are delivered to the yards in box cars, whereas the smaller sizes are often delivered in open hopper cars as well. All the lignite, subbituminous and non-caking bituminous lump sizes are unloaded by wheelbarrow with care to prevent undue breakage. In some cases the coal is hand-picked or forked in the car and placed in bags for distribution or storage. The stoker sizes and slack coming in open cars are either unloaded by crane or dumped into a track hopper for subsequent distribution by elevator and conveyor to overhead bins. When these smaller sizes come in box cars, as during the winter months, they are usually unloaded by wheelbarrow or by handshovelling into covered storage sheds.

Caking bituminous coals used mainly for steam purposes come in box cars as well as open hoppers, the former being unloaded by handshovelling and wheelbarrow, whereas the latter, usually consisting of mine run, stoker or slack sizes, are unloaded by crane or dumped into track hoppers for subsequent distribution to bins. Many of the yards are equipped with portable truck loaders which are also used for putting down the coal in either closed or open storage.

Briquettes are stored both in the open and under cover, and are usually unloaded from the box cars by shovelling or by wheelbarrow.

Coals for domestic distribution are usually put up in 100 pound bags, there being no charge for ordinary sacking. The lump sizes of the "domestic" type coals are always forked before bagging, the size of the fork depending on the size of the coal. The smaller sizes (such as stoker coal), stored in overhead bins, usually pass over a screen, with mesh ranging with the size of coal, before delivery to bag or truck. In those cases where blends of lignite and bituminous coal are made up for stoker use the mixing is done rather crudely on the ground. Some consumers, especially the larger ones, prefer to receive their coals separately and mix them in their cellars.

Dust proofing of various coal sizes has become almost standard practice. Oil treatment seems to be most prevalent although some coals are treated with Calcium Chloride (e.g. Wescan stoker). Dust proofing is usually confined to the stoker sizes, mine run and slack, although in some cases some of the small lump sizes are also treated.

In many cases the coals are dust proofed at the mine before shipment, but it should be noted that the larger retail dealers in Winnipeg are also equipped to oil treat coals. Most of them use a hot oil process (similar to the Viking) manufactured by the Link-Belt Company. The spray nozzles are usually fitted to the discharge end of a portable truck loader, the coal being treated during loading for distribution. No extra charge seems to be made for oil treatment.

According to a semi-official price list issued at intervals by a retail coal dealers association* in Winnipeg the Domestic and Steam Coals marketed in Winnipeg at their prices are as follows:-

	Domestic Coals (1) (August 1940) Cost per ton	Steam Coals (2) (July 1941) Cost per ton
	Canadian Coals	
Saskatchewan Lignite		
Dominion, M &S, Pinto (Deep Seam)		
Lump and Cobble	$ 6.75	$ 5.80
Stove	6.50	5.50
Stoker	6.25	5.00
Bienfait, Eastern, High Test Monogram, Roche Percee, Klimax		
Lump and Cobble	6.25	5.40
Stove	6.25	5.35
Stoker	6.25	5.00
Edmonton (Clover Bar District)		
Lump	11.00	---
Egg	10.25	---
Drumheller		
Lump	12.00	---
Egg	11.50	---
Stove	11.00	---
Nut Pea and Stoker Nut Pea	9.75	8.70
Screenings	---	6.50
Carbon-Aetna and Granular (Drumheller)		
Lump	11.00	---
Egg	10.50	---
Galt		
Lump	12.00	---
Stove	11.50	---
Stoker	10.00	---
Foothills, McLeod River & Minehead		
Lump	13.00	---
Stove	12.50	---
Nut	11.00	---
Pea Stoker	10.50	9.45

*Winnipeg Retail Coal Exchange - Brett, Sec'y.

	Domestic Coals	Steam Coals
Saunders Creek (Alexo & Bighorn)		
Lump	$ 13.75	$ ---
Cobble	---	12.75
Nut	12.00	11.25
Stoker	11.00	9.75
Screenings	---	9.50
Coal Valley		
Cova Nut Pea	---	9.20
Bellevue		
Washed Furnace	13.75	11.50
Mine Run	---	10.50
1-5/8" Screenings	---	9.85
Greenhill		
Mine Run	---	10.50
Washed Furnace	13.25	---
Nut Pea & Stoker	(Being marketed in 1941)	10.25
1-5/8" Screenings	---	9.85
International		
Mine Run	---	10.60
1-1/2" Screenings	---	9.95
McGillivray		
Lump	---	11.75
Mine Run	---	10.50
Screenings	---	10.00
Mohawk		
Mine Run	---	10.35
Stoker	---	10.35
Screenings	---	9.60
Michel		
Cobble	13.50	12.75
Mine Run	---	10.95
1/4" to 1-1/2" Stoker	12.00	10.85
Screenings	---	10.35
Mountain Park		
Lump	---	12.75
Mine Run	---	10.95
Stoker	---	10.70
Screenings	---	10.45
Cadomin		
Lump	---	12.75
Mine Run	---	10.95
Stoker	---	10.65
Screenings	---	10.45
Luscar		
Screenings	---	10.45
K. D. Coal		
Mine Run	---	10.80
Screenings	---	10.30

	Domestic Coals	Steam Coals
Canmore		
Cobble	$ 13.75	$ ---
Stoker	12.50	10.95
Mine Run	---	11.20
1" Screenings	---	10.45
Briquettes		
Canmore	13.75	13.50
Greenhill	13.50 (1941)	13.25
Brazeau	13.50	13.25
Heat-Glo Carbonized	12.25	12.50
	American Coals	
Pocahontas		
Lump, Egg, Stove	16.75	16.75
Nut	15.00	14.00
Mine Run	14.00	13.20
Screenings	12.00	11.45
Elkhorn		
Lump	---	14.00
Dock Run	---	12.75
Stoker-Screened	14.00	13.75
Stoker (80-20, i.e.20% Screenings)	13.60	---
Screenings	---	12.75
Youghiogheny & Pathfinder		
Lump	---	13.50
Dock Run	---	12.40
Screenings	---	11.15
American Anthracite		
Stove & Nut	19.00	---
Pea	17.00	17.50
	COKE	
Imported, Stove and Nut	16.00	15.75
Algoma, Stove and Nut	15.75	15.50
Michel, Stove and Nut	14.75	---
Winneco, Stove and Nut	14.25	14.50
Winneco, Pea	13.25	13.50
Restaurant Coal		
Drumheller, Carbon, Aetna and Comet Stove Lump	---	10.50

(1) It should be noted that these are 1940 prices. The 1941 price list had not been issued in August 1941, due to no decision having been reached as to increases on account of cost of living bonus in addition to increased cost F.O.B. mine. Prices may be about 25¢ higher per ton. No charge is made for ordinary sacking.

(2) The steam coals are quoted for delivery by truck or team in bulk to apartment buildings, steam plants etc. 50¢ per ton extra is charged for sacking steam coal.

In addition to the above, as noted before, various stoker coal mixtures are marketed, using Saskatchewan lignite as a base, and some bituminous coking coal as a "sweetner". Elkhorn coal was the preferred "sweetner" but recently such Canadian coals as Michel and Greenhill have been used successfully. Below is given a list of some of the mixtures prepared by Thos. Jackson & Sons Ltd. using Michel coal with Saskatchewan lignite and Rosedale subbituminous coal. For comparison the price per ton as of October 1946, is also shown.

	Price per ton
25% Michel; 75% Sask Lignite	$ 7.75
33-1/3% Michel; 66-2/3% Sask. Lignite	8.25
50% Michel; 50% Sask. Lignite	9.15
50% Michel; 50% Rosedale Nut Pea	10.90

General

A study of the price list of coals given above reveals some rather interesting information.

1. Although the freight rate from the Coalspur and Saunders Areas to Winnipeg is the same, the Saunders coals command a higher price than the Coalspur area coals.

2. Of all the Drumheller coals only one, that from the Aetna Coal Co. in the East Coulee district, is singled out as of lower value, it being classed with the Carbon and Edmonton area coals, and the "granular" coals from the Drumheller area.

3. The deep seam lignite coals from Saskatchewan, in the Estevan area sell at a higher price than the shallow seam coals as those mined in the open strips by the Western Dominion Coal Mines Ltd. (Klimax or Monogram), Eastern Collieries of Bienfait Ltd. and Roche Percee Coal Mining Co. Ltd. It should be noted that, according to information received from dealers in Winnipeg, the deep seam coal is preferred for domestic handfired furnaces, and is unsuitable for stokers because the ash "runs" when forced draft is used.

4. Of the Coalspur area steam coals coming from the Mynheer seam only the price of Coal Valley coal is quoted. However, it is understood that there is an agreement between the Coal Valley and Sterling operators, whereby one replaces the other when necessary.

5. Although all the Alberta bituminous coking coals are quoted on for steam purposes only the "washed furnace" size from Greenhill and Bellevue are listed as domestic coals. However it should be noted that during 1941 Greenhill ordinary stoker and their special Wescan stoker was also marketed for domestic use.

For record purposes the price of Wood in Winnipeg as of August 1, 1941 is given below.

	Cord (Long)	Load Cut (164 cu.ft. per load)
Poplar	$ 7.00	$ 8.25
Slabs	--	8.25
Pine	8.25	9.25
Tamarac	9.50	10.50
Birch	9.75	10.75
Oak	9.75	10.75
Ash	9.00	10.00
Maple	--	10.00

The above prices are for delivery to the lane. $1.00 per load extra is charged for delivery from lane to basement, or where it is possible to back a truck to the basement chute, delivery to the basement is 50¢ extra per load.

Miscellaneous Information.

In Regina, Sask. The Pragnell Coal Co. Ltd. marketed during 1940-41 a 50 - 50 mixture of Canmore Briquettes and Drumheller stove coal under the name of "Brixto". About 7,500 tons were sold at $10.60 per ton.

In addition to a large quantity of Heatglow Briquettes, selling at $11.50 per ton, about 7,000 tons of Canmore briquettes at $12.25 per ton and about 600 tons of Brazeau briquettes at $11.90 per ton were also marketed.

R.I.C.S. 180

DEPARTMENT OF MINES

MINES BRANCH—FUEL RESEARCH LABORATORIES

Physical and Chemical Survey Report No. 89

Study of Coal From
Beban Tipple Mines, Wellington Seam, Nanaimo,
Vancouver Island
Operated By
Chambers, R.H., and Hamilton Extension Mine
In Cooperation With
Canadian Collieries (Dunsmuir) Ltd., Nanaimo, B.C.

By
E. Swartzman

DIVISION OF FUELS & FUEL TESTING
OTTAWA, February, 1943.
SIGNED, ...

Report of Investigations--Carbonization Section - 180

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I

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Chambers Extension Mine and the Hamilton Extension Mine, Wellington Seam, worked in the Nanaimo area, near Nanaimo, British Columbia, by Chambers, Ralph H. and the Hamilton Extension Mine in cooperation with the Canadian Collieries (Dunsmuir) Ltd. Both these mines operating on a small scale on a salvage basis deliver their coal to a common tipple, called the Beban tipple. This is situated near the Canadian Collieries (Dunsmuir) Ltd. washery at Nanaimo, and all the coal is delivered to the washery and distributed by the Canadian Collieries (Dunsmuir) Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-eight reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the Beban tipple mines was sampled at the mine by an official from the Fuel Research Laboratories in the presence of representatives from the operating companies. The combined sample, which weighed approximately 1940 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railway Company, officials of the British Columbia Department of Mines, and various members of the Canadian Collieries (Dunsmuir) Ltd., and Beban tipple operators for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H. Nicolls of the Fuel Research Laboratories under whose direction the major portion of the chemical analyses

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Beban tipple Mines, Wellington Seam, was collected at the tipple during July 1941 from trucks of coal as they were being dumped for screening. A sample of the unprepared run-of-mine coal, weighing approximately 1940 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M), investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and C.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, AND BULK DENSITY

Screen Sizes*	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	32.8	32.8	1.31	44.25	7.6
2 - 4 in.	14.2	47.0	1.32	41.25	10.8
1½ - 2 in.	3.8	50.8	1.34	42.25	12.8
1 - 1½ in.	7.5	58.3	1.37	42.50	17.9
¾ - 1 in.	4.7	63.0	1.41	42.50	18.3
½ - ¾ in.	7.0	70.0	1.39	42.75	18.1
¼ - ½ in.	10.2	80.2	1.32	43.25	22.3
1/8 - ¼ in.	7.7	87.9	1.33	43.00	21.9
#48 - 1/8 in.	8.9	96.8	1.34	50.50	24.6
0 - #48 in.	3.2	100.0			29.7
Mine Run		100.0	—	—	15.0
Plus 1½ in.		50.8	—	—	9.3
0 - 1½ in.		49.2	—	55.50	20.6
¾ - 1½ in.		12.2	—	—	18.7
0 - 1/8 in.		12.1	1.34	50.50	25.4

		As Received
Average Size of Run-of-Mine	in.	2.898

* All screens 1/8 in. and larger are round-hole screens. No. 48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test 2 - 3 in. Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	61.0	42.5
1½ - 2 in.		10.0	11.5
1 - 1½ in.		10.0	12.5
¾ - 1 in.		4.5	7.0
½ - ¾ in.		4.0	6.0
0 - ½ in.		10.5	20.5
Av'g Size in.	2.500	1.915	1.567
Size Stab'ty %		76.6	62.7

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	61.9
0 - 1½ in.	61.5
0 - 1/8 in.	70.9

also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the Beban tipple Mines are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coal from the Wellington Seam of the Beban tipple Mines.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite,
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

5. Crushing Test

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics

---

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Roban tipple Mines coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 INCH LUMP
(Crusher set at 1½ inch)

		Screen Analysis	
		Before Crushing %	After Crushing %
8 - 10 in.	%	20.1	
7 - 8 in.	%	19.8	
6 - 7 in.	%	22.9	
5 - 6 in.	%	16.8	
4 - 5 in.	%	20.4	1.4
3 - 4 in.	%		4.8
2 - 3 in.	%		35.9
1½ - 2 in.	%		12.2
1 - 1½ in.	%		12.2
3/4 - 1 in.	%		7.4
½ - 3/4 in.	%		8.0
1/4 - ½ in.	%		7.6
1/8 - ¼ in.	%		4.8
0 - 1/8 in.	%		5.7
Average Particle Size---in.		6.625	1.652
Size Reduction	%		24.94

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the Beban tipple Mines, Wellington Seam were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.
2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.
3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, as shown in Table VII. Data on temperature lags are presented because of their bearing on the clinkering properties.
4. The Chemical Analyses of Ash, which are shown in Table VIII.

N.B. The sulphur forms were not determined as this coal is very low in sulphur.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULFUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis: Ash %	Dry Basis: Volatile Matter %	Dry Basis: Fixed Carbon %	Dry Basis: Sulphur %	Dry Basis: Calorific Value BTU/Lb.
Plus 4 in.	1.5	7.6	38.5	53.9	0.4	-----
2 - 4 in.	1.6	10.8	37.9	51.3	0.4	13,120
1½ - 2 in.	1.4	12.8	37.0	50.2	0.4	-----
1 - 1½ in.	1.5	17.9	35.4	46.7	0.4	-----
¾ - 1 in.	1.4	18.3	35.3	46.4	0.4	-----
½ - ¾ in.	1.5	18.1	35.2	46.7	0.4	-----
¼ - ½ in.	1.5	22.3	35.1	42.6	0.4	-----
1/8 - ¼ in.	1.5	21.9	34.0	44.1	0.4	-----
#48 - 1/8 in.	1.0	24.6	33.2	42.2	0.4	-----
0 - #48 in.	1.1	29.7	33.9	36.4	0.4	-----
Mine Run	1.5	15.0	36.4	48.6	0.4	12,455
Plus 1½ in.	1.6	9.3	38.6	52.1	0.4	13,390
0 - 1½ in.	1.8	20.6	34.3	45.1	0.4	11,550
¼ - 1½ in.	1.6	18.7	35.1	46.2	0.4	11,840
0 - 1/8 in.	1.5	25.4	33.3	41.3	0.4	10,690

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	69.7	4.9	0.4	1.4	8.6	15.0

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash °F.
Plus 4 in.	2190	2250	2360	170	60	110	7.6
2 - 4 in.	2190	2250	2280	90	60	30	10.8
1½ - 2 in.	2250	2340	2500	250	90	160	12.8
1 - 1½ in.	2400	2490	2590	190	90	100	17.9
¾ - 1 in.	2400	2480	2580	180	80	100	18.3
½ - ¾ in.	2350	2420	2480	130	70	60	18.1
¼ - ½ in.	2370	2430	2500	130	60	70	22.3
1/8 - ¼ in.	2320	2420	2470	150	100	50	21.9
#48 - 1/8 in.	2370	2470	2550	180	100	80	24.6
0 - #48	2340	2430	2470	130	90	40	29.7
Mine Run	2350	2450	2560	210	100	110	15.0
Plus 1½ in.	2400	2490	2530	130	90	40	9.3
0 - 1½ in.	2380	2450	2570	190	70	120	20.6
⅜ - 1½ in.	2330	2460	2510	180	130	50	18.7
0 - 1/8 in.	2360	2480	2520	160	120	40	25.4

TABLE VIII

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run	41.7	7.5	21.8	16.8	3.5	---	1.1	1.1	1.0	1.0	4.7	100.2

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4 inch screen, all prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult ..	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult .	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash percent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I and II. All of the data used in the construction of the curves are presented in Tables IX to XVII inclusive.

TABLE IX

Float and Sink Data on 1½" Slack

– Ash –

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± .10 Specific Gravity Distribution: Gravity	± .10 Specific Gravity Distribution: Calculated Ordinate
								1.35	39.6
	Floats 1.30	55.8	6.0	55.8	6.0	100.0	16.9	1.40	30.5
Sinks 1.30	" 1.40	21.5	10.3	77.3	7.2	44.2	30.6	1.45	14.8
" 1.40	" 1.50	6.3	22.3	83.6	8.3	22.7	49.9	1.55	4.6
" 1.50	" 1.60	1.4	29.0	85.0	8.7	16.4	60.5	1.65	2.8
" 1.60		15.0	63.4	100.0	16.9	15.0	63.4	1.75	2.5
Curve No.	4		2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F.	Softening Point °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.
	Floats 1.30	6.1	39.3	54.6	Good	0.4	2435	2510	2590	155	75	80
Sinks 1.30	" 1.40	10.4	37.9	51.7	Good	0.4	2225	2290	2325	100	65	35
" 1.40	" 1.50	22.6	33.8	43.5	Fair	0.6	2370	2550	2640	270	180	90
" 1.50	" 1.60	29.5	31.2	39.3	Poor	0.7	2370	2520	2600	230	150	80
" 1.60		64.5	19.6	15.9	Agglomerate	0.2	2600	2850+	2850+	50+	50+	+

TABLE XI

Float and Sink Data on 1½ - 4 in. Lump

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± .10 Specific Gravity Distribution Gravity	± .10 Specific Gravity Distribution Calculated Ordinate
	Floats 1.30	54.2	6.1	54.2	6.1	100.0	13.1	1.35	95.9
Sinks 1.30	" 1.40	35.4	9.6	89.6	7.5	45.8	21.5	1.40	38.2
" 1.40	" 1.50	0.7	22.5	90.3	7.6	19.4	61.9	1.45	9.9
" 1.50	" 1.60	0.9	31.4	91.2	7.8	9.7	64.8	1.55	0.7
" 1.60		8.8	68.2	100.0	13.1	8.8	68.2	1.65	0.5
Curve No.		4	2	1,2,4	1	3	3	5	5

TABLE XII

Float and Sink Data on Plus 4" Lump (Crushed)

- Ash -

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %
	Floats 1.30	33.2	9.6	33.2	9.6	100.0	9.1
Sinks 1.30	" 1.40	60.5	8.4	93.7	8.8	66.8	8.8
" 1.40	" 1.50	5.5	11.9	99.2	9.0	6.3	12.9
" 1.50	" 1.60	0.1	22.1	99.3	9.0	0.8	19.6
" 1.60		0.7	19.2	100.0	9.1	0.7	19.2
Curve No.		4	2	1,2,4	1	3	3

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE

0 to 1½ Inch Slack

		Raw Coal	Clean Floats	Coal 1.60	Refuse Sinks 1.60
Weight	%	100.0	83.2		16.8
Proximate Analysis (dry basis)					
Ash	%	20.6	8.9		67.0
Volatile Matter	%	34.3	37.2		18.0
Fixed Carbon	%	45.1	53.9		15.0
Sulphur	%	0.4	0.4		0.2
Calorific Value	B.T.U./lb	11550	13480		----
Fusion Point of Ash	°F.	2450	2190		2800
Melting Range of Ash	°F.	190	290		200+
Coking Properties		Good	Good		Non-agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE

1½ to 4 Inch Lump

		Raw Coal	Clean Floats	Coal 1.60	Refuse Sinks 1.60
Weight	%	100.0	96.1		3.9
Proximate Analysis (dry basis)°					
Ash	%	11.2	8.6		56.5
Volatile Matter	%	37.7	38.4		23.5
Fixed Carbon	%	51.1	53.0		20.0
Sulphur	%	0.4	0.5		0.4
Calorific Value	B.T.U./lb	13060	13510		----
Fusion Point of Ash	°F.	2270	2450		2480
Melting Range of Ash	°F.	125	150		150
Coking Properties		Good	Good		Non-agglomerate

° Calculated

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE

Plus 4 Inch Lump (Crushed)

		Raw Coal	Clean Floats	Coal 1.60	Refuse Sinks 1.60
Weight	%	100.0	99.2		0.8
Proximate Analysis (dry basis)					
Ash	%	7.6	6.8		26.1
Volatile Matter	%	38.5	39.3		32.5
Fixed Carbon	%	53.9	53.9		41.4
Sulphur	%	0.4	0.4		0.4
Calorific Value	B.T.U./lb	13590°	13730		----
Fusion Point of Ash	°F.	2250	2500		2350
Melting Range of Ash	°F.	170	130		230
Coking Properties		Good	Good		Poor

° Calculated

TABLE XVI

SCREEN ANALYSIS AND CHEMICAL ANALYSIS

(Dry Basis of 1½" Slack

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
¾ - 1½ inch	24.8	24.8	18.1	0.4	2485
1/8 - ¾ inch	50.6	75.4	21.0	0.4	2425
0 - 1/8 inch	24.6	100.0	25.4	0.4	2480

TABLE XVII

FLOAT AND SINK DATA ON SCREENED SIZES USING A SELECTED GRAVITY OF (Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F.	Weight %	Ash %	F.P.A. °F.
¾ - 1½ in.	85.7	8.8	2360	14.3	63.9	2760
1/8 - ¾ in.	81.1	9.3	2180	18.9	64.6	2850
0 - 1/8 in.	66.2	8.6	2320	33.8	56.8	2500

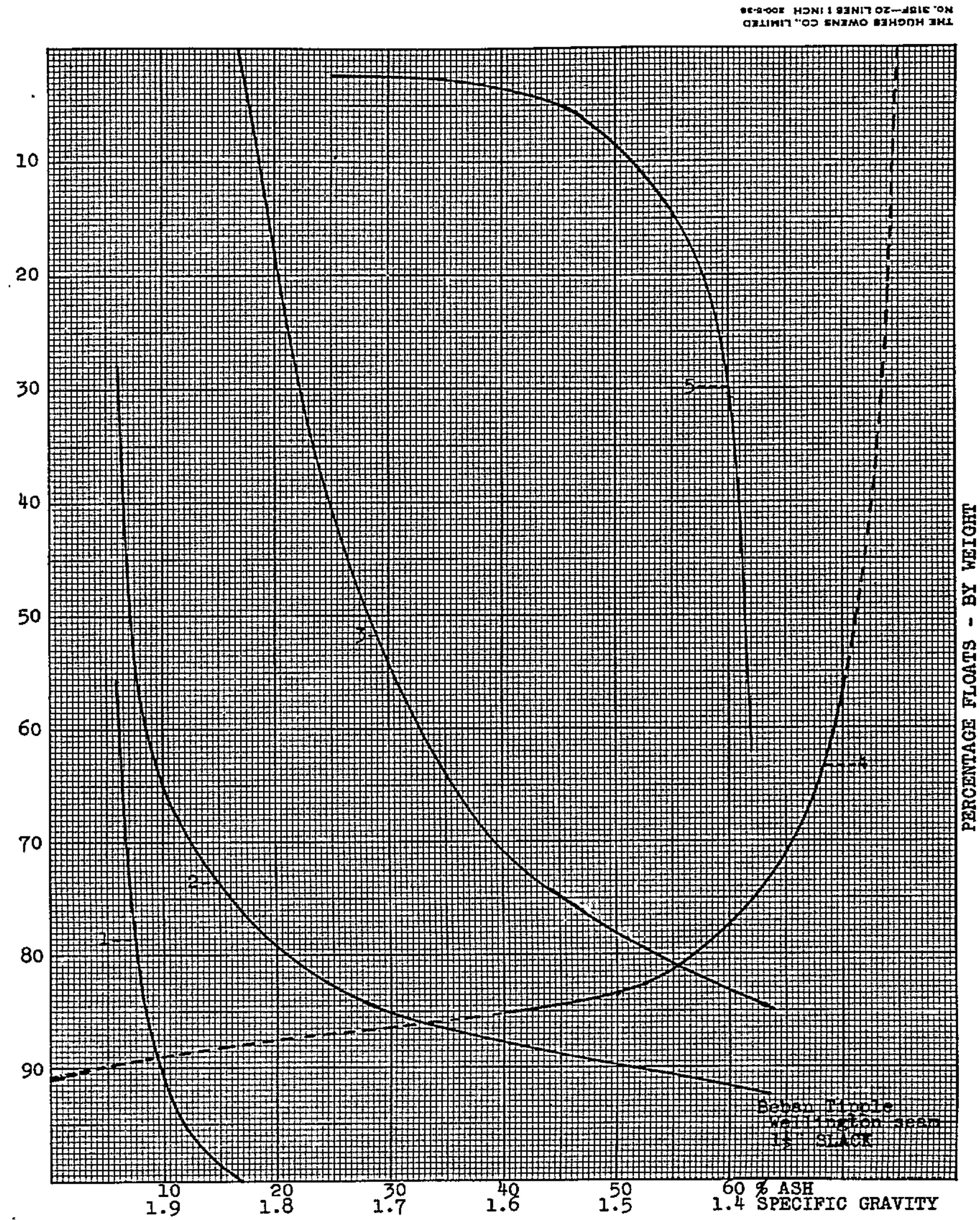

FIG.1 - Washability Curves for 1½" Slack - Beban Tipple, Wellington Seam.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity.
Curve 5 - ±.10 specific gravity distribution.

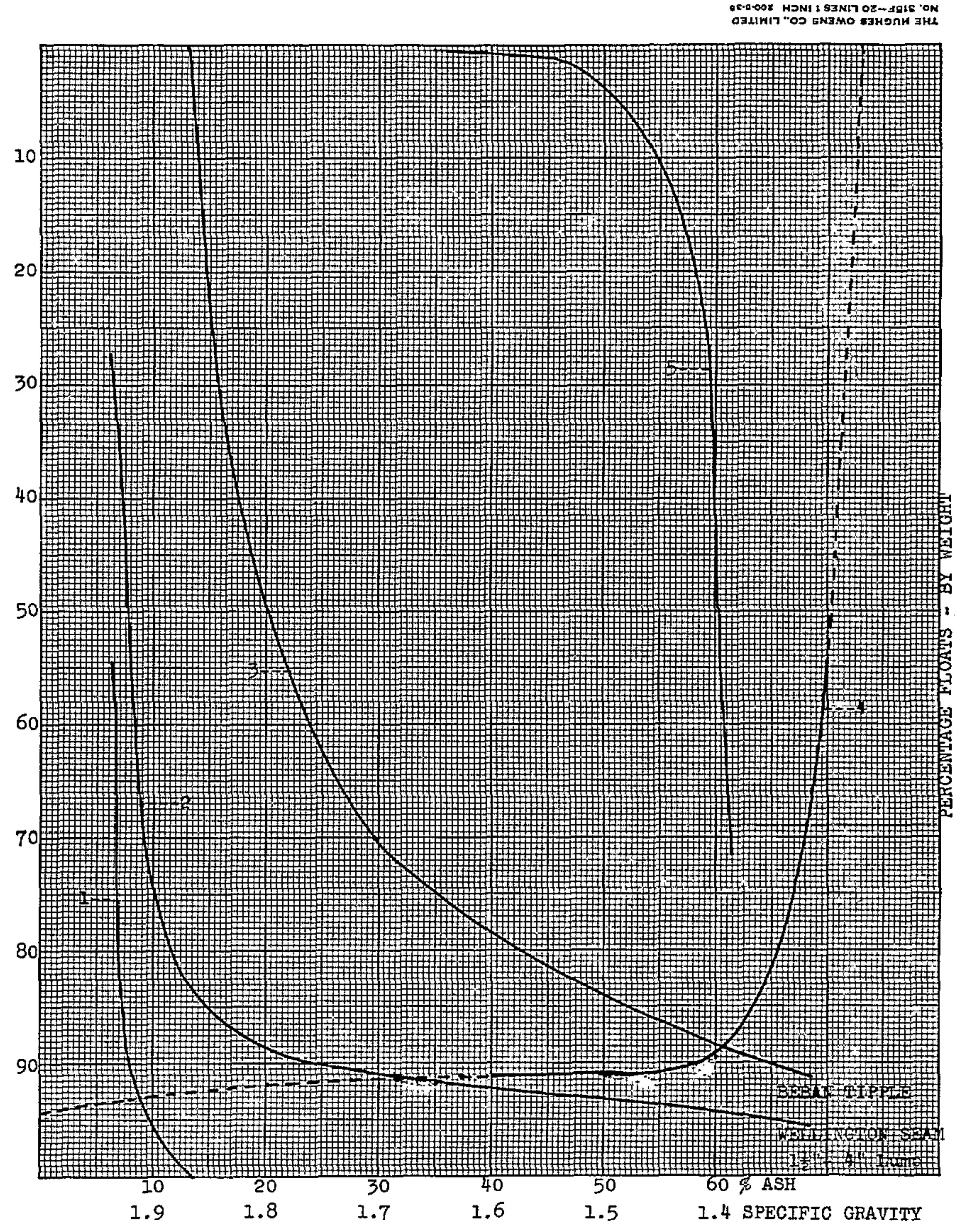

FIG.II - Washability Curves for 1½" - 4" Lump - Beban Tipple, Wellington Seam.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity.
Curve 5 - $\pm$.10 specific gravity distribution.

V

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Beban tipple mines coal are shown in Table XVIII.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard. The results of this test are also given in Table XVIII.

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant by-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737 - 2.

TABLE XVIII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

AS INDICATED BY A

"SWELLING INDEX" TEST

		$1\frac{1}{2}$ in. Slack Washed at 1.60 Sp.Gr.
Volatile Matter at 600°C. (D.B.) . . %		29.6
Swelling Index		50.7
Section--Coke Classification Chart . .		VI
Specific Volatile Index		155.6
Section--Coal Classification Chart . .		C-Subbituminous; agglomerating
Ash per cent in coal (dry)		8.9
PHYSICAL PROPERTIES OF BY-PRODUCT COKE--		
Size on wharf	% on 3" screen	40.0
	Breeze: %-1/2"	4.0
Shatter test	Index: % on 2" screen	35.0
	Breeze: %-1/2"	5.0
Abrasion test	Index: % on $1\frac{1}{2}$" screen	65.0
	Dust: %-1/16"	5.5
Density	App. Specific Gravity	0.85
	lbs. per cubic foot .	25.0
Transverse shrinkage		Very good.
Appearance of natural surface		Steel grey, Irregular
Shape		Triangular, very fingery
Strength		Very fragile
Cross fracture		Med. to large amt. Steppy
Longitudinal fracture		Large amount.
Cell structure		Medium to large.
Sponge		Medium amount.
Pebbly seam		None.
REMARKS		This coal will make a very poor coke in standard by-product ovens. However in suitable equipment a good domestic coke might be prepared.

Caking Properties	Gray Caking Index
Mine Run	45

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Beban tipple Mines, Wellington Seam operated by Chambers R.H. and Hamilton Extension Mine in cooperation with the Canadian Collieries (Dunsmuir) Ltd. in the Nanaimo area, British Columbia, was collected at the mine tipple by sampling from freshly mined coal. In this way approximately 1,940 pounds of coal, representative of the seam at these mines at the time of sampling during July 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 12.1% of the coal was below 1/8 inch in size, 32.8% was above 4 inch in size, and 14.2% was 2 to 4 inch in size, the remaining 40.9% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 2.90 inch, yielding 49.2% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability tests on the coal from the Beban tipple Mines are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was quite friable, the size stability being 76.6% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing. Reduction in ash content will no doubt materially improve the grinding characteristics of the coal.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicated that, when the coke cutter was set at $1\frac{1}{2}$ inch, the coal was reduced in size to 24.9% of that of the uncrushed lumps, that is from an average particle size of 6.625 inches to an average particle size of 1.652 inches. This crushing resulted in the production of 60.3% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 15.4% of 1/2 to 1 inch 'stoker' coal, and 6.2% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 18.1% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes range widely in ash content. As the size decreased from the +4 inch lump to the 0-48 mesh dust the ash increases from 7.6% to 29.7%. It is noteworthy that the sizes above $1\frac{1}{2}$ inch are appreciably lower in ash than the sizes composing the $1\frac{1}{2}$ inch slack. This is indicated by the analyses of the composites. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 15.0% ash, the +1½ inch lump 9.3% ash, and the 0 to 1½ inch slack 20.6% ash. The sulphur content of this coal is low and uniform for all the sizes examined, being 0.40%.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 156 which places it in the agglomerating subbituminous class of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile A bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is medium carbon and high oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table VIII gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is fairly uniform ranging from 2250°F to 2490°F. The fusibility of the ash seems to vary with the ash content of the coal, the lower ash lump sizes showing a somewhat lower ash fusion temperature than the higher ash smaller sizes. Examination of the float-and-sink data for the 1½" slack indicates that the mineral matter of the high ash material is of such a nature as to have a relatively higher softening temperature, 2800°F, than the lower ash fractions. Removal of this high ash fraction affects the composite ash in a manner to lower the ash fusibility.

Laboratory Washing Tests

The washing tests on the coal from the Beban tipple Mines were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X,

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2

it will be noted that the $1\frac{1}{2}$ inch slack has a high inherent ash content of 6.0% and a relatively low sulphur content of 0.4% as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 55.8% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the $\pm$.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 83.2% clean coal having 8.9% ash and 0.4% sulphur; these data are shown in Table XIII. It should be noted that the sulphur reduction is negligible, and this is due to the fact that the sulphur occurs mainly as organic material. The washing data for the $1\frac{1}{2}$ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The inherent ash is high in amount, the $1\frac{1}{2}$ to 4 inch lump showing 6.1% ash in 54.2 % of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 9.6% ash in 33.2% of the coal floating at the same gravity. Washing the $1\frac{1}{2}$ to 4 inch lump at a selected gravity of 1.60 would be relatively simple, but because of the apparent variation in quantity of free stone in these sizes the quantity of rejects will vary to some extent. The coal may be washed down to about 8.5% ash. Washing the crushed +4 inch lump in a similar manner is rather difficult unless free stone is present. If properly handpicked the ash will be so low that washing will not be effective. It is thus concluded that the sample of Wellington seam coal, as obtained at the Beban tipple Mines is amenable to cleaning by either wet or dry processes, and the ash could be reduced to less than 10% but would result in a high refuse loss.

<u>Coking Properties</u>

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the Beban tipple Mine, indicated that the coal had only fair coking characteristics, in so far as use in standard by-product ovens is concerned. The Swelling Index was 50.7, which according to the coke classification chart, should result in a poor domestic coke as indicated in Table XVIII. Processing the coal in suitable equipment such as Curran Knowles ovens may result in the preparation of a good domestic product.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Beban tipple Mines coal indicated a coal that is fairly strong caking, the caking index being 45.

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Physical and Chemical Survey Report No. 84

STUDY OF COAL FROM

WELLINGTON NO. 8 (TIMBERLANDS) MINE, WELLINGTON SEAM,

NANAIMO AREA, VANCOUVER ISLAND.

OPERATED BY

CANADIAN COLLIERIES (DUNSMUIR) LTD., NANAIMO, B.C.

BY

E. SWARTZMAN

Fuel Research Laboratories
Bureau of Mines
Ottawa Canada

VHJ

April, 1942

Physical and Chemical Survey Report No. 84

Study of Coal from

Wellington No. 8 (Timberlands) Mine, Wellington Seam,

Nanaimo Area, Vancouver Island.

Operated by

Canadian Collieries (Dunsmuir) Ltd., Nanaimo, B.C.

Table of Contents

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Wellington No. 8 Mine; Wellington Seam, worked in the Nanaimo area, Cranberry district, in close proximity to McKay's Lake near Nanaimo, British Columbia, by the Canadian Collieries (Dunsmuir) Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-three reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the Wellington seam was sampled at the mine by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. It should be noted that this mine was closed down since 1928 and was reopened during the summer of 1941. As the mine was not yet in operation at the time of the writer's visit to the property the sample of coal for the Survey was obtained from a fresh face on the 1st right level at a point about 200 feet in from the main slope. The combined sample, which weighed approximately 2203 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Insutrial Development of the Canadian Pacific Railway Company, officials of the

British Columbia Department of Mines, and various members of the Canadian Collieries (Dunsmuir) Ltd., for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H. NICOLLS of the Fuel Research Laboratories under whose direction the major portion of the chemical analyses was conducted.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Wellington No. 8 Mine, Wellington Seam, was collected at the mine during July 1941 from a fresh face exposed within a few weeks after the mine was de-watered. The coal was hand-pick mined, and a sample of the unprepared run-of-mine coal, weighing approximately 2203 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability.

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.), with R.E. Gilmore of the Fuel Research Laboratories

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, and BULK DENSITY

Screen Sizes[a]	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	26.2	26.2	1.29	45.50	11.5
2 - 4 in.	21.5	47.7	1.28	42.00	10.9
1½ - 2 in.	6.3	54.0	1.26	41.75	12.2
1 - 1½ in.	10.1	64.1	1.25	41.75	12.2
3/4 - 1 in.	5.8	69.9	1.22	41.75	12.0
1/2 - 3/4 In.	6.8	76.7	1.20	41.25	13.0
1/4 - 1/2 in.	8.2	84.9	1.22	40.75	12.8
1/8 - 1/4 in.	5.5	90.4	1.23	40.25	13.3
#48 - 1/8 in.	6.9	97.3	1.21	49.50	16.3
0 - #48	2.7	100.0			26.3
Mine Run		100.0		-----	13.4
Plus 1½ in.		54.0		-----	13.2
0 - 1½ in.		46.0		52.50	13.6
3/4 - 1½ in.		15.9		-----	13.3
0 - 1/8 in.		9.6	1.21	49.50	18.2

	As Received
Average Size of Run-of-Mine ....in.	2.74

[a] All screens 1/8 in. and larger are round-hole screens. No.48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the Wellington No. 8 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1, was used for evaluating the grindability of the coal from the Wellington Seam of the Wellington No. 8 Mine.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite;
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal.

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Methodof Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test		
	2 - 3 in.		
	Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	59.5	46.5
1½ - 2 in.		13.5	16.0
1 - 1½ in.		10.3	11.3
3/4 - 1 in.		4.2	5.2
1/2 - 3/4 in.		4.0	5.7
0 - 1/2 in.		8.5	15.3
Av'g Size in.	2.500	1.936	1.701
Size Stab'ty %		77.4	68.0

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	58.4
0 - 1½ in.	63.9
0 - 1/8 in.	73.3

Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

5. Crushing Test.

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at 1½in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Wellington No. 8 Mine coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 INCH LUMP
(Crusher set at 1½ inch)

	Screen Analysis	
	Before Crushing %	After Crushing %
12 to 14 in.	5.3	
10 - 12 in.	5.7	
8 - 10 in.	10.7	
7 - 8 in.	8.8	
6 - 7 in.	17.9	
5 - 6 in.	21.0	
4 - 5 in.	30.6	2.4
3 - 4 in.		9.6
2 - 3 in.		39.2
1½ - 2 in.		12.4
1 - 1½ in.		11.7
3/4 - 1 in.		6.4
1/2 - 3/4 in.		5.7
1/4 - 1/2 in.		5.7
1/8 - 1/4 in.		3.4
0 - 1/8 in.		4.5
Average Particle Size-in.	6.635	1.910
Size Reduction %		28.79

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the Wellington No. 8 Mine, were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.

2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.

3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, which is given in Table VII. Data on temperature lags are presented because of thiir bearing on the clinkering properties.

4. The Chemical Analyses of Ash, which are shown in Table VIII.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/Lb.
Plus 4 in.	0.8	11.5	34.7	53.8	0.4	-----
2 - 4 in.	0.9	10.9	35.3	53.8	0.4	13310
1½ - 2 in.	0.9	12.2	35.0	52.8	0.4	-----
1 - 1½ in.	0.9	12.2	35.4	52.4	0.4	-----
3/4 - 1 in.	0.9	12.0	35.5	52.5	0.4	-----
1/2 - 3/4 in.	0.7	13.0	35.0	52.0	0.4	-----
1/4 - 1/2 in.	0.9	12.8	34.9	52.3	0.4	-----
1/8 - 1/4 in.	0.9	13.3	34.2	52.5	0.4	-----
#48 - 1/8 in.	0.7	16.3	33.2	50.5	0.4	-----
0 - #48	0.6	26.3	32.2	41.5	0.5	-----
Mine Run -	0.8	13.4	34.1	52.5	0.4	12920
Plus 1½ in.	0.8	13.2	34.6	52.2	0.4	12965
0 - 1½ in.	0.9	13.6	34.7	51.7	0.4	12835
3/4 - 1½ in.	0.8	13.3	34.5	52.2	0.4	12940
0 - 1/8 in.	1.0	18.2	33.6	48.2	0.4	11955

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	72.6	5.1	0.4	1.3	7.2	13.4

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2080	2200	2240	160	120	40	11.5
2 - 4 in.	2200	2290	2330	130	90	40	10.9
1½ - 2 in.	2090	2200	2240	150	110	40	12.2
1 - 1½ in.	2090	2190	2250	160	100	60	12.2
3/4 - 1 in.	2060	2200	2240	180	140	40	12.0
1/2 - 3/4 in.	2150	2230	2280	130	80	50	13.0
1/4 - 1/2 in.	2150	2240	2280	130	90	40	12.8
1/8 - 1/4 in.	2150	2230	2280	130	80	50	13.3
#48 - 1/8 in.	2140	2260	2300	160	120	40	16.3
0 - #48	2160	2320	2360	200	160	40	26.3
Mine Run	2150	2230	2340	190	80	110	13.4
Plus 1½ in.	2100	2200	2240	140	100	40	13.2
0 - 1½ in.	2100	2200	2240	140	100	40	13.6
3/4 - 1½ in.	2080	2180	2210	130	100	30	13.3
0 - 1/8 in.	2120	2230	2250	130	110	20	18.2

TABLE VIII

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run												

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4-inch screen prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of

wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult ..	Efficient process; high tonnage
10 - 15	Difficult..............	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult .	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the total sulphur of this coal is very low, a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in the following tables:

TABLE IX

Float and Sink Data on 1½" Slack

– Ash –

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
Floats 1.30	43.3	7.1	43.3	7.1	100.0	12.3	1.35	95.4
Sinks 1.30 Floats 1.40	46.6	11.7	89.9	9.5	56.7	16.2	1.40	52.0
" 1.40 " 1.50	4.1	21.5	94.0	10.0	10.1	37.0	1.45	15.9
" 1.50 " 1.60	1.5	30.5	95.5	10.3	6.0	47.7	1.55	2.9
" 1.60	4.5	53.4	100.0	12.3	4.5	53.4	1.65	1.2
							1.75	0.7
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack
(Dry Basis)

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.30	7.2	36.5	56.3	Good	0.4	2440	2510	2550	110	70	40
Sinks 1.30 Floats 1.40	11.8	34.1	54.1	Good	0.5	2130	2210	2260	130	80	50
" 1.40 " 1.50	21.7	30.9	47.4	Fair to Good	0.4	2040	2140	2300	260	100	160
" 1.50 " 1.60	30.9	29.9	39.2	Poor	0.3	2190	2330	2440	250	140	110
" 1.60	54.1	22.6	23.3	Agglomerate	0.2	2210	2340	2440	230	130	100

TABLE XI

Float and Sink Data on 1½ - 4 in. Lumps

- A h -

Specific Gravity			Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats	1.30	43.4	6.8	43.4	6.8	100.0	9.4	1.35	100.0
Sinks 1.30	"	1.40	55.0	11.1	98.4	9.2	56.6	11.4	1.40	56.6
" 1.40	"	1.50	1.6	20.8	100.0	9.4	1.6	20.8	1.45	17.0
Curve No.		4		2	1,2,4	1	3	3	5	5

TABLE XII

Float and Sink Data on Plus 4 in. Lumps (Crushed)

- Ash -

Specific Gravity			Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
									1.35	96.4
	Floats	1.30	34.1	7.1	34.1	7.1	100.0	10.9	1.40	62.8
Sinks 1.30	"	1.40	57.7	9.8	91.8	8.8	65.9	12.9	1.45	15.0
" 1.40	"	1.50	3.9	25.3	95.7	9.5	8.2	34.7	1.55	3.1
" 1.50	"	1.60	1.8	34.4	97.5	9.9	4.3	43.3	1.65	0.9
" 1.60			2.5	49.7	100.0	10.9	2.5	49.7	1.75	0.3
Curve No.		4		2	1,2,4	1	3	3	5	5

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE
0 to 1½ Inch Slack

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	93.9	6.1
Proximate Analysis (dry basis)			
Ash .... %	13.6	10.2	43.4
Volatile Matter .... %	34.7	35.9	25.4
Fixed Carbon .... %	51.7	53.9	31.2
Sulphur .... %	0.5	0.5	0.3
Calorific Value .... B.T.U./lb.	12835	13520	----
Fusion Point of Ash .... °F.	2200	2290	2300
Melting Range of Ash .... °F.	140	150	200
Coking Properties	Good	Good	Agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE
Plus 4 Inch Lump (Crushed)

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	94.1	5.9
Proximate Analysis (dry basis)			
Ash .... %	11.5	9.2	37.1
Volatile Matter .... %	34.7	35.3	26.5
Fixed Carbon .... %	53.8	55.5	36.4
Sulphur .... %	0.4	0.5	0.3
Calorific Value .... B.T.U./lb.	13220*	13635	----
Fusion Point of Ash .... °F.	2200	2390	2380
Melting Range of Ash .... °F.	160	190	310
Coking Properties	Good	Good	Poor

* Calculated

TABLE XV

SCREEN ANALYSIS AND CHEMICAL ANALYSIS
(Dry Basis of 1½" Slack)

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	34.6	34.6	13.3	0.4	2180
1/8 - 3/4 inch	44.6	79.2	13.0	0.4	2230
0 - 1/8 inch	20.8	100.0	18.2	0.4	2230

TABLE XVI

FLOAT AND SINK DATA ON SCREENED SIZES
USING A SELECTED GRAVITY OF 1.60
(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F.	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ inch	96.9	10.3	2290	3.1	42.0	2350
1/8 - 3/4 inch	94.2	10.2	2230	5.8	41.7	2270
0 - 1/8 inch	77.0	8.8	2240	23.0	51.0	2270

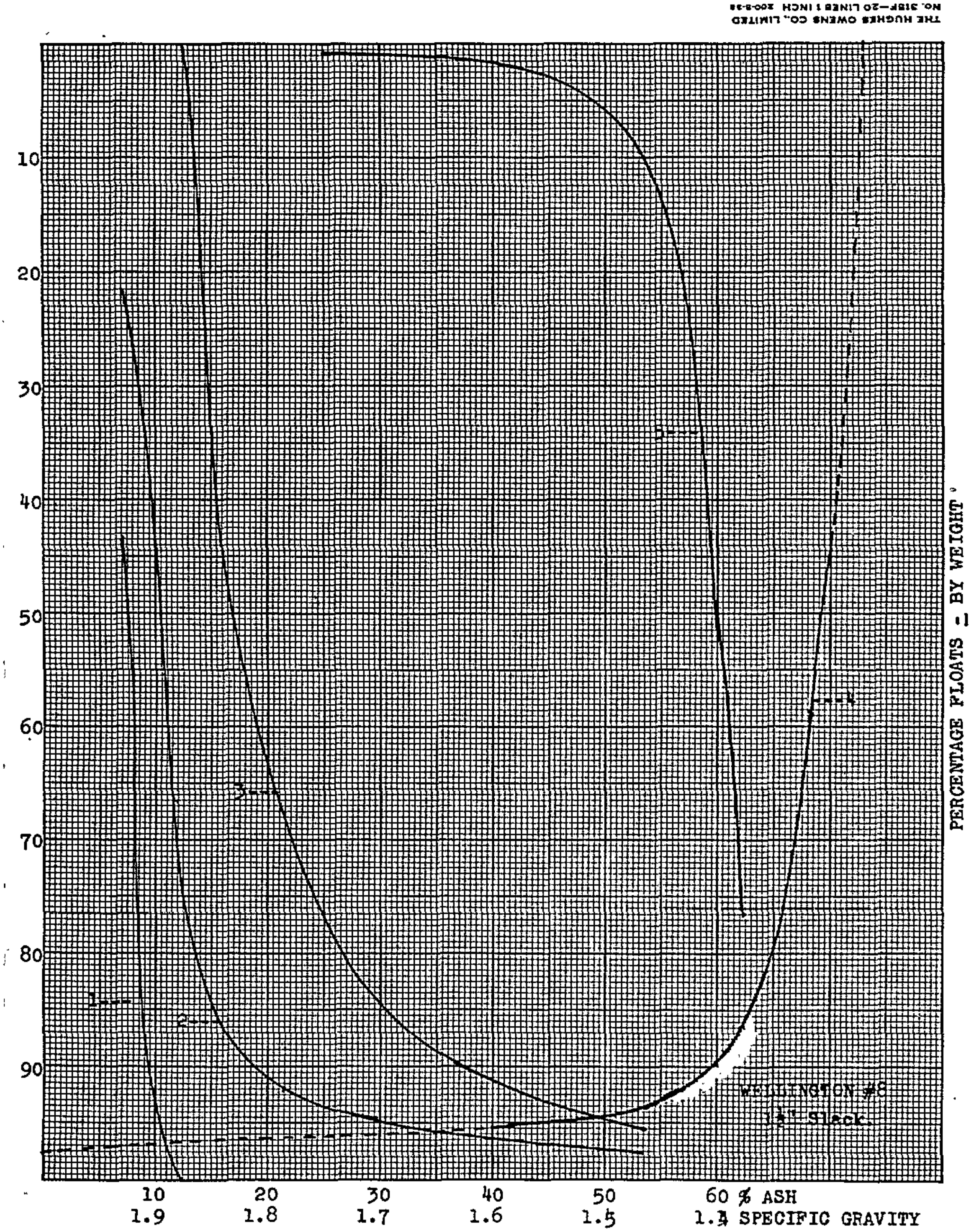

FIG. I - Washability Curves for 1½" Slack Wellington No. 8 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

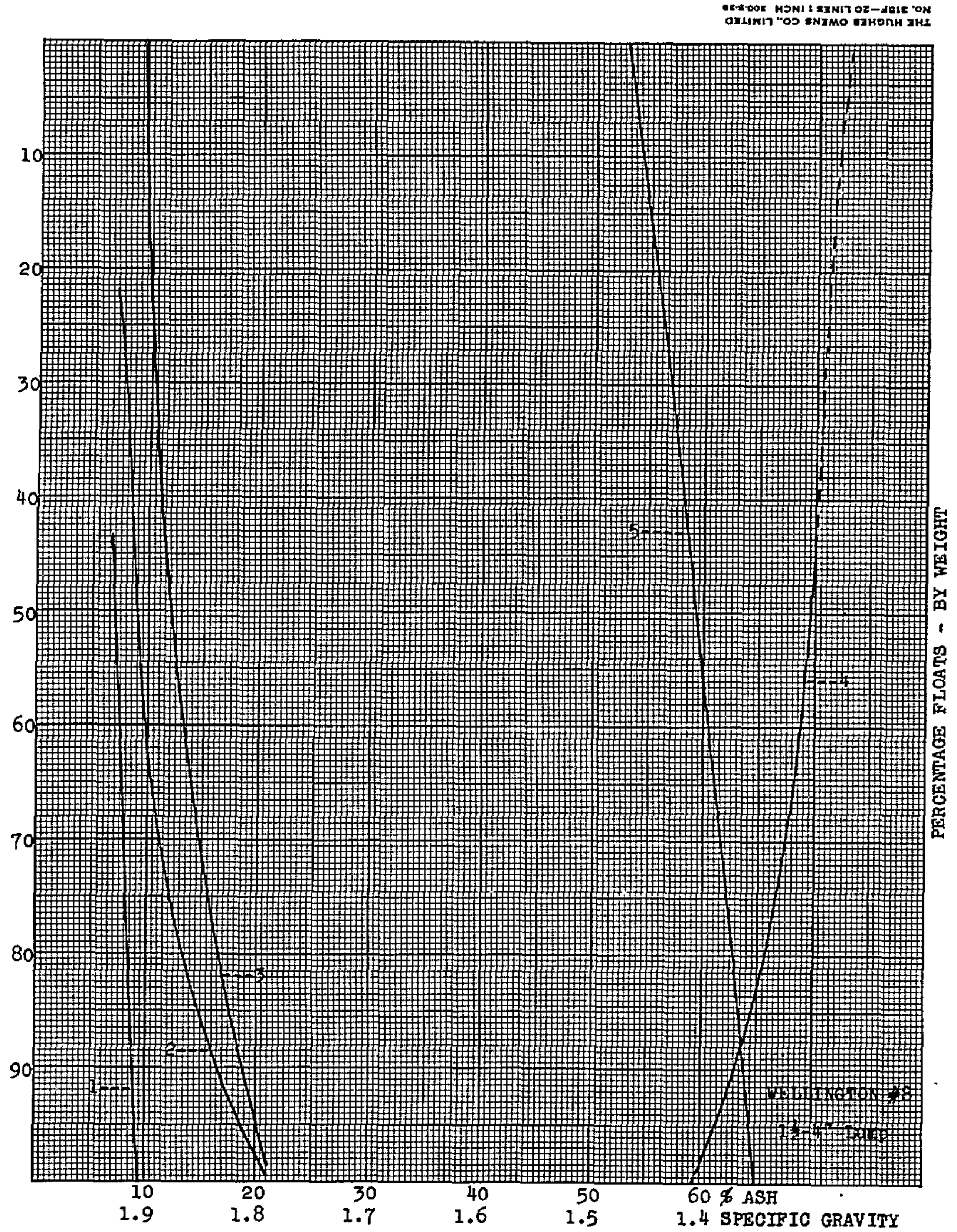

FIG. II - Washability Curves for 1½"- 4" Lump - Wellington No.8 Mine

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

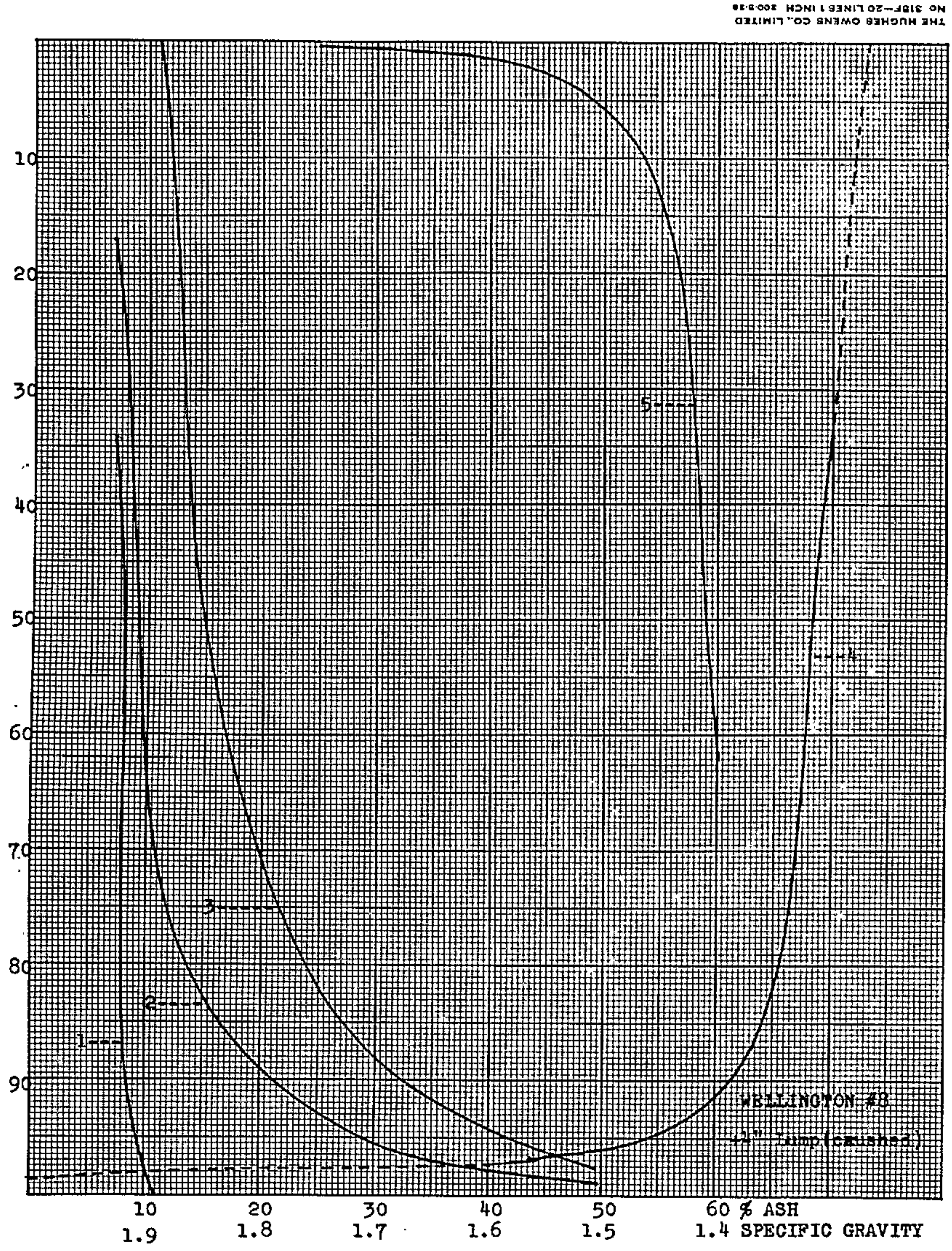

FIG.III - Washability Curves for Plus 4-in.Lump - Wellington No.8 Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Wellington No. 8 mine coal are shown in Table XVII.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard.

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant by-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737-2.

The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designed as the 'caking index'. The higher the 'caking index' the greater are the coking properties. The results of this test conducted on the Wellington No. 8 Mine are shown in Table XVII.

TABLE XVII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A
"SWELLING INDEX" TEST

		0-1½ in. Slack Washed at 1.60 Sp. Gr.
Volatile Matter at 600°C. (D.B.) ...... %		29.5
Swelling Index		603
Section--Coke Classification Chart		Border of VII & V
Specific Volatile Index		161.2
Section--Coal Classification Chart		Parabituminous 0
Ash per cent in coal (dry) ....%		10.2
PHYSICAL PROPERTIES OF BY-PRODUCT COKE --		
Size on wharf	(% on 3" screen	50.0
	(Breeze: %-1/2"	4.0
Shatter test	(Index: % on 2" screen ..	55.0
	(Breeze: %-1/2"	3.0
Abrasion test	(Index: % on 1½" screen .	85.0
	(Dust: %-1/16"	3.0
Density	(App. Specific Gravity ..	0.95
	(Lbs. per cubic foot	26.0
Transverse shrinkage		Good
Appearance of natural surface		Steel grey; Irregular
Shape		Triangular
Strength		Hard to Fragile
Cross fracture		Medium, somewhat steppy
Longitudinal fracture		Medium amt.
Cell structure		Medium to small
Sponge		Small amt.
Pebbly seam		None
REMARKS		This coal should make a fair domestic by-product coke.

CAKING PROPERTIES

	Gray Caking Index
Mine Run Sample	58

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Wellington No.8 Mine, Wellington Seam, operated by the Canadian Collieries (Dunsmuir) Ltd. in the Nanaimo area, Cranberry district, British Columbia, was collected at the mine by sampling from a freshly exposed face. In this way approximately 2,203 pounds of coal, representative of the seam at this mine at the time of sampling during July 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 9.6% of the coal was below 1/8 inch in size, 26.2% was above 4 inch in size, and 21.5% was 2 to 4 inch in size, the remaining 42.7% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 2.74 inch, yielding 46.0% of 1½" slack. It should be noted that as this coal was hand mined and not loaded into cars it received far less abuse than would be usual under normal operation when machine mining and possibly mechanical loading would be used. Thus under regular production conditions the quantity of slack and fines would be greater than exhibited by this sample, with an attendent proportionate reduction in the larger lump sizes.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the Wellington No. 8 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 77.4% after two drops. This is a further indication that under normal mining and handling conditions the average particle size of the mine run coal would be substantially lower than is indicated by the sample used in these tests.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No.737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing. This conforms with the results obtained in most other low rank bituminous coals.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 28.8% of that of the uncrushed lumps, that is, from an average particle size of 6.635 inches to an average particle size of 1.910 inches. This crushing resulted in the production of 63.3% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 12.1% of 1/2 to 1 inch 'stoker' coal, and 12.0% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 13.6% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes are uniformly medium in ash content with the fines passing a 1/8 inch screen, indicating a substantial increase in ash content with a decrease in size. The coal lumps retained on a 1/8 inch screen are more or less uniform, varying in ash from 10.9% to 13.3%, whereas the fines (0-1/8 in.) had an ash content of 18.2%, with the dust (0-48 mesh) containing 26.3% ash. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 13.4% ash, the +1½ inch lump 13.2% ash, and the 0 to 1½ inch slack 13.6% ash. The sulphur content of this coal is very low and uniform for all the sizes examined, and hence will occur mainly in the organic form. Visual examination of the coal indicated that there was no or very little pyrite present. The moisture content for all the sizes, was uniform on the 'as received' basis, with an average of 0.8% for the mine-run coal.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 161 which places it in the parabituminous class of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile A bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a medium carbon and relatively high

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1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2

oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table VIII gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is uniformly low ranging from 2190 °F. to 2320 °F. The fusibility of the ash does not vary with the ash content of the coal. Examination of the float-and-sink data indicates that although the mineral matter of the low ash material is of such a nature in the 0 - 1½" slack sizes as to have a relatively higher softening temperature, (2510°F.), than the higher ash fractions it does not affect the composite ash in a manner to raise the ash fusibility materially when some of the high ash fractions are removed.

Laboratory Washing Tests

The washing tests on the coal from the Wellington No. 8 Mine, were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be noted that the 1½ inch slack has a high inherent ash content of 7.1%, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 43.3% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 93.9% clean coal having 10.2% ash; these data are shown in Table XIII. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The results of the tests on these sizes are somewhat similar to that obtained with the 1½ inch slack. The inherent ash is high in amount, the 1½ to 4 inch lump showing 6.8% ash in 43.4% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 7.1% ash in 34.1% of the coal floating at the same gravity.

Washing the 1½ to 4 inch lump if it contained more than 10% ash, at a selected gravity of 1.60 would be relatively simple, but a reduction in ash below 10% is not expected. The particular sample tested contained less than 10% ash and, as indicated by the washability curves could not be cleaned to a lower ash content. Washing the crushed +4 inch lump in a similar manner would yield about 94.1% clean coal containing about 9.2% ash (see Table XIV). It is thus concluded that the sample of Wellington coal, as obtained at the Wellington No. 8 Mine, is not very amenable to cleaning by either wet or dry processes, and the ash could not economically be reduced to much less than 10%. It should be noted that crushing the +4 inch lump materially aided in improving the washing characteristics of this size.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the Wellington No. 8 Mine, indicated that the coal had fairly good coking characteristics, in so far as use in standard by-product ovens is concerned. The Swelling Index was 603, which according to the coke classification chart, should result in a fair domestic coke as indicated in Table XVII.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Wellington No. 8 Mine coal indicated a coal that is strongly caking, the caking index being 58.

Report of Investigations--Carbonization Section - 175

Physical and Chemical Survey Report No. 85

STUDY OF COAL FROM
NO. 10, SOUTH WELLINGTON MINE, DOUGLAS SEAM,
NANAIMO AREA, VANCOUVER ISLAND.
OPERATED BY
CANADIAN COLLIERIES (DUNSMUIR) LTD., NANAIMO, B.C.

BY

E. SWARTZMAN

Fuel Research Laboratories
Bureau of Mines
Ottawa Canada

VHJ

June, 1942

TABLE VIII

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run	36.5	5.1	20.4	23.8	4.5	0.1	1.7	0.5	0.2	1.3	5.4	99.5

For Insertion in R.I.C.S-174 — #8 Wellington

Physical and Chemical Survey Report No. 85

Study of Coal from

No. 10, South Wellington Mine, Douglas Seam,

Nanaimo Area, Vancouver Island.

Operated by

Canadian Collieries (Dunsmuir) Ltd., Nanaimo, B.C.

Table of Contents

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the No. 10 South Wellington Mine, Douglas seam, worked in the Nanaimo area, Cranberry district, about seven miles south of the City of Nanaimo, British Columbia, by the Canadian Collieries (Dunsmuir) Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-four reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the Douglas seam was sampled at the mine by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 2582 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial Development of the Canadian Pacific Railway Company, officials of the British Columbia Department of Mines, and various members of the Canadian Collieries (Dunsmuir) Ltd., for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H.NICOLLS of the Fuel Research Laboratories

under whose direction the major portion of the chemical analyses was conducted.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the No. 10 Mine, Douglas Seam, was collected at the mine during July 1941 from representative mine cars as they were being dumped for screening. A sample of the unprepared run-of-mine coal, weighing approximately 2582 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity.

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.), with R.E.Gilmore of the Fuel Research Laboratories as Chairman, has investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for

Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and " on the assumption that friability may be measured by an index or percentage, it amy also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the No. 10 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coal from the Douglas Seam of the No. 10 Mine.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite;
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, and BULK DENSITY

Screen Sizes†	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	17.8	17.8	1.32	45.0	8.7
2 - 4 in.	13.5	31.3	1.35	44.0	12.4
1½ - 2 in.	3.0	34.3	1.35	44.0	12.0
1 - 1½ in.	6.9	41.2	1.34	44.3	12.3
3/4 - 1 in.	4.8	46.0	1.33	44.0	13.5
1/2 - 3/4 in.	7.8	53.8	1.34	43.5	14.6
1/4 - 1/2 in.	11.6	65.4	1.35	43.5	15.9
1/8 - 1/4 in.	11.1	76.5	1.35	43.0	19.4
#48 - 1/8 in.	16.1	92.6	1.41	49.0	23.2
0 - #48	7.4	100.0			26.8
Mine Run		100.0			16.5
Plus 1½ in.		34.3			9.7
0 - 1½ in.		65.7		57.5	19.3
3/4 - 1½ in.		11.7			14.0
0 - 1/8 in.		23.5	1.41	49.0	23.9

		As Received
Average Size of Run-of-mine	in.	1.80

† All screens 1/8 in. and larger are round-hole screens. No.48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test 2 - 3 in.		
	Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	52.0	33.5
1½ - 2 in.		15.0	14.5
1 - 1½ in.		8.0	14.0
3/4 - 1 in.		5.5	5.5
1/2 - 3/4 in.		5.0	7.0
0 - 1/2 in.		14.5	25.5
Av'g Size in.	2.500	1.778	1.415
Size Stab'ty %		71.1	56.6

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	81.6
0 - 1½ in.	82.3
0 - 1/8 in.	92.0

5. Crushing Test.

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch No. 10 Mine coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 INCH LUMP
(Crusher set at 1½ inch)

	Screen Analysis	
	Before Crushing %	After Crushing %
8 - 10 in.	14.0	
7 - 8 in.	12.4	
6 - 7 in.	15.7	
5 - 6 in.	25.8	
4 - 5 in.	32.1	0.3
3 - 4 in.		3.0
2 - 3 in.		32.8
1½ - 2 in.		13.2
1 - 1½ in.		13.0
3/4 - 1 in.		7.9
1/2 - 3/4 in.		8.4
1/4 - 1/2 in.		9.6
1/8 - 1/4 in.		6.0
0 - 1/8 in.		5.8
Average Particle size-in.	6.075	1.505
Size Reduction -------- %		24.77

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the No. 10 Mine, were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.
2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.
3. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, which is given in Table VII. Data on temperature lags are presented because of their bearing on the clinkering properties.
4. The Chemical Analyses of Ash, which are shown in Table VIII.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis: Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/Lb
Plus 4 in.	2.0	8.7	38.6	52.7	0.4	-----
2 - 4 in.	2.0	12.4	37.5	50.1	0.5	12650
1½ - 2 in.	1.9	12.0	37.3	50.7	0.7	-----
1 - 1½ in.	1.8	12.3	37.5	50.2	0.4	-----
3/4 - 1 in.	1.8	13.5	38.2	48.3	0.5	-----
1/2 - 3/4 in.	1.8	14.6	37.0	48.4	0.5	-----
1/4 - 1/2 in.	1.8	15.9	36.4	47.7	0.5	-----
1/8 - 1/4 in.	1.8	19.4	35.0	45.6	0.5	-----
#48 - 1/8 in.	1.5	23.2	34.2	42.6	0.5	-----
0 - #48	1.5	26.8	33.5	39.7	0.5	-----
Mine Run	2.0	16.5	36.4	47.1	0.5	12130
Plus 1½ in.	2.1	9.7	38.2	52.1	0.4	13170
0 - 1½ in.	2.0	19.3	35.5	45.2	0.5	11745
3/4 - 1½ in.	1.9	14.0	37.1	48.9	0.5	12390
0 - 1/8 in.	1.9	23.9	34.4	41.7	0.5	11030

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	68.7	5.0	0.5	1.3	8.0	16.5

TABLE VII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2290	2350	2400	110	60	50	8.7
2 - 4 in.	2230	2290	2330	100	60	40	12.4
1½ - 2 in.	2180	2250	2300	120	70	50	12.0
1 - 1½ in.	2180	2250	2300	120	70	50	12.3
3/4 - 1 in.	2180	2250	2300	120	70	50	13.5
1/2 - 3/4 in.	2060	2160	2200	140	100	40	14.6
1/4 - 1/2 in.	2180	2260	2310	130	80	50	15.9
1/8 - 1/4 in.	2220	2330	2370	150	110	40	19.4
#48 - 1/8 in.	2230	2320	2350	120	90	30	23.2
0 - #48	2230	2320	2370	140	90	50	26.8
Mine Run	2090	2210	2250	160	120	40	16.5
Plus 1½ in.	2160	2370	2410	250	210	40	9.7
0 - 1½ in.	2100	2360	2390	290	260	30	19.3
3/4 - 1½ in.	2090	2210	2280	190	120	70	14.0
0 - 1/8 in.	2110	2300	2350	240	190	50	23.9

TABLE VIII

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run	38.0	7.8	20.5	18.6	5.8	0.1	0.5	1.1	1.2	0.9	5.3	99.8

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4-inch screen prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

± .10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult ...	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult ..	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur. However, as the total sulphur of this coal is very low, a detailed study of the washing characteristics with reference to this material is unnecessary.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in the following tables:

TABLE IX

Float and Sink Data on 1½" Slack

– Ash –

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
							1.35	86.3
Floats 1.30	22.5	5.4	22.5	5.4	100.0	14.8	1.40	66.8
Sinks 1.30 " 1.40	52.0	9.7	74.5	8.4	77.5	17.5	1.45	25.7
" 1.40 " 1.50	10.5	18.3	85.0	9.6	25.5	33.5	1.55	10.4
" 1.50 " 1.60	4.1	24.8	89.1	10.3	15.0	44.1	1.65	5.0
" 1.60	10.9	51.3	100.0	14.8	10.9	51.3	1.75	3.1
Curve No. 4		2	1,2,4	1	3	3	5	5

TABLE X

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.30	5.5	39.0	55.4	Good	0.4	2040	2200	2240	200	160	40
Sinks 1.30 " 1.40	10.0	39.0	51.0	Good	0.5	2060	2210	2250	190	150	40
" 1.40 " 1.50	18.7	35.4	45.9	Fair	0.4	2080	2180	2210	130	100	30
" 1.50 " 1.60	25.2	32.9	41.9	Poor	0.4	2100	2240	2300	200	140	60
" 1.60	52.3	25.5	22.2	Weak Agglomerate	0.4	2100	2250	2310	210	150	60

TABLE XI

Float and Sink Data on $1\frac{1}{2}$-4 in. Lump

– Ash –

Specific Gravity			Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
									1.35	93.6
	Floats	1.30	11.6	5.5	11.6	5.5	100.0	13.9	1.40	83.0
Sinks 1.30	"	1.40	74.4	9.1	86.0	8.6	88.4	15.0	1.45	28.2
" 1.40	"	1.50	5.7	16.0	91.7	9.1	14.0	46.2	1.55	3.9
" 1.50	"	1.60	2.2	18.9	93.9	9.3	8.3	67.0	1.65	1.9
" 1.60			6.1	84.3	100.0	13.9	6.1	84.3	1.77	1.2
Curve No.			4	2	1,2,4	1	3	3	5	5

TABLE XII

Float and Sink Data on Plus 4 in. Lump (Crushed)

– Ash –

Specific Gravity			Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
	Floats	1.30	1.1	7.0	1.1	7.0	100.0	9.3	1.40	92.0
Sinks 1.30	"	1.40	80.3	7.0	81.4	7.0	98.9	9.3	1.45	26.8
" 1.40	"	1.50	10.7	13.1	92.1	7.7	18.6	19.1	1.55	10.3
" 1.50	"	1.60	6.4	19.7	98.5	8.5	7.9	27.2	1.65	3.0
" 1.60			1.5	59.4	100.0	9.3	1.5	59.4	1.75	0.5
Curve No.			4	2	1,2,4	1	3	3	5	5

TABLE XIII

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE

0 to $1\frac{1}{2}$ Inch Slack

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	88.9	11.1
Proximate Analysis (dry basis)			
Ash .... %	19.3	11.8	60.6
Volatile Matter .... %	35.5	37.3	22.7
Fixed Carbon .... %	45.2	50.9	16.7
Sulphur .... %	0.5	0.5	0.5
Calorific Value ...... B.T.U./lb.	11,745	12,970	----
Fusion Point of Ash .... °F.	2360	2250	2250
Melting Range of Ash .... °F.	290	180	190
Coking Properties	Good	Good	Non-agglomerate

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, and REFUSE
$1\frac{1}{2}$ to 4 Inch Lump

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	98.0	2.0
Proximate Analysis (dry basis)			
Ash .... %	12.3	9.0	33.1
Volatile Matter .... %	37.5	38.3	34.4
Fixed Carbon .... %	50.2	52.7	32.5
Sulphur .... %	0.6	0.5	0.5
Calorific Value ........B.T.U/lb.	12,665	13,135	----
Fusion Point of Ash .... °F.	2285	2540	2450
Melting Range of Ash .... °F.	110	140	150
Coking Properties	Good	Good	Agglomerate

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
Plus 4 Inch Lump (Crushed)

	Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight .... %	100.0	97.7	2.3
Proximate Analysis (dry basis)			
Ash .... %	8.7	8.6	53.9
Volatile Matter .... %	38.6	37.9	26.9
Fixed Carbon .... %	52.7	53.5	19.2
Sulphur .... %	0.4	0.4	0.3
Calorific Value ...... B.T.U/lb.	13,185	13,200	----
Fusion Point of Ash .... °F.	2350	2480	2200
Melting Range of Ash .... °F.	110	130	170
Coking Properties	Good	Good	Agglomerate

TABLE XVI

SCREEN ANALYSIS AND CHEMICAL ANALYSIS

(Dry Basis of 1½" Slack)

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	17.8	17.8	12.8	0.5	2250
1/8 - 3/4 inch	46.4	64.2	16.8	0.5	2260
0 - 1/8 inch	35.8	100.0	23.9	0.5	2300

TABLE XVII

FLOAT AND SINK DATA ON SCREENED SIZES
USING A SELECTED GRAVITY OF 1.60

(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F.	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ in.	91.2	11.1	2330	8.8	46.2	2210
1/8 - 3/4 in.	89.0	11.7	2220	11.0	56.2	2210
0 - 1/8 in.	75.9	14.7	2360	24.1	49.9	2230

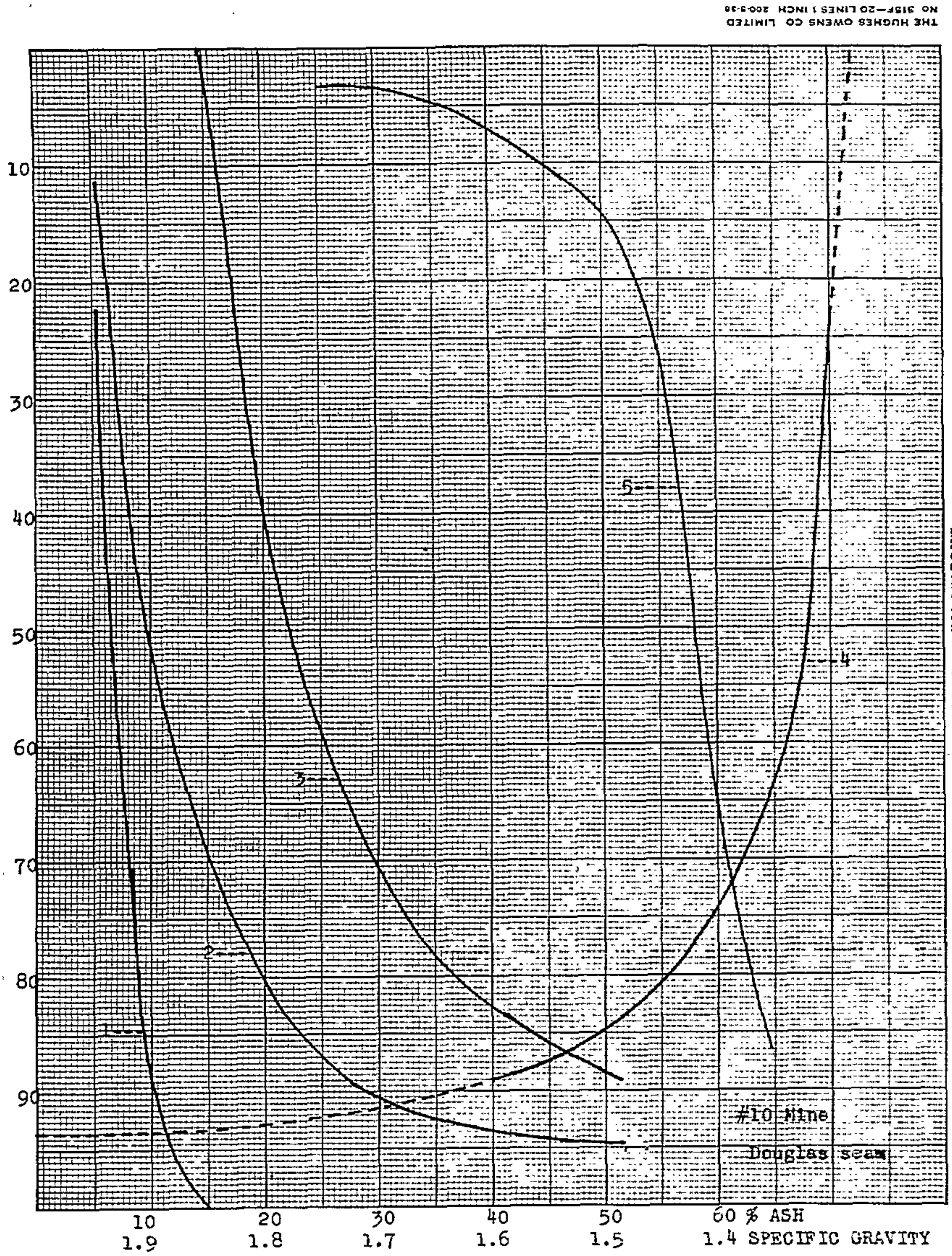

FIG. 1 - Washability Curves for 1½" Slack - No. 10 Douglas Mine

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

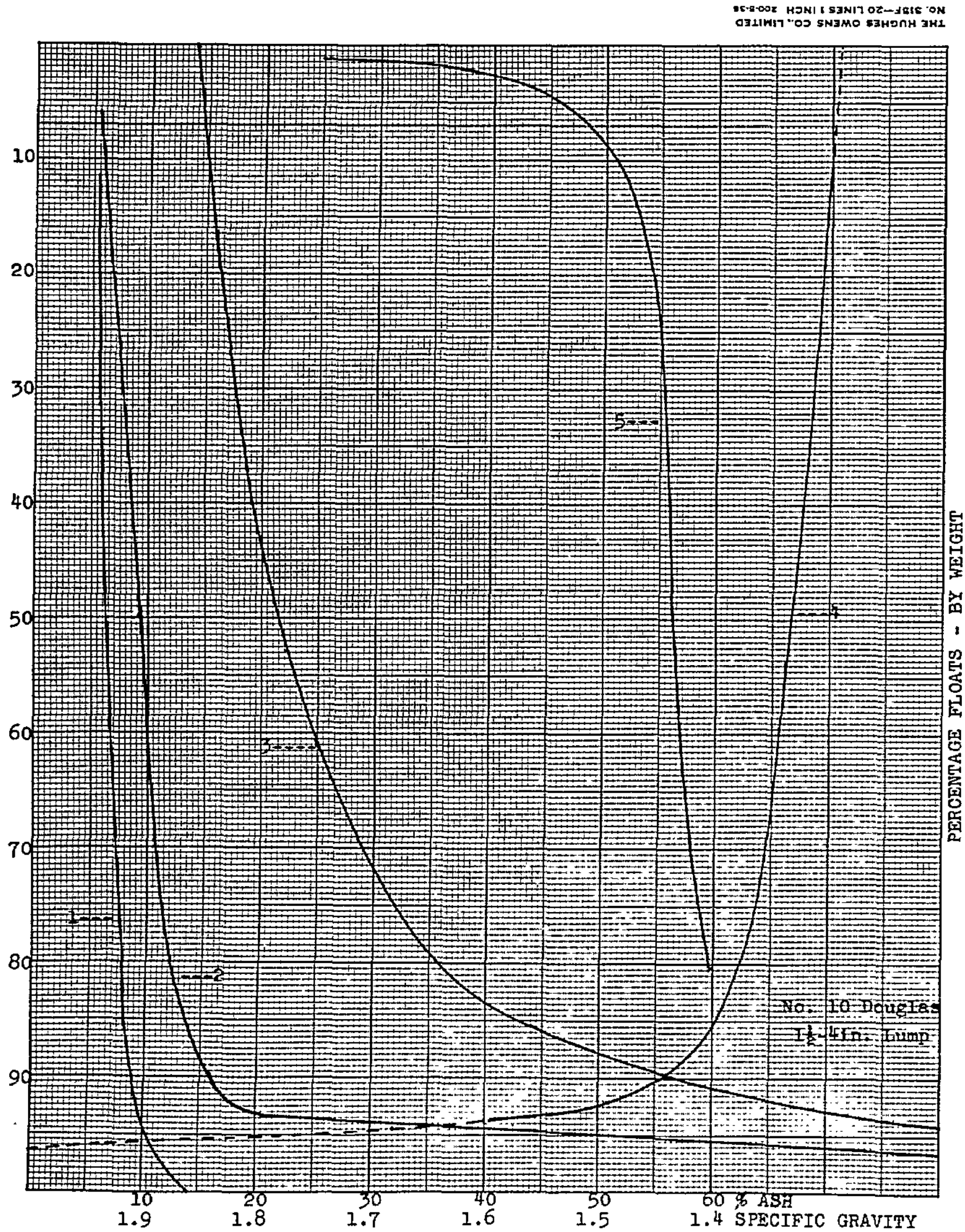

FIG. 11 - Washability Curves for 1½"- 4" Lump - No.10 Douglas Mine.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

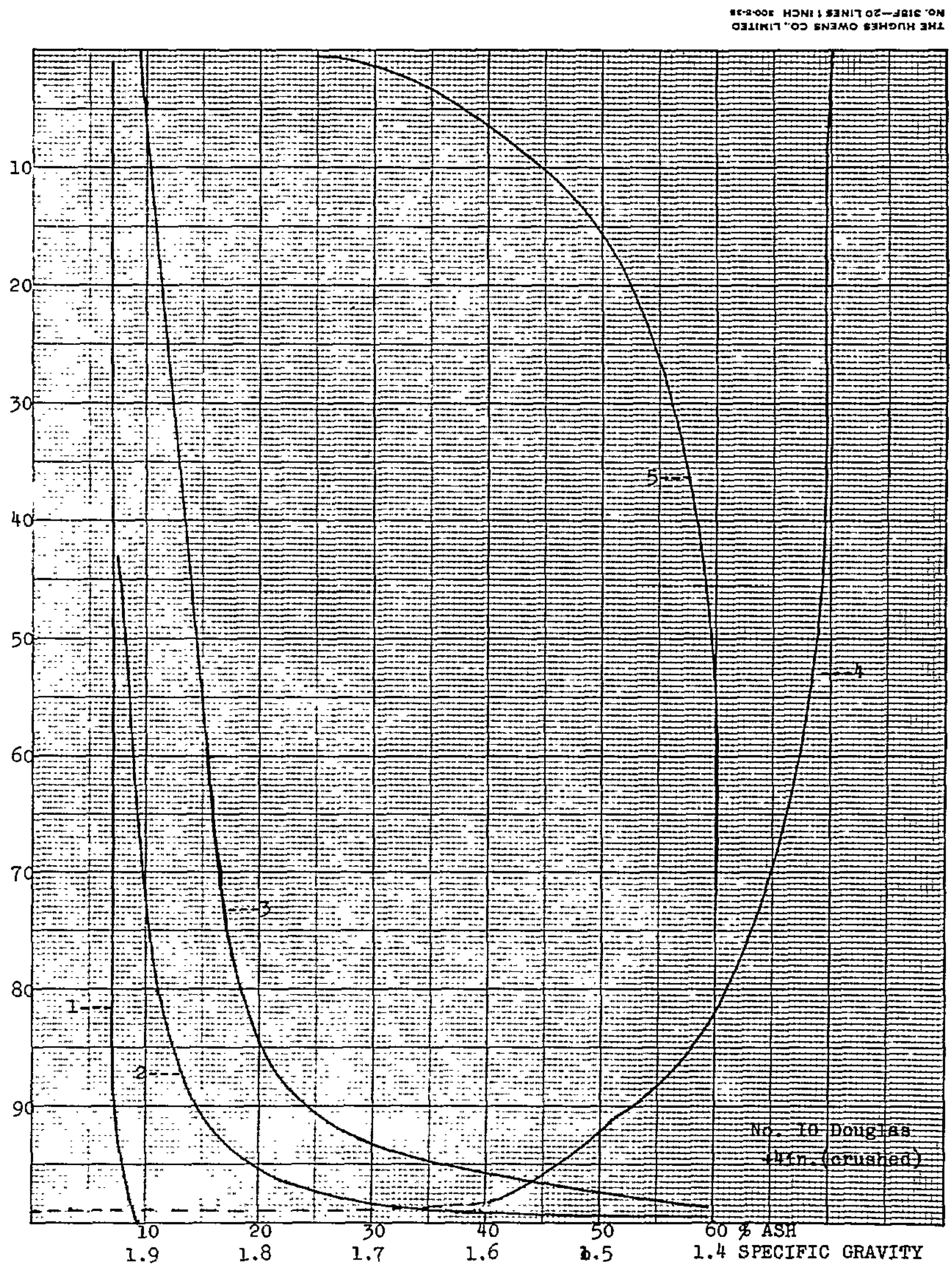

FIG.III - Washability Curves for Plus 4-in. Lump - No. 10 Douglas

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

V

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch. 1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the No. 10 mine Douglas seam coal are shown in Table XVIII.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While those tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard.

1/ " A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant By-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737-2.

The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designed as the 'caking index'. The higher the 'caking index' the greater are the coking properties. The results of this test conducted on the No. 10 Mine coal are shown in Table XVIII.

TABLE XVIII

PHYSICAL PROPERTIES OF BY-PRODUCT COKES
AS INDICATED BY A
"SWELLING INDEX" TEST

		0-1½" Slack Washed at 1.60 Sp.Gr.
Volatile Matter at 600°C. (D.B.) ...... %		29.1
Swelling Index		198
Section--Coke Classification Chart		VI
Specific Volatile Index		150.1
Section--Coal Classification Chart		C-Subbituminous-Agglomerating
Ash per cent in coal (dry) ....%		11.8
PHYSICAL PROPERTIES OF BY-PRODUCT COKE		
Size on wharf	(% on 3" screen	40.0
	(Breeze: %-1/2"	3.5
Shatter test	(Index: % on 2" screen ..	35.0
	(Breeze: %-1/2"	5.0
Abrasion test	(Index: % on 1½" screen .	65.0
	(Dust: %-1/16"	5.0
Density	(App. Specific Gravity ...	0.9
	(Lbs. per cubic foot	25.0
Transverse shrinkage		Very good
Appearance of natural surface		Steel grey, irregular
Shape		Triangular; very fingery
Strength		Very fragile
Cross Fracture		Med. to large amt. steppy
Longitudinal fracture		Large amt.
Cell structute		Med. to Large
Sponge		Med. amt.
Pebbly seam		None
REMARKS		This coal cannot be used alone for the manufacture of satisfactory domestic or metallurgical coke in standard by-product ovens.

CAKING INDEX

	Gray Caking Index
Mine Run Sample	63.0

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the South Wellington No. 10 Mine, Douglas Seam, operated by the Canadian Collieries (Dunsmuir) Ltd. in the Nanaimo area, Cranberry district, British Columbia, was collected at the mine by sampling from representative mine cars at the tipple. In this way approximately 2,532 pounds of coal, representative of the seam at this mine at the time of sampling during July 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 23.5% of the coal was below 1/8 inch in size, 17.8% was above 4 inch in size, and 13.5% was 2 to 4 inch in size, the remaining 45.2% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 1.80 inch, yielding 65.7% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes.

The results of the friability test on the coal from the No. 10 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 71.1% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be relatively easy to grind in comparison to the general run of coal used for powdered fuel firing.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 24.8% of that of the uncrushed lumps, that is, from an average particle size of 6.075 inches to an average particle size of 1.505 inches. This crushing resulted in the production of 59.0% of 1 to 3 inch 'stove' (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 16.3% of 1/2 to 1 inch 'stoker' coal, and 3.3% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 21.6% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes passing a 4 inch screen and retained on a 1 inch screen are uniformly medium in ash content (12.0%) with the lumps retained on a 4 inch screen being much lower at 8.7%. The smaller sizes passing a 1 inch screen increase in ash with a decrease in size.

varying in ash from 13.5% for the 3/4-1 inch size to 26.8% for the dust (0-48 mesh). The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 16.5% ash, the +1½ inch lump 9.7% ash, and the 0 to 1½ inch slack 19.3% ash. The sulphur content of this coal is very low and uniform for all the sizes examined, and hence will occur mainly in the organic form. Visual examination of the coal indicated that there was no or very little pyrite present. The moisture content for all the sizes, was uniform on the 'as received' basis, with an average of 2.0% for the mine-run coal.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 150 which places it in the subbituminous class of coals of the agglomerating or weakly coking type. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile A bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a mdeium carbon and relatively high oxygen material.

Table VII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table VIII gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is uniformly low ranging from 2160 °F. to 2350 °F. The fusibility of the ash does not vary with the ash content of the coal. Examination of the float-and-sink data indicates that the mineral matter of the various fractions is of such a nature in the 0 - 1½ inch slack sizes as to have relatively the same low softening temperature.

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2.

Laboratory Washing Tests

The washing tests on the coal from the No. 10 Mine were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables IX and X, it will be noted that the 1½ inch slack has a medium inherent ash content of 5.4%, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 22.5% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 88.9% clean coal having 11.8% ash; these data are shown in Table XIII. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XI and XII respectively. The inherent ash is medium in amount for the 1½ and 4 inch lump showing 5.5% ash in 11.6% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 7.0% ash in 81.4% of the coal floating at a gravity of 1.40. Washing the 1½ to 4 inch lump at a selected gravity of 1.60 would be relatively simple, and would result in the production of approximately 98.0% clean coal containing 9% ash. The +4 inch coal is so low in ash, that it approaches the inherent ash content and thus even on crushing could not be reduced in ash content by cleaning. It is thus concluded that the 1½ inch slack from the Douglas seam coal, as well as the 1½-4 inch lump, as obtained at the No. 10 Mine, are amenable to cleaning by either wet or dry processes, but the ash could not economically be reduced to much less than 10 - 12%, whereas the large lump (+4 inch) if low in ash after handpicking, cannot be further reduced in ash content.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods has been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the No. 10 Mine, indicated that the coal had poor coking characteristics, in so far as use in standard by-product ovens is concerned. The Swelling Index was 198, which according to the coke classification chart, would result in a poor domestic coke as indicated in Table XVIII.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the No. 10 Mine coal indicated a coal that is strongly caking, the caking index being 63.

R.I.C.S. - 178

DEPARTMENT OF MINES
MINES BRANCH—FUEL RESEARCH LABORATORIES

Physical and Chemical Survey Report No. 87

Study of Coal From

Comox No.5 Mine, No.2 Seam, Comox Area,

Vancouver Island

Operated By

Canadian Collieries (Dunsmuir) Ltd., Nanaimo, B.C.

By

E. Swartzman

DIVISION OF FUELS & FUEL TESTING

OTTAWA,..

SIGNED,..

Report of Investigations--Carbonization Section - 178

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Table of Contents

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Comox No.5 Mine; No.2 Seam, worked in the Comox area, about 1½ miles Northwest of Cumberland, British Columbia, by the Canadian Collieries (Dunsmuir) Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-six reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the Comox No.2 seam was sampled at the mine according to instructions of an official from the Fuel Research Laboratories and in the presence of representatives from the operating company. The combined sample, which weighed approximately 1828 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgment is due the Department of Industrial development of the Canadian Pacific Railway Company, officials of the British Columbia Department of Mines, and various members of the Canadian Collieries (Dunsmuir) Ltd., for the aid given in connection with the collection of the sample of coal herewith reported, and to J.H.H. NICOLLS of the Fuel Research Laboratories under direction by him the major portion of the chemical analyses was conducted.

PHYSICAL PROPERTIES

1. Screen Analyses

The sample of coal from the Comox No.5 Mine, No.2 Seam, was collected at the mine during July 1941 from mine cars as they were being dumped for screening. A sample of the unprepared run-of-mine coal, weighing approximately 1828 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability.

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.), investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured by an

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, AND BULK DENSITY

Screen Sizes*	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash
Plus 4 in.	13.2	13.2	1.39	41.75	10.0
2 - 4 in.	33.2	46.4	1.40	42.00	11.4
1½ - 2 in.	7.1	53.5	1.38	43.25	12.1
1 - 1½ in.	8.5	62.0	1.39	43.75	12.4
3/4 - 1 in.	5.3	67.3	1.35	43.50	11.4
1/2 - 3/4 in.	6.9	74.2	1.32	42.75	10.8
1/4 - 1/2 in.	9.3	83.5	1.33	42.25	10.4
1/8 - 1/4 in.	6.4	89.9	1.31	41.50	10.8
#48 - 1/8 in.	7.6	97.5	1.30	48.75	12.5
0 - #48	2.5	100.00			22.8
Mine Run		100.00	- -	- -	10.6
Plus 1½ in.		53.5	- -	- -	11.7
0 - 1½ in.		46.5	- -	51.00	13.1
3/4 - 1½ in.		13.8	- -	- -	10.4
0 - 1/8 in.		10.1	1.30	48.75	14.9

		As Received
Average Size of Run-of-Mine	in.	2.005

* All screens 1/8 in. and larger are round-hole screens. No. 48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test 2 - 3 in. Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	66.0	52.0
1½ - 2 in.		10.0	11.0
1 - 1½ in.		7.0	10.0
3/4 - 1 in.		4.5	5.5
1/2 - 3/4 in.		4.0	5.5
0 - 1/2 in.		8.5	16.0
Av'g Size in.	2.500	1.998	1.737
Size Stab'ty %		79.9	69.5

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	62.5
0 - 1½ in.	65.0
0 - 1/8 in.	68.0

index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the Comox No.5 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials. 2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No. 737-1, was used for evaluating the grindability of the coal from the No.2 Seam of the Comox No.5 Mine.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite;
6 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these te sts are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

5. Crushing Test.

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England.

The rolls were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Comox No. 5 Mine coal are shown in Table IV.

Table IV.
Crushing Test On Plus 4 inch Lump
(Crusher Set at 1½ inch)

	Screen Analysis	
	Before Crushing %	After Crushing %
6 - 7 in.	6.1	
5 - 6 in.	18.2	
4 - 5 in.	75.7	0.8
3 - 4 in.		1.4
2 - 3 in.		33.3
1½- 2 in.		19.7
1 -1½ in.		14.2
¾ - 1 in.		6.7
½ - ¾ in.		6.8
¼ - ½ in.		7.9
1/8-¼ in.		4.0
0 -1/8 in.		5.2
Average Particle Size - - in.	4.805	1.583
Size Reduction - - - - - %		32.9%

1/ Quoted from the above mentioned publication of the Mines Branch.

2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove - machine Method", A.S.T.M. Designation D 409 - 35T.

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the Comox No. 5 Mine, No. 2 Seam were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.
2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.
3. The Sulphur Forms in the coal which were determined according to the accepted Powell method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid, the pyritic sulphur by oxidation with nitric acid, and the organic sulphur by the calculated difference between the inorganic sulphur and the total sulphur, the results being shown in Table VII.
4. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, as shown in Table VIII. Data on temperature lags are presented because of their bearing on the clinkering properties.
5. The Chemical Analyses of Ash, which are shown in Table IX.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis: Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/Lb.
Plus 4 in.	1.7	10.0	33.2	56.8	2.7	- - -
2 - 4 in.	1.6	11.4	33.6	55.0	3.1	13525
1½ - 2 in.	1.8	12.1	33.0	54.9	3.5	- - -
1 - 1½ in.	1.8	12.4	32.9	54.7	3.5	- - -
3/4 - 1 in.	1.8	11.4	33.6	55.0	3.3	- - -
1/2 - 3/4 in.	1.8	10.8	33.5	55.7	3.1	- - -
1/4 - 1/2 in.	1.8	10.4	33.6	56.0	3.0	- - -
1/8 - 1/4 in.	1.9	10.8	33.7	55.5	2.8	- - -
#48 - 1/8 in.	1.5	12.5	33.3	54.2	2.6	- - -
0 - #48	1.7	22.8	31.2	46.0	2.5	- - -
Mine Run	1.7	10.6	33.6	55.8	2.9	13525
Plus 1½ in.	1.7	11.7	32.9	55.4	2.9	13460
0 - 1½ in.	1.9	13.1	33.1	53.8	3.0	13090
3/4 - 1½ in.	1.7	10.4	33.1	56.5	3.1	13630
0 - 1/8 in.	1.8	14.9	32.6	52.5	2.6	12735

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	75.8	5.0	2.9	1.2	4.5	10.6

TABLE VII

SULPHUR FORMS

(As received basis)

	Total Sulphur % of Coal	Sulphate Sulphur % of Coal	Sulphate Sulphur % Sulphur	Pyritic Sulphur % of Coal	Pyritic Sulphur % Sulphur	Organic Sulphur % of Coal	Organic Sulphur % Sulphur
Mine Run	2.85	0.13	4.5	1.33	46.7	1.39	48.8

TABLE VIII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F.	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2200	2330	2390	190	130	60	10.0
2 - 4 in.	2160	2320	2370	210	160	50	11.4
1½ - 2 in.	1980	2100	2160	180	120	60	12.1
1 - 1½ in.	1980	2100	2160	180	120	60	12.4
3/4 - 1 in.	2000	2100	2190	190	100	90	11.4
1/2 - 3/4 in.	2000	2100	2190	190	100	90	10.8
1/4 - 1/2 in.	2020	2140	2220	200	120	80	10.4
1/8 - 1/4 in.	2030	2150	2240	210	120	90	10.8
#48 - 1/8 in.	2000	2120	2180	180	120	60	12.5
0 - #48 in.	2010	2110	2190	180	100	80	22.8
Mine Run	1950	2100	2180	230	150	80	10.6
Plus 1½ in.	1950	2080	2150	200	130	70	11.7
0 - 1½ in.	2020	2150	2180	160	130	30	13.1
3/4 - 1½ in.	2080	2190	2310	230	110	120	10.4
0 - 1/8 in.	2060	2140	2300	240	80	160	14.9

TABLE IX

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run												

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By the successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump, and +4 inch lump crushed to pass a 4-inch screen, all prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of

wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult . . .	Efficient process; low tonnage
20 - 25	Exceedingly difficult	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash percent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur.

Curves showing the reduction in ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in Tables X to XVIII inclusive.

TABLE X

Float and Sink Data on 1½" Slack
Ash & Sulphur

Specific Gravity	Weight %	Ash %	Sulphur %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Floats Sulphur %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	Cumulative Sinks Sulphur %	±.10 Specific Gravity Distribution Gravity	±.10 Specific Gravity Distribution Calculated Ordinate
										1.35	91.5
Floats 1.30	22.6	4.1	1.7	22.6	4.1	1.7	100.0	11.2	3.2	1.40	72.3
Sinks 1.30 " 1.40	54.9	8.0	2.6	77.5	6.9	2.3	77.4	13.2	3.6	1.45	45.9
" 1.40 " 1.50	15.2	16.8	5.2	92.7	8.5	2.8	22.5	26.0	6.1	1.55	7.0
" 1.50 " 1.60	2.3	23.3	7.2	95.0	8.9	2.9	7.3	45.1	8.0	1.65	1.5
" 1.60	5.0	55.1	8.3	100.0	11.2	3.2	5.0	55.1	8.3	1.75	0.8
Curve No.	4	2		1,2,4	1		3	3		5	5

TABLE XI

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity	Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphur %	Initial Deformation °F	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
Floats 1.30	4.1	34.5	61.4	Good	1.7	2070	2190	2350	280	120	160
Sinks 1.30 " 1.40	8.1	34.2	57.7	Good	2.6	2200	2310	2360	160	110	50
" 1.40 " 1.50	17.1	32.9	50.0	Good	5.2	2100	2210	2300	200	110	90
" 1.50 " 1.60	23.8	31.0	45.2	Fair	7.2	2040	2180	2210	170	140	30
" 1.60	56.2	21.0	22.8	Nonagglomerate	8.3	1990	2110	2220	230	120	110

TABLE XII

Float and Sink Date on 1½" – 4 in. Lump

– Ash –

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± 10 Specific Gravity Distribution Gravity	± 10 Specific Gravity Distribution Calculated Ordinate
Floats 1.30	2.3	4.6	2.3	4.6	100.0	11.4	1.40	87.8
Sinks 1.30 " 1.40	68.4	9.3	70.7	9.1	97.7	11.6	1.45	41.0
" 1.40 " 1.50	17.2	10.1	87.9	9.3	29.3	16.8	1.55	14.9
" 1.50 " 1.60	7.4	14.7	95.3	9.8	12.1	26.4	1.65	3.8
" 1.60	4.7	44.7	100.0	11.4	4.7	44.7	1.75	1.0
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE XIII

Float and Sink Data on Plus 4 in. Lump (Crushed)

– Ash –

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± 10 Specific Gravity Distribution Gravity	± 10 Specific Gravity Distribution Calculated Ordinate
Floats 1.30	1.8	5.4	1.8	5.4	100.0	9.0	1.40	95.4
Sinks 1.30 " 1.40	82.7	7.0	84.5	7.0	98.2	9.1	1.45	53.2
" 1.40 " 1.50	11.8	15.8	96.3	8.0	15.5	20.1	1.55	5.2
" 1.50 " 1.60	2.2	22.1	98.5	8.4	3.7	34.0	1.65	0.8
" 1.60	1.5	51.5	100.0	9.0	1.5	51.5		
Curve No.	4	2	1,2,4	1	3	3	5	5

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE
0 to 1½ Inch Slack

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	96.2	3.8
Proximate Anaysis (dry basis)				
Ash	%	13.1	8.7	53.0
Volatile Matter	%	33.1	34.4	21.8
Fixed Carbon	%	53.8	56.9	25.2
Sulphur	%	3.0	2.8	6.9
Calorific Value	B.TU/lb	13,090	13,860	- -
Fusion Point of Ash	°F.	2190	2290	
Melting Range of Ash	°F.	160	170	
Coking Properties		Good	Good	Agglomerate

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
1½ to 4 Inch Lump

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	95.3	4.7
Proximate Analysis (dry basis)				
Ash	%	11.5	9.8	44.7
Volatile Matter	%	33.5	34.1	
Fixed Carbon	%	55.0	56.1	
Sulphur	%	3.2	2.9	
Calorific Value	B.T.U./lb	13530	13770	
Fusion Point of Ash	°F.	2280	2280	
Melting Range of Ash	°F.	200	200	
Coking Properties		Good	Good	

* Calculated

TABLE XVI

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE
Plus 4 Inch Lump (Crushed)

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	96.3	3.7
Proximate Analysis (dry basis)				
Ash	%	10.0	7.8	34.0
Volatile Matter	%	33.2	34.4	
Fixed Carbon	%	56.8	57.8	
Sulphur	%	2.7	2.3	
Calorific Value	B.T.U./lb.	13740	14100	
Fusion Point of Ash	°F	2320	2400	
Melting Range of Ash	°F	210	130	
Coking Properties		Good	Good	

TABLE XVII

SCREEN ANALYSIS & CHEMICAL ANALYSIS

(Dry Basis of 1½" Slack

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	29.7	29.7	12.0	3.4	2100
1/8 - 3/4 inch	48.6	78.3	10.6	3.0	2130
0 - 1/8 inch	21.7	100.0	14.9	2.6	2140

TABLE XVIII

FLOAT AND SINK DATA ON SCREENED SIZES
USING A SELECTED GRAVITY OF
(Dry Basis)

Screen Sizes	Floats			Sinks		
	Weight %	Ash %	F.P.A. °F.	Weight %	Ash %	F.P.A. °F.
3/4 - 1½ in.	95.0	9.8	2150	5.0	56.9	2070
1/8 - 3/4 in.	96.5	8.7	2090	3.5	49.9	2150
0 - 1/8 in.	82.6	6.9	2110	17.4	47.9	2470

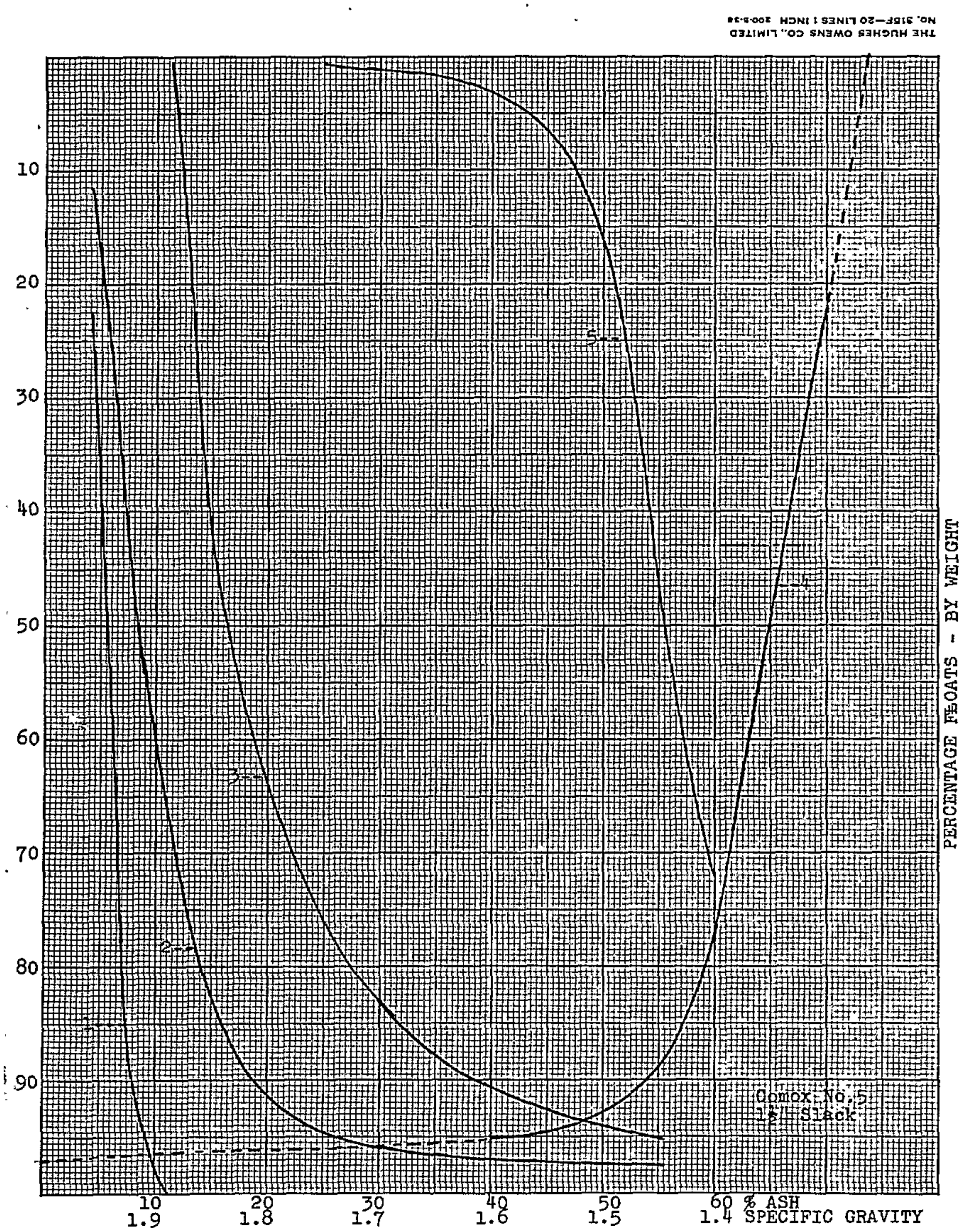

FIG. I - Washability Curves for 1½" Slack - Comox No. 5.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

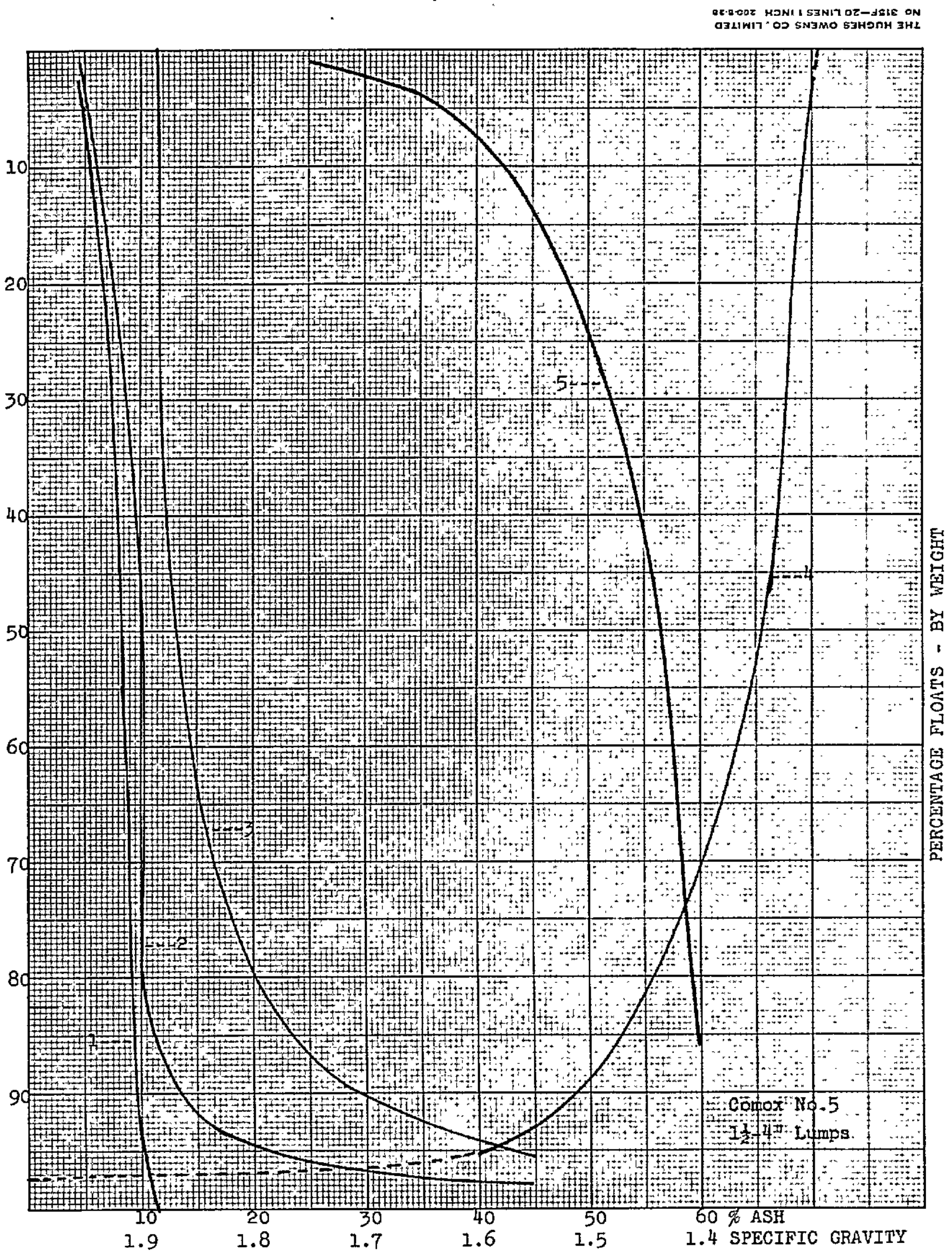

FIG.II - Washability Curves for 1½"- 4" Lump - Comox-No. 5.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

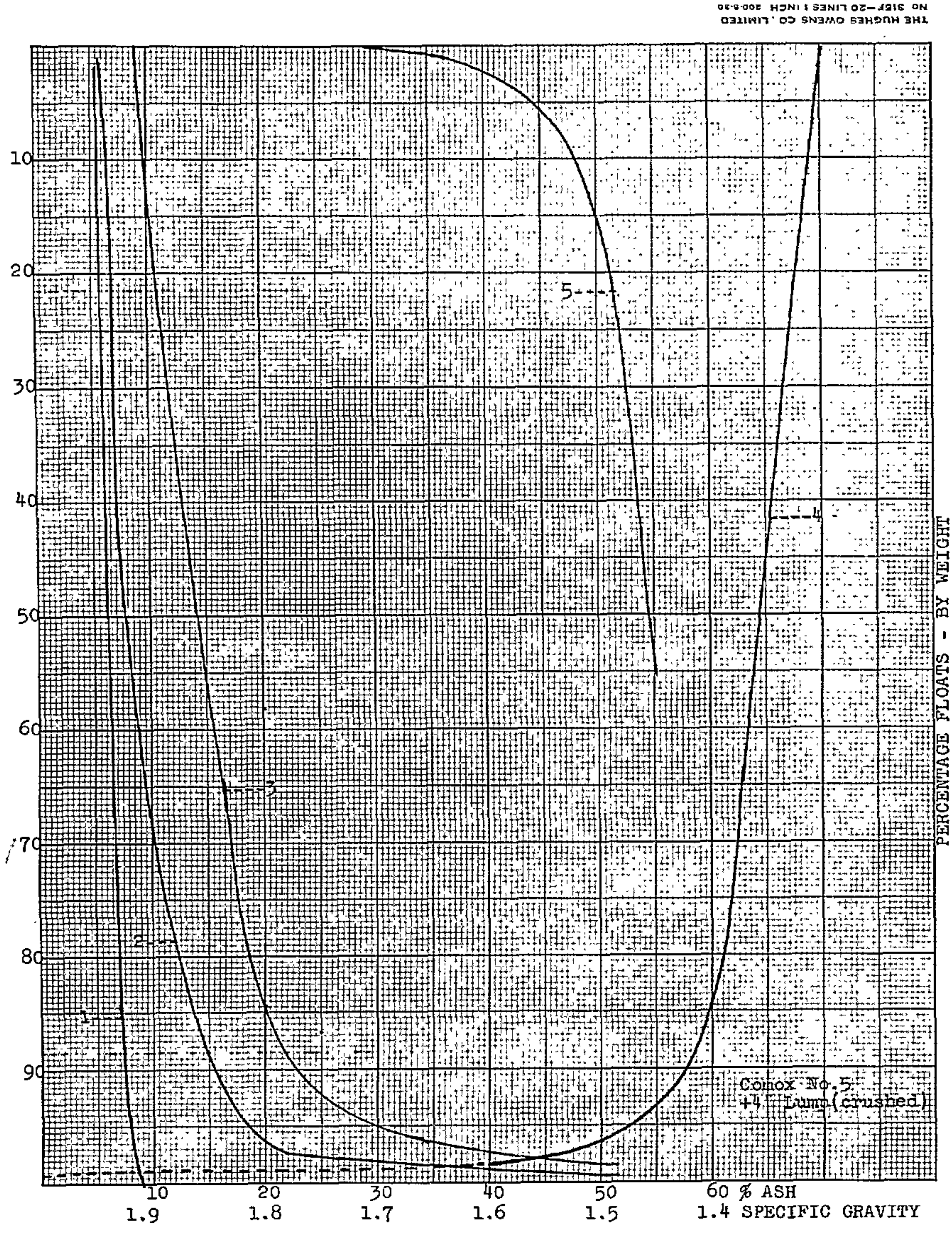

FIG.III - Washability Curves for Plus 4-in. Lump - Comox No. 5.

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Comox No. 5 mine coal are shown in Table XIX.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard.

1/ "A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant by-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737-2.

The ratio of the mixture of sand and coal, which on carbonization will form a sufficiently strong button to support a weight of 500 grammes, is designed as the 'caking index'. The higher the 'caking index' the greater are the coking properties. The results of this test conducted on the Comox No. 5 Mine are shown in Table XIX.

TABLE XIX

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

AS INDICATED BY A

"SWELLING INDEX" TEST

		0-1½" Slack Washed at 1.60 sp.gr.
Volatile Matter at 600°C. (D.B.) %		28.2
Swelling Index		1080
Section--Coke Classification Chart		IV
Specific Volatile Index		169.8
Section--Coal Classification Chart		D-Parabitiminous
Ash per cent in coal (dry) %		8.7
PHYSICAL PROPERTIES OF BY-PRODUCT COKE-		
Size on wharf	(%on 3" screen	40.0
	(Breeze: %-1/2"	3.0
Shatter test	(Index: % on 2" screen	45.0
	(Breeze: %-1/2"	3.0
Abrasion test	(Index: % on 1½" screen	85.0
	(Dust: %-1/16"	4.0
Density	(App. Specific Gravity	1.0
	(Lbs. per cubic foot	27.5
Transverse shrinkage		Good
Appearance of natural surface		steel grey, smooth
Shape		slightly triangular
Strength		Hard
Cross fracture		Med. amt., steppy.
Longitudinal fracture		Medium Amount
Cell structure		Dense
Sponge		Very little
Pebbly seam		None
REMARKS		This is a true gas coal & may be used, if required, without other coals in the preparation of a good grade of standard by-product coke.

CAKING PROPERTIES

	Gray Caking Index
Mine Run	66

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Comox No. 5 Mine, No. 2 Seam, operated by the Canadian Collieries (Dunsmuir) Ltd. in the Comox area, Cumberland district, British Columbia, was collected at the mine by sampling from freshly mined coal. In this way approximately 1828 pounds of coal, representative of the seam at this mine at the time of sampling during July 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal (as received) which were conducted at the Fuel Research Laboratories are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 10.1% of the coal was below 1/8 inch in size, 13.2% was above 4 inch in size, and 33.2% was 2 to 4 inch in size, the remaining 43.5% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 2.005 inch yielding 46.5% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of those sizes.

The results of the friability test on the coal from the Comox No. 5 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 79.9% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 757-1. Although the finer sizes appear to be slightly more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing.

The results of the crushing tests conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 32.9% of that of the uncrushed lumps, that is from an average particle size of 4.805 inches to an average particle size of 1.583 inches. This crushing resulted in the production of 67.2% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for "stove' coal), 13.5% of 1/2 to 1 inch 'stoker' coal, and 2.2% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 17.1% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes retained on a 48-mesh screen are uniformly medium in ash content with dust passing a 48-mesh screen, indicating a substantial increase in ash content. The coal lumps retained on a 48-mesh screen are more or less uniform, varying in ash from 10.0% to 12.5%, whereas the dust (0-48 mesh) had an ash content of 22.8%. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 10.6% ash, the +1½ inch lump 11.7% ash, and the 0 to 1½ inch slack 13.1% ash. The sulphur content of this coal is medium and uniform for all the sizes examined, varying between 2.5% and 3.3%. Reference to Table VII indicates that 46.7% of the total sulphur is in the pyritic form. The moisture content for all the sizes, was uniform on the 'as received' basis, with an average of 1.7% for the mine-run coal.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 170 which places it in the parabituminous class (True Gas type) of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile A bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a medium carbon and medium oxygen material.

Table VIII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table IX gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is uniformly low ranging from 2190°F. to 2330°F. The fusibility of the ash does not vary with the ash content of the coal, although it is of interest to note that the ash of those sizes retained on a 2 inch screen have an F.P.A. about 200°F. higher than the coal passing this screen. Examination of the float-and-sink fractions of the 0-1½ inch slack indicates that there is practically no difference in their ash fusion temperatures.

Laboratory Washing Tests

The washing tests on the coal from the Comox No. 5 Mine, were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2.

curves shown in Section IV. Referring to Tables X and XI, it will be noted that the 1½ inch slack has a medium inherent ash content of 4.1% and a relatively high sulphur content of 1.7%, as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 22.6% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 96.2% clean coal having 8.7% ash and 2.8% sulphur, these data are shown in Table XIV. It should be noted that the sulphur reduction is negligible, and this is due to the fact that the pyrite occurs mainly as finely divided material. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XII and XIII respectively. The results of the tests on these sizes are somewhat similar. The inherent ash is medium in amount, the 1½ to 4 inch lump showing 4.6% ash in only 2.3% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 5.4% ash in 1.8% of the coal floating at the same gravity. Washing the 1½ to 4 inch lump if it contained more than 10% ash, at a selected gravity of 1.60 would be relatively simple, but a reduction in ash below 10% is not expected. The particular sample tested contained less than 11.4% ash and could be washed at a gravity of 1.60 to yield 95.3% of clean coal containing 9.8% ash. Washing the crushed +4 inch lump in a similar manner would yield a slightly cleaner product, it being possible to produce an 8% ash coal with a varying loss in refuse depending on the ash content of the raw material which seems to vary to some degree. It is thus concluded that the sample of Comox No. 2 Seam coal, as obtained at the Comox No. 5 Mine, is not very amenable to cleaning by either wet or dry processes, and the ash could not economically be reduced to much less than 10%. It should be noted that crushing the +4 inch lump materially aided in improving the washing characteristics of this size.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the Comox No. 5 Mine, indicated that the coal had fairly good coking characteristics, in so far as use in standard by-product ovens is concerned. The Swelling Index was 1,080, which according to the coke classification chart, should result in a good domestic coke as indicated in Table XIX.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Comox No. 5 Mine coal indicated a coal that is strongly caking, the caking index being 66.

Report of Investigations--Carbonization Section - 179

Physical and Chemical Survey Report No. 88

STUDY OF COAL FROM

COMOX NO. 8 MINE, NO. 2 SEAM, COMOX AREA

VANCOUVER ISLAND.

OPERATED BY

CANADIAN COLLIERIES (DUNSMUIR) LTD., NANAIMO, B.C.

BY

E. SWARTZMAN

Fuel Research Laboratories
Bureau of Mines
Ottawa Canada

January, 1943

Physical and Chemical Survey Report No. 88

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I

INTRODUCTION

The following report deals with a Physical and Chemical study of a sample of coal from the Comox No. 8 Mine; No. 2 Seam, worked in the Comox area, near Cumberland, British Columbia, by the Canadian Collieries (Dunsmuir) Ltd. This study is part of the investigation dealing with the physical and chemical characteristics of the coal seams being worked in the province of British Columbia. Eighty-seven reports have already been issued on the Physical and Chemical Survey of various coal seams throughout Canada, and, accordingly, this present investigation was conducted in a manner similar to that adopted for the previous studies. The report, is therefore, presented in sections dealing with the following subjects:

1. Physical Properties,
2. Chemical Properties,
3. Washing Characteristics,
4. Coking Properties, and
5. Discussion of Results.

The unprepared run-of-mine coal from the Comox No. 8 Mine was sampled at the mine by an official from the Fuel Research Laboratories in the presence of representatives from the operating company. The combined sample, which weighed approximately 2252 pounds, was bagged and shipped to the Fuel Research Laboratories at Ottawa.

Acknowledgement is due the Department of Industrial Development of the Canadian Pacific Railway Company, officials of the British Columbia Department of Mines, and various members of the Canadian Collieries (Dunsmuir) Ltd., for the aid given in connection with the collection of the samples of coal herewith reported, and to J.H.H. Nicolls of the Fuel Research Laboratories under whose direction the major portion of the chemical analyses was conducted.

II

PHYSICAL PROPERTIES

1. Screen Analysis

The sample of coal from the Comox No. 8 Mine, No. 2 Seam, was collected at the mine during July 1941 from mine cars as they were being dumped for screening. A sample of the unprepared run-of-mine coal, weighing approximately 2252 pounds was collected. This sample was used for the screening tests, standard round-hole screens made from 1/4 inch plate being employed. The results of these tests are presented in Table I.

2. Bulk Density and Apparent Specific Gravity

The bulk density, that is, the weight per cubic foot, was determined on various screened sizes and mixtures of sizes by measurement with either a two- or one-cubic foot box. The apparent specific gravity of the various screened sizes was determined by the modification of the method for determining the apparent gravity of coke, as outlined in A.S.T.M. Standards on Coal and Coke, Designation D 167-24. The results of the above two tests are presented in Table I.

3. Friability

Friability, which is an important property in the selection of coal for various uses, is a physical characteristic implying degradation due to breakage along fracture lines, or due to inherent weakness in the coal lump. The "Coal Friability" Sub-Committee of the American Society for Testing Materials (A.S.T.M.), investigated several methods for the determination of this property with a view to the final adoption of a standard method. The results of this work, including the method considered for adoption, i.e., the "Drop Shatter Test for Coal" have been published in 1935 by the Department of Mines under the title "Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.P. Connell, Mines Branch publication No. 762. This tentative method was used for testing the relative 'size stability' of single sizes. The term 'size stability' is the antonym of friability and "on the assumption that friability may be measured

TABLE I

SCREEN ANALYSIS, SPECIFIC GRAVITY, AND BULK DENSITY

Screen Sizes*	As Received % by weight	As Received % Cumulative	Specific Gravity	Bulk Density lbs. per cu. ft.	Ash %
Plus 4 in.	30.7	30.7	1.31 (1)	52.00	16.9
2 - 4 in.	10.1	40.8	1.32 (1)	47.50	21.6
1½ - 2 in.	3.5	44.3	1.31 (1)	47.50	29.5
1 - 1½ in.	6.7	51.0	1.31 (1)	48.00	26.4
3/4 - 1 in.	4.8	55.8	1.31 (1)	47.00	23.6
1/2 - 3/4 in.	7.9	63.7	1.42	46.25	20.6
1/4 - 1/2 in.	11.6	75.3	1.38	45.00	18.5
1/8 - 1/4 in.	8.7	84.0	1.38	42.75	17.8
#48 - 1/8 in.	10.7	94.7)	1.36	51.25	16.9
0 - #48	5.3	100.0)			24.5
Mine Run		100.0			19.5
Plus 1½ in.		44.3			18.6
0 - 1½ in.		55.7		59.75	20.5
3/4 - 1½ in.		11.5			24.6
0 - 1/8 in.		16.0	1.36	51.25	18.3

	As Received
Average Size of Run-of-Mine..................in.	2.93

* All screens 1/8 in. and larger are round-hole screens. No.48 is Tyler 48-mesh with nominal aperture of 0.295 mm.

(1) As this coal was heavily loaded with free rock, it was all removed in conducting the gravity tests on those sizes retained on a 3/4 in. screen.

TABLE II

SIZE STABILITY

Screen Sizes	Screen Analysis Before and After Drop-Shatter Test, 2 - 3 in.: Before Test %	After 2 Drops %	After 4 Drops %
2 - 3 in.	100.0	63.0	48.5
1½ - 2 in.		15.0	16.5
1 - 1½ in.		8.0	11.0
3/4 - 1 in.		3.5	4.5
1/2 - 3/4 in.		3.0	5.0
0 - 1/2 in.		7.5	14.5
Av'g Size in.	2.500	2.006	1.741
Size Stab'ty %		80.2	69.6

TABLE III

GRINDABILITY

Screen Size of Coal Tested	Hardgrove Index
Mine Run	67.4
0 - 1½ in.	68.8
0 - 1/8 in.	68.4

by an index or percentage, it may also be assumed that the complement of a given friability index will be the corresponding size stability index". 1/

The results of the friability study of the coal from the Comox No. 8 Mine are shown in Table II. The sample of the single size tested was 2 to 3 inch.

4. Grindability

For the determination of the grindability, or the ease of pulverizability of a coal, the method developed by Mr. Hardgrove of the Babcock & Wilcox Company has been accepted as a tentative standard by the American Society for Testing Materials.2/ This method, which has been described by C.E. Baltzer and H.P. Hudson in Mines Branch publication No.737-1, was used for evaluating the grindability of the coal from the No. 2 Seam of the Comox No. 8 Mine.

For comparison, three samples of varying screen sizes were selected for testing, as follows:

Mine-run composite;
0 to 1½ inch slack, and
0 to 1/8 inch slack.

The results of these tests are shown in Table III, the indices representing the relative pulverizability of the coal. Increased resistance to grinding is indicated by the lower values, the standard easily pulverized coal having a value of 100.

5. Crushing Test

In washing coal or in preparing special sizes and size mixtures for the market it is often necessary to crush lump coal. The relative quantity of the various sizes produced, using the same crusher and crusher setting, varies from coal to coal and is dependent to a great degree on the friability of the coal. However a standard friability test conducted on any given size or mixture of sizes may not yield information of a type that would be satisfactory in evaluating the crushing characteristics

1/ Quoted from the above mentioned publication of the Mines Branch.
2/ "Tentative Method of Test for Grindability of Coal by the Hardgrove-machine Method", A.S.T.M. Designation D 409-35T.

of a coal. Therefore, a crushing test on several hundred pounds of +4 inch coal was conducted, using a special double-roll coke cutter manufactured by G. Waller & Son Limited in England. The rolls were set at 1½ in. for these tests with a view to preparing the maximum quantity of 'stove' coal (1 to 3 inch) with the minimum amount of fines. The results of this crushing test on a sample of +4 inch Comox No. 8 Mine coal are shown in Table IV.

TABLE IV

CRUSHING TEST ON PLUS 4 INCH LUMP
(Crusher set at 1½ Inch)

		Screen Analysis	
		Before Crushing %	After Crushing %
12 - 14 in.	%	6.8	
10 - 12 in.	%	9.1	
8 - 10 in.	%	23.8	
7 - 8 in.	%	14.7	
6 - 7 in.	%	9.1	
5 - 6 in.	%	19.9	
4 - 5 in.	%	16.6	3.0
3 - 4 in.	%		3.6
2 - 3 in.	%		34.5
1½ - 2 in.	%		14.2
1 - 1½ in.	%		11.9
3/4 - 1 in.	%		6.9
½ - 3/4 in.	%		7.3
¼ - ½ in.	%		7.4
1/8 - ¼ in.	%		4.4
0 - 1/8 in.	%		6.8
Average Particle Size[1]	-in.	7.563	1.669
Size Reduction	%		22.07

III

CHEMICAL PROPERTIES

The various screen sizes obtained from the screening tests of the coal from the Comox No. 8 Mine, No. 2 Seam were subjected to certain chemical analyses as follows:

1. The Proximate Analyses, including the sulphur and the calorific value, which are shown in Table V.
2. The Ultimate Analyses for a selected size mixture, which are presented in Table VI.
3. The Sulphur Forms in the coal which were determined according to the accepted Powell method, whereby the sulphate sulphur is determined by extraction with hydrochloric acid, the pyritic sulphur by oxidation with nitric acid, and the organic sulphur by the calculated difference between the inorganic sulphur and the total sulphur, the results being shown in Table VII.
4. The Fusibility of Ash including the Melting Range and the Softening and Fluid Intervals, as shown in Table VIII. Data on temperature lags are presented because of their bearing on the clinkering properties.
5. The Chemical Analyses of Ash, which are shown in Table IX.

TABLE V

CHEMICAL ANALYSES OF COAL

PROXIMATE, SULPHUR, AND CALORIFIC VALUE

Screen Sizes	Moisture (as rec'd) %	Dry Basis: Ash %	Volatile Matter %	Fixed Carbon %	Sulphur %	Calorific Value BTU/lb
Plus 4 in.	1.2	16.9	30.1	53.0	1.7	---
2 - 4 in.	1.3	21.6	29.3	49.1	2.5	11615
1½ - 2 in.	1.3	29.5	27.7	42.8	3.1	---
1 - 1½ in.	1.3	26.4	28.7	44.9	3.4	---
3/4 - 1 in.	1.4	23.6	29.0	47.4	3.4	---
1/2 - 3/4 in.	1.4	20.6	30.0	49.3	3.2	---
1/4 - 1/2 in.	1.3	18.5	30.9	50.6	3.1	---
1/8 - 1/4 in.	1.5	17.8	31.5	50.7	3.0	---
#48 - 1/8 in.	1.0	16.9	30.9	52.2	2.7	---
0 - #48	1.0	24.5	31.7	43.8	2.5	---
Mine Run	1.6	19.5	30.9	49.6	2.5	12,000
Plus 1½ in.	1.2	18.6	30.1	51.3	2.1	12,060
0 - 1½ in.	1.6	20.5	30.9	48.6	3.0	11,720
3/4 - 1½ in.	1.5	24.6	29.4	46.0	3.6	11,100
0 - 1/8 in.	1.5	18.3	32.2	49.5	2.6	11,950

TABLE VI

ULTIMATE ANALYSES

Sample	Dry Basis: Carbon %	Hydrogen %	Sulphur %	Nitrogen %	Oxygen %	Ash %
MINE RUN	67.6	4.6	2.5	1.0	4.8	19.5

TABLE VII

SULPHUR FORMS
(As received basis)

	Total Sulphur % of Coal	Sulphate Sulphur % of Coal	Sulphate Sulphur % Sulphur	Pyritic Sulphur % of Coal	Pyritic Sulphur % Sulphur	Organic Sulphur % of Coal	Organic Sulphur % Sulphur
Mine Run	2.46	0.20	8.13	1.18	47.97	1.08	43.90

TABLE VIII

FUSIBILITY OF ASH

Screen Sizes	Initial Deformation °F	Softening Temperature °F.	Fluid Temperature °F.	Melting Range °F.	Softening Interval °F.	Flow Interval °F.	Ash %
Plus 4 in.	2240	2350	2500	260	110	150	16.9
2 – 4 in.	2200	2280	2360	160	80	80	21.6
1½ – 2 in.	2100	2260	2450	350	160	190	29.5
1 – 1½ in.	2150	2250	2460	310	100	210	26.4
3/4 – 1 in.	2200	2240	2320	120	40	80	23.6
½ – 3/4 in.	2210	2270	2350	140	60	80	20.6
1/4 – 1/2 in.	2220	2300	2370	150	80	70	18.5
1/8 – 1/4 in.	2200	2300	2400	200	100	100	17.8
#48 – 1/8 in.	2480	2560	2600	120	80	40	16.9
0 – #48	2320	2440	2500	180	120	60	24.5
Mine Run	2140	2250	2290	150	110	40	19.5
Plus 1½ in.	2250	2300	2400	150	50	100	18.6
0 – 1½ in.	2200	2270	2320	1[illegible]0	70	50	20.5
3/4 – 1½ in.	2100	2200	2270	1[illegible]0	100	70	24.6
– 1/8 in.	2120	2210	2290	1[illegible]0	90	80	18.3

TABLE IX

CHEMICAL ANALYSIS OF ASH

SAMPLE	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	MnO %	Na_2O %	K_2O %	P_2O_5 %	TiO_2 %	SO_3 %	Total %
Mine Run												

IV

LABORATORY WASHING TESTS

Coal washing, generally speaking, depends on the difference in specific gravities of the coal and refuse, and this difference has been used in the laboratory for many years through the use of float-and-sink tests to differentiate between these materials. By successive separation of a coal at various gravities, washability curves may be constructed which will indicate for any given coal the theoretical ash content and yields of both clean coal and refuse obtainable at any given gravity.

The data obtained from this test on the 1½ inch slack, 1½ to 4 inch lump and +4 inch lump crushed to pass a 4-inch screen, all prepared from the run-of-mine coal, are presented in several tables and have been plotted as shown in the accompanying curves. The method used for plotting the curves is patterned after that of J.R. Campbell of the American Rheolaveur Corporation to which has been added the 'specific gravity distribution' curve as suggested by B.M. Bird of the Battelle Memorial Institute. The curves represent the following information:

Curve 1, which is the cumulative float and ash per cent curve, represents the variation of the ash.

Curve 2, represents the variation in ash per cent of the material with variation in gravity at which the separation is made.

Curve 3, represents the cumulative sink per cent according to the recovery as in Curve 1.

Curve 4, represents the variation in recovery according to the specific gravity.

Curve 5, the ± .10 specific gravity distribution curve, represents a measure of the comparative difficulty of separation according to specific gravity and with respect to the point of separation.

According to B.M. Bird, the degree of difficulty of

wet washing a coal as represented by the specific gravity distribution curve may be summarized in the following table.

±.10 Curve	Degree of Difficulty	Preparation
Per cent		
2 - 7	Simple	Almost any process; high tonnage
7 - 10	Moderately difficult ..	Efficient process; high tonnage
10 - 15	Difficult	Efficient process; medium tonnage
15 - 20	Very difficult	Efficient process; low tonnage
20 - 25	Exceedingly difficult .	Very efficient process; low tonnage
Above 25	Formidable	Limited to a few exceptionally efficient processes.

For the ordinary wet washing study of a coal, 10 per cent on the curve is used, and the specific gravity representing this point is selected for the washing of a composite sample, the clean coal and refuse fractions of which are studied for their various properties. When applying the float-and-sink data to a dry cleaning study of a coal, 3 per cent on the specific gravity distribution curve is used. If a horizontal line is drawn from either of these points on Curve 4 (Specific Gravity curve), the points at which it cuts the other lines represents the following:

Curve 1, the average ash per cent of the separated coal.

Curve 2, the actual ash per cent of the heaviest piece of material left in the coal, and likewise the lightest piece of material in the refuse.

Curve 3, the average ash per cent of the refuse extracted.

What has been said above with respect to ash applies similarly to sulphur.

Curves showing the reduction of ash which is possible under varying conditions of washing the different sizes are presented in Figures I, II and III. All of the data used in the construction of the curves are presented in Tables X to XVIII inclusive.

TABLE X

Float and Sink Data on 1½" Slack

– Ash –

Specific Gravity		Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	± .10 Specific Gravity Distribution Gravity	± .10 Specific Gravity Distribution Calculated Ordinate
								1.35	79.2
	Floats 1.30	28.0	4.9	28.0	4.9	100.0	22.0	1.40	49.5
Sinks 1.30	" 1.40	35.5	9.8	63.5	7.6	72.0	28.7	1.45	21.0
" 1.40	" 1.50	7.0	22.0	70.5	9.1	36.5	47.0	1.55	11.8
" 1.50	" 1.60	6.0	29.1	76.5	10.6	29.5	52.9	1.65	8.5
" 1.60		23.5	59.0	100.0	22.0	23.5	59.0	1.75	6.3
Curve No.		4	2	1,2,4	1	3	3	5	5

TABLE XI

Chemical Analysis and Fusibility of Ash on Float and Sink Portions of 1½" Slack

Specific Gravity		Ash %	Volatile Matter %	Fixed Carbon %	Coking Properties	Sulphux %	Initial Deformation °F.	Softening Point °F	Fluid Temperature °F	Melting Range °F	Softening Interval °F	Flow Interval °F
	Floats 1.30	5.0	33.2	61.8	Good	1.6	2350	2390	2410	60	40	20
Sinks 1.30	" 1.40	10.0	33.1	56.9	Good	2.3	2050	2070	2190	140	20	120
" 1.40	" 1.50	22.4	30.8	46.8	Good	4.7	2170	2270	2360	190	100	90
" 1.50	" 1.60	29.7	28.8	41.5	Fair	6.3	1950	2150	2210	260	200	60
" 1.60		60.3	19.3	20.4	Agglomerate	3.8	2220	2450	2550	330	230	100

TABLE XII

Float and Sink Data on 1½ - 4" Lump

\- Ash -

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
Floats 1.30	6.3	5.6	6.3	5.6	100.7	31.5	1.40	62.5
Sinks 1.30 " 1.40	15.6	9.0	21.9	8.0	93.7	33.2	1.45	59.6
" 1.40 " 1.50	21.9	9.4	43.8	8.7	78.1	38.0	1.55	27.2
" 1.50 " 1.60	6.0	29.9	49.8	11.3	56.2	49.2	1.65	10.0
" 1.60	50.2	51.5	100.0	31.5	50.2	51.5	1.75	8.0
Curve No. 4		2	1,2,4	1	3	3	5	5

TABLE XIII

Float and Sink Data on Plus 4" Lump

\- Ash -

Specific Gravity	Weight %	Ash %	Cumulative Floats Weight %	Cumulative Floats Ash %	Cumulative Sinks Weight %	Cumulative Sinks Ash %	±.10 Specific Gravity Distribution: Gravity	±.10 Specific Gravity Distribution: Calculated Ordinate
Floats 1.30	39.9	6.3	39.9	6.3	100.0	20.0	1.35	89.8
Sinks 1.30 " 1.40	34.5	8.5	74.4	7.3	60.1	29.2	1.40	43.0
" 1.40 " 1.50	1.9	24.7	76.3	7.8	25.6	57.0	1.45	21.2
" 1.50 " 1.60	0.9	27.0	77.2	8.0	23.7	59.6	1.55	2.6
" 1.60	22.8	60.9	100.0	20.0	22.8	60.9	1.65	1.2
Curve No. 4		2	1,2,4	1	3	3	5	5

TABLE XIV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL AND REFUSE

0 to 1½ Inch Slack

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	79.5	20.5
Proximate Analysis (dry basis)				
Ash	%	20.5	9.5	56.1
Volatile Matter	%	30.9	32.1	23.2
Fixed Carbon	%	48.6	58.4	20.7
Sulphur	%	3.0	2.3	5.5
Calorific Value	BTU./lb.	11,720	13,695	
Fusion Point of Ash	°F.	2270	2170	2300
Melting Range of Ash	°F.	120	260	150
Coking Properties		Good	Good	Agglomerate

TABLE XV

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE

1½ to 4 Inch Lump

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	32.8	67.2
Proximate Analysis (dry basis)				
Ash	%	45.8 *	8.6	64.0
Volatile Matter	%	21.8	31.3	17.1
Fixed Carbon	%	32.4	60.0	18.9
Sulphur	%	2.2	1.5	2.5
Calorific Value	BTU./lb.	8260	13,925	
Fusion Point of Ash	°F.	2270	2350	2730
Melting Range of Ash	°F.	250	190	250
Coking Properties		Fair	Good	Agglomerate

* Calculated

TABLE XVI

CHEMICAL ANALYSES OF RAW COAL, CLEAN COAL, AND REFUSE

Plus 4 Inch Lump (Crushed)

		Raw Coal	Clean Coal Floats 1.60	Refuse Sinks 1.60
Weight	%	100.0	91.1	8.9
Proximate Analysis (dry basis)				
Ash	%	16.9	7.5	58.8
Volatile Matter	%	30.1	33.2	20.1
Fixed Carbon	%	53.0	59.3	21.1
Sulphur	%	1.7	1.7	4.8
Calorific Value	BTU./lb.	12,590	14,015	
Fusion Point of Ash	°F.	2350	2330	2280
Melting Range of Ash	°F.	270	280	250
Coking Properties		Good	Good	Agglomerate

TABLE XVII

SCREEN ANALYSIS AND CHEMICAL ANALYSIS

(Dry Basis of 1½" Slack)

Screen Sizes	Weight %	Cum. weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ inch	20.6	20.6	25.2	3.4	2250
1/8 - ¾ inch	50.6	71.2	18.9	3.1	2300
0 -1/8 inch	28.8	100.0	18.3	2.6	2210

TABLE XVIII

FLOAT AND SINK DATA ON SCREENED SIZES

USING A SELECTED GRAVITY OF

(Dry Basis)

Screen Sizes	Floats				Sinks			
	Weight %	Ash %	Sulphur %	F.P.A. °F.	Weight %	Ash %	Sulphur %	F.P.A. °F.
3/4 - 1½ in.	68.9	13.1	2.8	2200	31.1	55.9	2.8	2550
1/8 - 3/4 in.	83.0	11.3	2.7	2240	17.0	55.5	2.7	2450
0 - 1/8 in.	80.8	7.8	2.2	2150	19.2	57.8	2.2	2380

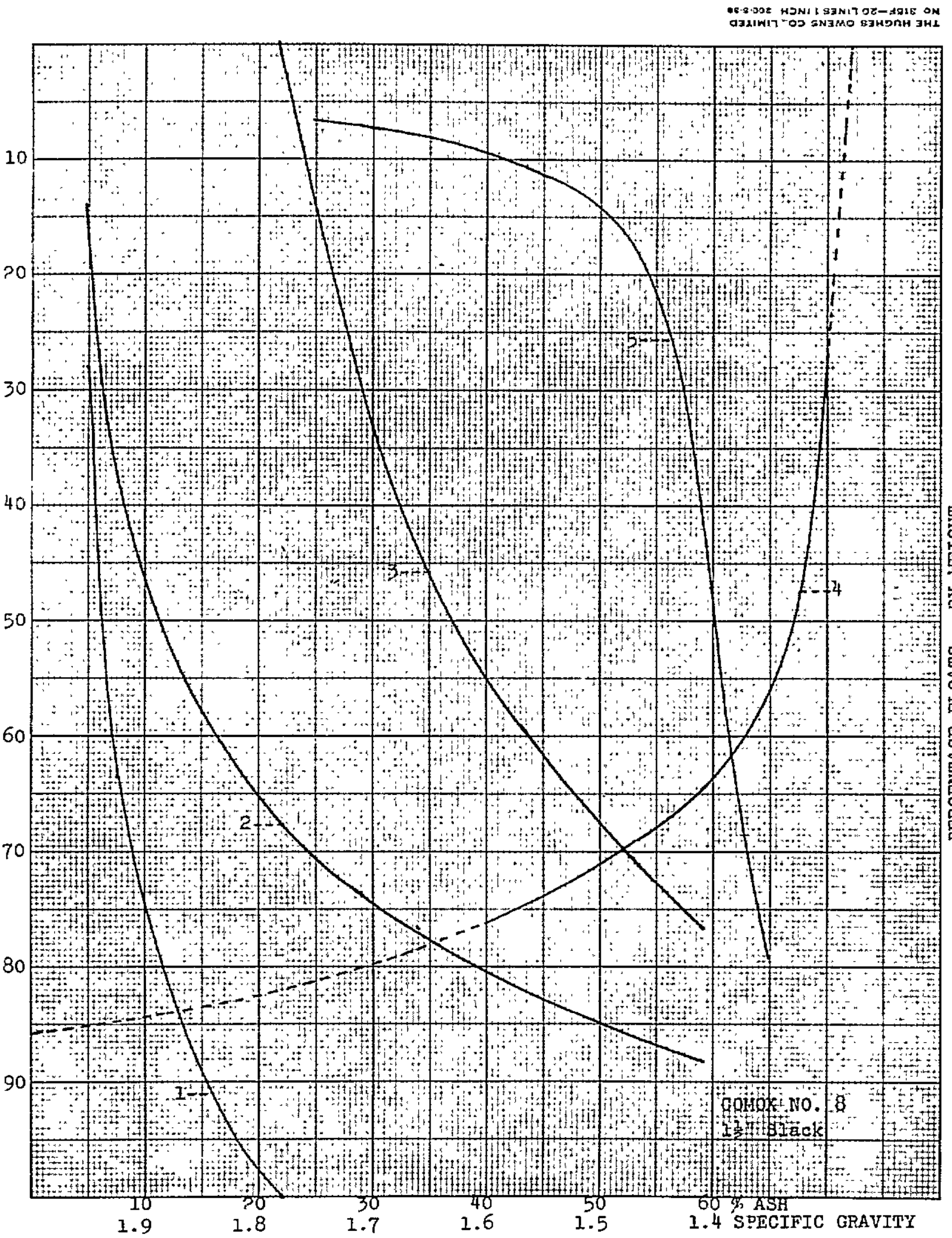

FIG. 1 - Washability Curves for 1½" Slack - Comox No 8

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity.
Curve 5 - ±.10 specific gravity distribution.

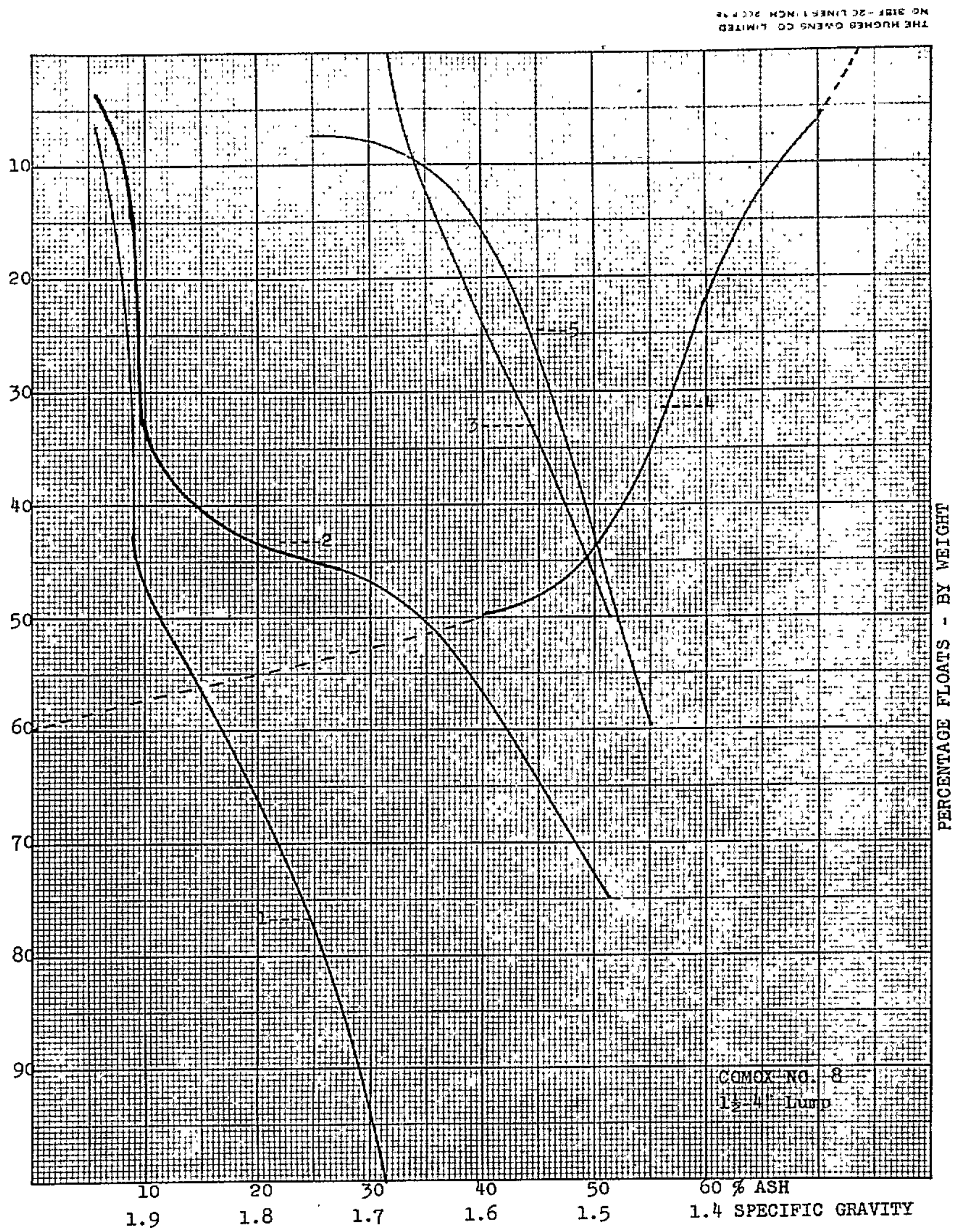

FIG. 11 - Washability Curves for 1½" - 4" Lump - Comox No.8

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

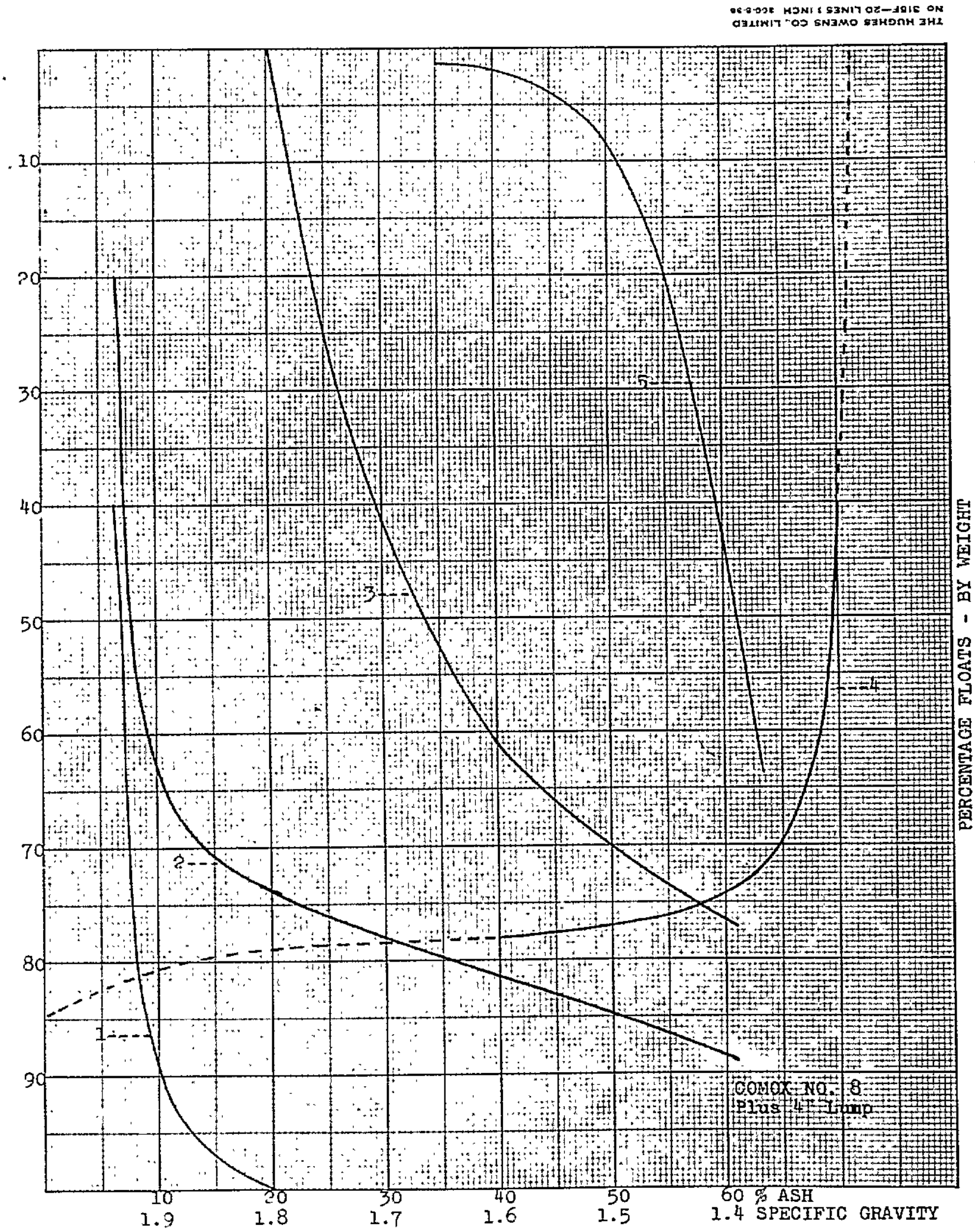

FIG.111 - Washability Curves for Plus 4-in. Lump - Comox No.8

Curve 1 - Cumulative coal-ash percentage (float)
Curve 2 - Actual ash percentage.
Curve 3 - Cumulative slate-ash percentage (sink)
Curve 4 - Specific gravity
Curve 5 - ±.10 specific gravity distribution.

V

COKING PROPERTIES

1. Swelling Index Test

In order to predict the physical properties of by-product coke made from any given coal, a laboratory test has been developed at the Fuel Research Laboratories. This has been outlined and published by the Mines Branch.1/ The test consists of determining the volatile matter and the percentage of swelling of the coke button at a temperature of 600°C. From these data the 'swelling index' is calculated, and by the aid of a coke classification chart the coal is located in a particular group. The various groups are arbitrarily delimited according to the physical properties of the coke made from the coals in these groups.

The results obtained by means of this test for the Comox No. 8 mine coal are shown in Table XIX.

2. Caking Index Test

It has been shown that those coals which are recognized as falling within the best coke-producing class are capable of withstanding a higher admixture of inert material and will yield a carbonized residue of definite crushing strength than are the more inferior coals. The phenomenon has been thoroughly studied and the methods have been developed for the determination of the 'caking index'. While these tests are of uncertain value for the purpose of assessing a wide range of coals in their application to the production of by-product coke, a knowledge of the 'caking value' is important when it is desired to mix inert carbonaceous material or non-coking coals, with coking coals.

The method developed by Gray and as modified at the Fuel Research Laboratories in which 25-gramme mixtures of coal and sand in varying proportions are carbonized in Illium crucibles at 950°C. has been adopted as a standard.

1/ " A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant by-Product Coke", by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 737 - 2.

PHYSICAL PROPERTIES OF BY-PRODUCT COKES

AS DETERMINED BY A

"SWELLING INDEX" TEST

	0 - 1½ in. Slack Washed at 1.60 Sp. Gr.
Volatile Matter at 600°C(D.B.). . .%	26.0
Swelling Index	1000
Section--Coke Classification Chart .	IV near III
Specific Volatile Index	170
Section--Coal Classification Chart .	D: Parabituminous
Ash per cent in coal (dry) . . . .%	9.5
PHYSICAL PROPERTIES OF BY-PRODUCT COKE--	
Size on wharf (% on 3" screen . .	40.0
(Breeze: %-1/2" . .	2.0
Shatter test (Index: % on 2" screen	50.0
(Breeze: %-1/2" . .	2.5
Abrasion test (Index: % on 1½" screen	90.0
(Dust: %-1/16" . .	3.5
Density (App. Specific Gravity.	1.0
(Lbs. per cubic foot. .	27.5
Transverse shrinkage	Good
Appearance of natural surface . . .	steel grey, smooth.
Shape	square
Strength.	hard
Cross fracture.	Med. amt: fairly square
Longitudinal fracture	Medium amount
Cell structure.	Dense
Sponge	very little
Pebbly seam	none
REMARKS	This is a true gas coal & may be used, if required, without blending with other coals in the preparation of a good grade of standard by-product coke.

Caking Properties

	Gray Caking Index
Mine Run - - - - - - - - -	63

VI

SUMMARY AND DISCUSSION OF RESULTS

The run-of-mine sample of coal from the Comox No. 8 Mine, No. 2 Seam, operated by the Canadian Collieries (Dunsmuir) Ltd. in the Comox area, British Columbia, was collected at the mine by sampling from freshly mined coal. In this way approximately 2,252 pounds of coal, representative of the seam at this mine at the time of sampling during July 1941, was collected and shipped to the Fuel Research Laboratories for the investigation as to the physical and chemical properties.

Physical Properties

The results of the screening tests on the run-of-mine coal which were conducted at the Fuel Research Laboratories (as received) are shown in Table I. This table contains the percentage of the various screened sizes on the 'as received' basis. On this basis it will be noted that 16.0% of the coal was below 1/8 inch in size, 30.7% was above 4 inch in size, and 10.1% was 2 to 4 inch in size, the remaining 43.2% being distributed between the other sizes. The average size of the run-of-mine coal 'as received' was 2.93 inch, yielding 55.0% of 1½" slack.

The bulk density and apparent specific gravity of the various screened sizes are given in Table I. The results agree very well with other coals of similar rank and ash contents, the individual screen sizes above 1/8 inch having uniformly lower bulk density than mixtures of these sizes. Due to the high proportion of free stone in this coal the gravities were conducted on the coal freed from the stone. For comparison the 3/4 - 1 in. size was tested before and after freeing from the stone, the results being as follows: 1.47 as received and 1.31 when freed from the stone. The bulk densities would be similarly effected.

The results of the friability test on the coal from the Comox No. 8 Mine are shown in Table II. One single size, prepared from the run-of-mine coal, was tested according to the method described in publication No. 762 of the Mines Branch. In addition to the standard 2-drop test, the table contains the results of a 4-drop test on the sample. This latter procedure is preferred for mixed sizes because of the cushioning effect of the fines, but was included in this case to indicate the effect of more prolonged handling. It is noteworthy that the size tested, namely, 2 to 3 inch, was rather friable, the size stability being 80.2% after two drops.

The grindability indices for three sizes of mixed coal prepared from the run-of-mine coal are given in Table III. These indices are reported on the basis of the Hardgrove-machine method which has been described in Mines Branch publication No. 737-1. Although the finer sizes appear to be comparatively more amenable to grinding than the coarser material, the results as a whole indicate a coal that would be rather difficult to grind in comparison to the general run of coal used for powdered fuel firing. Reduction in ash content will no doubt materially improve the grinding characteristics of the coal.

The results of the crushing test conducted on the +4 inch lumps are shown in Table IV. This test indicates that, when the coke cutter was set at 1½ inch, the coal was reduced in size to 22.1% of that of the uncrushed lumps, that is from an average particle size of 7.563 inches to an average particle size of 1.669 inches. This crushing resulted in the production of 60.6% of 1 to 3 inch 'stove' coal (this size is approximately comparable to the standard Anthracite Institute size for 'stove' coal), 14.2% of 1/2 to 1 inch 'stoker' coal, and 6.6% of 3 to 5 inch 'egg' coal. All these commercial sizes were produced with a resultant formation of 18.6% of 0 to 1/2 inch slack.

Chemical Properties

The proximate and ultimate analyses of the various screen sizes are shown in Tables V and VI respectively. It will be noted, referring to Table V, that the various sizes are comparatively high in ash content as the size decreases from the +4 in. lump to the 1½ - 2 in. size the ash increases from 16.9% to 29.5%. All the sizes below the 1½ in. screen show a more or less uniform decrease in ash with a decrease in size to 16.9% for the 48 mesh-1/8 in. fines. The dust (0 - 48 mesh) showed an appreciably increase to 24.5%. The composites vary in ash content according to the properties of the sizes included, the run-of-mine yielding 19.5% ash, the +1½ inch lump 18.6% ash, and the 0 to 1½ inch slack 20.5% ash. The sulphur content of this coal is medium and fairly uniform for all the sizes examined, varying between 2.5% and 3.4%. Reference to Table VII indicates that 48.0% of the total sulphur is in the pyritic form.

The volatile matter of the coal is high in quantity and based on the Specific Volatile Index 1/ method of classification this coal has an index of approximately 170 which places it in the parabituminous class (True Gas type) of coals. According to the A.S.T.M. classification Designation D 388-38T, where rank is based on the fixed carbon and calorific value calculated to the mineral-matter-free basis, this coal is classed as a high volatile A bituminous coal.

Table VI gives the ultimate analyses of the mine-run composite. The coal is a medium carbon and medium oxygen material.

Table VIII shows the results of the ash fusion determinations for various sizes of the coal, whereas Table IX gives the chemical analysis of the ash of a mine-run composite of sizes. It will be noted that the softening temperature of the ashes for the various sizes is fairly uniform ranging from 2240°F to 2560°F.

1/ "Classification of Coal Using Specific Volatile Index" by R.A. Strong, E.J. Burrough and E. Swartzman - Mines Branch publication No. 752-2

The fusibility of the ash does not vary regularly with the ash content of the coal although the lower ash finer sizes show a somewhat higher ash fusion temperature. Examination of the float-and-sink data indicates that although the mineral matter of the low ash material is of such a nature in the 0 - 1½" slack sizes as to have a relatively higher softening temperature, (2350°F), than the higher ash fractions it does not affect the composite ash in a manner to raise the ash fusibility when some of the high ash fractions are removed.

Laboratory Washing Tests

The washing tests on the coal from the Comox No. 8 Mine, were conducted in the standard manner on samples of 1½ inch slack, 1½ to 4 inch lump, and crushed +4 inch lump, prepared from the run-of-mine coal. The results are given in a series of tables and curves shown in Section IV. Referring to Tables X and XI, it will be noted that the 1½ inch slack has a medium inherent ash content of 4.9% and a relatively high sulphur content of 1.6% as indicated by the fraction floating at a specific gravity of 1.30. At this gravity 28.0% of the coal is recovered. Washing this coal at a specific gravity of 1.60, which according to the ±.10 specific gravity distribution curve represents simple wet washing, would result in the production of approximately 79.5% clean coal having 9.5% ash and 2.3% sulphur; these data are shown in Table XIV. It should be noted that the sulphur reduction is negligible, and this is due to the fact that the pyrite occurs mainly as finely divided material. The washing data for the 1½ to 4 inch lump and crushed +4 inch lump are shown in Tables XII and XIII respectively. The inherent ash is medium to high in amount, the 1½ to 4 inch lump showing 5.6% ash in only 6.3% of the coal recovered at a specific gravity of 1.30, whereas the +4 inch crushed lump indicated 6.3% ash in 39.9% of the coal floating at the same gravity. Washing the 1½ to 4 inch lump at a selected gravity of 1.60 would be relatively simple, but because of the apparent great variation in quantity of free stone in these sizes the quantity of rejects will vary greatly, and will usually be high. The particular samples tested contained 31.5% and 45.8% ash respectively (see Tables XII and XV) and on separation at 1.60 yielded 49.8% clean coal with 11.3% ash in the first case, and only 32.8% clean coal containing 8.6% in the second case. Washing the crushed +4 inch lump in a similar manner would yield about 91.1% clean coal containing about 7.5% ash (see Table XVI). It is thus concluded that the sample of Comox No. 2 seam coal, as obtained at the Comox No. 8 Mine, is amenable to cleaning by either wet or dry processes, and the ash could be reduced to less than 10% but would result in a high refuse loss. It should be noted that crushing the +4 inch lump materially aided in improving the washing characteristics of this size.

Coking Properties

The phenomenon of coking, whereby a coal becomes plastic and then fuses to a solid mass, is considered to be a combination of two reactions, one resulting in the swelling of the plastic mass, and the other being responsible for the ultimate binding or 'caking'. Various methods have been introduced for the determination of these two properties with a view to predicting the reaction of a coal in by-product ovens. A method developed at the Fuel Research Laboratories for determining the swelling properties has been presented in detail in Mines Branch publication No. 737-2. The calculated value 'swelling index' is a comparative measure of the swelling properties, and the higher the index the greater the swelling. This index is used in combination with a specific coke classification chart to locate the coal in a group, the physical properties of the coke made from coals falling in this group being known. The results of this test, as applied to the washed 1½ inch slack coal from the Comox No. 8 Mine, indicated that the coal had fairly good coking characteristics, in so far as use in standard by-product ovens is concerned. The Swelling Index was 1000, which according to the coke classification chart, should result in a good domestic coke as indicated in Table XIX.

The method developed by Gray is used at the Fuel Research Laboratories for determining the binding or caking properties of a coal. The 'caking index' determined by this method and described in Section V does not lend itself to exact correlation with the reaction of a coal to coking, but may, however, have a certain value in determining its suitability for stoker use. The test is being studied in this connection at the Fuel Research Laboratories but, as yet, no definite correlation has been established. The result of this test on the Comox No. 8 Mine coal indicated a coal that is strongly caking, the caking index being 63.
