881

P.I.C.S. - 173

#881

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

#881

Physical and Chemical Survey Report No. 83

STUDY OF COAL FROM

MIDDLESBORO NO. 3 SEAM, NO. 4 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

#681

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.

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 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 K.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[a]	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	31.8
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

[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.

"Coal Friability Tests" by R.E. Gilmore, J.H.H. Nicolls, and G.F. 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 1¼ 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.	67.3

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. 3 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 - 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	
3 - 4 in.		9.4
2 - 3 in.		52.6
1½ - 2 in.		14.6
1 - 1½ 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.	6.080	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.	5.3	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	23.4	33.8	43.8	0.6	-----
/48 - 1/8 in.	5.8	34.1	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	64.5	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

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		17.2	5.7	17.2	5.7	100.0	21.7	1.35	80.1
Sinks 1.30	"	1.40	46.6	10.2	63.8	11.9	82.8	25.1	1.40	69.1
" 1.40	"	1.50	17.7	25.7	81.5	14.9	36.2	33.1	1.45	41.1
" 1.50	"	1.60	7.0	39.8	88.5	16.6	18.5	51.9	1.55	16.6
" 1.60			11.5	81.2	100.0	21.7	11.5	61.1	1.65	5.7
									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		6.0	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-Agglutinate	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 1½ - 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 1½ 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
1½ 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	35.7	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.	2550	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

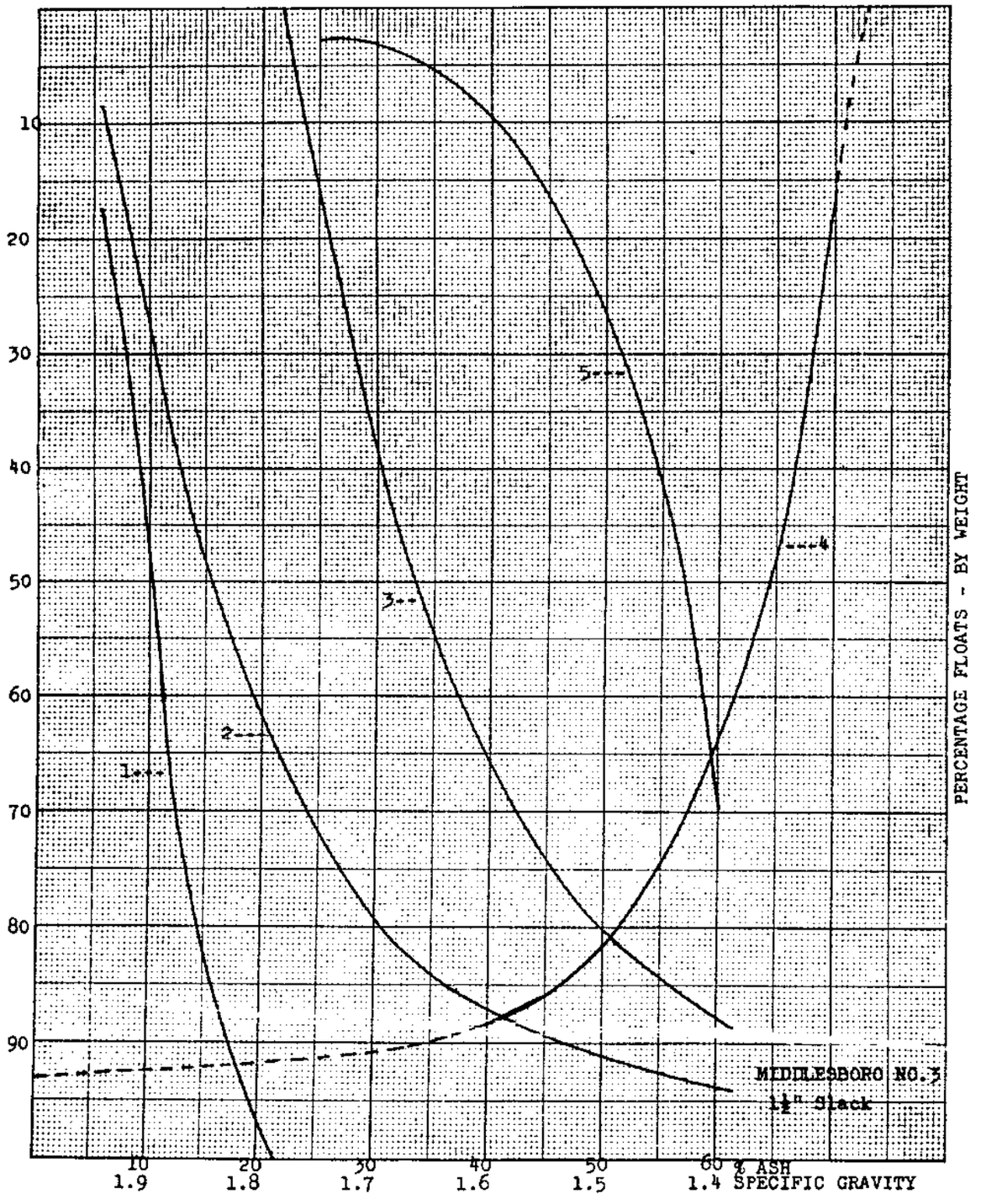

FIG. 1 - Washability Curves for 1½" Slack Middlesboro No. 3 Mine.

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

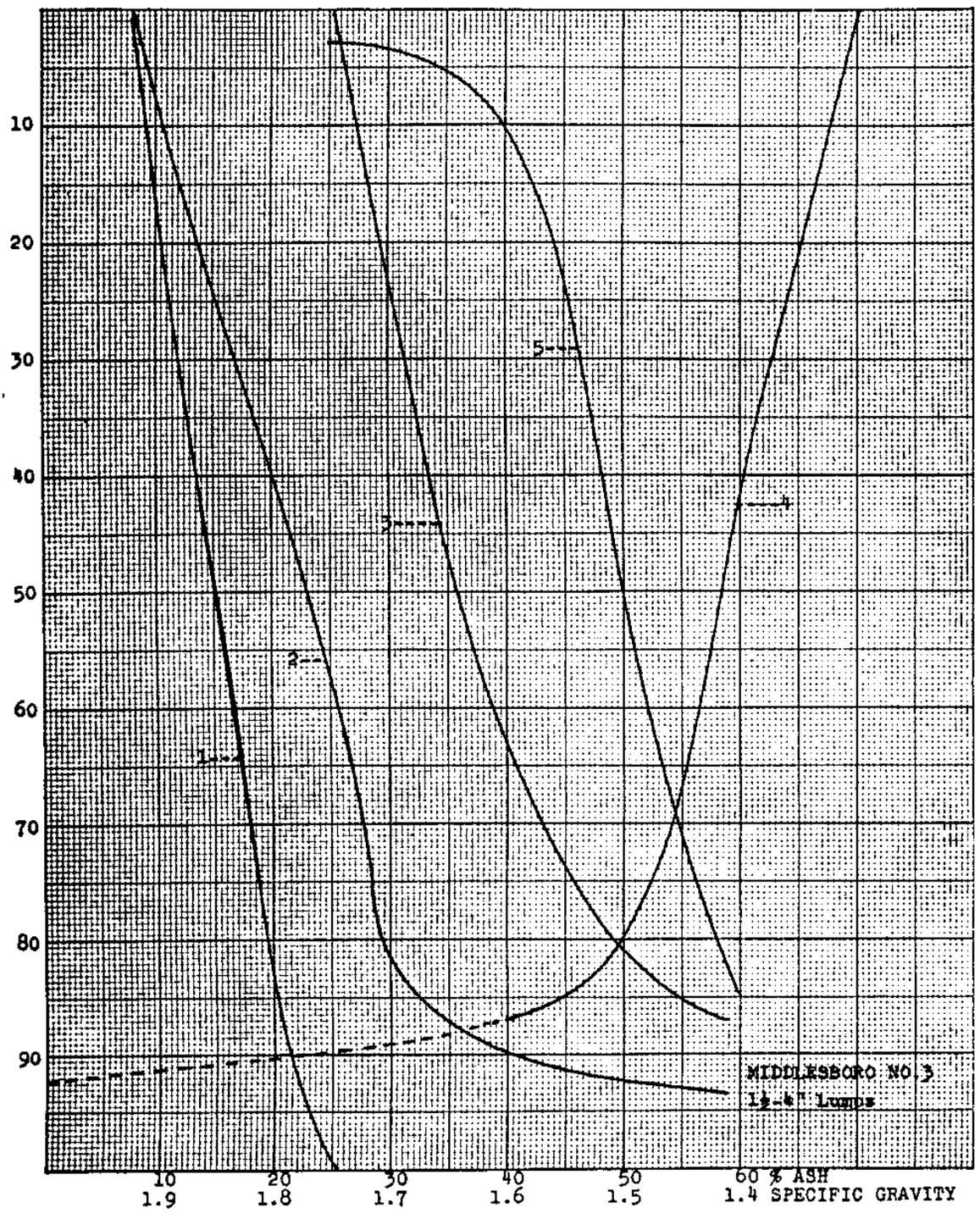

FIG. 11 - Washability Curves for 1½" - 4" Lump - Middlesboro No.3 Mine

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.

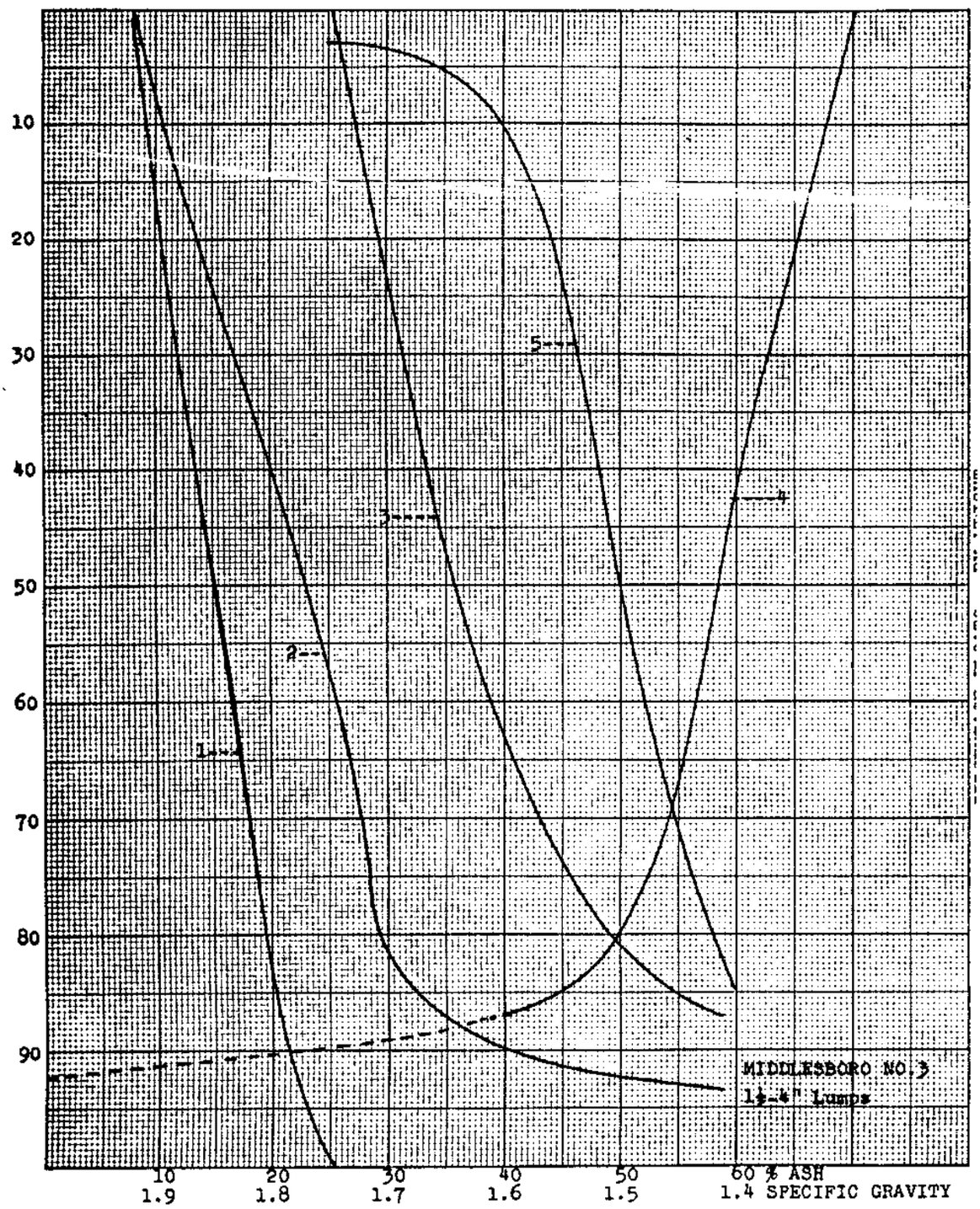

FIG. 11 - Washability Curves for 1½" - 4" Lump - Middlesboro No.3 Mine

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.

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 do. 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 - 1½ 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.

VII

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-I. 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 inherent 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 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 Middlesboro No. 3 mine, indicated that the coal was non-coking, in so far as use in standard by-product ovens is concerned.