PROVINCE OF ALBERTA

Research Council of Alberta — *Report No. 35*

University of Alberta, Edmonton, Alberta

COALS OF ALBERTA

Their Occurrence, Analysis and Utilization

by

Edgar Stansfield and W. Albert Lang

Part I—Occurrence, Classification and Production

Part II—Notes on Analyses, Special Tests and Terms

Part III—General Properties of Coal

Part IV—Preparation and Utilization of Coal

Part V—Combustion of Coal

Part VI—Analytical and Technical Data by Coal Areas

A compilation of test and other data obtained by the staff of the Research Council of Alberta working in co-operation with the Mines Branch of the Department of Lands and Mines of Alberta. References to, and data from, published reports of the Fuel Testing Division, Bureau of Mines, Canada, are also included.

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Preface and Acknowledgements

This report is based mainly on tests and analyses made in the laboratories of the Research Council of Alberta, at the University of Alberta, Edmonton. Additional information is included from the Geological Division of the Research Council of Alberta, from the Mines Branch of the Department of Lands and Mines of Alberta, and from publications of the Canadian Bureau of Mines.

Analyses and tests of the Research Council are based on all samples received, and on information and publications available up to early in 1944. The latest statistics of coal production, then available, were for 1943, and the latest list of operating mines was that of the Canadian Bureau of Mines dated January 1, 1944. Revised and supplementary information can be obtained by consulting later publications, of the Research Council of Alberta and of the Canadian Bureau of Mines, as these become available; and by consulting the successive Annual Reports of the Mines Branch of the Department of Lands and Mines of Alberta.

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The maps and figures were drawn by Mr. Arnold E. Murray.

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PART I

Introduction, Occurrence, Classification and Production

THE COALS OF ALBERTA*

Coal-bearing beds in Alberta occur in three different geological horizons namely, the Edmonton, the Belly River, and the Blairmore-Kootenay. The first two horizons are in the Upper Cretaceous formation and the third in the Lower Cretaceous.

Coal was formed largely from plant material. The accumulated plant material becomes more compact with time so that coal is a mineral product which is always getting older, and with age the character of the coal changes. It is important to understand that the chief factors that determine the character and therefore the classification by rank of the coal are age and pressure. In Alberta the Blairmore-Kootenay coals of Lower Cretaceous age are more mature than most of the Belly River or Edmonton coals that are of Upper Cretaceous age. Pressure on the other hand matures a coal more rapidly than age. This is why the rank of most Alberta coals increases from east to west, that is, from the plains to the foothills and mountains where the coal seams have been affected to a greater degree by the mountain-building forces. This, for example, explains why the Lethbridge coal is of higher rank than the Redcliff coal, although the coals in the two areas are of the same age.

For convenience in compiling analytical data and for ease of reference the parts of the province in which coal has been mined have been divided by the Research Council of Alberta into districts known as coal areas. The coal areas are shown in the large map at the end of the report and in a key map on p. 94.

There are at the time of preparation of this report 50 coal areas, but new areas may be added if new mines are opened outside present areas.

CANADIAN CLASSIFICATION OF COAL BY RANK

In the past the coals of Alberta were classed, and output statistics collected, under four heads:

Anthracite coal—mined at Bankhead in the Cascade area.

Bituminous coal—all coals, other than anthracite, mined from the Kootenay geological horizon in the mountains of western Alberta.

Subbituminous coal—coals mined in the foothills.

Domestic coals—coals mined in the prairies.

No exact definitions of these classes were made; and changes of classification were sometimes found advisable.

In 1934 a tentative classification, the joint work of United States and Canadian chemists, fuel technicians, geologists, and others, was adopted by the American Society for Testing Materials. This classi-

*Adapted from Coal Areas of Alberta by J. A. Allan, Research Council of Alberta No. 34, Part 5, 1943.

fication was later slightly modified. It was referred to Canadian coal operators in 1937 and as no objections were raised it was adopted for Canada in 1938.

This A.S.T.M. classification* is employed throughout this report. It might be noted that coals are not only classed by rank, a classification which indicates the degree of transformation of the original plant material towards anthracite; but are also classed by grade and by type. Grade classification gives a commercial evaluation of the coal as sold, and type classification is based on the origin of the coal; but neither of these is here discussed.

In the classification by rank, as shown in Table 1, high rank coals are classified primarily according to the percentage of fixed carbon in the dry and pure, that is mineral-matter-free, coal; whilst lower rank coals are classified according to the heat value of the mineral-matter-free coal, but moist as the coal occurs in the seam. Secondary distinctions are made according to whether the coal is agglomerating, that is forms a firm button in the volatile matter test, or otherwise; and according to the coal being weather resistant, that is loses less than 5% through disintegration in the accelerated weathering test, or otherwise.

TABLE 1

Classification of Coals by Rank

Legend: F.C.=Fixed Carbon. B.t.u.=British thermal units.

Class	Group	Limits of Fixed Carbon or B.t.u., Mineral-Matter-Free Basis	Requisite Physical Properties
I.—Anthracitic	1. Meta-anthracite	Dry F.C., 98% or more	
	2. Anthracite	Dry F.C., 92% or more and less than 98%	
	3. Semianthracite	Dry F.C., 86% or more and less than 92%.	Non-agglomerating [1]
II.—Bituminous [3]	1. Low volatile bituminous coal	Dry F.C., 78% or more and less than 86%	
	2. Medium volatile bituminous coal	Dry F.C., 69% or more and less than 78%	
	3. High volatile A bituminous coal	Dry F.C., less than 69% and moist [2] B.t.u. 14,000 [4] or more	
	4. High volatile B bituminous coal	Moist [2] B.t.u. 13,000 or more and less than 14,000	
	5. High volatile C bituminous coal	Moist B.t.u. 11,000 or more and less than 13,000 [4]	Either agglomerating or non-weathering [5]
III.—Subbituminous	1. Subbituminous A coal	Moist B.t.u. 11,000 or more and less than 13,000 [4]	Both weathering and non-agglomerating
	2. Subbituminous B coal	Moist B.t.u. 9,500 or more and less than 11,000 [4]	
	3. Subbituminous C coal	Moist B.t.u. 8,300 or more and less than 9,500 [4]	
IV.—Lignitic	1. Lignite	Moist B.t.u less than 8,300	Consolidated
	2. Brown coal	Moist B.t.u less than 8,300	Unconsolidated

1 If agglomerating, classify in low-volatile group of the bituminous class.

2 Moist B.t.u. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

3 It is recognized that there may be non-caking varieties in each group of the bituminous class.

4 Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of B.t.u.

5 There are three varieties of coal in the high-volatile C bituminous coal group, namely, Variety 1, agglomerating and non-weathering; Variety 2, agglomerating and weathering; Variety 3, non-agglomerating and non-weathering.

*Specification D388-38.

The following formulae have been used for calculating the fixed carbon and heat value on the above bases.

$$\text{Dry, mm-free F.C.} = \frac{\text{F.C.}}{100-(\text{M}+1.1\text{A}+0.1\text{S})} \times 100$$

$$\text{Moist, mm-free B.t.u.} = \frac{\text{B.t.u.}}{100-(1.1\text{A}+0.1\text{S})} \times 100$$

Where:

mm=Mineral matter
B.t.u.=British thermal units
F.C.=percentage of fixed carbon
M=percentage of moisture
A=percentage of ash
S=percentage of sulphur, and

Moist refers to coal containing its natural bed moisture, but not including visible water on the surface of the coal.

The following diagram shows graphically the boundaries selected for the different classes. Coals with more than 69% fixed carbon, on the dry, mineral-matter-free basis are classified by this fixed carbon, whilst coals with lower fixed carbon are classified by their heat value on the moist, mineral-matter-free basis. The chart also shows that in some cases coals with certain percentages of fixed carbon or with certain heat values, can be placed in either of two classes according to their agglomerating and weathering properties.

It must be noted that the above is only an abbreviated description of the classification with some details omitted.

OCCURRENCE AND PRODUCTION OF ALBERTA COAL

The locations from which the different ranks of coals have been mined in Alberta are shown in Table 2 and in eight skeleton maps of the coal areas—Maps 2-9.

Table 3 shows for each rank of coal the areas where such coal has been mined. In Table 4 the coal areas are listed with the classification of the coal mined in each.

Table 5 gives the coal production in Alberta for the years 1941, 1942 and 1943, tabulated by class and area.

It can be seen, in Table 2, and in the eight skeleton maps, that the distribution of the coal ranks is irregular within the mountains forming the western boundary of the Province; but that progressively lower ranked coals are found with increasing distance east of the mountain face. Since rank and moisture content of coal are closely related, maps 10 and 11 show clearly, as might be expected, that as the distance east of the mountain face increases the moisture content also increases. Similar curves, paralleling the mountain face, could be drawn for heat content and for other analytical values.

It has been found that in Alberta the rank of the coal is primarily dependent upon the mountain building pressure to which it has been subjected, and only to a lesser degree dependent upon its geological age or the depth of the seam below the surface.

All the coals of Alberta are of Post-Carboniferous age, and therefore younger than the Carboniferous coals of Great Britain, Nova Scotia and New Brunswick, and the eastern United States. Those coals in and near the mountains, however, have been subjected to such prolonged and intense mountain building pressure that they

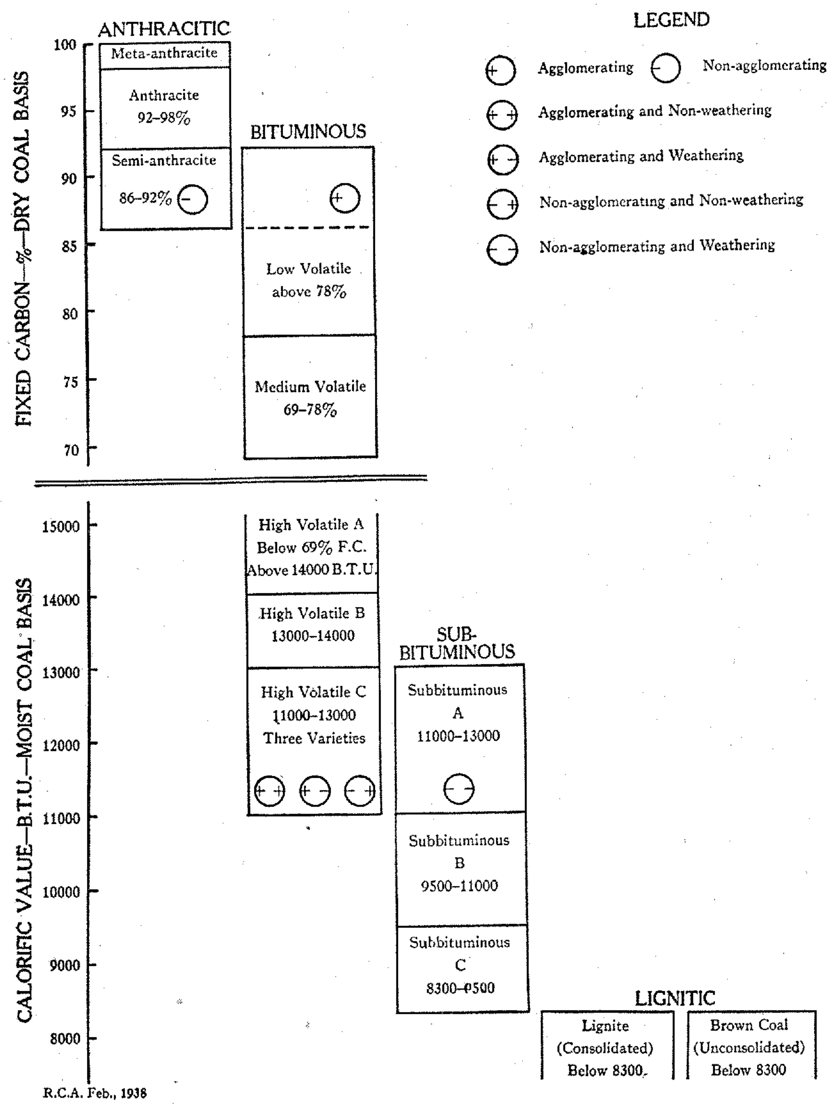


Fig. 1.—Canadian Classification of Coal by Rank. Graphical representation of Canadian (A.S.T.M.) classification by rank, illustrating the relations of requisite physical (agglomerating and weathering) properties of overlapping groups. All analyses on the mineral-matter-free basis.

have been converted to high rank coals, comparable with those of the Carboniferous age.

TABLE 2

Coal Ranks and Locations Where Mined

(As shown by Sampling and Analysis)

Meta-anthracite	None
Anthracite	None
Semi-anthracite—Cascade Area	Tp. 26, R. 11, W. of 5th meridian Tp. 24 R. 10, W. of 5th meridian
Low volatile bituminous	See map 2
Medium volatile bituminous	" " 3
High volatile A bituminous	" " 4
High volatile B bituminous	" " 5
High volatile C bituminous	" " 6
Subbituminous A	" " 7
Subbituminous B	" " 8
Subbituminous C	" " 9
Lignite—Pakowki Area	Tp. 9, R. 5, W. of 4th Tp. 8, R. 3 and 4, W. of 4th Tp. 7, R. 2, W. of 4th
Brown Coal	None

TABLE 3

Coal Ranks and Areas Where Mined

Inclusion of an area under a rank does not necessarily mean that this rank of coal is now being mined in that area, and exclusion of an area under a rank does not necessarily mean that such a rank of coal may not be mined in the area in the future.

Anthracitic Coals:

Meta-Anthracite.
Anthracite.
Semianthracite—Cascade.

Bituminous Coals:

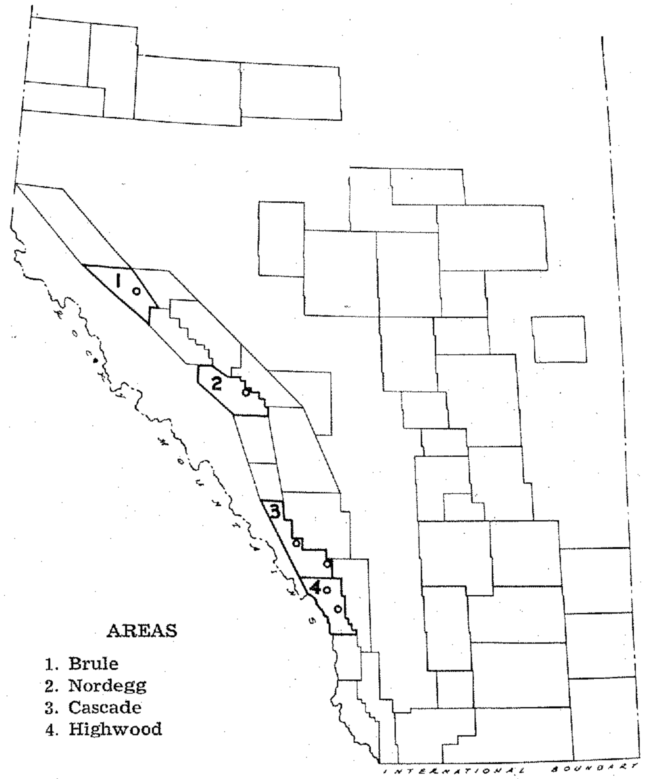
Low volatile bituminous—Brule, Cascade, Highwood, Nordegg.
Medium volatile bituminous—Crowsnest, Mountain Park, Oldman.
High volatile A bituminous—Crowsnest, Mountain Park, Pincher.
High volatile B bituminous—Magrath, Morley, Pekisko, Pincher, Prairie Creek.
High volatile C bituminous—Coalspur, Halcourt, Lethbridge, Magrath, Pincher, Prairie Creek, Saunders.

Subbituminous Coals:

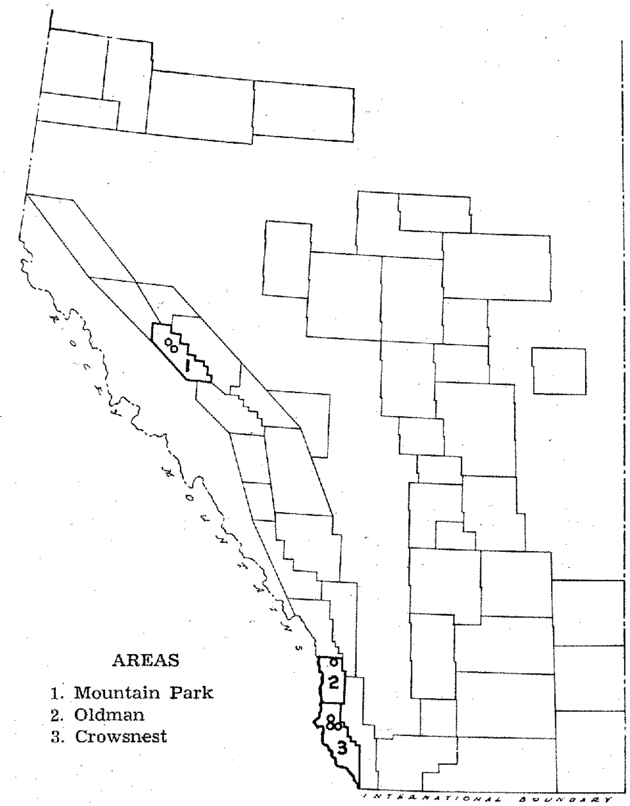
Subbituminous A—Carbon, Champion, Milk River, Taber.
Subbituminous B—Ardley, Big Valley, Brooks, Camrose, Carbon, Castor, Champion, Drumheller, Edmonton, Gleichen, Halcourt, Milk River, Pembina, Taber, Wetaskiwin, Whitecourt.
Subbituminous C—Camrose, Castor, Edmonton, Pakowki, Redcliff, Sexsmith, Sheerness, Westlock.

Lignitic Coals:

Lignite—Pakowki.
Brown Coal.

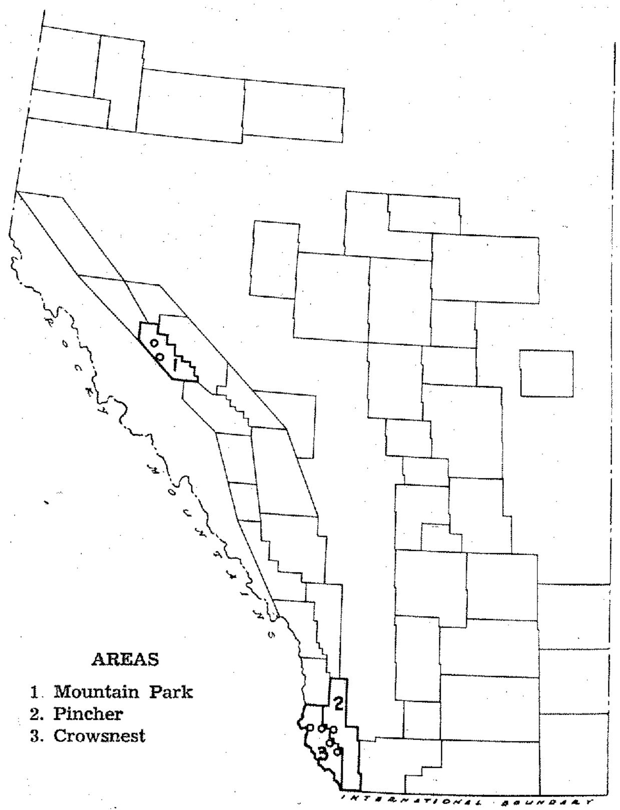


Map 2.—Low Volatile Bituminous

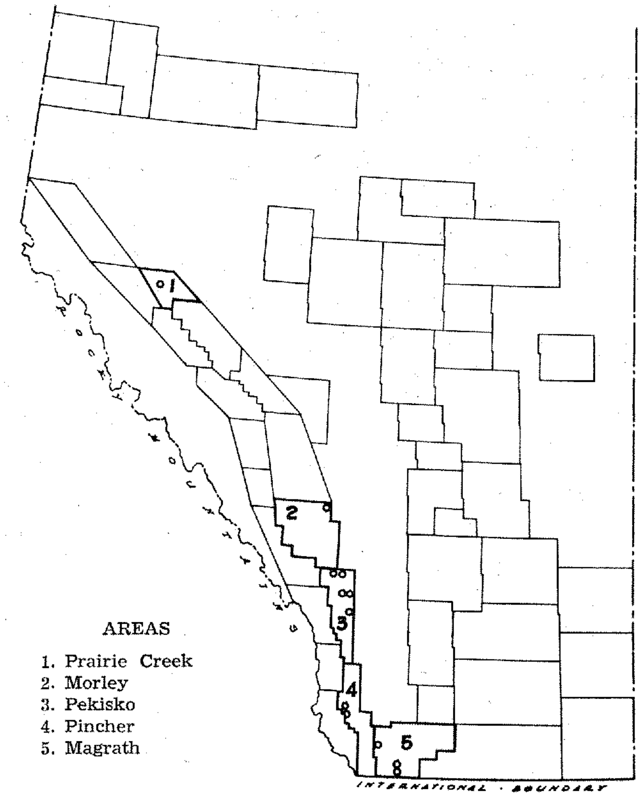


Map 3.—Medium Volatile Bituminous

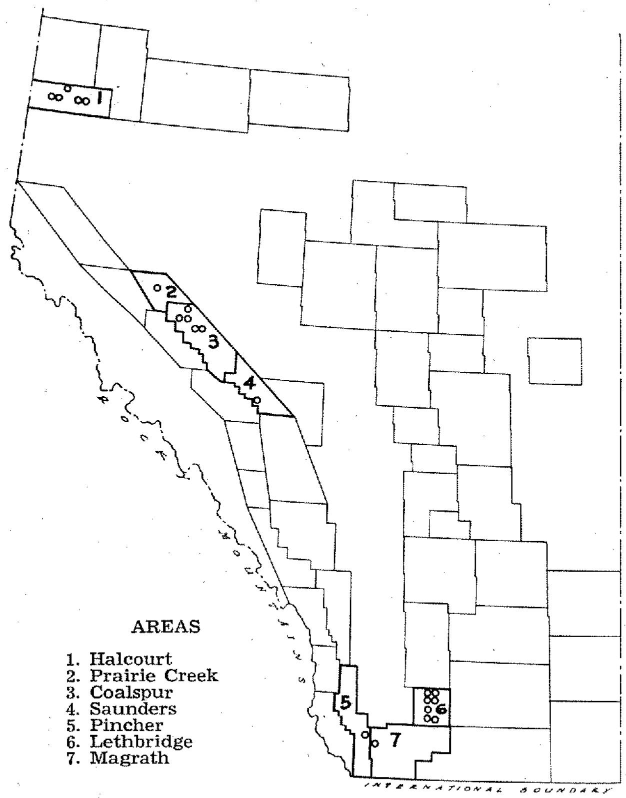
COAL CLASSIFICATION BY RANK



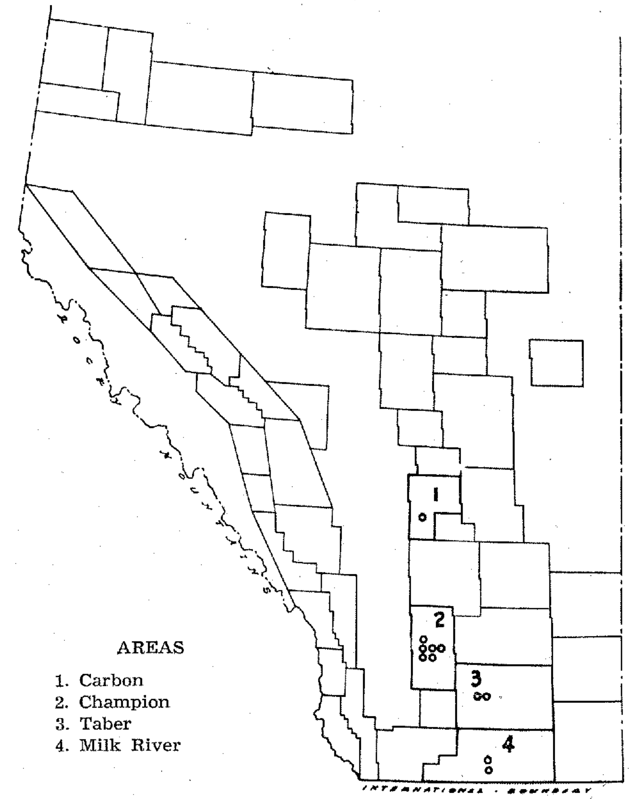
Map 4.—High Volatile A Bituminous



Map 5.—High Volatile B Bituminous

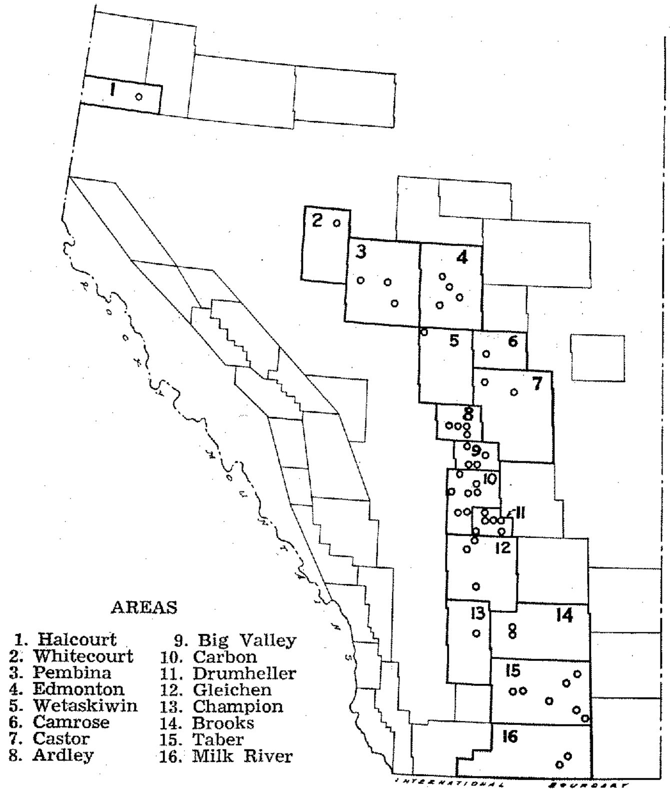


Map 6.—High Volatile C Bituminous

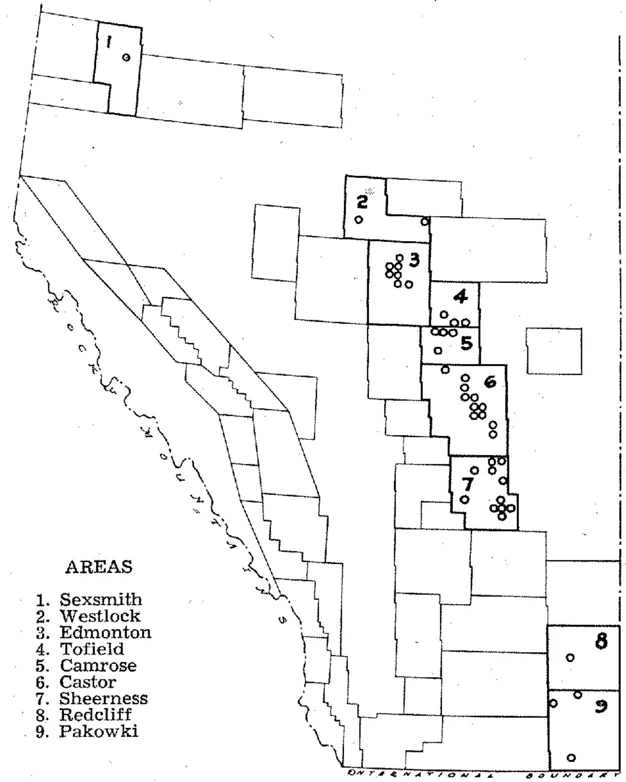


Map 7.—Subbituminous A

COAL CLASSIFICATION BY RANK

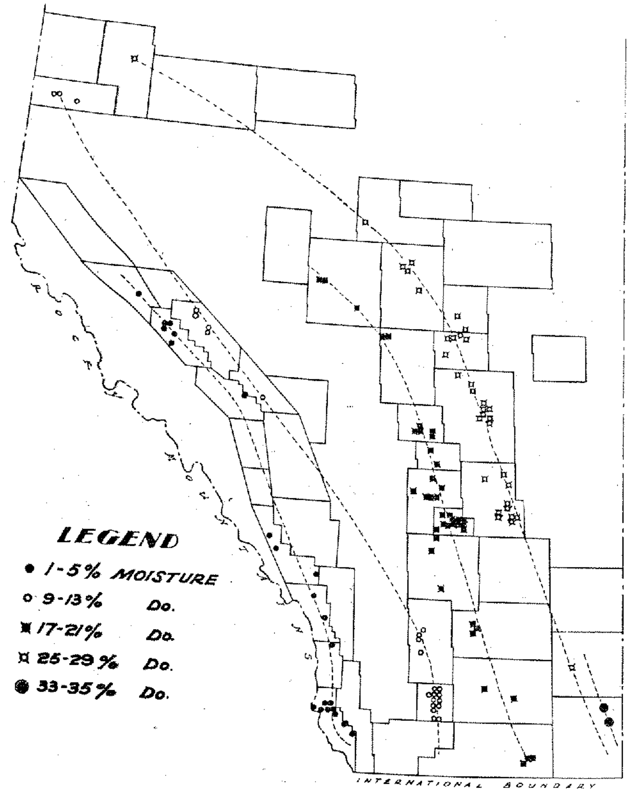


Map 8.—Subbituminous B

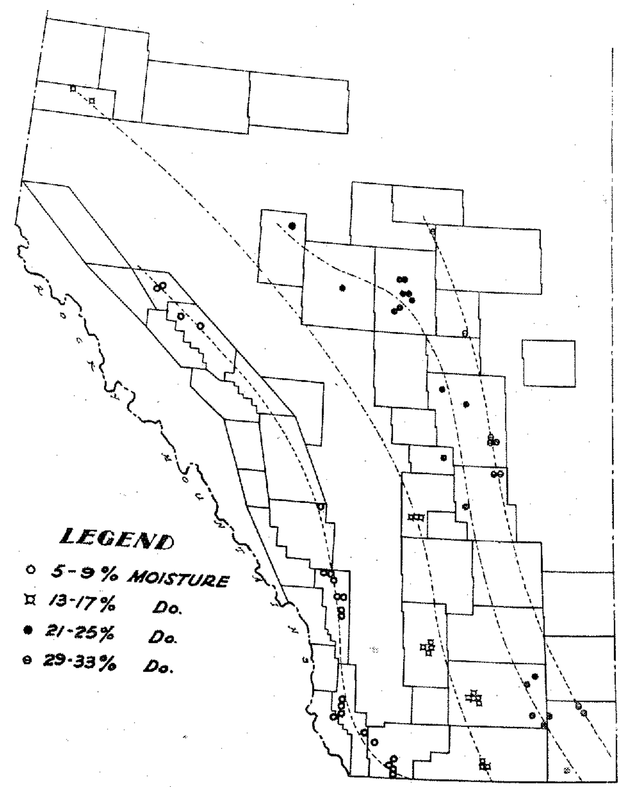


Map 9.—Subbituminous C

COAL CLASSIFICATION BY RANK



Map 10



Map 11

DISTRIBUTION OF ALBERTA COALS BY MOISTURE CONTENT

TABLE 4

Coal Areas and Classification of Coal Mined Therein

Where more than one rank of coal has been mined in an area, the rank or ranks principally mined are listed first, but ranks of secondary importance are listed as also mined. In a few cases classifications are still doubtful and changes may be required when more information is available. The fact that a rank of coal is listed for an area does not necessarily mean this rank is now being mined in that area. Those areas only from which sufficient samples have been analysed to warrant classification are included in the list.

Ardley	Subbituminous B.
Big Valley	Subbituminous B.
Brooks	Subbituminous B.
Brule	Low volatile bituminous.
Camrose	Subbituminous C, also subbituminous B.
Carbon	Subbituminous B, also subbituminous A.
Cascade	Low volatile bituminous, also semianthracite.
Castor	Subbituminous C, also subbituminous B.
Champion	Subbituminous A, also subbituminous B.
Coalspur	High volatile C bituminous.
Crowsnest	Medium volatile bituminous, also high volatile A bituminous.
Drumheller	Subbituminous B.
Edmonton	Subbituminous B and subbituminous C.
Gleichen	Subbituminous B.
Halcourt	High volatile C bituminous, also subbituminous B.
Highwood	Low volatile bituminous.
Lethbridge	High volatile C bituminous.
Magrath	High volatile B bituminous, also high volatile C bituminous.
Milk River	Subbituminous A and subbituminous B.
Morley	High volatile B bituminous.
Mountain Park	High volatile A bituminous and medium volatile bituminous.
Nordegg	Low volatile bituminous.
Oldman	Medium volatile bituminous.
Pakowki	Subbituminous C and lignite.
Pekisko	High volatile B bituminous.
Pembina	Subbituminous B.
Pincher	High volatile B bituminous, also high volatile A and high volatile C bituminous.
Prairie Creek	High volatile B and high volatile C bituminous.
Redcliff	Subbituminous C.
Saunders	High volatile C bituminous.
Sexsmith	Subbituminous C.
Sheerness	Subbituminous C.
Taber	Subbituminous A and subbituminous B.
Tofield	Subbituminous C.
Wetaskiwin	Subbituminous B.
Westlock	Subbituminous C.
Whitecourt	Subbituminous B.

TABLE 5

Coal Outputs in Alberta, by Rank and by Area

Where two ranks of coal are mined in an area the output is listed by the rank of the larger production.

Area	Output in Tons 1941	1942	1943
Anthracite Coals:			
Cascade—output listed under bituminous class.			
Bituminous Coals:			
Cascade	322,202	337,659	343,476
Coalspur	509,933	658,061	713,082
Crowsnest	2,021,155	2,170,222	1,962,557
Halcourt	3,595	2,403	1,873
Highwood	700	271	....
Lethbridge	339,579	470,065	579,234
Magrath	21	....	....
Mountain Park	985,751	932,403	843,411
Nordegg	341,549	367,064	320,549
Pekisko	6,977	10,786	11,802
Pincher	823	606	451
Prairie Creek	16,988	....	1,828
Saunders	50,732	64,094	64,789
Total	4,600,005	5,013,634	4,843,052
Subbituminous Coals:			
Ardley	10,916	5,938	10,239
Big Valley	4,006	4,708	12,836
Brooks	11,446	14,097	30,381
Camrose	54,786	47,627	63,834
Carbon	57,207	63,750	68,391
Castor	43,006	42,482	59,764
Champion	13,203	12,369	11,776
Drumheller	1,458,455	1,785,021	1,838,738
Edmonton	477,637	514,479	457,002
Gleichen	25,642	21,979	21,369
Halcourt—output listed under bituminous coals.			
High Prairie	....	....	191
Milk River	3,848	1,368	2,634
Pakowki	635	469	419
Pembina	66,746	58,980	53,611
Redcliff	25,837	24,969	28,165
Rochester	1,980	3,289	7,287
Sexsmith	88	....	....
Sheerness	39,205	50,490	58,933
Taber	14,852	13,191	20,596
Tofield	56,485	73,368	85,313
Westlock	1,314	....	....
Wetaskiwin	2,546	1,783	3,272
Whitecourt	219	288	179
Total	2,370,059	2,740,645	2,834,930
Lignite Coals:			
Pakowki—output listed under subbituminous coals.			
Total, all coals	6,970,064	7,754,279	7,677,982

Areas not listed had no output.

Outputs taken from the Annual Reports of The Mines Branch of the Department of Lands and Mines of Alberta for 1941, 1942 and 1943.

ALBERTA COALS SUMMARIZED FOR READY REFERENCE

Five Groups—Characteristics and Analysis

The classifications of coal are somewhat complicated and the layman is apt to become confused. The following grouping is offered as simple and easily remembered. The five groups here described are referred to in a number of the following sections of this report.

It may be noted that the first two groups are commonly classed as steam coals and the last three as domestic coals. However, the smaller sizes of domestic coals are widely used for steam raising in Alberta and Saskatchewan.

The coals in each group show notable variations in analysis. The typical analysis given has been selected as representative of large production. Mines with coal cleaning plants may ship a cleaner coal. Detailed analyses of all the coals are given in the analysis section of this report.

Group I

Low volatile, non-coking, bituminous coals from mountain areas.

Canadian Classification: Low volatile and medium volatile bituminous, and some semianthracite.

Important areas: Cascade, Nordegg, Mountain Park (Luscar Mine). If the Highwood area is developed it will be included in this group.

Characteristics: A good storage, weather resistant, coal. Burns with a short, slightly smoky flame. Used for railways and steam raising in general. This coal, when briquetted, is also used for domestic heating.

Output: Total for group, 996,000 tons in 1943. Two coal cleaning and two briquetting plants are operated.

Typical Analysis: Moisture %, 1½; Ash %, 8½; Volatile matter %, 15; Fixed carbon %, 75; Heat value, B.t.u./lb., 14,000.

Group II

High volatile, coking, bituminous coals from mountain areas.

Canadian classification: High volatile A and B bituminous coal.

Important Areas: Crowsnest, Mountain Park (Cadomin and Mountain Park mines).

Characteristics: A good storage, weather resistant coal. Burns with a medium to long, smoky flame. Used for railways and steam raising in general. Also used for making coke, as smithy coal, and in cement industry.

Output: Total for group, 2,486,000 tons in 1943. One briquetting, one coking and four coal cleaning plants are operated.

Typical Analysis: Moisture %, 1½; Ash %, 12½; Volatile matter %, 25; Fixed carbon %, 61; Heat value, B.t.u./lb., 13,200.

Group III

Subbituminous coals, principally from foothills areas.

Canadian classification: High volatile C bituminous.

Important areas: Coalspur, Lethbridge, Prairie Creek, Saunders.

Characteristics: A good storage, weather resistant coal. It is a free-burning, non-coking coal that burns with a long, slightly smoky flame. Used for domestic and steam raising purposes. It is a strong coal and can be shipped and stored reasonably well.

Output: Total for group, 1,359,000 tons in 1943. Two coal cleaning plants are operated.

Typical Analysis: Moisture %, 10; Ash %, 10; Volatile matter %, 34; Fixed carbon %, 46; Heat value, B.t.u./lb., 10,900.

Group IV

Domestic coals—fair storage. From prairie areas.

Canadian classification: Subbituminous A, B and C.

Important areas: Carbon, Drumheller, Edmonton, Pembina, Taber.

Characteristics: Can be stored, with care, under cover. It is a free-burning, non-coking coal, that ignites easily and burns with a long, smokeless flame. Used for domestic heating and also for steam raising. It can be shipped in box cars.

Output: Total for group, 2,533,000 tons in 1943.

Typical Analysis: Moisture %, 19; Ash %, 7; Volatile matter %, 30; Fixed carbon %, 44; Heat value, B.t.u./lb., 9,700.

Group V

Domestic coals—poor storage. From prairie areas.

Canadian classification: Subbituminous B and C.

Important areas: Camrose, Castor, Sheerness, Tofield.

Characteristics: Will not store well. It is a free-burning, non-coking coal, that ignites easily and burns with a long, smokeless flame. Used for domestic heating and also for steam raising. It can be shipped in box cars.

Output: Total for group, 304,000 tons in 1943.

Typical Analysis: Moisture %, 27; Ash %, 7; Volatile matter %, 28; Fixed carbon %, 38; Heat value, B.t.u./lb., 8,300.

WHAT A CONSUMER SHOULD KNOW

The large consumer of coal generally knows the qualities he desires in the coal he purchases; but the small consumer may find it more difficult to chose a suitable coal. Information of guidance to a consumer is given in many sections of this report; but attention is called to the following:

Part I—Alberta coals summarized for ready reference.

Part II—Significance of an analysis of coal.

Part III—Density and bulk weight. Storage of coal. Fusibility of coal ash and clinker formation. Comparative data for other fuels.

Part IV—Coal sizing. Steam production and boiler trials. Domestic heating, furnace and stoker coals. Smithy coal.

Part VI—Analytical and miscellaneous data by areas arranged alphabetically.

Map of coal areas.

The ultimate concern of the consumer should be to purchase that coal which will yield the greatest returns for the money expended. In other words, he should consider the cost per unit of heat generated rather than the cost per ton of coal purchased. The consumer should, therefore, be aware of those factors upon which the heating value of any coal depends, also of those outside factors such as transportation, handling and maintenance costs which affect the ultimate cost of heat produced.

The chemical analysis of a coal gives a picture of its character and of its heat value. The latter, generally expressed as B.t.u. per pound, depends on both the actual and the relative percentages of fixed carbon and volatile matter. All coals, however, also contain moisture and mineral matter and these not only do not produce heat themselves but are responsible for heat loss. The significance of moisture and ash in coal is discussed on page 22, and the usefulness of net heat value on page 33.

The Canadian Government Purchasing Standards Committee in February, 1940, published a tentative specification for coal—No. 18 G.P. 1-1940. This can be obtained from the Codes and Specifications Section of the National Research Council, Ottawa. They give two methods by which it is possible to compare the effective fuel values of two coals and thus to reduce their price to a common basis for comparison, assuming that both can be burned with equal efficiency.

The basis for one is the cost per unit of heat value and for the other the cost per ton of combustible matter. The latter method should only be used with similar coals, since, as shown in Part V, page 84 of this report, the heat value of the volatile matter present in the coal varies notably with the rank of the coal.

For the first method the following equation can be used. The therm, or 100,000 B.t.u., is taken as the unit of heat.

$$\text{Cost per therm} = \frac{100{,}000}{\text{B.t.u. per lb. of coal}} \times \frac{\text{cost per ton of coal}}{2000}$$

For the second method the equation is:

$$\text{Cost per ton of combustible matter} = \frac{\text{cost per ton of coal} \times 100}{100 - (\text{ash \%} + \text{moisture \%})}$$

The above quoted specification also includes examples of two methods for computing price adjustments for use where coal is supplied on a tender, which specifies the analysis of the coal to be delivered, but where the analysis of the coal delivered varies from that of the tender. One is an adjustment of the price of the B.t.u., dry basis, and on moisture as delivered. A tolerance of 2 per cent being allowed for each. The other is an adjustment of price on the basis of combustible matter, a tolerance of 2 per cent again being allowed.

Method 1.

(a) B.t.u. adjustment.

$$\text{Adjustment} = \text{Contract price} \left[1 - \frac{\text{B.t.u., dry basis, in delivered coal}}{0.98 \times \text{B.t.u., dry basis, guaranteed}}\right]$$

(b) Moisture adjustment.

$$\text{Adjustment} = \text{Contract price} \left[1 - \frac{100 - \text{moisture \% as delivered}}{98 - \text{moisture \% as guaranteed}}\right]$$

Total adjustment = (a) + (b).

Method 2.

Equations changed to be applicable to analyses of coal on the as delivered basis.

$$\text{Adjustment} = \text{Contract price} \left[1 - \frac{100 - (\text{ash \%} + \text{moisture \% as delivered})}{98 - (\text{ash \%} + \text{moisture \% as guaranteed})}\right]$$

PART II

Notes on Analyses, Special Tests and Terms

THE SIGNIFICANCE OF AN ANALYSIS OF COAL

Many of the qualities of a coal are revealed by its proximate, ultimate and calorific analyses. The evaluations made in a proximate analysis are conventional and do not represent actual specific constituents of the coal, nor has their determination an absolute significance. Their empirical determination, however, does give a measure of the quality of the coal and the proximate analysis is used as criterion for classification and for combustion.

The ultimate analysis is more precise than the proximate in that it determines the percentages of the elements which go to make up the coal substance. The ultimate analysis does, however, serve as a guide to the nature and rank of the coal and is often used for classification. Furthermore, the ultimate analysis of a coal is essential for calculating the amount of air required for its economical combustion and for other combustion data. It is, therefore, valuable for the efficient design and control of power plants.

The calorific analysis of a fuel gives a definite measure of the potential heat value which it contains, and is therefore a prime consideration when buying coal.

Moisture.—Moisture is inherent in the coal substance, but it may be increased by seepage in the mine or by subsequent wetting. Moisture also may be lost from coal if the coal is exposed to a dry atmosphere. High moisture in a coal usually indicates a free-burning, smokeless fuel, but otherwise moisture is a disadvantage. It is uneconomical to pay freight on water, and a high moisture coal stores badly.

Ash.—Ash is the inorganic residue remaining after complete ignition of the coal. It is derived from the mineral constitutents in the coal. Ash not only has no heating value, but may by clinkering interfere with combustion. Freight must be paid not only on coal but also on its impurities. A slag forming coal may damage furnace equipment, and removal of ashes involves expense. A low ash is essential for some uses. Some Alberta coals are naturally clean, and a number of Alberta operators are equipped to sell a washed coal.

Volatile Matter and Fixed Carbon.—Volatile matter is that portion of a coal, other than moisture, that is driven off as a gas or vapour by a heat treatment in the absence of air. The remaining material, after correction for ash content, is reported as fixed carbon. The percentage of fixed carbon divided by the percentage of volatile matter is known as fuel ratio.

The combustion characteristics, the uses for which a coal is suited and the amount of heat to be derived are dependent on the amount of fixed carbon and volatile matter. The coking property of a coal is closely tied to its volatile matter content. Both the low volatile and the high volatile, high moisture coals are non-coking, whilst the coals with intermediate volatile are the coking bituminous coals. The percentages of volatile matter and fixed carbon have also been used extensively for classifying coals. The higher rank coals are classified on a basis of fixed carbon by the A.S.T.M. standard specifications.

When coal is burned in a furnace the volatile matter coming off burns with a flame, but incomplete combustion due to lack of air causes a black smoke consisting of droplets of tar and particles of carbon. The tarry volatiles have a high heat value and such material if unconsumed represents a direct loss of heat. Part of the unburned volatiles may settle as soot in furnace casings, flue pipes and chimney where it not only interferes with heat transference, but is a distinct fire hazard. Smoke is also a public nuisance.

In order to ensure as complete combustion of the volatile matter as possible, and therefore smokeless combustion, three conditions are essential, namely, (1) sufficient air (2) intimate mixture of air and fuel, (3) sufficient secondary air over the fuel bed. The consumer can, by recognized methods of good firing, reduce the potential smoke tendencies of a coal to a minimum.

Fuels of Group I, having a large amount of fixed carbon and a relatively small amount of volatile matter, burn with a short flame; and the whole process of combustion takes place at or near the fuel bed. Such coals can be burned in domestic installations without visible smoke. Group II coals have a relatively large percentage of tarry volatile matter and therefore burn with a longer flame, producing visible smoke. These high volatile fuels are usually used on railways and for power installations where the coal can be burned efficiently and without smoke. The volatile matter of Group III coals, although high, contains a higher percentage of oxygenated compounds and burns with little smoke. The high volatile, low rank coals of Group IV and V are free-burning and smokeless when properly fired.

Calorific Value.—In the purchase of a fuel the consumer desires that coal which will give him the greatest number of recoverable heat units for his money, provided it also has suitable firing properties for his installation. The cost of a coal is largely based on its heat or calorific value. Nevertheless, a high heat value coal, if carelessly fired, or if not suited to the particular installation, may give poorer results than a lower heat value coal carefully fired and suited to the installation. The heat value of a coal is usually stated as gross B.t.u. per pound although actually the net B.t.u. is a better criterion of the recoverable heat (see page 33). Coal is sold at a price per ton, but it would be more logical if it were sold on a heat basis.

Carbon and Hydrogen.—Carbon and hydrogen are the two most important elements in the coal substance. High rank coals are high in carbon and low in hydrogen, while the low rank coals are low in carbon and high in hydrogen. Broadly speaking, the carbon of a coal may be considered as having the same significance as fixed carbon, and hydrogen as having the same significance as volatile matter, but the percentages of these elements in the coal are mainly used in exact calculations of combustion data. The higher the hydrogen content of the coal the greater the drop from gross to net calorific value.

Sulphur.—Sulphur occurs in coal in three forms namely, (1) as organic compounds in the coal substance, (2) as iron pyrites (FeS_2), and (3) as gypsum ($CaSO_4.2H_2O$). Sulphur, if present either as pyritic or as organic sulphur, contributes a trivial amount of heat when the coal is burned, but is objectionable if present in considerable amounts since the products of combustion will combine with any condensed moisture to form a corrosive liquid. Sulphur is also deleterious in fuels used for metallurgical purposes since it may pass into the metal under treatment. Some of the sulphur, however, is driven off during carbonization or coking so that there is less sulphur in coke or char than in the original coal.

Nitrogen.—Nitrogen occurs in coal to the extent of 1 to 2 per cent. Its only importance is in the recovery of ammonia from carbonization and coking processes with by-product recovery. Now, however, that most of the industrial ammonia is made synthetically the nitrogen content of most coal is not of particular significance.

Oxygen.—The amount of oxygen in a coal has an important bearing on its rank and properties. Low oxygen coals are high in rank and heat value, while high oxygen coals are low in rank and heat value. With coking coals an increase in oxygen usually means a decrease in coking quality. High oxygen coals have the merit that they are free burning and practically smokeless.

TECHNICAL DETAILS OF SAMPLING AND ANALYSIS

The following is a summary of the methods employed in sampling and analysis, for the information of samplers and analysts. These specifications are in principle those of the American Society for Testing Materials* with certain modifications to make them more exact and suited to Alberta coals.

Sampling.—The analyses in this report are, in the main, based on samples taken by the Provincial Mine Inspectors by a specified method.† These are channel samples, about 4″×3″, taken across the seam, from a cleaned, fresh, working face selected to represent as closely as possible the normal output of the mine. The Inspector includes or rejects clay or shale bands or other "partings" in the seam, according as, in his judgment, these are included or excluded from the coal as shipped from the mine. The samples are crushed, to less than ½″ size, and reduced by the method of cone and quarter, and then filled into quart sealers with rubber gaskets for shipment to the laboratory. The above is done quickly at the mine face to avoid loss of moisture.

Air-Drying and Preparation of Laboratory Sample. — The coarsely crushed coal, as received in the laboratory, is subjected to a preliminary partial drying, termed "air-drying", before the sample is pulverized for analysis. Air-drying is carried out, (a) to bring the coal to such a condition that it will not either lose or gain moisture appreciably during the subsequent crushing, grinding and weighing for analysis, (b) to facilitate grinding—coal cannot be ground if too moist, (c) to evaluate the moisture holding property of the coal.

A simple procedure has been developed by the R.C.A. for air-drying coal without oxidation. The coal (100-200 grams) is subjected for 48 hours to a relative humidity of 32% at 30°C in an evacuated desiccator containing a saturated solution of magnesium

*Specification D271-42.
†Research Council of Alberta, First Annual Report (1921), p. 17.

chloride, and crystals of the same, to maintain the humidity. The air-dried sample is then crushed and finely ground in a ball mill for further analysis. The use of a ball mill minimizes loss of moisture.

All determinations made subsequently on this air-dried laboratory sample have to be calculated to the "as received" basis with consideration of the moisture loss during air-drying.

Moisture.—The ground, air-dried sample is used for this and subsequent determinations. The moisture remaining at this stage is determined by the loss in weight when one gram of the sample is dried for one hour, at 106°C, in a rapid stream of dry natural gas, and cooled in an evacuated desiccator.

The total moisture, to be reported as the moisture in the coal "as received", is calculated from the percentage loss of weight during air-drying, and the percentage loss in the moisture determination on the air-dried sample.

Capacity Moisture.—A simple procedure has also been developed* by the R.C.A. whereby it is possible to distinguish between the true water of the coal substance, termed capacity moisture, and the free or adventitious water. The method employed is as in air-drying—exposure for 48 hours at 30°C, in an evacuated desiccator and controlled humidity—but in this case 5 gram portions are used, and successive portions are dried at some ten humidities ranging between 11% and 98% relative humidity, by use of a suitable selection of salts. A fresh portion of the original sample, crushed to 14 mesh size, is used for this determination. The moisture held by the coal after attaining equilibrium with the controlled humidity, is determined by drying in vacuum, at 105-110°C, for three hours.

The retained moisture in each portion, plotted against the relative humidity to which it was brought to equilibrium, gives a series of ten points which lie along a curve. This curve if extrapolated from the 98% humidity point to 100% humidity, gives the capacity moisture of the coal.

As a routine method it has been found, based on several hundred full curve determinations, that the percentage moisture retained in this test by a coal dried over a saturated solution of potassium sulphate (97.6% relative humidity), when multiplied by $\frac{100}{98.6}$ gives the capacity moisture of the coal. A test over a saturated solution of ammonium nitrate (60% relative humidity) is also made in routine analyses as a further measure of the moisture holding capacity of the coal.

Ash.—One gram portions of the laboratory sample are completely burned in an electric muffle furnace—with free access of air —at a temperature of 725±25°C.

Volatile Matter.—Two alternative methods are used for this determination according to the character of the coal. The quick heat method is used for all high rank, low moisture coals. The pre-heat method is used for all high moisture coals. The boundary has been chosen so that coals, from any area where samples have been tested that retain more than 10% moisture after air-drying to 60% humidity, are tested by the pre-heat method. Coals which are close to the boundary line are found to give from 1 to 1½% less volatile

*E. Stansfield and K. C. Gilbart. Trans. A.I.M.M.E., Coal Division (1932), pp. 125-147.

matter by the pre-heat method than by the quick heat method. Lethbridge Area coals, which are in this category, are now tested by the pre-heat method.

A vertical electric furnace* is employed for both methods. This is closed at the top, and the crucible is introduced into the furnace from below. Standard practice is to use a furnace open at the top. This inversion gives an initial heating of the coal from the top and thus reduces the tendency to spark. It also gives a very steady temperature, less convection currents and consequently a less oxidizing atmosphere.

In the quick heat method one gram portions of the laboratory sample are each heated for seven minutes at a temperature of 950±20°C in a 20 c.c. platinum crucible with a well fitting, capsule shaped lid. The loss in weight represents the moisture and volatile matter in the coal. If the loss due to moisture is subtracted the remainder is volatile matter.

High moisture coals, if tested by the quick heat method, spark badly and the results are erroneous. A pre-heat method is therefore employed. In the method used until recently, one gram portions were each weighed into a platinum crucible as before; but the crucible set on a cold 3″ scorifier which was placed in an electric muffle furnace at 800±25°C. It was left in the pre-heat furnace for five minutes and immediately transferred to the volatile matter furnace, and heated for six minutes at 950±20°C.

The above method, in general, gave remarkably concordant results, but a few exceptional samples have been noted, which tended to spark even by this method. A revised method therefore has been adopted recently which works well even with such samples. The temperatures towards the opening at the bottom of the furnace were calibrated, and the crucible is given its preheat by moving it up into the furnace by timed steps as follows: 3 minutes at 500°C, 2 minutes at 700°C, 1 minute at 850°C, and 6 minutes at 950°C. The temperatures were measured by a thermocouple touching the side of the crucible just above the level of the coal.

This method is in accordance with the A.S.T.M. method of D271-42, but is far more specific. The results are in close agreement with those by the earlier method.

Fixed Carbon.—The non-volatile residue left in the platinum crucible in the volatile matter determination is fixed carbon and mineral impurities. The percentage of this residue, minus the percentage of ash as found above, gives the percentage of fixed carbon. The nature of the above residue is recorded as a guide to the coking properties of the coal.

Proximate Analysis.—The four percentages thus found in the air-dried coal—moisture, ash, volatile matter, and fixed carbon—add up to 100, and constitute the analysis known as "proximate". The values thus found can be calculated to the "as received" basis by allowance for the moisture lost in air-drying, or calculated to the "dry" basis by elimination of the moisture in the air-dry analysis.

The ratio of fixed carbon divided by volatile matter is known as "fuel ratio".

Calorific Value.—The gross calorific value is determined by the complete combustion of the coal in compressed oxygen in a bomb

*Research Council of Alberta, Tenth Annual Report (1929), p. 17.

calorimeter.* The bomb is of stainless steel, 315 c.c. volume, and the bomb and calorimeter have a water equivalent of 2,250 grams. A weight of coal is taken estimated to give a rise of 2.5°C, and oxygen is charged to 375 lbs. per sq. in., or to 400 lbs. for difficultly combustible fuels. This gives at least five times as much oxygen as is theoretically required for the combustion. A platinum hair wire and a short cotton thread are used for firing, and the temperature rise is measured with a standardized Beckmann thermometer. The water equivalent of the calorimeter is restandardized, using standard benzoic acid, with each fresh oxygen cylinder. The cooling correction is found from the initial and final rates of cooling by means of a nomogram. The usual corrections are made for firing heat; thermometer bore irregularities, setting factor, and emergent stem; and for sulphur and nitrogen. The calorific value is calculated by the following equation which permits ample accuracy with a slide rule:

Calorific value,

$$\text{in B.t.u. per lb.} = 10{,}000 + \frac{R}{W} 4{,}050 + \frac{8{,}100 - 10{,}000\,W}{W}$$

This is derived from the equation $\text{B.t.u./lb.} = \frac{(2+R)\ 2250 \times 1.8}{W}$

where weight of coal in grams $= W$

the rise in temperature $= 2^\circ + R^\circ$ Centigrade, and

the water equivalent of the calorimeter $= 2250$ grams.

The equation is suitably adjusted whenever a change is made in the water equivalent.

The net calorific value is calculated by deducting from the gross value 91.2 B.t.u. per pound for each one per cent of hydrogen in the coal.

Ultimate Analysis.—This analysis determines the elements carbon, hydrogen, sulphur, nitrogen and oxygen. The percentages of these elements, together with the percentage of ash found in the proximate analysis, are assumed to add up to 100%. The determinations are made on the air-dried laboratory sample, and the results later calculated to the "as received" and "dry" bases.

Carbon and Hydrogen.—These elements are determined, as in the regular method for the analysis of organic compounds, by burning a fifth of a gram of the coal in a current of pure, dry oxygen and collecting and weighing the carbon dioxide and the water produced. The R.C.A. has developed a modification of the apparatus† which has been found to be conducive to ease of operation, prolonged life of the quartz combustion tube, and consistently good results even in the hands of beginners.

Sulphur.—The method normally employed for sulphur determination is the Eschka process as specified by the A.S.T.M. Recently, with low sulphur coals—below 0.5%—the sulphur has been determined in the rinsings from the bomb calorimeter by precipitation with benzidine hydrochloride followed by titration with standard alkali. These results have been found to be in reasonable agreement with those of the Eschka process, and the saving in time is considerable.

Nitrogen. — The method employed is the Kjeldahl-Gunning method as specified by the A.S.T.M.

*E. Stansfield and J. W. Sutherland, Can. Jour. Research, Vol. 3 (1930), pp. 464-472.
†E. Stansfield and J. W. Sutherland, Can. Jour. Research, Vol. 3 (1930), pp. 318-320.

Oxygen.—No satisfactory method has yet been devised for the determination of oxygen. The percentage reported as oxygen in an ultimate analysis is merely the value obtained by subtracting from 100 the sum of all the other percentages, including that of ash.

Moisture.—Moisture is not included as such in an ultimate analysis, as the hydrogen and the oxygen of the water are included in the reported values of these elements.

Fusion Temperatures of Coal Ash.—Two methods have been used for the determination of the fusibility of coal ash, one according to A.S.T.M. specifications, the other a modification thereof. In the latter method the conditions specified by the A.S.T.M. with respect to size and shape of cones, rate of heating and atmosphere are followed exactly, but, instead of only heating 3 or 4 cones at once and closely watching their behaviour, a batch of 20 or more different cones are simultaneously heated to some prearranged temperature, and then rapidly cooled and withdrawn from the furnace. Similar batches are likewise heated to other temperatures until for each ash a series of cones is obtained heated to temperatures at 45°F (25°C) intervals, and covering the range from the initial deformation to the fluid temperature, or to the maximum temperature obtainable in the furnace. The series can then be arranged in order and examined at leisure for the fusion characteristics. Fig. 4, p. 43.

Two furnaces have been used, a No. 3 gas-fired Melter's Furnace, and a molybdenum wound, electric, resistance furnace. Some difficulties are experienced with the gas-fired furnace at temperatures above 2600°F, but the electric furnace can be heated to 2800°F without difficulty.

The A.S.T.M. specifications call for a mildly reducing atmosphere around the cones. In both methods employed by the R.C.A., and in both furnaces, this required atmosphere is ensured by vapourizing a methyl alcohol-water mixture, containing 51% of alcohol by volume, and passing the vapours through a refractory tube into the ash cone chamber. The alcohol is decomposed, also some of the steam, producing a mixture containing about 50% reducing gases (hydrogen and carbon monoxide), and 50% oxidizing gases (steam and carbon dioxide).

TYPICAL AND MODIFIED ANALYSES OF COAL

Typical analyses in this report have been prepared from a study of all analyses made on channel samples submitted by the Provincial Mine Inspectors; analyses published by the Bureau of Mines at Ottawa have also been consulted. These channel samples were taken in the mines to represent the average of the seam, with omission of such partings as are discarded on the picking belt or elsewhere in the commercial preparation of the coal. The moistures reported are not intended to include free moisture on the surface of the coal. (See section on capacity moisture.), Typical analyses are not applicable to weathered coals.

Enough samples have been received from each of the principal producing districts to warrant the preparation of a typical analysis; but such preparation has been difficult or impossible for some of the less important districts.

Modified Analyses.—It is recognized that owing to particular conditions in any mine or tipple, or owing to the operation of a coal cleaning plant, the operator concerned may regularly, or at times, market a coal which differs notably from the typical analysis given for the district in which the mine is situated, either in moisture, in ash, or in both. Such a condition cannot be met in an ordinary way, but, as a novel solution of this difficulty, equations are given under many districts whereby an operator wishing to tender on a coal which differs markedly from the typical in moisture or ash, can calculate the corresponding analysis. Note, however, that these equations are not applicable to weathered coals.

As an example of the use of equations; an operator, in district A of the Crowsnest area, sees the typical moisture and ash given as 1.5 and 14.3% respectively, but he wishes to tender on coal from his coal washing plant with 1.0% moisture and 8.0% ash.

The equation for fixed carbon is given as:

$F.C.=74.0-0.74\ (M+1.16\ A)$ where M=percentage of moisture and A=percentage of ash, or 1.0 and 8.0 as above.

$$\text{Therefore } F.C.=74.0-0.74\ (1.0+1.16\times 8.0)$$
$$=74.0-0.74\ (1.0+9.28)$$
$$=74.0-7.6=66.4\% \text{ to the nearest } 0.1\%.$$

The equation for volatile matter is:

$$V.M.=100-(M+A+F.C.)$$
$$=100-(1.0+8.0+66.4)=24.6\%.$$

The equation for heat value is:

$$B.t.u.=15{,}700-157\ (M+1.16A)$$
$$=15{,}700-157\ (1.0+1.16\times 8.0)$$
$$=15{,}700-157\ (1.0+9.28)$$
$$=15{,}700-1610=14{,}090 \text{ to the nearest 10 B.t.u.}$$

The modified proximate analysis thus becomes as shown below, with the typical analysis also shown for comparison.

	Modified	Typical
Moisture %	1.0	1.5
Ash %	8.0	14.3
Volatile Matter %	24.6	23.6
Fixed Carbon %	66.4	60.6
Calorific value, gross B.t.u. per lb.	14,090	12,860

Similar equations may be developed for the change in ultimate analysis with variations in moisture and ash; but it was not feasible to include these in this report. The probable effect of changes in moisture and ash on the ultimate analysis may be obtained by application to the Research Council of Alberta, if sufficient data is available for the purpose with respect to the mine or district in question.

In explanation of the above equations it may be pointed out that whilst each additional one per cent of moisture in a sample depresses the heat value, and fixed carbon, by one per cent; each additional one per cent of ash usually depresses these values by more than one per cent. The reason for the latter is well known; the mineral matter or mineral impurity of a coal is generally decomposed, with loss of weight, during the burning operation required for the determination of ash. One and one tenth per cent of mineral matter in the coal usually leaves about one per cent of ash when the coal is burned; but this ratio of mineral matter to ash varies with the composition of the mineral matter. An increase of one per cent of mineral matter will cause a depression of one per cent in heat value, for example; but an increase of one per cent of ash, representing an increase of more than one per cent of mineral matter, will cause a depression of more than one per cent.

If in any district the heat values, fixed carbon percentages, and other constituent percentages on the dry basis, of all available analyses of fresh coal, are separately plotted against the corresponding ash percentages, on the dry basis, it will usually be found that the resulting points lie fairly closely along a straight line. The inclination of the line varies with the ratio of mineral matter to ash, and with some other factors. The equations supplied under the headings of modified analyses, are numerical representations of the mean line found applicable for the plotted values of fixed carbon and of heat in each district.

An example of such a plotting is shown in Fig. 2 where the dry, B.t.u. per pound values, for coals in the Nordegg area, are plotted against the corresponding dry, ash percentages. It can be seen that if a mean line were drawn through the points, most of them would lie close to the line.

In earlier work of the Research Council of Alberta* charts were prepared to show how proximate and ultimate analyses, of fresh coal, varied with the moisture and the ash. In this report equations are given instead of charts; but Fig. 3 shows an example of the charts that could be prepared if the use of a chart were preferred to the use of an equation.

The chart shown is for district A of the Crowsnest area, as previously worked out by equations for a modified analysis with 1% moisture and 8% ash. It can be seen on the upper part of this chart that the 8% ash ordinate cuts the 1% moisture line at A. A horizontal line from this point cuts the fixed carbon scale at 66.4%. Similarly, in the lower part of the curve, the 8% ash ordinate cuts the 1% moisture line at B, and a horizontal line from this point cuts the calorific value scale at 14,090 B.t.u. As before the volatile matter per cent is calculated by subtracting from 100 the sum of the moisture, ash and fixed carbon percentages. This gives 24.6%.

Charts can be supplied, on squared paper, on a scale for convenient use, for any district or area for which equations have been given, at a charge of $1.00.

Charts could also be supplied for any individual mine, by arrangement; but as this would involve a considerable programme of sampling and analysis a charge of $75.00 would be made.

*Sixteenth Annual Report (1935), p. 13.

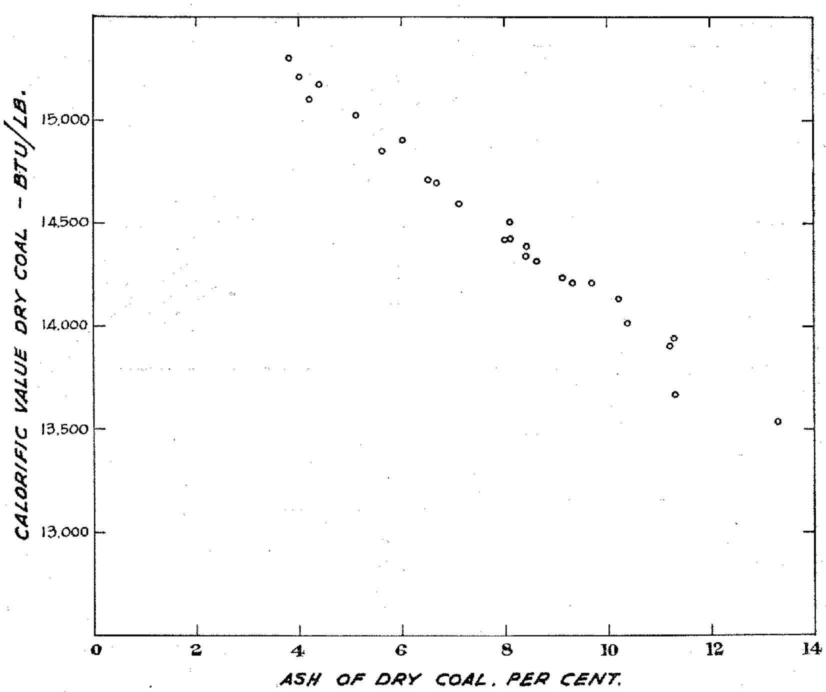


Fig. 2.—Chart showing relation between Calorific Value and Ash Percentage of a Coal.

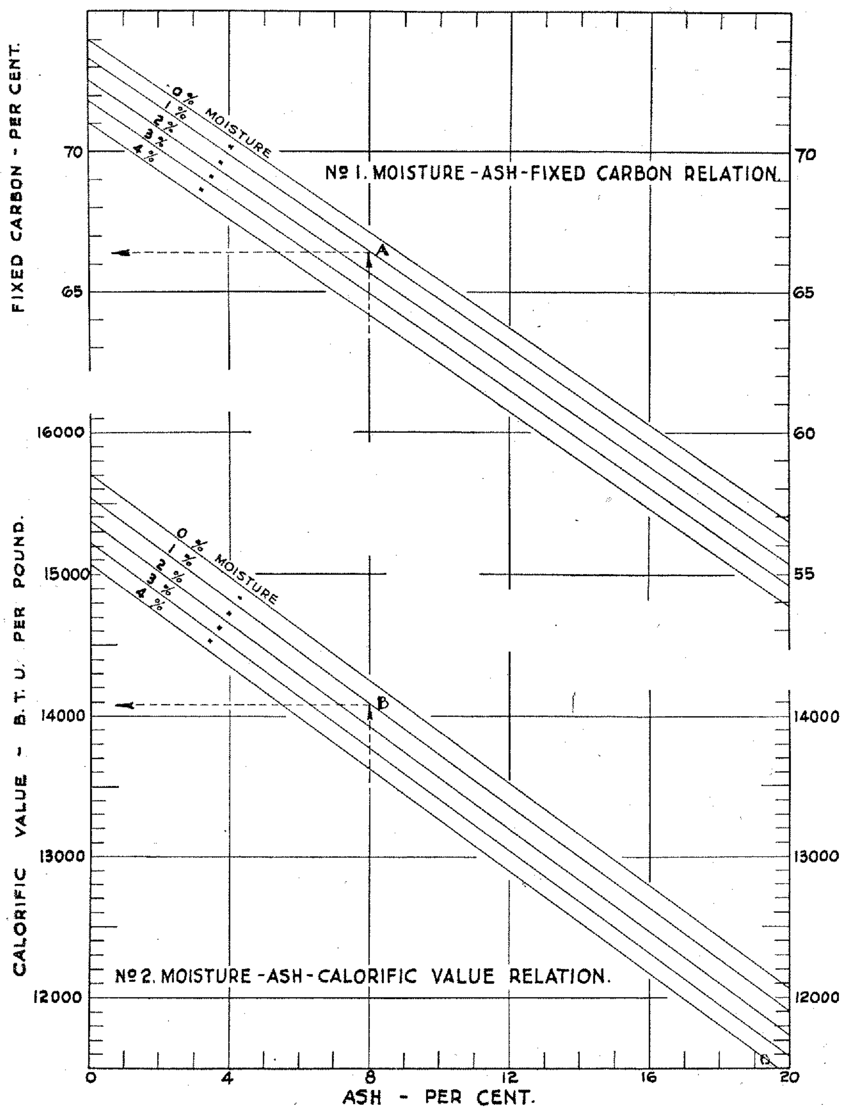


Fig. 3.—Chart showing Fixed Carbon and Calorific Value in relation to Ash and Moisture.

MOISTURE AND CAPACITY MOISTURE

All coals contain moisture which is definitely part of the coal substance. Coal may also have free moisture, on the surface, and in the cracks if, for example, the mine from which the coal was taken is a wet mine; but, on the other hand a sample of coal may have been partially dried before it reaches the chemist. A coal analysis therefore may show either more moisture or less moisture in the sample than the true moisture of that coal.

A method was developed* in 1931, in the laboratories of the Research Council of Alberta, by which a distinction can be made between the moisture that really belongs to the coal and additional or free, surface moisture. The same method will also indicate if there has been a partial drying of the moisture of the coal, but in this case the true moisture cannot be determined if the partial drying has been more than slight. A coal which has been notably dried will not take up again as much moisture as it held originally.

The true or inherent moisture of a coal has been called the "capacity moisture" of the coal and defined as the least moisture in the coal that will give a relative humidity of 100%, or in other words, will behave as though free moisture were present.

Capacity moisture is of great importance in coal classification, and of lesser importance in ordinary analyses. Nevertheless in many analyses reported from these laboratories, the capacity moisture is given where this differs notably from the actual moisture found in the sample; as it is certain that free moisture will evaporate from the coal more easily than will inherent moisture, and therefore is less of a drawback.

It is of interest to note that far more samples have been received here showing excess moisture than have been received showing partial drying. In this report "typical moistures" are not intended to include free moisture.

GROSS AND NET CALORIFIC VALUES

When the coal is burned in a bomb calorimeter, as in the determination of its calorific value, the products of combustion are cooled to room temperature, and the steam is condensed to water and thus gives up its latent heat to the calorimeter. In the ordinary combustion of coal, on the contrary, the products of combustion enter the chimney at too high a temperature for the steam to have condensed, so that not only the sensible heat of the gases, but also the latent heat of the steam is lost. The loss of sensible heat can be minimized by combustion control and by the use of suitable equipment, so this loss can fairly be charged against the plant and its operation. The loss of latent heat, however, cannot be avoided in ordinary practice, so it is unfair to charge this loss against the plant. Two calorific values are therefore recognized:

Gross calorific values in which the products of combustion are assumed cooled to ordinary temperatures (60°F), and the steam condensed to water as in the calorimeter determination.

Net calorific values in which the products of combustion are assumed cooled to ordinary temperatures, but with the steam uncondensed. Net calorific values, in B.t.u. per pound, are calculated from gross calorific values, in the same units, by deducting 91.2

*E. Stansfield and K. C. Gilbart, Trans. A.I.M.M.E., Coal Division (1932), pp. 125-147.

B.t.u. per pound for each one per cent of hydrogen in the coal as fired. This figure allows for another slight correction which need not be explained here.

If two coals are compared, of equal gross calorific value, but one with low, and the other with high hydrogen content, it will be found that the former is distinctly the better fuel. Two coals of equal net calorific value, on the contrary, will be found to be nearly equal in fuel value regardless of their hydrogen content.

Gross calorific values are generally used in Canada and in the United States, but the net values give a better picture of the relative commercial values of different types of coal, and are often used in some other countries. The adoption of the net value has been delayed in America because its calculation requires the hydrogen content of the coal, and this is seldom known.

Gross calorific values are given in this report, unless the contrary is stated. The approximate deduction to be made for the coal of each area, or district, to give the net value, is generally given. The deduction ranges from about 2% to 9% of the gross heat value of Alberta coals.

MINERAL MATTER IN COAL AND ASH OF COAL

The mineral matter in a coal is not the same as the ash left when the coal is burned, either in composition or in weight. The relation between them varies; but, on an average, ten parts of mineral matter leaves only 9 parts of ash.

All ordinary analyses, proximate and ultimate, show the percentage of ash of the coal, not the percentage of mineral matter in the coal. This is standard procedure, well understood by all coal chemists, and the matter is quite immaterial to the ordinary coal consumer.

Whenever it is necessary to calculate an exact analysis of pure coal, as for example for purposes of coal classification, the matter is quite different, and it is necessary to convert the ash per cent of the coal to a mineral matter percentage. This change also involves a change in the volatile matter percentage. The relation between mineral matter and ash is discussed at greater length in Part V under "Coal as analyzed and as pure coal".

The slope of a mean line drawn through the points in the curve of Fig. 2 gives a measure of the ratio of mineral matter to ash, and this graphical method is regularly employed by the R.C.A. to determine this ratio. The equations given in the analytical section for calculating the modified calorific value of coal all contain a factor based on the relation of mineral matter to ash. This ratio has been found to vary with Alberta coals from 1.0 to 1.3 but the average value is slightly above 1.1.

PART III

General Properties of Coal

DENSITY AND BULK WEIGHT

The density of a piece of coal can be determined comparatively easily, and a large number of determinations have been made. From this value can be calculated such values as the number of cubic feet of solid coal in the seam to be mined to produce one ton, and the number of tons of coal for each foot thickness of the seam, per acre. The bulk weight of coal, that is the weight of mined coal that can be stored in a bin per unit of volume of the bin, is harder to determine, and can only be done satisfactorily on a larger scale than is practicable in the laboratory. Very few values are available for Alberta coal. These two subjects are discussed below.

Density.—The density of a lump of coal can be determined by weighing it first in air and then in water. The density, or weight per unit volume of the solid coal, as in the seam, varies more with the cleanliness of the coal, and with the types of mineral impurities present, than it does with the character of the coal itself. Since a number of mineral impurities of different densities may occur in the same seam of coal, in different proportions in different places in the seam, it is impossible to state exactly the density of any coal even when its ash percentage is known. In this report all values given are averages of many determinations. Values will be found reported under the separate areas in Part VI. The values are expressed in three ways, (1) as specific gravity, that is as its density relative to the density of water at 77°F., (2) as tons per hundred cubic feet, and (3) as tons per acre foot. The values are given as the average values for coal with 5%, 10% and 15% ash respectively, where data is available. It may be seen that the densities reported for the separate areas are not identical, but that the differences are not large.

Bulk weight.—The bulk weight of coal varies with the coal, with its size, and with its cleanliness. Reliable results can only be obtained by weighing and measuring large volumes, and to complete the record the coal should be sampled and its ash determined. No such complete records are known. A number of operators, however, have made determinations of their own coals, and kindly reported the results to Mr. A. A. Millar, at that time Chief Inspector of Mines. The tests reported were for coals from the Cascade, Coalspur, Crowsnest, Drumheller, Edmonton, Lethbridge, Mountain Park, Pembina and Prairie Creek areas. Averaged values showed the following volumes of bin required, in cubic feet, per ton of the following sizes of coal: Run-of-mine, 36½; lump, 38½; egg, stove and briquettes, 40; nut and pea, 39; slack, 38½. Individual values reported varied from 32 to 44 cubic feet per ton.

IGNITION TEMPERATURE

Coals vary notably in the ease with which they may be set on fire or ignited. It is often supposed that there is a definite temperature to which any coal must be heated to set it on fire; this, however, is not the case. Most coals actually oxidize, which is the same chemical process as in burning, very slowly at ordinary temperatures; and under suitable conditions this may gradually accelerate until it becomes open combustion. It would obviously be impossible with such a gradual transformation to state that any particular temperature was that of ignition. A number of empirical tests, however, have been devised in which temperatures are determined which have a definite relation to the ease of ignitability of the coals tested. Two such methods have been used by the R.C.A. In the first the temperature measured is essentially that at which the above slow oxidation changes to rapid oxidation; whilst in the second the temperature measured is the lowest temperature of an air blast that will set particles of coal on fire within a brief time. The first method, employed but not published, is a modification of the test developed by R. V. Wheeler.* It ascertains the temperature at which a sample of fine, dry coal will commence to oxidize with notable rapidity in a current of oxygen at the same temperature. The results can be closely duplicated.

The second method† is more obvious in its significance. The temperatures are higher than those of the first test and cannot be as closely duplicated; but they appear to give a better picture of the relative ease of ignitability of a series of coals. This test always shows that when 20 or 30 particles of the same coal are subjected to the hot blast, there are seldom more than 1 or 2 which catch fire when near the low limit temperature. Different parts of the same coal therefore differ notably in their ease of ignition, but the lowest temperature is the significant temperature, since if any particle catches fire it at once ignites the rest.

Comparative results of ignition temperatures of Alberta coals by groups, as obtained by both the Wheeler and R.C.A. methods, are given in Table 6. A maximum, minimum and average value is given for each test. There is considerable overlapping between the ignition temperatures of the coals of each group, but the results indicate that the higher the rank of coal the higher is its temperature of ignition.

TABLE 6

Ignition Temperature—Coals by Groups

	Wheeler Method (oxidizing temp.)		R.C.A. (firing temp.)	
Group I.:				
Maximum °F	238		568	
Minimum °F	222		486	
Average °F		230		526
Samples tested	5		5	
Group II:				
Maximum °F	231		545	
Minimum °F	209		483	
Average °F		220		506
Samples tested	5		5	
Group III:				
Maximum °F	188		500	
Minimum °F	175		379	
Average °F		183		450
Samples tested	10		9	
Groups IV and V:				
Maximum °F	191		408	
Minimum °F	163		316	
Average °F		179		358
Samples tested	20		17	

*Fuel in Science and Practice, III (1924), p. 366.
†R.C.A. Sixteenth Annual Report (1935), p. 17.

STORAGE OF COALS

Industrial concerns and power plants frequently store large quantities of coal in order to guard against stoppage of supplies from labour or transportation or other troubles. Seasonal fluctuations in the demand for coal for heating also necessitates storage by the operator or dealer; and even the householder may buy his coal in the summer and store for use in the winter. Coal tends to deteriorate in storage, and there are possibilities of serious loss from spontaneous combustion. The allied problems of storage and oxidation of coal are therefore of considerable economic importance. It can be definitely stated, however, that the problem of the storage of the different ranks of Alberta coal is the same as the problem of storage of the same ranks of coal elsewhere.

Coal does deteriorate in storage, to different extent with different ranks; but on the whole the deterioration is notably less than is commonly supposed, unless the coal is so badly stored that spontaneous combustion occurs. The loss in heat value is hard to measure, and will vary largely, but the U.S. Bureau of Mines suggest values not exceeding 1.2% for the first year with the bituminous coals they tested, and not exceeding 2 or 3% with the subbituminous coals. A coking coal does show a decrease in coking properties during storage and fresh coal should be used, if possible, for coke making. A complaint is sometimes made that stored coal is "dead" in the fire; but the actual depreciation in fuel value is probably slight. High moisture coals tend to dry out in storage, with consequent "slacking" or breaking down of the lumps. This will be discussed later under weathering.

Some of the principal factors involved in coal storage are outlined in the following section; but the problem is so complicated that it cannot be dealt with fully, and anyone without experience who needs to store considerable coal should consult more detailed reports.

Information Circular 7235 (1943) of the U.S. Bureau of Mines discusses the storage of coal at length, and gives seven satisfactory methods of storage.

Oxidation, Self Heating and Spontaneous Combustion.—All coals contain unstable compounds which are capable of absorbing oxygen from the air at ordinary atmospheric temperatures; but some coals contain more of these compounds than do others. This atmospheric oxidation is strictly a surface action; it may go on rapidly when the coal is freshly mined and slow down as the surface becomes oxidized; but go on with renewed activity whenever fresh surfaces are exposed by breakage. Such oxidation generates heat, and the rate of oxidation increases very rapidly as the temperature rises. If the heat generated is not carried away as fast as it is formed, the temperature of the coal rises, the rates of oxidation and of heat generation increase, and these may even result in open burning of the coal—"spontaneous combustion". Oxidation and self heating are almost inevitable in stored coal, but spontaneous combustion is less frequent. The more usual course is for the coal to gradually warm up and then cool off again. If the temperature rises to 120°F the pile should be carefully watched, and if it seems likely to pass 160°F serious trouble may be expected unless action is taken at once. It may be seen from the above that air provides the oxygen for the oxidation. If air could be excluded the coal would not heat. Also air will carry away the heat generated; so if there is a big flow of air the coal will oxidize but not heat. The dangerous situation is in between, with enough air to supply oxygen, but not enough to remove the heat.

The rate of oxidation and the danger of spontaneous combustion are dependent on the rank of the coal, its moisture content, presence of pyrite, the coal sizing, method of piling, size of pile, ventilation of pile, temperature of coal as piled, external sources of heat, etc. These factors, discussed below, are complex in action and it is often hard to foresee the combinations that will cause trouble.

Low rank coals oxidize more rapidly than do high rank coals, as shown later. The low rank, high moisture coals also tend to dry out and slack in storage thus producing fine coal with fresh surface for oxidation. Such coal is more difficult to store than coal which does not slack, and in general is stored under cover. Pyrites oxidize in moist air, but its effect is probably over emphasized. However, Alberta coal is notably low in pyrite content. The coal sizing is an important factor; with lump coal the surface exposed for oxidation is so small in relation to the weight that no trouble can be expected, with fine coal the conditions are reversed. The method of piling, size of pile and ventilation of pile are also important. Either little air, or ample ventilation is safe; the intermediate condition is dangerous. If in building a pile segregation of sizes occurs there may be ample ventilation through the larger sizes, and very little ventilation through the closely packed, fine coal; but in between these two zones there will almost inevitably be a danger zone. The larger, and, more especially, the higher the pile, the more certain there is to be a danger zone. The temperature of the coal as piled is another important factor; coal stored in the winter is less likely to give trouble than coal stored in summer. Again, if a pile is built in such a way that the advancing face is to the south, coal heated by the sun may be buried under a further load of coal and such a hot spot is extremely likely to give trouble. Care should be taken to avoid steam pipes, or other sources of heat such as wood, oily rags, etc., under or near coal.

Practical methods of storing coal can be divided into two groups, the first with exclusion or restriction of air, and the second with ample ventilation.

In the first of these the coal may be stored under water; or slack or fine coal stored on an impervious foundation, packed down layer by layer as the pile is built, and preferably with the sides, or the sides and top of the pile, capped with an air tight capping or covering.

In the second of these the coal should be stored on a well drained, open foundation such as a bed of cinders. With sized coals the natural air circulation will be ample if the lumps are not crushed during piling, and if the coal does not slack. With run-of-mine or fine coal this method is more difficult. The Canadian Pacific Railway, however, has for years stored run-of-mine coal successfully, in large piles, by contriving ventilation holes regularly and closely spaced over the whole pile, each hole extending from top to bottom of the pile. In small piles the natural ventilation will often suffice. Storage of domestic coal in a residence very rarely gives trouble; the quantity stored is seldom large, and sized coal is generally used.

The temperatures in a coal pile may be followed by inserting pointed rods, at intervals, from top to bottom of the pile, then lifting these from time to time, feeling their warmth and putting them back in fresh spots; or by inserting pipes, down which thermometers can be lowered; or by the use of automatic danger signals which can be purchased.

Tests have been made with a number of Alberta coals which show their relative oxidizability. In these tests* samples of the coals were ground continuously in an atmosphere of oxygen at 86°F for 120 hours in a sealed ball mill. The amount of oxygen absorbed, expressed as a percentage of the weight of pure, dry coal in the mill, is shown in the following table for coals from 17 areas. It must be noted that although the actual values have no commercial significance, as coal in practice is not ground finely in oxygen, they do show relative degrees of oxidizability. The high rank coals are the less susceptible to oxidation.

TABLE 7

Oxygen Absorption

Area	Number of Tests Made	Oxygen absorbed in 120 hours % by weight
Carbon	1	2.6
Coalspur	3	1.5
Crowsnest	4	0.4
Drumheller	4	2.7
Edmonton	10	3.1
Halcourt	1	1.8
Lethbridge	5	1.8
Milk River	1	2.1
Mountain Park	3	0.5
Nordegg	2	0.4
Pekisko	1	0.9
Prairie Creek	3	1.0
Redcliff	1	3.0
Saunders	1	1.9
Sheerness	3	3.2
Taber	1	2.4
Wetaskiwin	1	2.6

The amount of heat given out by the slow oxidation of coal is a matter of considerable interest. Tests made in this laboratory, for which however great accuracy is not claimed, showed that the heat given out, when expressed in terms of the oxygen absorbed, varied little if at all with the rank of the coal. Fifty-two tests, on twelve different coals, oxidized at temperatures from 85° to 150°F, gave an average value of 102 B.t.u. per cubic foot of air measured at 32°F and 29.92 inches of mercury, on the assumption that all the oxygen in the air was absorbed. In Table 18, Part V, column 12 shows, for all the many coals studied, the amount of heat given out in burning; this again being expressed as B.t.u. per cubic foot of air. These values also vary little with rank, and the average value for all ranks is 107 B.t.u. These results show therefore, that for the same amount of oxygen involved, the heat given out by slow oxidation at temperatures below 150°F is approximately 95% of the heat given out in ordinary high temperature combustion.

Weathering and the Weathering Index.—As already stated, high moisture coals tend to lose moisture when exposed to the atmosphere, and the lumps then break up or slack. It is desirable to have a method for evaluating the weathering qualities of coals since those with notable slacking tendency should be stored under cover, or in closed bins. The weathering properties of coal moreover are

*E. Stansfield, W. A. Lang and K. C. Gilbart. Trans. A.I.M.M.E., Coal Division (1934), pp. 243-254. Also R.C.A. Fifteenth Annual Report (1934), pp. 66-71.

used as a secondary factor for placing certain coals in the Canadian (A.S.T.M.) classification scheme.

A laboratory test, known as the accelerated weathering test, has therefore been devised for testing weathering characteristics. Small lumps of coal are subjected to a standardized cycle of air drying, immersion in water, and air drying; and the percentage by weight determined of the coal so broken down that it will pass through square holes of ¼″ side. This is called the weathering index. Coals with a weathering index of less than 5 are called non-weathering. That is they are good storage coals. The test is difficult to standardize exactly, and the results of one laboratory may differ from those of another.

Coals from sixteen different areas have been tested in these laboratories, and weathering indexes determined, varying from less than one to over ninety. Tests have also been run in the Fuel Research Laboratories in Ottawa. The results can be summarized by stating that coals in Groups I and II are non-weathering, that is good storage coals with weathering indexes seldom exceeding 1. Coals of Groups IV and V are weathering coals with high indexes; those of Group IV ranging from about 5 to 50 and those of Group V ranging from about 30 to 90.

Coals of Group III are closer to the boundary line. However, the great majority of the tests made in Edmonton with these coals gave indexes below five; and it seems probable that where the tests gave higher values the sample tested was not a fresh, unweathered coal. The coals of this group, that is from the Coalspur, Lethbridge, Prairie Creek and Saunders areas, are therefore classed definitely in this report as non-weathering.

FRIABILITY

By friability, as applied to coal, is meant its liability to break or crumble into smaller pieces when subjected to handling; hence a friability test serves to determine relative handling properties. It is important not only to the producer but also to the retailer and consumer. Friability is a physical characteristic and is related to such factors as cleavage, fracture, tenacity, hardness and elasticity.

Methods for the measurement of friability are difficult to formulate and apply. The difficulty of the problem is further increased because, with high moisture coals, friability increases rapidly as the coals lose moisture. Mining methods may develop fracture lines in the lumps, and these may notably influence the results of a friability test. The interpretation of friability data should therefore only be made with a knowledge of the previous handling of the coal sample.

A comprehensive study of friability was made by the Mines Branch, Ottawa, and the results reported in "Coal Friability Tests" —R. E. Gilmore, J. H. H. Nicolls and G. P. Connell, Mines Branch, Ottawa, 1935, Bulletin No. 762.

A friability test* developed in these laboratories allow the results to be expressed by one value, called "Strength Index". The strength index is actually the reverse of friability and shows the percentage of coal that resists breakage during the test. Results by this test indicate that some coals from the mountain areas are liable to be friable owing to their having been subjected to mountain building pressure and movements. The coals from the foothills and

*R.C.A. Eleventh Annual Report (1930), p. 18.

the prairies are generally stronger than those from the mountain areas. Many of the high moisture coals are notably strong when first mined, but if allowed to dry out may become extremely friable.

PULVERIZABILITY OR GRINDABILITY OF COAL

The increased use of powdered coal emphasizes the need for information on the ease of grinding various coals. Several laboratory grindability tests have been developed, and by means of such tests it is possible to find the pulverizing characteristics of a coal and to compare these with those of a standard coal for which the pulverizing mill performance is known. In the laboratory test the ease or difficulty with which a coal can be pulverized is given by the grindability index. A high grindability index indicates a coal that is easily ground whereas a low value indicates a coal that is difficult to grind.

Large scale pulverizing tests are also made. In these the power used per ton of fuel pulverized, to a measured fineness, is determined.

The Research Council of Alberta has not made any tests on pulverizability of coal. The following data and references are to tests on Alberta coals made and published by the Fuel Testing Division of the Bureau of Mines at Ottawa.

Laboratory tests* have been reported on coals from Coalspur, Crowsnest, Drumheller, Mountain Park, Prairie Creek and Saunders areas.

Large scale pulverization tests† have also been reported. The following data, Table 8, have been selected from this report.

TABLE 8

Power Used During Large Scale Pulverization, and Screen Analysis of Pulverized Fuel

Area	Coal	Power k.w.h.	Screen Analysis % Passing 100 mesh	200 mesh
Cascade	X	45.0	96.0	85.3
Crowsnest	O	45.8	91.4	77.8
"	P	45.6	93.1	79.4
"	R	46.7	93.0	78.3
"	V	43.1	96.2	87.0
Mountain Park	Q	42.1	94.6	82.1
"	S	44.7	94.5	81.0
"	T	47.4	96.9	87.6
"	U	45.0	94.0	81.1
Nordegg	W	52.0	93.5	79.8
Saunders	N	42.6	75.9	53.7

Note: Power stated in kilowatt hours per net ton of coal pulverized.

FUSIBILITY OF COAL ASH AND CLINKER FORMATION

The temperature in a coal fire is often higher than the softening or fusion temperature of the ash; under these circumstances the ash particles adhere together to form the well known lumps called clinker. The formation of clinker is thus a factor of the temperature of the fire and the temperature at which the ash fuses. The temperature of clinkering and the character of the clinker formed are important factors affecting the commercial value of any coal. Some clinkers are hard and glassy, may adhere to the fire bars, and

*Memorandum Series, No. 70 (1939).
†Report No. 790 (1938).

may cause considerable trouble in the fire; other clinkers are soft and friable.

The determination of the fusion temperature of coal ash in a laboratory is necessarily made on a finely powdered sample. The test therefore similates the condition when pulverized coal is fired; but notably differs from the condition in an ordinary coal fire where there may be separate lumps of impurities each having its own fusion temperature, which temperature however may be notably lowered at points of contact with other lumps.

The laboratory test is the best available, and does give an indication of the probable clinkering tendencies of the coal in a furnace. The final judgment, however, must rest on actual experience.

In this test small cones of the powdered ash are made, of a standard size and shape, and heated, with a controlled rate of temperature rise, in a mildly reducing atmosphere. The cones are carefully watched and three temperatures noted at which certain specific changes occur. These are: (1) Initial Deformation Temperature—when the first rounding of the tip, or a definite bending of the cone occurs. (2) Softening Temperature—when the cone fuses down to a spherical lump, or the tip touches the base. (3) Fluid Temperature—when the cone flows over the base.

When a single temperature, a "fusion temperature", is requested or reported the softening temperature, as defined above, is the one given. The difference in temperature between initial deformation and softening temperature is called the softening interval whilst the difference between softening temperature and fluid temperature is called the flowing interval.

Figure 4 shows ash cones, from 8 different coals, after heating to a number of different temperatures. The wide variations possible in the behaviour of different coal ashes is there illustrated.

Samples of coal from adjacent mines, or even from different places in the same mine, may show notably different ash fusion characteristics. It is therefore difficult to report specific ash fusion temperatures for any area or district. In the detailed reports of areas, figures are given for the usual range of ash softening temperatures (low and high values), all exceptionally low or high softening temperatures being omitted. The usual softening and flowing intervals are also given where sufficient data are available.

See Table 22 p. 174

In general, it is noted that the steam coals mined in the mountains have high ash-fusion temperatures, whilst the domestic coals from the prairies have low ash-fusion temperatures.

In general also, for any particular coal, the ash fusion temperature increases as the percentage of ash in the coal increases. A cleaned coal therefore usually has a lower ash fusion temperature than has the run-of-mine coal from the same mine. Occasionally, however, the reverse has been noted.

The clinkering character of a coal is of importance in its commercial evaluation. For most purposes a coal with little clinkering tendency is preferred; but in certain cases, as for example with underfeed domestic stokers, slagging producer-gas plants, and some pulverized coal-fired plants, a fusible ash is desired.

Fieldner and Selvig have suggested* that coals may be divided into the three following classes according to softening temperature of the ash.

*Trans. A.I.M.M.E. 74 (1926), p. 464.

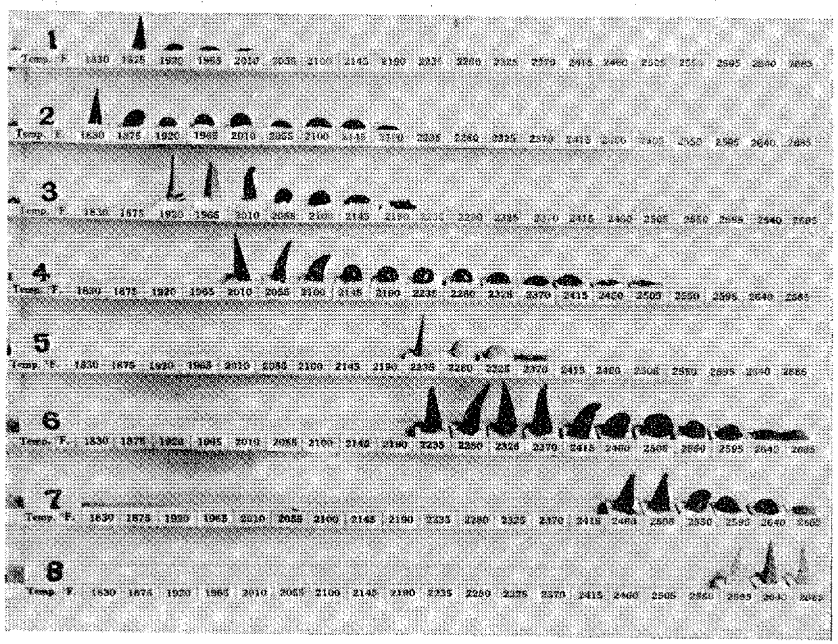


Fig. 4.—Ash Fusion Cones

Class I, refractory ash, softening above 2600°F. May be regarded as practically non-clinkering.

Class II, ash of medium fusibility, softening between 2200° and 2600°F. The clinkering characteristics will depend upon the furnace temperatures, the kind of stoker, and the distribution of the ash forming constituents in the coal.

Class III, easily fusible ash, softening below 2200°F. Form considerable clinker which may, in many cases of high furnace temperatures, spread over the grates.

E. Swartzman of the Fuel Research Laboratory, Ottawa, says in a valuable article* discussing the chemical composition of coal ash in relation to the formation and character of clinker:

"Whereas the softening temperature of an ash is determined in the laboratory on small quantities of finely ground and intimately mixed preoxidized materials under rigidly standardized conditions, in the furnace, the mineral matter is unevenly distributed as varying size particles and is exposed to conditions of temperature, atmosphere, time, and manner of travel through the fuel bed, which are variable. Under such conditions clinker formation may take place either through complete fusion of the ash, or by the cementing together of varying sized lumps of mineral matter, which are themselves relatively infusible. For clinker to form in any quantity, a sufficient amount of slag of a low enough viscosity must be produced to permit it either to run together into masses or to flow between other particles of infusible matter so as to cement them into aggregates. Thus the extent and rate of clinkering depends on the quantity and viscosity of the easily fusible material and upon changes produced in the properties of this material after melting by the incorporation of the more refractory material."

*Canadian Chemistry and Process Industries 27 (1943), p. 676.

TABLE 9

Analyses of Ash from Alberta Coals

	Reference	Year Coal Sampled	% Ash in Sample	Fusion Temperatures °F Initial deformation	Fusion Temperatures °F Softening	Fusion Temperatures °F Fluid	% Silica	% Alumina	% Ferric oxide	% Calcium oxide	% Magnesia	% Sodium oxide / % Potassium oxide	% Titanium dioxide	% Sulphur trioxide	% Phosphorous pentoxide	% Unaccounted
Brule Area	1	1914	......	......	......	......	61.1	29.6	2.3	2.7	0.4	0.3 0.3	2.5	......	......	0.8
	2	1923	16.7	+2600	+2600	+2600	59.2	28.6	3.6	3.5	1.2	0.4	2.1	0.5	0.7	0.2
Big Valley Area	2	1922	11.8	2400	2460	2600	52.3	27.6	2.8	11.8	1.0	3.6	1.2	0.1	0.0	......
Camrose Area	2	1923	4.8	2010	2080	2370	36.3	21.9	7.6	19.3	1.6	5.4	1.0	6.0	1.3	......
Cascade Area	1	1913	......	......	......	......	54.3	29.1	8.1	2.5	1.3	0.9 1.7	1.0	......	......	1.1
	2	1923	7.2	2060	2240	2370	36.1	31.7	14.5	2.8	1.6	4.3	1.4	0.1	8.2	......
	1	1934	......	......	......	......	60.4	26.9	3.2	3.6	0.0	1.5 0.8	1.1	1.3	1.6	......
	3	1944	7.6	......	......	......	51.3	37.5	8.4	1.3	......	......	......	1.3	......	0.2
Coalspur Area	2	1923	......	2330	2420	2600	59.8	23.8	3.0	8.0	1.0	2.2	1.2	1.6	0.3	......
	2	1923	......	2190	2220	2280	42.1	13.0	4.3	32.4	1.7	......	0.7	1.9	0.2	3.7
	3	1944	17.0	2300	2370	2520	60.4	23.3	3.6	9.5	......	......	......	2.3	......	0.9
Crowsnest Area	1	1914	......	......	......	......	59.8	31.6	2.7	2.4	0.9	0.3 0.1	1.4	......	......	0.8
	1	1914	......	......	......	......	52.5	33.2	4.3	5.5	1.5	0.7 0.4	1.3	......	......	0.6
	2	1923	17.4	2600	+2600	+2600	55.3	32.8	5.4	2.9	0.6	0.6	2.0	0.8	0.1	......
	2	1923	13.8	2600	+2600	+2600	59.0	27.2	6.0	1.9	1.3	......	2.5	0.1	0.6	1.4
	1	1934	......	+2700	+2700	+2700	51.2	25.9	9.7	3.5	0.9	......	......	......	......	8.8
Drumheller Area	1	1934	......	1910	1990	2080	38.0	16.9	6.7	12.8	1.8	8.1 0.2	0.3	13.4	1.4	0.4
	1	......	......	......	......	......	56.7	23.9	4.3	6.8	......	......	......	......	......	8.3
	3	1944	11.0	2240	2300	2490	53.3	25.6	6.3	5.9	......	......	......	3.0	......	5.9
	3	1944	8.5	......	......	......	40.1	21.0	12.2	9.4	......	......	......	10.2	......	7.1

Edmonton Area	2	1921	6.1	2120	2240	2370	46.8	21.6	4.0	18.8	1.2	5.3		0.9	0.9	0.5	......
	2	1922	6.5	2100	2240	2370	55.2	21.7	5.0	9.9	1.1	4.4		0.9	1.9	0.5	......
	1	1935	......	2040	2090	2110	29.7	17.3	8.0	18.3	0.1	10.2	0.5	0.3	12.6	2.9	0.1
	3	1944	11.4	2300	2340	2520	54.0	24.5	4.1	8.2	......	......		......	4.9	......	4.3
Lethbridge Area	2	1923	9.3	2060	2150	2330	49.2	18.6	5.2	13.8	1.6	4.0		1.3	3.8	3.0	......
	2	1923	9.8	2150	2240	2370	45.7	24.1	7.6	12.7	1.9	3.7		0.9	3.5	0.4	......
	3	1944	11.4	2190	2280	2390	52.6	25.6	5.4	9.0	......	......		......	4.2	......	3.2
	3	1944	13.5	......	......	......	52.9	27.1	5.1	7.5	......	......		......	4.5	......	2.9
Nordegg Area	2	1923	14.5	2370	2510	+2600	53.1	26.4	5.2	6.2	1.9	2.2		1.6	3.6	0.4	......
Saunders Area	1	1935	......	2120	2150	2170	34.0	15.8	11.1	20.5	1.1	3.1	0.5	0.4	12.2	0.8	0.5
	3	1944	8.8	2190	2230	2430	42.8	23.3	8.7	15.5	......	......		......	6.1	......	3.6
Sheerness Area	3	1944	7.2	......	......	......	38.4	24.4	5.9	17.0	......	......		......	8.8	......	5.5
Tofield Area	3	1944	6.2	......	......	......	28.7	29.8	5.1	18.9	......	......		......	10.6	......	6.9

NOTES:

Reference 1.—Bureau of Mines, Ottawa, No. 779 (1937), pp. 131, 132.

" 2.—A. G. Scroggie, M.Sc. thesis (1924), Univ. of Alberta.

" 3.—Research Council of Alberta. Unpublished.

All temperatures rounded to nearest 10°F and all percentages to nearest 0.1%. All constituents are recorded as percentages of the oxides. Manganous oxide was determined in four samples, but in no case did this exceed 0.02%.

"Where the fuel bed is disturbed during combustion, either by poking or slicing, or churned up as in an underfeed stoker, the tendency toward clinker formation is enhanced. In such cases it has been found that the softening temperature of the ash is more likely to be a measure of the clinkering characteristics than in those cases where the coal fire is relatively undisturbed such as in hand fired furnaces or chain grate furnaces, where the type of clinker formed is mainly affected by the distribution of the ash in the coal."

The relation between the fusion temperatures of a coal ash, and its chemical composition is complex. The complete analysis of an ash is a long and tedious operation, so it is comparatively seldom made. Records are available of 33 analyses of ash of Alberta coal, and these are shown in Table 9. It may be noted that there is no regularity in the analyses, even from the same area. The analyses vary widely even in samples from the same mine. If it is realized that the mineral impurities in a coal sample may be derived, and in notably varying proportions, from the inherent minerals of the original plants, from infiltrations through the coal bed, from the floor, from the roof, and from partings, the reason for the above irregularities is obvious.

Coals for blower and for underfeed stoker installations are required to clinker. The Fuel Research Laboratories at Ottawa have worked on methods to increase clinkering tendencies. In their Canadian patent No. 413226 of June 15, 1943, they suggest, with coals containing less than 6% lime in the ash, adding iron oxide until the percentage of silica plus alumina in the ash, divided by the percentage of iron oxide, gives a figure between 4 and 6.

SOLUBILITY IN ORGANIC SOLVENTS

The action of organic solvents on coal is of both scientific and industrial importance. The amount of material extracted from any coal depends on the coal, the fineness of grinding, the solvent used, and the time and temperature of extraction. The temperature of extraction can be raised by the use of high pressure. Tests have been made of the amount of material dissolved from different coals by different solvents, and also of the effect on extraction of different gases in the reaction chamber. Extraction with certain solvents has been made under atmospheric and also under high pressures. Data available for a number of coals are given in Table 10.

Extractions have also been made with certain solvents not given in the table. One, tetralin, always gave a greater weight of extract than the weight of coal used. It was evident that a chemical reaction took place between the coal substance and the solvent. Tetralin is one of the solvents used in the hydrogenation extraction process referred to elsewhere.

Work on solubility was planned to ascertain whether the valuable material montan wax, extracted commercially from certain European coals, could be obtained from any Alberta coal. No coal was found to contain this material in appreciable amount. The work, however, was continued because of the valuable information it gave as to the relative characters of the coals tested. It is suggested for example that this work may be significant with respect to the choice of coals for hydrogenation.

All extractions were made using the soxhlet principle which gives a continuous flow of fresh solvent over the coal. The temperature of the solvent, in contact with the coal, was maintained near its boiling point. The extractions were continued until the solution showed only a small amount of extract was being removed under the conditions of the test.

The results given in Table 10 can only be taken as comparative. Higher percentages of extracts could have been obtained in every case by finer grinding of the coal, by more prolonged extraction and, in the pressure extractions, by the use of higher temperatures and pressures.

TABLE 10

Solubility in Organic Solvents

A.—Soxhlet extraction—Test of solvents

Area	Rank of Coal	75% Benzene 25% Ethyl alcohol		Pyridine		Phenol	
		Time hours	Extract %	Time hours	Extract %	Time hours	Extract %
Nordegg	Low vol. bit.	30	0.2	26	0.6	68	17.7
Mountain Park	Med. vol. bit.	......	......	......	......	60	29.8
Crowsnest	"	......	......	......	......	60	41.9
"	High vol. A bit.	57	0.7	......	......	......	......
"	"	......	......	......	......	60	28.8
"	"	......	......	......	......	60	43.1
Mountain Park	"	30	0.3	41	22.0	68	30.6
"	"	......	......	......	......	60	36.9
Pincher	"	68	10.4	41	22.8	......	......
Coalspur	High vol. C bit.	......	......	......	......	60	21.5
Saunders	"	30	3.3	26	11.4	......	......
Lethbridge	"	53	5.3	26	11.2	......	......
"	"	......	......	......	......	60	27.6
Champion	Sub-bit. A	57	3.7	......	......	......	......
Drumheller	Sub-bit. B	30	2.9	26	7.7	68	28.3
"	"	......	......	......	......	60	23.6
Gleichen	"	......	......	......	......	60	14.3
Edmonton	"	38	2.3	......	......	......	......
"	"	......	......	......	......	60	19.0
Sheerness	Sub-bit. C	30	2.4	26	6.2	68	9.4
Pakowki	"	48	3.0	......	......	......	......

B.—Soxhlet extraction—Test of atmosphere

Area	Rank of Coal	Time hours	Extract %	Extract %	Extract %	Extract %
	Solvent 75% benzene, 25% ethyl alcohol					
	atmosphere		oxygen	sulphur dioxide	ammonia	methane
Crowsnest	High vol. A bit.	57	1.2	1.2	1.0	0.7
Lethbridge	High vol. C bit.	53	5.4	6.8	5.7	5.3
Edmonton	Sub-bit. B	38	2.7	9.9	5.7	2.3
Pakowki	Sub-bit. C	53	3.6	6.6	3.3	3.0

C.—Soxhlet extractions—Pressure

Area	Rank of Coal	Time hours	Temperature °F	Pressure p.s.i.	Extract %
	Solvent 75% benzene, 25% methyl alcohol				
Mountain Park	Med. vol. bit.	24	410	250	0.3
Crowsnest	"	24	410	250	1.9
Mountain Park	High vol. A bit.	24	410	250	12.5
Crowsnest	"	24	410	250	9.6
"	"	24	410	250	2.5
Coalspur	High vol. C bit.	24	410	250	5.7
Lethbridge	"	24	410	250	10.6
Drumheller	Sub-bit. B	24	410	250	5.0
Gleichen	"	24	210	250	4.1
Edmonton	Sub-bit. C	24	410	250	2.4
	Solvent 66% benzene and 34% ethyl alcohol				
Nordegg	Low vol. bit.	130	460	650	1.6
Crowsnest	High vol. A bit	400	390	500	10.9
Saunders	High vol. C bit.	390	450	600	14.8
Lethbridge	"	430	390	500	18.6
Drumheller	Sub-bit. B	200	450	600	18.2
Sheerness	Sub-bit. C	370	390	500	22.1

NOTES:
1. Extracts are expressed as per cent by weight of the pure, dry coal.
2. Temperatures, in °F, and pressure in pounds per square inch, are those in the extraction chamber.
3. Time of extraction is given as hours during which the extraction was working at the desired temperature or desired temperature and pressure.

SOLUBILITY IN ALKALIES

All coals are made up of varying proportions of three types of materials: (1) resins and hydrocarbons, (2) resistant plant remains, and (3) ulmins. The ulmins have resulted from the decay of the woody structures of the plants from which the coal was derived. They are brown to black in colour; they are also easily oxidized. In the original plants, in peat, and in the low rank coals comparatively little metamorphosed from peat, the ulmins are almost completely soluble in alkalies. With coals of more advanced metamorphism the ulmins are found to be less soluble, whilst anthracites and even high rank bituminous coals contain very little alkali-soluble ulmins. The ulmins in such coals, however, can be oxidized, and then become alkali-soluble.

A determination of the alkali-soluble ulmins in a coal therefore, gives an indication of the degree of metamorphism or coalification of the coal; that is, essentially, the rank of the coal. It is also found that the oxidizability of a coal is closely related to the percentage of alkali-soluble ulmins it contains. A method for this determination has been developed in this laboratory.* Table 11 gives results obtained with 13 fresh coals. A weathered, that is oxidized, coal will give an abnormally high result. The coals are arranged in order of descending rank.

*E. Stansfield and K. C. Gilbart, Trans. A.I.M.M.E., Coal Division (1932), pp. 165-170. Also Fuel in Science and Practice, XI (1932), p. 347.

TABLE 11

Solubility in Alkalies—Ulmins

Area	Horizon	Distance east of mountain face, miles	Rank of Coal	Moisture as mined %	Soluble ulmins, pure dry coal %
Cascade	Kootenay	....	Semianthracite	2.2	0.0
"	"	....	Low volatile bit.	1.4	0.0
Nordegg	"	....	"	1.7	0.0
"	"	....	"	1.6	0.0
Crowsnest	"	....	Medium volatile bit.	1.4	0.0
"	"	....	High volatile A bit.	1.2	0.0
"	"	4	"	3.3	0.2
Pincher	Belly River	6	"	4.9	1.9
Saunders	"	5	High volatile C bit.	9.7	2.9
"	"	5	"	12.0	2.0
Lethbridge	"	60	"	9.8	11.4
Champion	Edmonton	60	Subbituminous A	12.9	45.0
Taber	Belly River	92	"	15.0	13.4
Carbon	Edmonton	80	"	17.8	14.4
"	"	85	"	17.4	17.5
Drumheller	"	95	Subbituminous B	18.6	14.7
"	"	100	"	18.7	19.2
"	"	100	"	18.5	12.2
"	"	105	"	18.6	16.3
"	"	100	"	20.7	15.5
"	"	105	"	20.0	14.7
Taber	Belly River	110	"	18.8	39.5
Drumheller	Edmonton	105	"	20.1	23.5
Taber	Belly River	135	"	22.6	48.8
Big Valley	Edmonton	115	"	23.4	40.6
Redcliff	Belly River	155	Subbituminous C	26.6	52.6
Sheerness	Edmonton	140	"	25.6	39.2
"	"	140	"	28.1	24.8
"	"	145	"	29.1	43.5
Castor	"	155	"	29.0	39.7
Pakowki	"	157	"	30.3	56.1

MICROSTRUCTURE AND SPORES

When a bed of coal is found, it is frequently important to know to which geological horizon it belongs and, if possible, to which seam in that horizon. This information may be sought by the coal operator, or by the well driller or petroleum geologist who would like to use the coal seams as markers.

The chemical analysis of a coal if considered in relation to its location, may give a fair indication of the horizon but cannot give seam identification. Even the horizon may be doubtful as local geological conditions can have notably affected the composition of the coal. This uncertainty is increased at the lower depths penetrated by a bore hole.

It is known that coal is formed from plant remains; and that long intervals of time occurred between the deposition of one seam of coal and the next, possibly extending over millions of years. It is certain that changes of life would have occurred in the interval, and that such changes might still be identifiable in the more resistant parts of the plants, namely their spores. Between the formation of coal in one period or horizon and in the next, the time interval would be far longer than that between successive seams in the same horizon, and here it is expected that distinct changes in spore content may be determined, although it is not likely that a complete change of spores will be found. Some spores will probably be present in all three Alberta horizons; but some may be plentiful in the oldest horizon, scarce in the second and missing in the third. It is further possible, however, that certain spores may occur only in definite structures, in which case they could be used as markers.

In England and the United States considerable progress has been made in this field of investigation, and seam identification by spores has been found practicable. The spores are examined by three methods: (1) in thin sections of the coal by transmitted light, (2) in polished sections by reflected light, and (3) after isolation by removal of the less resistant materials in the coal with chemical reagents. It has been found necessary in studying microspores in coal to record not only the types of spores present in the coal sample but also the prevalence of each type.

Comparatively little work has yet been done on the microscopic examination of Alberta coals and the correlation of coal seams on the basis of their spore content has not yet been proved feasible.

Four small lumps of coal were submitted to the late Dr. R. Thiessen, well known authority on coal structure of the U.S. Bureau of Mines, Pittsburgh. One lump of coal was from a mine in the Saunders area, two from mines in the Coalspur area and one from Lethbridge. Dr. Thiessen (private communication) emphasized the fact that the samples were too few and too small to represent the coal beds and that it was dangerous to draw conclusions under these conditions. His findings of the actual samples were as follows: "The outstanding characteristics of these coals are: (1) finely to micro-bandedness, (2) highly attrital nature with advanced state of decomposition and maceration, and (3) high concentration of 'opaque' matter".

"The most outstanding characteristic from a petrographic standpoint is the high concentration of 'opaque' matter. The 'opaque' matter in these coals is similar to the 'opaque' matter in the 'splint coals' of the Paleozoic times, in which it forms the splint-making ingredient, but it is less dense than in the Paleozoic coals. The three samples from Saunders and Coalspur contain a high enough concentration of 'opaque' matter to characterize them as 'semi-splint to splint' coals; the Lethbridge sample has a high enough concentration to characterize it as a semi-splint coal, as compared with the Paleozoic coals".

Dr. Thiessen's conclusions are understood to indicate that the free burning, non-coking quality of these coals may be owing to the nature of the plant remains from which they were formed, rather than to lack of geological age and metamorphoses. It is interesting to note that certain free burning, smokeless coals in the United States are sold at a premium as splint coals.

Dr. I. W. Jones* made a microscopic examination of certain Alberta coals, and found that Alberta coals are composed principally of materials derived from the woody parts of plants. Relatively few spores were found to be present. The resin content varied considerably between different coals. Because of their opacity considerable difficulty was experienced in making thin sections of many Alberta coals.

Dr. J. B. Simpson, Geological Survey of Great Britain (private communication), also found the spore content of Alberta coals low. A significant point observed in the coals he examined was the fact

*Can. Jour. Research, 14B (1936), p. 275.

that Kootenay coals contained only spores of cryptograms whereas the coals of the Belly River and Edmonton horizons had both spores and pollen grains. Dr. Simpson in his preliminary examination was able to identify certain specific spores and pollen grains.

The R.C.A. has made some studies on plant remains in coal. The work has been of a preliminary nature, mainly on the development of methods for studying the spore content. The polished section, and the chemical isolation of spores methods were tried and the latter preferred.

COMPARISON OF HEAT VALUES FOR VARIOUS SOLID, LIQUID AND GASEOUS MATERIAL

Solid Fuels.

The heat values for a number of solid substances, that have been analyzed in these laboratories, from time to time, are given in Table 12. The values can only be regarded as approximate since it must be realized that the heat value of any substance varies markedly with variations in moisture and ash content and with other factors. Heat values are given in the table as B.t.u. per pound of the material; given also are therms per ton for coal, charcoal, coke and grains, and therms per cord for wood. A therm is 100,000 B.t.u.

The calorific values for the five coals have been taken from the typical analyses for the groups given on pages 19-20 of this report, and are on the as received basis. The values for coke and charcoal are given on the dry basis; whereas the values for the wood samples have been calculated to the common basis of wood with 15% moisture, and the grain samples similarly calculated to a 10% moisture basis.

Since wood is sold by the cord an estimation has been made of the pounds of wood per cord for each species given, and these values used for calculating therms per cord.

TABLE 12

Heat Value of Solid Fuels Analyzed

Coal—as Received*	Calorific value B.t.u./lb.	Therms per ton
Group 1	14,000	2.80
Group 2	13,200	2.64
Group 3	10,900	2.18
Group 4	9,700	1.94
Group 5	8,300	1.66
Petroleum coke—(0.5% ash) dry	16,120	3.22
Beehive coke (17.2% ash) dry	14,450	2.89
Charcoal—dry	14,000	2.80
Grains—with 10% moisture:		
Wheat	7,380	1.48
Barley	7,340	1.47
Oats	7,760	1.55
Screenings	7,480	1.50
Weed seeds	8,240	1.65
Bran	7,690	1.54
Wood—with 15% moisture†:		Therms per cord
Birch	7,170	1.72
Jack Pine	7,620	1.53
Spruce	7,600	1.52
Tamarack	7,470	1.49
Poplar	7,320	1.41

*See pages 19 and 20 for typical analyses.

†Values for woods vary largely with types, conditions of growth, age, etc. The values given are based on analyses of Alberta woods analyzed in these laboratories. Estimated pounds per cord are—Birch 2,400, Jack Pine 2,010, Spruce 2,000, Tamarack 2,000, and Poplar 1,930.

Natural and Manufactured Gases.

In Table 13 are given typical analyses and corresponding heat values of the natural gases supplied to the cities of Calgary and Edmonton respectively, also typical analyses and heat values for a number of gases manufactured from coal or coke. All analyses are by volume. The calorific values are given as B.t.u. per cubic foot, dry, at 60°F and 30 inches of pressure (both gross and net).

TABLE 13

Analyses and Heat Values of Natural and Manufactured Gases

Fuel	Combustibles					Inerts		Calorific value in B.t.u. per cubic ft.	
	Illum C_2H_4 etc., %	CH_4, %	C_2H_6 and higher, %	CO, %	H_2, %	CO_2, %	N_2, %	Gross	Net
***Natural Gas:**									
Calgary city gas	.....	84.1	11.9	.....	.....	1.2	2.8	1095	991
Edmonton city gas	.....	91.1	3.2	.....	.....	0.0	5.7	990	893
†Manufactured Gas:									
Coal Gas:									
L.T.C. bit. coal	8	46	12	7	17	5	5	882	802
H.T.C. bit. coal	4	32	2	6	51	2	3	608	544
Coke oven	4	32	...	6	53	2	3	580	517
L.T.C. Edmonton coal	1	37	...	7	13	34	8	456	411
Water Gas:									
Carburetted	9	8	2	34	41	3	3	503	462
Blue	.....	1	.	44	47	3	5	306	281
Producer Gas:									
Mond	.....	3	...	15	26	12	44	164	148
Coke fuel	.....	1	...	30	10	4	55	140	134

*Dr. E. H. Boomer, University of Alberta, Edmonton. Unpublished.

†Data for manufactured gases from J. J. Humphreys, Fuel and Coal Symposium, McGill University, 1931, and Technical Data on Fuel, World Power Conference, 1932.

Gaseous and Liquid Fuels.

The heat values of a number of gaseous and liquid fuels are given in Table 14. The B.t.u. are given per pound and also per cubic foot at 60°F and 30 inches pressure for gases. The heat values for the petroleum products are given as B.t.u. per pound, and per Imperial gallon at 60°F. The gravity in degrees A.P.I. is also given. It may be noted that the thermal properties of such mixtures of hydrocarbons as constitute petroleum and its products are closely related to the density of the liquid. Some consistent differences have been found between data on paraffin and on naphthene base products of the same density, but these differences are small and of little significance in practical applications.

TABLE 14

Heat Value of Gaseous and Liquid Fuels

	Gravity petroleum products, degrees A.P.I.	Heat Value in B.t.u.					
		Per pound		Per Imperial gal. at 60°F		Per cubic foot at 60°F and 30″, dry	
		Gross	Net	Gross	Net	Gross	Net
*Gases:							
Carbon monoxide	......	4,347	4,347	......	......	322	322
Hydrogen	......	61,100	51,623	......	......	325	275
Acetylene	......	21,500	20,776	......	......	1,449	1,448
Methane	......	23,879	21,520	......	......	1,013	913
Ethane	......	22,320	20,432	......	......	1,792	1,641
Propane	......	21,661	19,944	......	......	2,590	2,385
N. Butane	......	21,308	19,680	......	......	3,370	3,118
N. Pentane	......	21,091	19,517	......	......	4,016	3,709
†Petroleum products:							
Naphtha	80	20,630	19,180	138,100	128,400	......	......
Gasoline	70	20,460	19,050	143,800	133,800	......	......
"	60	20,260	18,900	149,800	139,680	......	......
Crude oil distillate, kerosene, etc.	50	20,020	18,720	156,100	146,040	......	......
Crude oil distillate, kerosene, etc.	40	19,750	18,510	163,000	152,760	......	......
Crude oil, diesel fuel, etc.	30	19,420	18,250	170,200	159,960	......	......
Crude oil	20	19,020	17,930	177,700	167,520	......	......

*Data taken from Chemical Engineers' Handbook—Second Edition, McGraw-Hill, 1941.
†Data adapted from U.S. Bureau of Standards, Miscellaneous Publication 97, 1929.

PART IV

Preparation and Utilization of Coal

COAL SIZING

The Specification for Coal No. 18-GP-1, 1940, of the Canadian Government Purchasing Standards Committee contains the following table and notes:

TABLE 15

Sizing of Coal

The coal shall conform to any one, or group, of the following size designations, as required by the purchaser:

Size Designation	Size Limits (round-hole screens) (1)	Customary Trade Designation (2)
A	Retained on 1/8 inch screen (3)	Run-of-mine or dock-run
B	Retained on 1½ inch screen (3)	Lump
C	Passing 3 inch, retained on 2½ inch screen (4)	Egg
D	Passing 2½ inch, retained on 1½ inch screen (4)	Stove
E	Passing 2 inch, retained on 1/16 inch screen	Nut slack
F	Passing ¾ inch, retained on 1/32 inch screen	Slack
G	Passing 1½ inch, retained on ¾ inch screen	Stoker nut
H	Passing ¾ inch, retained on 3/8 inch screen	Stoker pea
J	Passing 9/16 inch, retained on 5/16 inch screen	Buckwheat No. 1(blower)
K	Passing 5/16 inch, retained on 3/16 inch screen	Buckwheat No. 2(blower)
L	Passing 3/16 inch, retained on 3/32 inch screen	Buckwheat No. 3(blower)

(1) Not more than 15 per cent by weight of the sample shall pass the screen defining the lower size limit and not less than 95 per cent shall pass that defining the upper size limit.
(2) Owing to variations in trade designations this column is given as a convenience only: the alphabetical designation given in the left-hand column shall govern.
(3) The purchaser may specify a maximum permissible size, in which case not less than 95 per cent of the coal shall pass the screen indicated.
(4) The purchaser may specify another maximum permissible size, in which case not less than 95 per cent of the coal shall pass the screen indicated.

The following is a summary of The Wartime Prices and Trade Board Administrator's Order No. A-289, July 11, 1942. Respecting the Grading of Coal Mined in the Province of Alberta:

1. Every person who mines coal in the Province and who sells and delivers such coal for domestic use shall—

   Grade such coal only in the sizes provided, designate in the invoice the area from which mined, and the name of the grade, and shall furnish the purchaser at the time of delivery with a true copy of the invoice.

2. The grades for such coal shall be known as "lump", "utility lump", "egg", "nut", "stoker" and "slack", except in Edmonton area, for local sales only, the grade "screened mine run" shall be permitted ,and "utility lump" not be used.

3. All such coal shall be graded by means of shaker screens having round hole perforations of the sizes, in inches, specified. Nevertheless in place of shaker screens it is permissible to use an equivalent screen of other types.
4. Order does not apply to coal sold for local domestic use and delivered to trucks, etc., at mine.

Size specifications—diameter in inches of round hole perforations

	Lethbridge Area	Edmonton Area	Other Areas
Lump coal—Over	4	4	4
Utility lump—Through	8 or 10	.....	8 or 10
Over	4	.....	4
Screened mine run*—Over	.....	2	.....
Egg coal—Through	4	4	4
Over	1¾†	2	2
Nut, stoker and slack—Through	1¾	2	2

Provided that nut coal, 1″x2″, and the various sizes of stoker and slack coal may be screened to meet the requirements of any purchaser thereof.

NOTES: *For local sales only.
†Galt mine only, egg coal through 4″ and over 1⅛″.

It can be seen that the above specification and order both refer to round hole screens. Actually, many mines in the Province are only equipped with bar screens, or other types.

No thorough test has been made of the equivalent sizing to be used to give the same screen analysis as a series of round hole screens. A few tests, however, have been made in these laboratories to determine equivalency between round hole and bar screens. In most cases only one test was made of the coals in any area. The results are given in the following table. It can be seen that although distinct differences were found, as was expected, between different coals, these differences were not large, and the table indicates that equivalent screening could be approximated for any coal by the use of a series of bar screens, each with a spacing 60% of the diameter of the round hole screen to be matched.

TABLE 16

Equivalency of Round Hole Perforation and Bar Screens

The sizes are given for bar screens, giving approximately the same screen analysis as the specified round hole perforation screens, with run-of-mine coal from each of the following coal areas.

All measurements are given in sixteenths of an inch, and also, for each bar screen size as a percentage of the corresponding round hole diameter.

Diameter of round hole perforations	48 (3″)		32 (2″)		24 (1½″)		16 (1″)		12 (¾″)		4 (¼″)		Average
Area	size	%	size	%	size	%	size	%	size	%	size	%	%
Big Valley	25	52	18	56	12	50	8	50	6	50	3	75	56
Brule	28	58	16	50	12	50	8	50	6	50	3	75	56
Camrose	30	63	21	66	16	67	12	75	9	75	3	75	70
Coalspur	28	58	16	50	12	50	8	50	6	50	3	75	56
Crowsnest	24	50	16	50	12	50	8	50	6	50	3	75	54
Drumheller	26	54	18	56	14	58	9	56	7	58	3	75	56
Edmonton	33	69	.....	.....	12	50	.....	.....	8	67	3	75	65
Mountain Park	29	60	16	50	12	50	8	50	6	50	3	75	56
Pembina	32	67	21	66	16	67	11	69	8	67	3	75	69
Saunders	25	52	20	63	16	67	12	75	8	67	3	75	66
Tofield	26	54	17	53	14	58	10	63	7	58	3	75	60
Average		58		56		56		59		58		75	60

COAL CLEANING AND WASHING

Coal as mined and brought to the tipple normally contains removable impurity. It is obviously desirable to remove as much of this impurity as is practicable, both to cut down freight on worthless matter and to supply the consumer with a good, clean fuel.

Many methods of cleaning are known and practised. Almost all the mines in the Province have picking belts where the visibly dirty lumps are removed by hand from the larger sizes. The same result can be achieved with some coals on a spiral chute. A more intensive cleaning, called coal washing, is frequently operated. This can treat both large and small sizes. There are many different washing processes; but they can all be grouped into two main classes, dry and wet washers. Coal washing frequently involves coal drying, if a coal moist as mined is to be dry washed, or if a washed coal is to be shipped in cold weather. Drying is more important with the finer sizes.

In the operation of a drying plant the ignition temperature of the coal is important. This subject is discussed elsewhere.

Tests have been made in the laboratories of the Research Council of Alberta and elsewhere, on the washability of many Alberta coals of Group I, II and III. The results of such tests show in tabular and graphic form the yield of cleaned coal obtainable with any particular ash content, and the corresponding amount of combustible lost in the discard. Such results are not of general interest; but they have in each case been reported to the operator concerned. Laboratory tests show the operator the best results that he could obtain; commercial operation will always fall short of this. Manufacturers of coal washing equipment will make tests and specify the results they can guarantee with their equipment, or large scale tests might be arranged in existing plants. Consumers should realize that they can buy a low ash coal from a mine operating a washing plant. The lower the ash in the washed coal, the higher the price the consumer must expect, and can afford, to pay. The optimum will in many cases depend on the distance the coal is to be shipped.

BRIQUETTING

During the mining, preparation and handling of coal a large percentage of fine coal is produced. For these fines there is a limited market, particularly if the coal is non-coking, and they are therefore a low value product.

Briquetting is a process for converting fine coal into a lump product of suitable size and shape for convenient handling and of such form as to allow free passage of air through the furnace during combustion. Briquettes to be satisfactory should also be strong, clean to handle, weatherproof and have good firing properties. They are made in a variety of sizes, shapes and weights; but a 2 to 4 oz. briquette is most common in Canada.

In the briquetting process, suitably sized material is heated and intimately mixed with a binder. The mass is then fed to a powerful press where it is moulded into briquettes.

Any type of coal, coke or char may be briquetted, but some materials are more difficult to briquette and require far more binder than do others to make a commercial product. The low volatile bituminous coals of Group I do not agglomerate in the fire and are apt to sift through the fire-bars or be blown up the stack. They are, however, high grade fuels and any clean fine coal which cannot be readily sold is well worth the cost of briquetting. The fines of coking bituminous coals of Group II agglomerate in the furnace fire, and so give little difficulty in combustion. Although there is not the same need of briquetting these fines, they can be briquetted, and with a minimum of binder. The coking property of the coal strengthens the briquette in the fire. The coals of Group III which normally contain about 10% of moisture require to be dried before being briquetted. The absence of coking material in the coal, and the presence of a high percentage of volatile matter, tend to make the briquettes disintegrate if thrown into a hot fire. Such coals, however, will usually make good briquettes if blended with about 10 per cent of a good coking coal. The domestic coals of Groups IV and V are high in moisture and low in heat value, and require to be carbonized before they are worth the cost of briquetting. The carbonization treatment increases the heat value by 20 to 30 per cent, but the char produced is a very porous material and a high percentage of binder is required to make a good briquette. The development of a really cheap and satisfactory method of briquetting char would have attractive possibilities in Alberta, because of the large deposits of these coals that can be mined cheaply. Carbonization followed by briquetting would increase the heat value some 30% and give an easily handled storable product. The shipping range and markets would thus be materially widened and the mines and process plants could be operated steadily throughout the year. This latter point is of great economic importance and would notably reduce the cost of the product.

Asphalt is the binder most commonly employed in America; in Europe coal tar pitch is frequently used. Experiments with a large number of other binders, both organic and inorganic, have been made in an attempt to develop a better and cheaper binder. If a cheap, good binder could be developed it might have a notable effect on the widening of Alberta's coal markets.

Attempts have been made from time to time to take advantage of the binding material inherent in certain coals, in order to briquette without the addition of outside binder. This usually involves higher temperatures and pressures than otherwise. This process has reached commercial operation.

The Research Council of Alberta has in its laboratory two semi-commercial briquette presses. A long series of tests have been made with these to study all the conditions essential for making good briquettes economically with the different grades of coal and with the regular binders. A long and painstaking search has also been made, so far without success, for the ideal cheap binder. A study of the binderless briquetting of certain Alberta coals is in progress.

The results of these investigations can be briefly summarized by stating that good commercial briquettes can be made as follows:

Group I coals: 94% coal, 6% asphalt.

Group II coals: 94% coal, 6% asphalt.

Group III coals after drying: 84% dry coal, 9% coking coal, 7% asphalt.

Groups IV and V after carbonization: 90% char, 10% asphalt.

A satisfactory briquette to be returned for admixture with run-of-mine coal to improve its sizing: 97% coal, 3% asphalt. Each 2% asphalt can be replaced by 1% flour.

The Fuel Research Laboratories of the Department of Mines, Ottawa,* have estimated the average cost of briquetting in the United States at $2.58 per ton exclusive of the cost of the coal. This sum is made up of $1.13 for binder, assuming 7½ per cent at $15.00 per ton, and $1.45 for the total cost of operation. It can be seen that, even under favourable conditions, the cost of binder must be an important item in the cost of the finished briquette.

Two briquetting plants built in the Province, in recent years, produced 220,000 tons of briquettes during 1943. These briquettes were sold largely for railway and domestic use. Because of their high heat value, good handling and storage properties this fuel found a ready market outside the Province.

The Research Council of Alberta has prepared two reports relative to briquetting.†

STEAM PRODUCTION AND BOILER TRIALS

A large percentage of the coal consumption of the world is coal burned in order to produce steam. Boiler trials are made in order to evaluate coals for the production of steam; but two types of these must be recognized.

(1) The operator of a boiler plant may run boiler trials on the different coals available for purchase, and thus find which coal is the best to buy for his plant. He is thus enabled to select a coal suited to the equipment installed, and the boiler trials satisfactorily meet his requirements.

(2) A government laboratory, or other testing plant, may endeavour to test a large number of coals in order to grade them according to merit for steam raising. Unfortunately, such a testing plant has seldom a wide range of testing equipment, and far too often the fact that coal M gave a higher evaporation than coal N does not prove that M was better than N, but only that M was better suited to the equipment and conditions of the test. Such boiler trials therefore may be entirely misleading, unless studied with a full appreciation of the difficulties and limitations under which the tests are made. The difficulties and limitations are probably less with pulverized coal trials than with hand fired or stoker trials.

A detailed report on a boiler trial may include as many as 80 items, and only by a study of such a report can the real significance of the trial be understood. The most frequently quoted value, however, is that termed "equivalent evaporation", or the pounds of water at 212°F converted to steam at 212°F per pound of coal fired. The efficiency of the boiler plant is also generally stated. This is the calculated heat required to convert the feed water evaporated into the steam thus produced, expressed as a percentage of the heat value of the coal burned to produce that steam.

The heat value of the coal, the efficiency of the boiler plant, and the equivalent evaporation are related by the following equation:

$$0.10306\,HK = 100\,E$$

where H=the heat value of the coal as fired, in B.t.u./pound
K=the efficiency of the boiler plant in per cent
E=the equivalent evaporation in pounds of water at 212°F converted to steam at 212°F.

This equation is based on the assumption that the latent heat of steam at 212°F is 970.3 B.t.u. per pound.

*R. A. Strong, E. Swartzman and E. J. Burrough, No. 775, 1937.
†E. Stansfield and W. A. Lang. Proc. 2nd International Conference on Bituminous Coal, Vol. I (1928), pp. 508-526.
†E. Stansfield, Trans. C.I.M. & M., Vol XL (1937), pp. 35-44.

Either the gross or the net heat values can be employed, but with the net heat values higher boiler plant efficiencies will be obtained, and there will be smaller variation of efficiency between high and low hydrogen content coals.

Calculation can be avoided by the use of the alignment chart of Fig. 5. The heat value of the coal is shown on scale H on the left, the equivalent evaporation on scale E on the right, and the boiler plant efficiency on the sloping scale K. A straight line from a particular heat value on H to a particular evaporation on E will cut the sloping scale at the corresponding boiler plant efficiency. Or a straight line from a particular heat value on H, to a particular efficiency on K, if continued will cut the line at E at the corresponding equivalent evaporation. For example, a straight line drawn from a heat value of 14,000 B.t.u. through a plant efficiency of 70% will give an equivalent evaporation of 10.1 lbs.

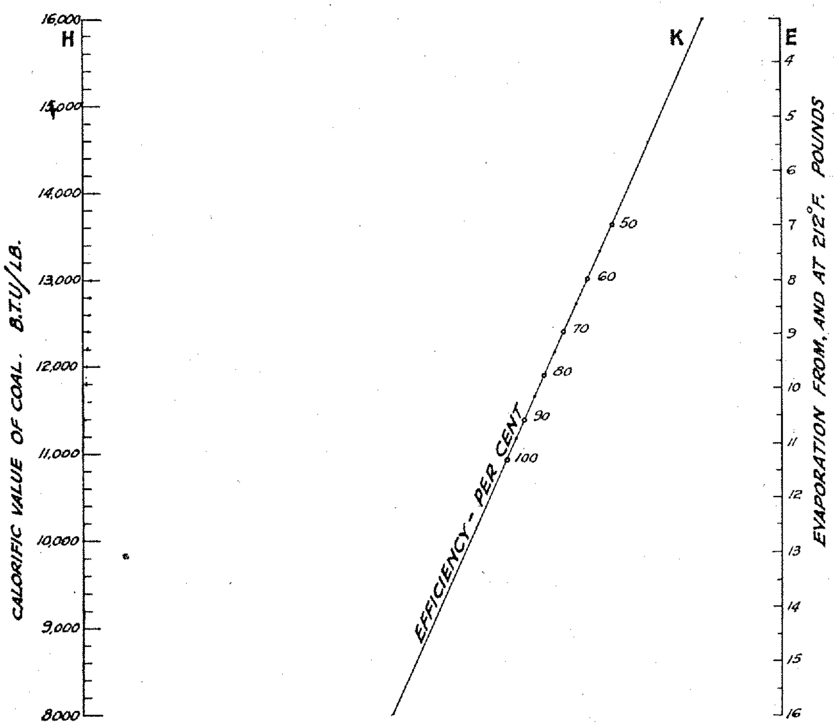


Fig. 5.—Nomogram—Boiler Efficiency and Equivalent Evaporation

The efficiency of a boiler plant depends far more on the equipment that on the coal, and high efficiency can be obtained with any ordinary coal and suitable equipment. It must be obvious, therefore ,that evaporations obtained with one coal in one set of boiler trials cannot be compared with those of another coal in another set of boiler trials to give the relative merits of the two coals.

A large number of references to steam production and to boiler trials with Alberta coals have been published. These show efficiencies ranging from 45% to 89%. The low efficiencies are with small boilers, without economizers, whilst the high efficiencies are with modern, high pressure plants, with pulverized coal firing, and with economizers to preheat the feed water, or the air for combustion, or both.

In view of all the above it has been decided to give references to such publications; but not to give any summary of the results reported.

It might be noted, however, that the reports cited include operating data on some large, modern boiler plants, and that these data show high efficiencies with both Alberta domestic and Alberta steam coals. Efficiencies as high as 80% are shown with domestic coal (Subbituminous B) in a stoker fired furnace, and as high as 89% with steam coal in a pulverized coal fired furnace.

The principal heat losses in a boiler plant are (1) radiation of heat from the outside of the boiler, (2) loss of incompletely burned coal through the grates or in the ashes, (3) loss of sensible heat in the flue gases, (4) loss of latent heat in the flue gases, and (5) loss of unburned material in the flue gases. The unburned material in the flue gases may include solid particles of coal and ash, called "fly ash"; solid particles of soot, vapours of tar, and combustible gases such as carbon monoxide, hydrogen and hydrocarbons.

The last four items in the above list are related to the character of the coal, and three of these losses can be reduced by the selection of equipment suited to the coal; but discussion of the means employed to reduce losses would be out of place in this report.

The following eight characteristics of any coal should be considered in relation to its use for the production of steam: (1) Total net heat value of the coal. (2) Distribution of heat value between the volatile and non-volatile fractions of the coal. This, it might be mentioned, is related to the percentages of volatile matter and fixed carbon in the coal. (3) Cleanliness of coal, as shown by the ash percentage. The dirtier is the coal, the more ash is there to be removed from the furnace and taken away. Also a high ash may involve increased loss of unburned fuel with the ash. (4) Clinkering properties of coal ash. This depends largely on the fusion temperature of the ash; in general a high fusion ash is preferred, but the reverse is sometimes the case. (5) Burning characteristics. Some coals burn much more freely than do others. Some burn with a short flame and others with a long flame (see 2 above), and some coals tend to cake or even to form coke in the fire bed. Some coals moreover tend to burn smokily and others to burn without smoke. However, all these types of coal can be burned without excessive losses in the flue gases if suitable equipment is provided. (6) Strength of coal. Some coals are strong and others friable. A friable coal is apt to result in the presence of a high percentage of fines in the coal as fired; on the other hand, if the coal is to be burned as pulverized coal extra power is required for pulverization if the coal is hard and strong. (7) Storage qualities. If the coal may require to be stored before being burned it is advisable to consider its storage properties, since some coals disintegrate rapidly when stored, unless protected from the weather. Also prolonged storage of most coals involves more or less risk of spontaneous combustion. (8) Ultimate analysis of coal; that is its carbon, hydrogen, oxygen, etc. content. Makers of boilers, before tendering on equipment to be supplied, commonly request the ultimate analysis of the coal expected to be burned. This assists them to specify the correct type of equipment. The ultimate analysis is also required for calculation of such combustion data as volume of air required per pound of coal.

Part V on combustion discusses further some of the above characteristics of the coal, and relates certain of them with the classification of the coal.

The following reports and articles refer to the use of Alberta coals for the production of steam:

Forty-One Steaming Tests, J. Blizard and E. S. Malloch, Mines Branch, Department of Mines, No. 496 (1920).

Investigations of Canadian Coals, B. F. Haanel and R. E. Gilmore, The Engineering Journal, XX (1937), p. 515.

The Burning of Low Rank Alberta Coals—The Steam Generating Plant. C. A. Robb. The Engineering Journal, XX (1937), pp. 555-564.

Experience in Burning Western Canadian Coals, E. W. Bull. The Engineering Journal, XX (1937), pp. 571-580.

DOMESTIC HEATING—FURNACE AND STOKER COALS

A.—Furnace Coals.

Comparative tests on a number of Alberta coals in domestic furnaces have been made, and reference to these is given later; but for reasons similar to those given in the section on steam production, the results of such tests may be quite misleading, so that no summary of the results is here given.

Two important considerations in domestic heating are, first, the character of the equipment and second, the character of the fuel. It must be recognized that few householders have the opportunity to select their equipment to suit a particular fuel; most householders must select a fuel to suit existing equipment.

Points to note about any equipment in relation to its suitability for use with a particular coal are: the size of the fire pot and of the free space over, and the spacing and arrangement of the grates. If the fire pot is small, in relation to the size of the house, a high heat value coal must be burned to avoid too frequent firing. If there is not ample space over the fire pot a low volatile coal may be necessary to avoid incomplete combustion of the volatile matter. Grates unsuited to the coal may result in loss of combustible with the ashes.

Most householders have their own favourite way of operating their furnaces, and these vary materially. It is difficult, when discussing coals, to limit comments to such as are equally applicable to all methods of firing. A number of coal characters are important, however, and need to be discussed.

Heat value.—The heat that can be obtained from the coal is obviously the chief consideration; but it should be related to the price. A high priced coal of high heating value may be more expensive than a cheaper coal of lower heating value. It is assumed here that efficiency of burning is taken into consideration. It is recognized that almost any coal can be burned efficiently in suitable equipment with good firing; but conversely any coal may be burned inefficiently if the equipment or the method of firing is unsuited to the coal.

Ash.—A high ash is obviously a disadvantage; it lowers the heat value of the coal, freight is paid on worthless material, it fills up the fire, interferes with combustion, and requires removal and disposal. If the ash clinkers, interference with combustion and difficulty of removal may be increased and loss of combustible through the grates may also be increased. It must be remembered that a small furnace, in relation to the size of the house, requires to be forced to generate the necessary heat; and some coals that would clinker in such a forced fire might not clinker in a furnace that did not need to be forced. An ash with a softening temperature below 2200°F. will probably clinker in any furnace.

It should be noted that clinkers vary notably in character, and consequently in the trouble they cause. Some householders even prefer a coal which will form a clinker tough and compact, yet porous enough not to block the air supply. Such clinker can be removed through the fire door, with less dust than when loose ashes are shovelled.

Smoke.—A smoky coal is undesirable because the heating surfaces of the furnace become soot covered, which prevents heat transference. Soot also collects in flue pipe and chimney, and smoke discharge from a chimney is a public nuisance. Some coals burn in ordinary domestic equipment with little or no smoke, and such coals are termed smokeless. Two totally dissimilar types of coal are smokeless. The first type includes anthracite and semi-anthracite. These contain so little volatile matter that it burns without smoke. Low volatile bituminous coals may be nearly smokeless, for the same reason. The second type, which includes the domestic coals of Alberta, contains considerable volatile matter, but this has a high oxygen content, and can be burned readily and completely, so that such coals are also smokeless. These coals are the Subbituminous A, B and C coals of the Canadian Classification. High Volatile C Bituminous coals of Alberta, which are also used for domestic heating, are only slightly smoky. More air must be admitted over the fire for high volatile than for low volatile coals to prevent smoke.

Ignition.—Some coals can be ignited much more easily than others, and will burn more freely. The coals of Group I are hard to ignite while the coals of Groups IV and V are easy. Free burning characteristics of domestic coals are in general an advantage and tend to facilitate complete combustion. Sometimes it is difficult to control the fire and avoid the necessity of frequent firing; but experience shows that this can be done by suitable control of the drafts and by maintaining a thick fire and ample ash on the grates.

Coking coals.—Coking bituminous coals are seldom used for domestic heating. The coke formed in the fire requires to be broken up to give satisfactory combustion and the coal is very smoky.

Sizing.—The size of coal suitable for any furnace depends partly on the size of the furnace and partly on the methods of firing employed. In general, however, free burning coals are fired in large lumps and difficultly burning coals in small lumps.

B.—Stoker Coals.

There are many automatic domestic stokers, but most of these are either of the underfeed or overfeed type. Stokers have come into common use because of convenience, and the ease of regulation by thermostatic control. Also the small coals burned are cheaper than the larger lump coals. The underfeed stoker was the earlier type, and was usually used with the higher rank coals. The overfeed stoker was developed later, specifically for the free-burning, lower rank coals.

The underfeed stoker can burn both coking and non-coking coals, and the underfeed system of firing makes it possible to burn coals which are too smoky for ordinary furnace use.

Since it is usual to remove the ashes through the fire door, a clinkering coal is desired. The clinker, however, should not be so compact as to interfere with the air blast, nor so porous and friable as to fall to pieces when handled. A clean coal is much to be desired, as otherwise frequent removal of clinker may be necessary to avoid interference with regular combustion.

The overfeed stoker is only satisfactory with free-burning, non-coking coals. The ash need not clinker, as the ash and clinkers fall off the grate into the ash pit or into a container under the furnace; difficulty however is sometimes encountered with a coal that forms a very solid clinker, as this may bridge across the fire pot and block the incoming coal.

Tests are in progress in the fuel laboratories of the Research Council of Alberta to ascertain which Alberta coals are best suited for use in underfeed and overfeed stokers, respectively.

Some domestic furnaces are equipped with blowers and fixed grates for burning buckwheat sizes of certain anthracites. E. Swartzman* discussing the fuel for such plants says that "in addition to being non-coking and smokeless it must exhibit the following characteristics:

(a) The ash must be of such a quality that its fusion or softening temperature is low enough to permit, under forced draft conditions, the formation of a clinker which is sufficiently strong to allow for its removal through the fire door of the furnace.

(b) The clinker should be tough and compact, yet porous enough to allow for the passage of air through it to the live fuel.

(c) The ash in the coal should be of such a nature that the resulting clinker is not bulky in comparison with the amount of coal fired, thus obviating the necessity of clinker removal from the furnace at too frequent intervals."

Experiments at the Fuel Research Laboratory at Ottawa have shown that coal from the Cascade area in Alberta, by the addition of a predetermined quantity of a suitable type of iron compound, could be made a satisfactory blower fuel.

Domestic heater, blower and underfeed stoker tests made in Fuel Research Laboratories at Ottawa have been published in detail, and also summarized.†

CARBONIZATION

The following is taken largely from a paper by E. Stansfield on Carbonization and Briquetting of Alberta Coals.**

Carbonization of coal is a decomposition by heat in a complete absence, or limited supply, of air, with the object of converting the coal into new products of greater value. The principal products primarily obtainable are: a solid residue which may be either a coke or a char; an organic liquid compound or tar; a watery liquid product commonly termed ammonia liquor; and a gas.

The original coal may be a smoky fuel; the coke or char is normally smokeless. Coke can be used for many metallurgical

*Canadian Chemistry and Process Industries, 27 (1943), p. 676.

†Investigations of Canadian Coals, B. F. Haanel and R. E. Gilmore. The Engineering Journal, XX (1937), p. 513.

**Trans. C.I.M. & M., Vol. XL (1937), p. 35.

and other processes for which coal is impossible or unsuitable, and it can be converted readily into a gaseous fuel. The tar may have value as a liquid fuel, and certain tars are the raw materials of the extremely important coal-tar industry, which gives dyes, chemicals, resins, flavours, explosives, and other products too numerous to mention. The gas, also, is a clean fuel, which can be piped to place of need and be used efficiently.

From any kind of coal, the relative amounts, and the chemical and physical characteristics, of the products can be widely varied at will by changes in the conditions of carbonization; even wider variations in the products can be made by variations in the kinds of coal treated. It should hardly need stating, however, that the sum of the weights of the products must be equal to the weight of the raw material—coal, water and, sometimes, air; and that the potential heat values of the products must be less than the potential heat value of the coal charged.

Two kinds of carbonization are commonly recognized, high-temperature carbonization (H.T.C.) and low-temperature carbonization (L.T.C.). The first is characterized as a heat treatment at a temperature of about 1,800°F. and the latter at about 1,000°F. Actually, the one kind may blend into the other and a "medium-temperature" carbonization is sometimes recognized with a temperature of the order of 1,300°F. It is better to regard L.T.C. as a treatment designed to give the more free-burning solid product, and, or, the higher yield of tars obtainable by the use of lower temperatures; rather than to set a definite temperature limit between the two processes. In general, the walls of the retort will not exceed 1,300°F. in L.T.C. When a coal is carbonized, the higher the temperature of carbonization the higher the ignition temperature of the coke or char and the less it is free-burning. For the open-grate fire and some other uses, a free-burning fuel is desirable. When coal is heated gradually, a comparatively large quantity of a "primary tar" is produced. If this primary tar is more strongly heated by contact with the hot walls of the retort or by passing over hot coke, it suffers a decomposition, with the deposition of carbon and the formation of gas and secondary tar. The secondary tar yield must therefore be less in amount than the primary tar yield from the same coal; but it should be noted that it is the secondary tar from bituminous coal which is the raw material for the coal-tar industry. The primary tars are more oily, and are sometimes referred to as "tar oils".

H.T.C., with suitable coal, is characterized by giving a strong coke, a tar with good marketable value, and a large yield of gas of medium calorific value.

The H.T.C. industry is a very large and well established industry in most of the commercial countries of the world where suitable coking bituminous coals are available. Comparatively little reference is made to this industry in the press. L.T.C. is in striking contrast. During the past forty years, at frequent intervals, sometimes in one place and sometimes in another, it has received wide publicity and has been heralded as a coming process which was going to revolutionize the coal industry, with great profit to the localities where it was to be introduced. Very many millions of dollars have been spent, most of them wasted, but the low temperature carbonization industry is still trivial in comparison with that of high temperature.

When a bituminous coal is heated in absence of air, it may soften and become plastic at a temperature between 700° and 800°F. It also decomposes with the evolution of gases and vapours. These gases and vapours give the plastic material a frothy or cellular structure and, as it decomposes, the plastic material soon hardens into the cellular material called coke. Decomposition begins at a temperature below the softening temperature and, if the coal is heated very slowly, the fusible material may so completely decompose below its softening temperature that the coal never softens at all. The decomposition temperature and velocity, and the softening temperature, of different coals, show notable variations. If the softening temperature is low and the decomposition temperature is high, the coal will coke readily; if these conditions are reversed, the coal may not coke at all. But a normally poor coking coal can sometimes be made into good coke by heating so rapidly that the softening temperature is reached before the fusible constituents have had time to decompose. A non-coking coal may fail to coke because of the reversed order of softening and decomposition temperatures, or because of scarcity of fusible constituents. In the latter case, only by a drastic change of the chemical character, as for example by partial hydrogenation, can it be converted into coke. Wood is a typical example of a non-fusing material. When pieces of wood are heated they shrink but do not soften or otherwise change their shape, and the charcoal finally produced retains the shape, and even the grain, of the original wood. Non-coking coals behave in a similar fashion, and, by analogy, the solid product of their carbonization is called char.

High Temperature Carbonization.

High-temperature carbonization may be employed to give coke as the main product, with tar and gas as by-products, or to give gas as a main product, with coke and tar as by-products. The coke and the gas industries are gradually coming closer together in their methods, and it is now quite common to install a coke-oven plant to supply a city with gas. Coke used to be made principally, and still is made in some places, in the bee-hive oven. This is a simple plant to operate, of comparatively low capital cost, and there are no by-products requiring markets; the heat is generated inside the oven by the combustion of the gas and vapours with the cautious admission of air over the charge. It is low in installation and operating cost, but is wasteful in burning not only all of the by-products but also some of the coke. Coke, and gas, are now made principally in retort ovens; these may be horizontal or vertical, continuous or intermittent. The heat passes to the coal from combustion flues, through the refractory walls of the retort. The tar and gases escaping from the retorts can be collected and saved. The heat is generated in the flues, which may attain a temperature of 2,600°F., by the combustion of part of the gas evolved, generally after such gas has been stripped of tar, ammonia, etc. There is normally a surplus of gas left for disposal.

Alberta has good coking coals of Kootenay age in the coal areas lying along the mountains. Such coal is mined in some seven large mines, with a total output of about 30 per cent of the total coal output of the Province. However, only 4 per cent of the coking coal mined in 1943 was made into coke in the Province; but no record is available of the coal shipped to coking plants outside the Province. All the coke of the Province is at present made in bee-hive ovens.

At one time, 80 retort ovens were operated at Lille, but without recovery of by-products. During the period 1905-1918, over 500 coke-ovens were in operation in the Province, but the present number is much less.

The very large capital outlay required for a retort coke-oven plant with by-product recovery could only be warranted if there were a good and steady market for the full output of at least two of the three principal products—coke, tar, and gas. This is not the present situation in Alberta. Since the freight rate for coal is lower than for coke, it may be preferable to erect a carbonization plant near the market, rather than near the coal mine.

It might be noted at this point that it is commonly important that only coals with a low ash percentage should be used for carbonization. The mineral impurities in the coal are all left in the coke or char, which thus has a higher ash percentage than the original coal. If a coal with 6.5 per cent ash is carbonized, giving a 65 per cent yield of coke, the ash of the coke is 10 per cent; similarly, a coal with 13 per cent ash will give a coke of 20 per cent ash. In a competitive coke market, the upper limit of ash in the coke is often regarded as 10 per cent. This naturally requires the use of a low-ash coal.

Coking tests* in commercial, bee-hive and retort coke oven plants were made in 1909 on coals from Bankhead, Bellevue, Canmore, Coleman, Hillcrest, Lille, Passburg and Taber.

Many small-scale tests of coking properties of Alberta coals, and also determinations of softening and decomposition temperatures, have been made in the laboratories of the Research Council of Alberta.† Both small- and large-scale tests have been made in the Fuel Research Laboratories of the Bureau of Mines at Ottawa. The results have been made available for the operators concerned.

Low Temperature Carbonization.

Low-temperature carbonization covers a wider field than H.T.C., because almost any fuel may be so treated. Hundreds of processes have been described. Some 800 were on record in 1933, and quite a large number have passed all the trials of infancy and grown up under the direction of competent engineers to the age of commercial operation. A few have reached prosperous maturity with payment of dividends.

The processes devised include vertical, horizontal, inclined, stationary, rotary, continuous, and intermittent retorts, with or without mechanical stirring of the charge. They include retorts heated from the outside, from the inside by partial combustion of the charge, and from the inside by the circulation of hot gases or vapours. The coal may be heated alone or heated in suspension in oil.

L.T.C. was first tried with coking bituminous coals. With H.T.C., the retort flues are very hot, up to 2,600°F., and there is a steep temperature gradient into the centre of the coal, which may not reach 1,600°F., so that the rate of heating is comparatively high. The coal commonly expands during the plastic stage, but at high temperatures it again shrinks, so that the final charge of coke can be easily discharged from the retort. With low-temperature carbonization, the rate of heating of the charge is comparatively low,

*Investigation of the Coals of Canada, J. B. Porter and R. J. Durley, Mines Branch, Department of Mines, Ottawa, Vol. 1, Part VI, 1912.
†R.C.A. Eighth Annual Report (1927), pp. 24-29.

and the discharge of the coke is more difficult. These handicaps have been overcome, but they involve additional expense and are an indication of some of the snags experienced by L.T.C. Markets must be found for the products of coke, tar, and surplus gas in the relative proportions in which they are produced; and the aggregate sales-price must exceed the cost of the coal by an ample margin to pay for the cost of processing and to provide a profit on the operation. Non-coking fuels are in many ways easier to handle, but the char is not easy to sell without briquetting and the tar may be less valuable. The ammonia liquor is commonly a source of annoyance rather than profit. It may not pay to process, and, if run into a lake or river, will cause pollution and kill the fish.

A study of the L.T.C. plants which have had any success makes clear several important facts. Coals vary widely in chemical and physical characteristics and no process can be successful which is not specifically suited to treat the particular coal employed. No plant has been successful that has not been located at some point with peculiar economic advantages, and that has not been planned to make use of these advantages. Attempts to adopt processes which have been successful in one country to different conditions in another country have rarely succeeded. Claims that a process is universal in application almost certainly prove ignorance, or worse. Even the best processes will infallibly fail to pay dividends in any but the more favourable locations.

It is suggested that the failure to develop L.T.C. in Alberta in the past has been due to adverse economic conditions, and not to lack of suitable coal or of a proven process.

The conditions specific to Alberta can now be discussed in relation to carbonization for local and also for distant markets. L.T.C. gives a smokeless, reasonably free-burning coke for the open fireplace in Great Britain, and a char for the domestic stove in Germany ;Alberta already has an abundant supply of cheap, smokeless coal well distributed over the Province. Great Britain, France, Germany, etc., have encouraged L.T.C. because of their lack of petroleum; Alberta has some petroleum, large reserves of bituminous sands, and is close to large petroleum supplies in the United States. Alberta has also squandered a high-grade natural gas for lack of a market. It is therefore difficult to see any economic favourability for L.T.C. for the local market of Alberta.

The outlook for carbonization for the Ontario market is slightly more hopeful. In Ontario, there is a large market for a smokeless, domestic fuel. Alberta mines a smokeless, domestic coal, but this does not have a high heat value, so that the freight rate per therm is high; moreover, this coal is not a good storage coal. If Alberta domestic or subbituminous coals could be up-graded by L.T.C. to form a high heat value, smokeless, storable fuel, it might be possible to keep mines and carbonizers working steadily throughout the year to supply the Ontario winter market. Unfortunately, neither the friable coke made from coking coals, nor the char made from non-coking coals, would suit the market; moreover, the freight rate per ton for these bulky fuels is higher than the freight rate for coal. Briquetting the char might solve the difficulty, but at present briquetting is an expensive operation since no satisfactory, cheap, smokeless and waterproof binder has yet been found. If advantage is to be taken of up-grading to reduce freight costs, the carbonization must be carried out in Alberta and local markets found for the tar oils and surplus gas, if any. At present, there is not a good outlook for such markets, and it is not reasonable to count on any better price for these tars than the price obtainable as fuel oils.

The outlook for L.T.C. in Alberta would materially improve if a cheap process were developed for converting the char into a dense, coherent, smokeless, storable fuel. It would also be improved if a plant for the hydrogenation of coal were established here. Such a plant could make gasoline from tar of any variety more easily than from coal, so that a good market for tar would be assured. Improved markets for L.T. tars will certainly come in the future, as they did many years ago for H.T. tars; but such improvement cannot be counted upon in the early (and difficult) stages of the industry.

The Fuel Research Laboratories of the Bureau of Mines at Ottawa have from time to time made L.T.C. tests on Alberta coals, and published them in their annual reports. A summary of results of tests made from 1919 to 1928 was prepared by the Research Council of Alberta, for inclusion in a News Letter to Coal Operators of the Province in January, 1931. These results are further summarized in the following table. The original reports should be consulted for further details.

Earlier tests, references 1 and 2, made on samples of about 1 oz.; later tests made on samples of 4½ to 6½ lbs. in a retort heated in a lead bath. Tests made at temperatures of about 1,110°F.

Calorific values are British thermal units (gross), per pound for coal, char and tar, and per cubic foot for gas. Tar yields are in Imperial gallons, and gas volumes are measured at 60°F. and 30 inches of mercury pressure.

The weight distribution is the weight of each of the products expressed as a percentage of the total weight of (moist) coal charged. The smallness of the losses shown are an indication of the accuracy of the work.

The thermal distribution is the total heat value of each of the combustible products expressed as a percentage of the total heat value of the coal charged. The heat value of the products must always be less than the heat value of the charge, as heat is given out and lost in the decomposition of coal owing to exothermic reactions. This is reported as loss.

In the yields, and in the weight distribution, "light oils" are included with the tar, even when shown separately in the original reports.

With the higher rank bituminous coals the coke, or char, has a lower heat value per pound than has the original coal. With lower rank coals the reverse is the case and low temperature carbonization may be employed to up-grade the coal to reduce shipping charges. These calorific value increases, negative or positive, are shown as percentages of the original heat values, dry, and moist as charged.

CONVERSION OF COAL TO LIQUID FUEL

The present is a transition period; an age of coal is changing gradually to an age of oil fuel—gasoline, diesel oil, fuel oil, etc. The enormous demands for oil for war has called renewed attention to dwindling world reserves of petroleum, and the need for alternative sources of oil. Coal is at present, and is likely to remain, the principal alternative source.

TABLE 17

Low Temperature Carbonization Tests

Coal Tested	A	B	C	D	E	F	G	G1	H	J	K	L	N	O	P	Q	S
Reference	5	5	6	6	5	5	4	4	3	3	3	3	1 & 2	2	2	1 & 2	3
Analysis—coal as charged:																	
Moisture ....%	1.0	1.2	1.2	1.9	1.4	0.7	7.2	7.7	7.9	6.7	12.0	21.4	24.5	26.4	23.2	17.3	16.5
Ash ....%	15.0	6.9	12.9	12.1	12.7	10.8	8.7	8.7	8.0	7.4	7.7	6.4	5.6	3.7	6.0	8.4	7.2
Volatile matter ....%	19.5	27.9	21.2	29.8	23.8	25.2	32.4	32.8	34.5	32.9	33.7	32.5	29.8	29.9	29.9	27.2	34.1
Fixed carbon ....%	64.5	64.0	64.7	56.2	62.1	63.3	51.7	50.8	49.6	53.0	46.6	39.7	40.1	40.0	40.9	47.1	42.2
Calorific value—as charged ....B.t.u.	12,980	14,260	13,370	13,160	13,070	13,580	11,260	11,190	11,280	11,750	10,480	8,680	8,810	8,080	8,890	9,570	9,860
dry coal ....B.t.u.	13,110	14,440	13,540	13,420	13,260	13,670	12,130	12,130	12,240	12,590	11,910	11,040	11,670	10,980	11,570	11,580	11,800
Temperature of test maximum ....°F.	1,110	1,110	1,110	1,110	1,110	1,110	1,130	1,120	1,110	1,090	1,130	1,110	1,110	1,110	1,110	1,170	1,170
Yields per 2000 lbs. charged:																	
Coke or char ....lbs.	1,706	1,574	1,700	1,500	1,630	1,628	1,420	1,390	1,394	1,446	1,262	1,080	1,000	960	1,020	1,160	1,168
Tar (dry) ....gallons	8.6	18.8	9.4	20.1	13.1	13.8	7.6	9.5	9.9	8.6	6.3	3.3	....	....	....	....	6.2
Gas ....cubic feet	3,360	3,740	3,460	4,250	3,340	3,540	3,310	3,350	3,290	3,100	5,000	4,500	....	....	....	....	4,540
Ammonium sulphate ....lbs.	5	8	8	11	7	8	7	7	6	9	13	6	....	....	....	....	....
Weight distribution:																	
Coke or char ....%	85.3	78.7	85.0	75.0	81.5	81.4	71.0	69.4	69.7	72.3	63.1	54.0	50	48	51	58	58.4
Tar (dry) ....%	4.4	9.3	4.7	10.2	6.5	6.9	3.7	4.8	4.9	4.4	3.1	1.6	....	....	....	....	3.2
Gas ....%	6.1	8.2	6.8	7.5	6.9	7.2	9.2	9.8	10.1	7.6	12.8	14.7	....	....	....	....	12.0
Liquor (water) ....%	3.5	4.2	3.7	6.8	5.4	4.3	15.8	15.8	15.5	15.5	21.6	30.4	....	....	....	....	25.7
Loss ....%	0.7	—0.4	—0.2	0.5	—0.3	0.2	0.3	0.2	—0.2	0.2	—0.6	—0.7	....	....	....	....	0.7
Thermal distribution:																	
Coke or char ....%	81.8	76.2	79.7	70.8	79.8	77.6	81.6	80.4	79.9	82.6	78.5	79.6	77	83	77	78	78.9
Tar ....%	5.7	11.0	5.1	12.4	8.5	8.6	5.4	7.0	7.1	6.1	5.0	3.1	....	....	....	....	5.1
Gas ....%	8.4	8.6	8.3	9.2	8.1	8.8	6.5	7.3	7.9	7.7	13.7	11.6	....	....	....	....	11.6
Loss (exothermic reactions) ....%	4.1	4.2	6.9	7.6	3.6	5.0	6.5	5.3	5.1	3.6	2.8	5.7	....	....	....	....	4.4
Analysis of coke or char:																	
Ash ....%	18.2	8.6	16.2	16.7	15.6	13.7	12.6	12.5	11.5	10.0	12.6	11.2	11.3	7.4	11.2	13.8	11.7
Volatile matter ....%	6.1	7.4	7.4	6.2	6.3	7.1	9.5	9.4	12.1	10.8	9.0	11.8	7.9	8.1	8.1	7.8	8.9
Fixed carbon ....%	75.7	84.0	76.4	77.1	78.1	79.2	77.9	78.1	76.4	79.2	78.4	77.0	80.8	84.5	80.7	78.4	79.4
Calorific value ....B.t.u.	12,240	13,810	12,540	12,420	12,630	12,930	12,940	12,960	12,920	13,430	13,040	12,750	13,430	14,130	13,480	12,900	13,320
Analysis of tar:																	
Calorific value per lb. ....B.t.u.	16,850	16,910	16,310	17,030	17,060	16,900	16,330	16,330	16,240	16,360	16,400	....	....	....	....	....	....
Specific gravity	1.07	1.03	1.04	1.04	1.02	1.04	0.97	1.01	0.99	1.11	1.02	0.98	....	....	....	....	0.99
Analysis of gas:																	
Calorific value per cubic ft. ....B.t.u.	650	660	640	570	630	670	440	490	520	580	580	450	....	....	....	....	500
Density (air equals 1.0)	0.48	0.58	0.52	0.47	0.55	0.54	0.74	0.77	0.81	0.65	0.73	0.86	....	....	....	....	0.70
Calorific value increase:																	
Dry coal to coke or char ....%	—7	—4	—7	—7	—5	—5	7	7	6	7	9	16	15	29	17	11	13
Moist coal to coke or char ....%	—6	—3	—6	—6	—3	—5	15	16	15	14	24	47	52	75	52	35	35

NOTES:

Coals tested: area, and location of mine:

A.—Brule, Brule.
B.—Mountain Park, Cadomin.
C.—Mountain Park, Luscar.
D.—Mountain Park, Mountain Park.
E.—Crowsnest Coleman.
F.—Crowsnest, Blairmore.
G.—Coalspur, Coal Valley, lump coal.
G1—Coalspur, Coal Valley, washed slack.
H.—Coalspur, Mercoal.
J.—Saunders, Harlech.
K.—Taber, Taber.
L.—Edmonton, Cardiff.
N.—Tofield, Tofield.
O.—Castor, Castor.
P.—Sheerness, Hanna.
Q.—Carbon, Trochu.
S.—Drumheller, Wayne.

References:

Summary Report, Mines Branch, Department of Mines, Ottawa.
No. 1 Report 542 (1919), pp. 30-39.
No. 2 Report 590 (1921), pp. 205-225.

Investigations of Fuels and Fuel Testing, Mines Branch, Ottawa.
No. 3 Report 618 (1923), pp. 1-10.
No. 4 Report 644 (1924), pp. 60-68.
No. 5 Report 689 (1926), pp. 12-33.
No. 6 Report 696 (1927), pp. 32-45.

Three methods for converting coal into oil are given below, two indirect and one direct.

Indirect Conversion by means of Carbonization.—When coal is carbonized, either at high or low temperatures in a by-product recovery plant, coal tar is produced. This tar can be distilled, to give a fuel oil, or it can be hydrogenated readily and thus converted, almost quantitatively, into gasoline and other oil products.

Carbonization only converts a comparatively small percentage of the coal into tar; the percentage varying with the coal and with the method used. In 1938, in Great Britain, the yield of liquid products averaged 5.2% of the weight of coal carbonized. The rest of the coal is converted into coke and gas. This method for the conversion of coal into oil is therefore limited in its possibilities by the limits of the markets for the coke and the gas concurrently produced; nevertheless, carbonization followed by hydrogenation of the tar is a recognized commercial process. Any coal can be carbonized, and produce tar, but as a commercial proposition carbonization is generally restricted to treatment of coking bituminous coals. This with present mining development in Alberta, would restrict operation to coals from the Crowsnest and Mountain Park areas.

Indirect Conversion by means of Gas Synthesis.—A liquid fuel can also be made from coal, by converting the coal into water gas in a gas producer, and then synthesising the carbon monoxide and hydrogen of that gas at comparatively low pressures and temperatures. This is commonly known as the Fischer-Tropsch process, but other similar processes are being developed.

Water gas is usually made by passing steam through a bed of red hot coke, but can be similarly made from any coal. The actual gas used for synthesis is water gas that has been completely purified from sulphur and adjusted to contain two volumes of hydrogen to one volume of carbon monoxide. This synthesis gas is passed at ordinary pressures, and at a carefully controlled temperature, over a suitable catalyst where it is converted into a mixture of hydrocarbons, which is essentially a synthetic petroleum. Some liquifiable gaseous hydrocarbons and some heavy hydrocarbons are produced, but a gasoline fraction is the main product.

The Fischer-Tropsch process, when compared with the hydrogenation process described later, requires very much lower capital investment and involves lower operational costs, largely owing to the low pressures employed; but at present gives a slightly lower yield of oil per ton of coal processed. This process has been rapidly perfected in recent years to a competitive position, so that there is already a strong possibility that a plant may be established in Alberta in the not too distant future.

The thermal efficiency of the process was, a few years ago, only about 25%, but a thermal efficiency of about 40% now seems possible. In other words, some 60% of the heat value of the coal will be lost, as the price of the change from a solid fuel to gasoline and other liquid fuels. The gasoline produced is of low octane value and low lead susceptibility; but this can be remedied by modern cracking methods. The diesel fuel on the contrary is of exceptionally high quality. The current refining operation of the liquid product of this process is reported to give 62% gasoline, 26% diesel oil, 10% gas and 2% paraffin wax.

Any coal could be used for the Fischer-Tropsch process so that its operation is not necessarily limited to any particular districts in Alberta.

Direct Conversion by Hydrogenation. — Petroleum contains roughly twice as much hydrogen in relation to carbon as does coal. Coal therefore may be converted to a product resembling petroleum by the addition of hydrogen. This process, known as hydrogenation, involves, in its simplest form, the suspension of finely powdered coal in a liquid medium and the treatment of this mixture in the presence of a catalyst with hydrogen at high temperatures and very high pressures: 850° to 950°F. and 250 to 275 atmospheres. In practice the process is carried out in several stages, and is complicated. Only large scale units are practicable, and the capital cost of a plant is very high—a $40,000,000 plant is suggested as the economic size.

Over 60% by weight of the coal processed is converted into a liquid product; the remainder forming an untreatable solid residue, gas and water. No by-products are produced for sale. Additional coal is required to produce the hydrogen and to supply heat and pressure. At least three or four tons of coal are therefore required to give one ton of gasoline; a thermal efficiency of 43% is claimed. The main product of the process is gasoline, and this has a high octane value, and high lead susceptibility.

Hydrogenation plants in Germany and Great Britain, even when primarily designed for the hydrogenation of coal, increase their gasoline outputs by also hydrogenating coal tar. The establishment of a hydrogenation plant would therefore act as an inducement to establish by-product recovery carbonization.

The process described above is that of Bergius. Recent modifications, the extraction-hydrogenation processes of Pott-Broche and of Uhde, involve the extraction of soluble material in coal with hydrogen carriers such as tetralin and phenol, coupled with hydrogenation. These involve lower pressures in the initial stages.

Any coal can be hydrogenated, but high rank coals are only treated with difficulty, and give poor yields. The low rank, high oxygen-content coals on the contrary are easily treated, but involve a high hydrogen consumption. The usual practice elsewhere is to treat the medium and high volatile A bituminous coals, and it may be assumed that in Alberta the same coals would be preferred. The coal is normally purified before treatment to a very low ash content; and the possibility of this treatment might have to be considered in selecting the optimum coal.

GAS PRODUCER COAL

The use of Alberta coal in gas producers in recent years has been negligible. This situation would probably change if the availability of natural gas dwindled or if Fischer-Tropsch plants for the manufacture of gasoline were established. It is certain that suitable Alberta coals could be supplied if a market developed for gas producer coals.

Gas producer tests were carried out in 1908 and 1909 at McGill University for the Dominion Government*, and in the Fuel Testing Laboratories in Ottawa.†

*Investigation of the Coals of Canada, J. B. Porter and R. J. Durley, Mines Branch, Department of Mines (1912), Vol. II, Part VIII.

†Gas Producer Trials with Alberta Coals, J. Blizard and E. S. Malloch, Mines Branch, Department of Mines, No. 565 (1921).

SMITHY COAL

Considerable Pennsylvania coal is still imported, at high cost, into Western Canada, although blacksmith tests sponsored by the Research Council of Alberta indicated that low-ash, coking coals, of low volatile or medium volatile bituminous rank, mined in Alberta can be used satisfactorily. Other Alberta coals, however, can be used for light work.

Seven Alberta coals were tested. The coals specified above formed a good arch on coking and were quick to heat up. Little trouble was experienced from clinker or from dirty fines, and good test welds were easily and quickly made.

Tests of six coals have been published in the following Annual Reports of the R.C.A.: 1922, pp. 27-29; 1923, pp. 26, 27; 1924, p. 23.

PART V

Coal Combustion

Data and Calculations, Related to Analyses and Classification

By E. STANSFIELD

FOREWORD

This paper was written for, and presented to, a Symposium on the Combustion of Solid Fuels, Division of Gas and Fuel Chemistry of the American Chemical Society, Boston, September, 1939. It has been revised for inclusion in this report on Alberta coals.

Methods and equations are given for calculating combustion data for any coal for which the ultimate analysis is available; but as such data have been calculated for a wide range of coals, data required for any other coal, in most cases, can be taken from the tables for coal of the same classification and similar proximate analysis, without the necessity of an ultimate analysis and tedious calculations.

INTRODUCTION

Coal chemists analyze samples of coal and combustion engineers, in the light of past experience, use these analyses to decide suitable methods and equipment for the combustion of such coals. Engineers also use the analyses to calculate the efficiency attained in combustion. It is probable, however, that neither the chemist nor the engineer takes full advantage of the analysis to deduce therefrom information with respect to the combustion character of a coal. This paper is an attempt to render more readily available combustion data with respect to coal. Equations are given by which calculations can be made, but approximate values may be estimated for other coals, without tedious calculations, by selecting from the wide range of coals studied a coal of the same rank and similar analysis, and ascertaining the data given for such coal in the tables and charts.

C. A. Seyler[1] has developed this subject with respect to British coals, on the basis of his own coal classification as used in Great Britain, far more thoroughly than was either possible or advisable in this paper; especially since much of Seyler's work is applicable to all coals.

Methods of coal analysis are not entirely the same in North America and Great Britain; America has its own system of coal classification, and it has a very wide range of coals. These facts warrant the study here attempted, but the writer wishes to acknowledge that the inspiration came from the work of Seyler.

The regular analysis of coal includes the ultimate, proximate, and calorific analysis; the last named is usually included with the proximate analysis. The ultimate analysis, as its name suggests, is more exact than the proximate, and is a valuable supplement to the

[1]Proc. South Wales Inst. of Engrs., Vol. 42 (1931), No. 3, Part 2, p. 557.

latter; but is more difficult and time consuming, and is comparatively seldom made. As far as possible the proximate analysis has been here used; but as will be seen the ultimate analysis is essential for many of the calculations. Ordinary coal as burned contains mineral impurities and water, and many of the relations it is desired to show between the analysis and combustion data may be notably masked thereby. There is therefore a temptation to confine such a study as the present one to pure dry or pure moist coal; but as it is ordinary coal which is burned, not pure coal, the coal as analysed has been taken where possible. Many exceptions have had to be made.

The time available for the preparation of this paper was too short for the work involved, and some errors may have been made. No search of the literature could be made, and apologies are tendered for omissions to give due credit to other workers.

COAL SAMPLES STUDIED

The coal samples for this study were chosen to give a good representation of every rank of coal from meta-anthracite to lignite. It was necessary to select samples for which both proximate and ultimate analyses were available, and it was desirable that all analyses should have been made under comparable conditions. These requirements were met by the selection of sixty-eight coals analysed by the U.S. Bureau of Mines and published in their Bulletins and Technical Papers. They were, with five exceptions, taken from a chart by Fieldner, Selvig and Frederic[2]. The similarity between United States and Canadian coals is such that there was little lost, and much gained, by the selection of coals from the States. The proximate analysis and classification of these coals are shown in Table 18, columns 5-9.

COAL AS ANALYSED AND AS PURE COAL

Coal as mined and burned contains mineral impurities, which are certainly not part of the coal substance. Such coal also contains moisture; some of this moisture may be an integral part of the coal substance and some may be merely surface wetting. In the classification of coal it is necessary to calculate the analysis of the coal as received by the chemist ("as received basis") to a mineral-matter-free basis, either moist as received or dry.

[2]U.S. Bureau of Mines. R.I. 3296, 1935.

TABLE 18
Coal Combustion Data, and Analyses

A.—Data on Basis of Production of One Therm. Net Heat				B.—Proximate Analysis of Coal						C.—Data on Basis of Coal as Received							
1 Weight of Coal lbs.	2 Relative Weight of Coal	3 Air for Combustion, c.f.	4 Flue Gas Produced, c.f.	5 Sample Number	6 Moisture, %	7 Ash, %	8 Volatile Matter, %	9 Calorific Value, B.t.u./lb.	10 Reduction Gross to Net C.V. %	11 Air Required c.f./lb. coal	12 Heat Generated B.t.u./c.f. air	13 Heat from Non-vols., %	14 Air for Non-vols., %	15 Flue Gas c.f./lb. coal	16 CO_2 in Dry Flue Gas, %	17 Heat Lost in Flue Gas, %	18 Flame Temp. °F.
Meta-Anthracite																	
7.62	1.09	966	982	A 1	2.8	7.8	1.2	13,300	1.3	127	105	97	98	129	20.1	15	3430
10.94	1.56	1016	1050	A 2	13.3	18.9	2.6	9,310	1.8	93	100	102†	99	96	20.7	16	3210
9.08	1.29	1037	1049	A 3	4.5	13.8	3.0	11.100	0.8	114	97	103†	97	116	20.7	15	3240
Anthracite																	
8.71	1.24	990	1020	B 1	6.9	14.0	3.4	11,740	2.2	114	103	94	94	117	19.6	16	3320
7.68	1.09	980	1003	B 2	2.1	9.8	5.7	13,290	1.9	128	104	90	91	131	19.6	16	3380
7.37	1.05	979	997	B 3	1.3	7.1	5.7	13,780	1.6	133	104	91	91	135	19.8	15	3400
7.36	1.05	981	1002	B 4	2.2	5.9	5.7	13,830	1.8	133	104	91	91	136	19.7	16	3390
7.97	1.14	962	985	B 5	3.4	11.5	6.8	12,780	1.8	121	106	89	91	124	19.8	15	3420
8.12	1.16	989	1015	B 6	4.4	12.2	7.5	12,590	2.2	122	103	88	88	125	19.4	16	3340
8.40	1.20	992	1015	B 7	7.6	9.3	7.3	12,100	1.6	118	103	91	91	121	20.2	16	3340
Semi-Anthracite																	
7.67	1.09	967	996	C 1	3.2	10.2	8.6	13,380	2.4	126	106	85	87	130	19.2	16	3400
7.82	1.11	976	1005	C 2	3.4	11.7	9.3	13,120	2.5	125	105	84	86	129	19.1	16	3370
7.48	1.07	967	995	C 3	2.1	9.3	9.8	13,700	2.4	129	106	84	86	133	19.0	16	3410
7.68	1.09	975	1004	C 4	2.8	10.1	11.9	13,360	2.5	127	105	82	84	131	18.9	16	3380
Low Volatile Bituminous Coal																	
7.20	1.03	967	998	D 1	1.5	7.8	15.8	14,290	2.8	134	107	76	79	139	18.8	16	3410
7.30	1.04	974	1009	D 2	3.4	6.9	16.2	14,110	3.0	133	106	76	78	138	18.6	17	3380
7.02	1.00	968	1003	D 3	3.1	3.9	18.2	14,690	2.9	138	107	74	77	143	18.8	16	3410
7.43	1.06	963	998	D 4	3.2	8.2	18.2	13,870	3.0	130	107	74	77	134	18.7	16	3400
7.30	1.04	968	1002	D 5	2.0	7.7	19.9	14,110	2.9	132	107	73	75	137	18.7	16	3400
Medium Volatile Bituminous Coal																	
8.39	1.20	980	1020	E 1	3.6	16.1	19.1	12,320	3.3	117	105	72	74	122	18.6	17	3330
7.19	1.03	945	980	E 2	1.0	8.6	21.5	14,330	3.0	131	109	70	74	136	18.6	16	3450
7.18	1.02	974	1010	E 3	3.4	5.3	22.5	14,370	3.1	136	106	70	72	141	18.7	17	3380
8.10	1.15	943	984	E 4	4.0	14.2	22.5	12,760	3.3	116	110	68	72	121	18.6	17	3420
7.30	1.04	969	1007	E 5	3.1	6.5	26.0	14,160	3.3	133	107	66	69	138	18.5	17	3390
7.67	1.09	980	1019	E 6	2.8	9.0	25.7	13,490	3.3	128	106	67	69	133	18.5	17	3350
7.46	1.06	961	1002	E 7	2.5	8.5	27.7	13,890	3.4	129	108	64	67	134	18.4	17	3400
High Volatile A Bituminous Coal																	
7.68	1.09	990	1031	F 1	2.3	10.0	29.7	13,490	3.5	129	105	63	64	134	18.3	17	3320
7.32	1.04	979	1020	F 2	2.8	5.8	35.0	14.150	3.4	134	106	58	60	139	18.5	17	3360
8.07	1.15	969	1019	F 3	3.3	12.2	34.1	12,910	4.0	120	108	57	59	126	18.2	18	3340
7.37	1.05	968	1011	F 4	3.2	5.0	33.3	14,050	3.5	131	107	61	63	137	18.5	17	3390
8.17	1.16	974	1021	F 5	3.2	12.5	35.0	12,720	3.8	119	107	56	59	125	18.3	17	3340
8.48	1.21	973	1021	F 6	2.5	14.7	37.9	12,260	3.8	115	107	53	55	120	18.3	17	3330
8.49	1.21	953	999	F 7	3.0	14.7	37.2	12,220	3.6	112	109	54	57	118	18.6	17	3380

TABLE 18.—Coal Combustion Data, and Analyses—Continued

A.—Data on Basis of Production of One Therm. Net Heat				B.—Promixate Analysis of Coal						C.—Data on Basis of Coal as Received							
1 Weight of Coal lbs.	2 Relative Weight of Coal	3 Air for Combustion, c.f.	4 Flue Gas Produced, c.f.	5 Sample Number	6 Moisture, %	7 Ash, %	8 Volatile Matter, %	9 Calorific Value B.t.u./lb.	10 Reduction Gross to Net C.V. %	11 Air Required c.f./lb. coal	12 Heat Generated B.t.u./c.f. air	13 Heat from Non-vols., %	14 Air for Non-vols., %	15 Flue Gas c.f./lb. coal	16 CO_2 in Dry Flue Gas, %	17 Heat Lost in Flue Gas, %	18 Flame Temp. °F.
7.56	1.08	966	1015	F 8	3.9	4.1	37.3	13,730	3.7	128	108	58	61	134	18.5	17	3380
8.10	1.16	977	1026	F 9	3.9	9.1	43.1	12,840	3.9	121	107	50	52	127	18.0	18	3340
8.32	1.19	976	1024	F 10	3.6	10.5	41.5	12,510	3.8	117	107	52	53	123	18.0	17	3340
8.36	1.19	967	1018	F 11	8.2	10.7	27.2	12,440	3.8	116	108	63	66	122	18.5	17	3350
9.49	1.35	990	1052	F 12*	4.4	19.0	46.0	11,070	4.7	104	106	40	41	111	17.7	19	3240
High Volatile B Bituminous Coal																	
8.78	1.25	973	1032	G 1	5.0	12.2	36.1	11,900	4.3	111	107	57	60	117	18.4	18	3310
8.42	1.20	967	1030	G 2*	7.0	6.2	46.7	12,450	4.6	115	108	47	49	122	17.8	18	3340
8.32	1.19	962	1021	G 3	7.2	5.9	42.2	12,540	4.2	116	108	52	55	123	18.6	18	3350
8.26	1.18	963	1021	G 4	7.1	5.2	40.8	12,620	4.1	117	108	54	57	124	18.7	18	3360
8.50	1.21	951	1005	G 5	8.8	7.5	29.9	12,220	3.8	112	109	64	68	118	18.9	17	3390
8.37	1.19	955	1013	G 6	7.6	6.0	33.6	12,440	4.0	114	109	62	66	121	18.7	18	3370
8.92	1.27	983	1044	G 7	7.1	10.4	37.0	11,720	4.4	110	107	56	58	117	18.5	18	3280
9.22	1.31	975	1035	G 8	10.4	12.3	39.3	11,350	4.4	106	107	49	51	112	17.9	18	3300
High Volatile C Bituminous Coal																	
9.47	1.35	991	1056	H 1	11.9	11.6	38.2	11,080	4.6	105	106	50	52	112	18.2	19	3250
10.25	1.46	983	1050	H 2	10.0	16.6	39.1	10,250	4.8	96	107	49	51	102	17.9	19	3250
9.08	1.29	975	1043	H 3	13.6	6.9	35.0	11,550	4.6	107	108	56	59	115	18.6	18	3300
9.68	1.38	980	1059	H 4	13.7	4.4	38.3	10,870	4.9	101	107	58	61	109	18.8	19	3260
Subbituminous A Coal																	
9.64	1.37	981	1052	J 1	12.3	8.4	31.9	10,890	4.7	102	107	63	66	109	18.8	19	3270
10.15	1.45	983	1055	J 2	10.8	11.9	34.2	10,340	4.7	97	107	61	63	104	18.8	19	3250
9.57	1.36	964	1042	J 3	12.7	5.5	41.2	11,000	5.0	101	109	54	57	109	18.8	19	3300
Subbituminous B Coal																	
10.40	1.48	985	1070	K 1	14.4	6.2	33.2	10,140	5.1	95	107	66	69	103	19.1	19	3230
10.57	1.51	1004	1103	K 2	21.2	2.9	34.1	10,060	6.0	95	106	61	62	104	18.8	20	3160
11.47	1.64	1001	1105	K 3	22.8	5.5	34.7	9,270	6.0	87	106	58	60	96	19.2	20	3150
11.64	1.66	984	1094	K 4	21.5	6.0	31.8	9,170	6.3	85	108	65	68	94	19.0	20	3170
11.83	1.69	969	1085	K 5	23.5	5.2	35.7	9,050	6.6	82	111	57	61	92	19.1	21	3200
Subbituminous C Coal																	
12.43	1.77	1007	1124	L 1	25.9	6.9	29.4	8,610	6.6	81	106	64	66	90	19.2	21	3100
12.37	1.76	996	1113	L 2	23.7	6.1	33.7	8,650	6.5	81	108	61	64	90	19.4	21	3130
13.70	1.95	1036	1178	L 3	29.1	8.0	32.0	7,940	8.0	76	105	57	58	86	18.3	23	2990
14.20	2.02	1011	1143	L 4	23.8	11.2	29.0	7,580	7.1	71	107	69	71	81	19.3	22	3040
13.99	1.99	1020	1168	L 5	33.3	5.9	29.0	7,770	8.0	73	107	60	62	84	19.2	23	3010
Lignite																	
14.17	2.02	1032	1175	M 1	31.9	7.1	26.5	7,640	7.6	73	105	66	67	83	19.3	23	2990
16.50	2.35	1039	1225	M 2	38.5	7.3	27.6	6,700	9.6	63	107	58	60	74	19.0	25	2890
17.53	2.50	1056	1246	M 3	39.2	8.4	24.7	6,310	9.5	60	105	64	65	71	19.3	25	2840
18.19	2.59	1037	1251	M 4	40.7	6.2	25.2	6,150	10.5	57	108	66	69	69	19.5	26	2840
20.78	2.96	1052	1305	M 5	45.9	7.1	22.5	5,470	12.0	51	108	65	68	63	19.8	28	2730

Column Headings and Notes for Table 18

A Section—Data on Basis of Production of One Therm Net Heat. Coal, air and flue gas involved in production of one therm (100,000 B.t.u.) of net heat:

Column 1. Weight of coal required, pounds.
2. Relative weight of coal, coal D 3 taken as 1.00.
3. Volume of air required for combustion, in cubic feet.
4. Volume of total flue gas produced in cubic feet.

B Section—Proximate Analysis of Coal:

Column 5. Sample number.
6. Moisture %.
7. Ash %.
8. Volatile matter %.
9. Calorific value, British thermal units per pound of coal.

C Section—Data on Basis of Coal as Received:

Column 10. Percentage reduction—conversion of gross to net calorofic value.
11. Air required for combustion of one pound of coal, in cubic feet.
12. Heat generated, in B.t.u. per cubic foot of air.
13. Heat from non-volatiles, as percentage of total heat.
14. Air required for non-volatiles, as percentage of total air.
15. Volume of flue gas in cubic feet per pound of coal.
16. Percentage of carbon dioxide in dry flue gas.
17. Percentage of heat lost in flue gas at 572°F. (300°C.), with 25% excess air.
18. Theoretical flame temperature, in degrees Fahrenheit, with 25% excess air.

NOTES:

All gas volumes calculated to standard temperature and pressure, 32°F. and 29.92 inches of mercury pressure (0°C and 760 mm.). The steam in the flue gas (column 15) assumed to remain uncondensed at this temperature. Complete combustion, without excess of air, was assumed for all calculations, except those for columns (17) and (18) where 25% excess air was assumed. The heat losses and flame temperatures of these two columns are calculated from an initial temperature of 32°F. Dry flue gas (column 16), is flue gas as analysed in the laboratory, with the steam removed by condensation.

†See comment on page 84.

*Cannel coal, and not subject to classification by rank.

The above calculations necessitate some assumptions which are notably uncertain. Thus the mineral impurities of a sample may include calcium and magnesium carbonates, iron pyrites, hydrated silicates, etc. In the determination of ash these compounds may be decomposed and oxidised and may be weighed as oxides, and without water of hydration. The ash found by the chemist usually weighs less than the mineral matter originally present in the coal, and weight driven off in the conversion of mineral matter to ash may be wholly or partially included as volatile matter in the recorded analysis. Furthermore, the carbon determined in the ultimate analysis may include not only carbon of the coal, but also carbon from the carbonates of the impurities, and this error will be accentuated in the correction of pure coal. It might be noted that this error is now frequently guarded against by a determination of carbonates, but the analyses available had not been so corrected. Similarly the hydrogen of the coal may be in error by inclusion of hydrogen from water of hydration not liberated during the determination of water. No correction for this error is yet readily available. Error in the computation of mineral matter, and of calorific value on a mineral-matter-free basis may also arise from uncertainty as to the form or forms in which sulphur exists in the coal.

In the calculations here made the approximation formulas recognized by the American Society for Testing Materials[3] for use in the classification of coal have been employed. The formulas for carbon hydrogen and oxygen have been added by analogy.

$$\text{Dry, mm.-free F.C.} = \frac{\text{F.C. (as det.)} \times 100}{100 - (\text{M} + 1.1\text{A} + 0.1\text{S})}$$

$$\text{Moist, mm.-free B.t.u.} = \frac{\text{B.t.u. (as det.)} \times 100}{100 - (1.1\text{A} + 0.1\text{S})}$$

[3]Specification D388—1938.

$$\text{Dry, mm.-free C} = \frac{\text{C (as det.)} \times 100}{100 - (\text{M} + 1.1\text{A} + 0.1\text{S})}$$

$$\text{Dry, mm.-free H} = \frac{[\text{H (as det.)} - 0.1119\text{M}]100}{100 - (\text{M} + 1.1\text{A} + 0.1\text{S})}$$

$$\text{Dry, mm.-free O} = \frac{[\text{O (as det.)} - (0.8881\text{M} + 0.1\text{A} + 0.1\text{S})]100}{100 - (\text{M} + 1.1\text{A} + 0.1\text{S})}$$

Where Mm=mineral matter, B.t.u.=British thermal units per pound, and F.C., M, A, S, C, H, and O=percentages of fixed carbon, moisture, ash, sulphur, carbon, hydrogen and oxygen respectively.

GROSS AND NET CALORIFIC VALUES

The calorific value of a coal sample is determined by burning with oxygen under pressure in a bomb immersed in water. The coal is therefore burned at constant volume, and the steam produced is condensed to water and gives up its latent heat to the system. On the contrary, in normal combustion coal is burned at constant pressure (atmospheric), and the products of combustion escape without the condensation of the steam. The latent heat is thus lost. Two calorific values are recognized, **gross**—in which the material is burned at constant volume, the products cooled to ordinary temperatures (60°F) and the steam condensed to water; and **net**—in which the material is burned at constant pressure (atmospheric), the products cooled to ordinary temperatures (60°F) but the steam assumed to be uncondensed. The A.S.T.M.[4] specifies the conversion of gross calorific values to net by the subtraction of 91.2 B.t.u. per pound for each one per cent of hydrogen in the coal as burned.

Net calorific values give the clearer comparison of the useful heat producing qualities of two coals, and might well be generally used; but the gross values are almost always employed in America. The difficulty about the former value is that its calculation involves a knowledge of the hydrogen content of the coal, and often this is not known. The gross calorific value is referred to in this paper unless the contrary is stated.

The tenth column of Table 18 shows the percentage amount to be subtracted from the gross calorific value to give the net value. It can be seen that the reduction is small with meta-anthracites and other high rank coals, but may rise to over ten per cent with lignites.

COAL CLASSIFICATION

The coal classification here employed is the classification by rank of the A.S.T.M.[3] This classification, which has been adopted in the United States and in Canada, provides for four main classes, divided into 13 groups, from the high rank, highly metamorphosed meta-anthracites, down to the low rank, little metamorphosed lignites and brown coals.

This classification divides the higher rank coals on the basis of their dry, mineral-matter-free, fixed carbon; and the lower rank coals on their moist, mineral-matter-free, calorific value. In certain cases knowledge of the agglomerating and weathering character of the coal is necessary for final decision as to rank.

[3]Specification D388—1938.
[4]Specification D407—1935 T.

The probable classification of each coal is indicated in Table 18. The samples have been numbered (column 5) with a prefixed letter indicating the class, to facilitate study of the different charts and tables.

COAL CHARTS

The coal samples studied have been represented in three different coal charts. In Fig. 6 they are plotted according to the above classification criteria, and the classification boundaries are also shown. It might be noted that as this chart is on a mixed basis, dry for the ordinates and moist for the abscissae, combustion data could not be shown satisfactorily.

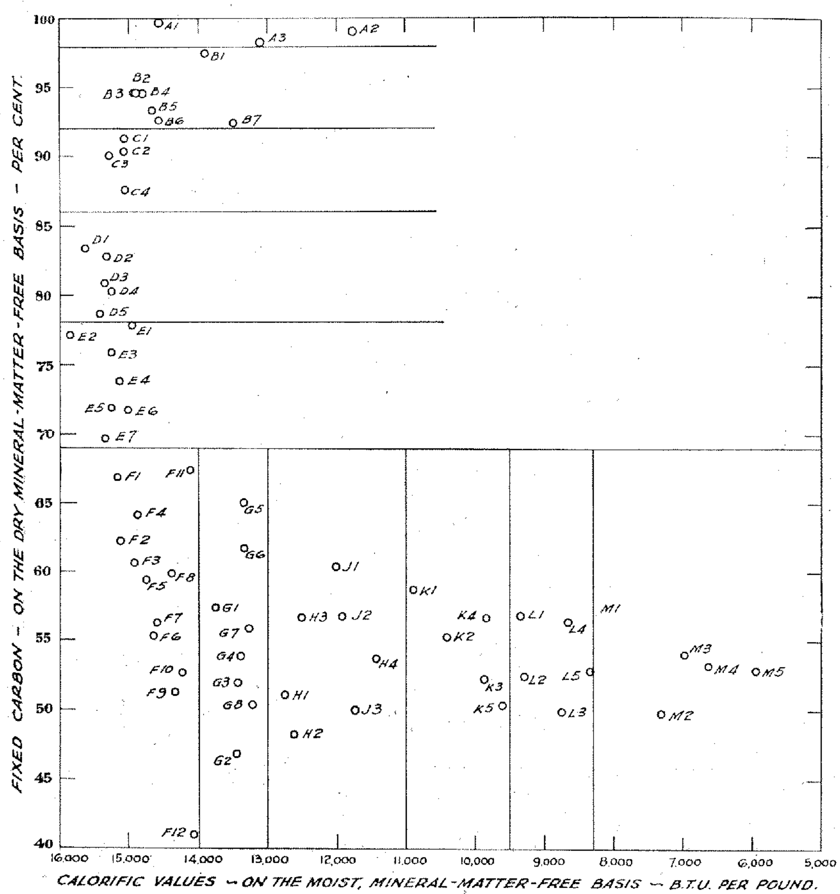


Fig. 6—Coal chart. Coals plotted on A.S.T.M. classification basis.

In Fig. 7 the coal samples are plotted according to their fixed carbon and calorific value, both on the as received basis. It may be noticed that the impurities and moisture in the samples notably change the arrangement of the samples from that shown in Fig. 6. The distribution of calorific value between the volatile and non-volatile portions of the coal is also shown on this chart.

In Fig. 8 the coal samples are plotted according to their carbon, hydrogen and oxygen percentages calculated to the pure coal basis, employed by Seyler. That is to a C+H+O=100 basis. The Seyler

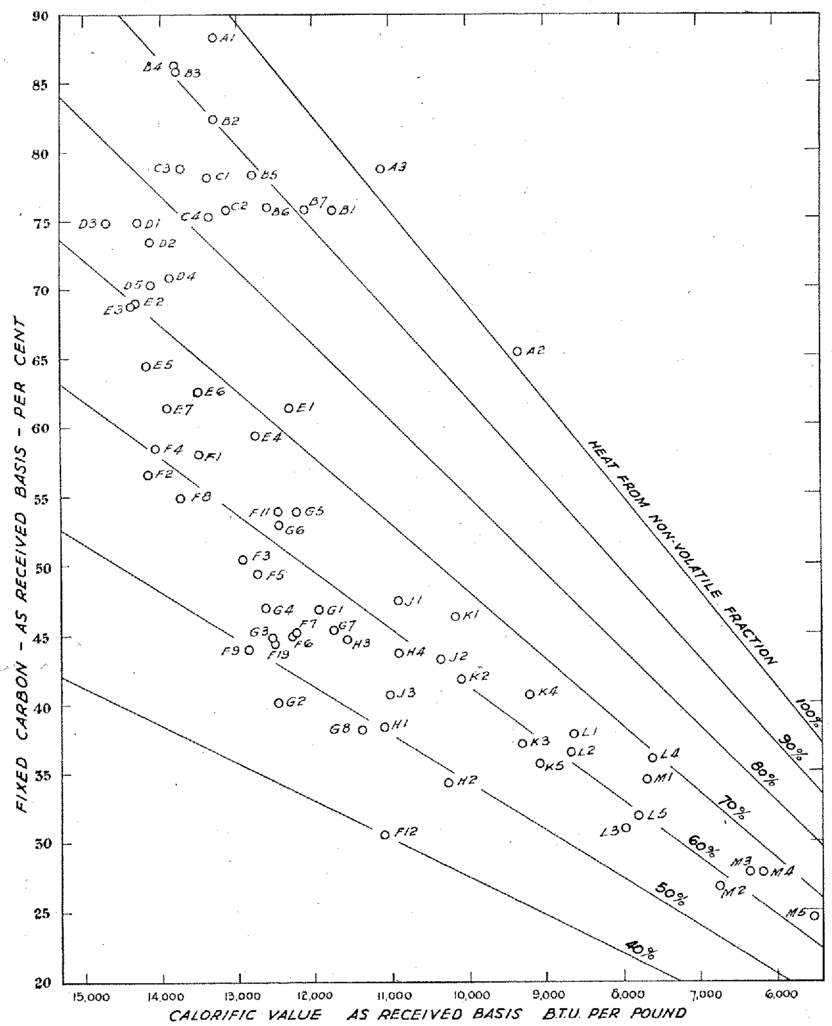


Fig. 7—Coal chart. Coals plotted on as received basis.

classification boundaries[6] are shown but not the class names. Charts based on the ultimate analysis of the pure coal are well adapted to show combustion data.

In Fig. 8 are shown dotted lines, with values from 18% to 21%, representing the percentages of carbon dioxide to be found in the flue gas with perfect combustion and no excess air. Also shown are lines of equal calorific value, or iso-cals, for gross and for net calorific values of 15,000, 13,000 and 11,000 B.t.u. per pound. The gross calorific values were calculated by the well known Dulong formula:

$$\text{B.t.u./lb.} = 145.4C + 77.5(8H - O) + 40.5S$$

where C, H, O and S represent the percentages of carbon, hydrogen, oxygen and sulphur in the coal. The net calorific values were calculated from the gross values as stated earlier.

[6]Proc. South Wales Inst. of Engrs. Vol. 21 (1900), p. 483; Vol. 22 (1901), p. 112. Reprinted, Fuel in Science and Practice, Vol. 3 (1924), p. 15, p. 41, p. 79.

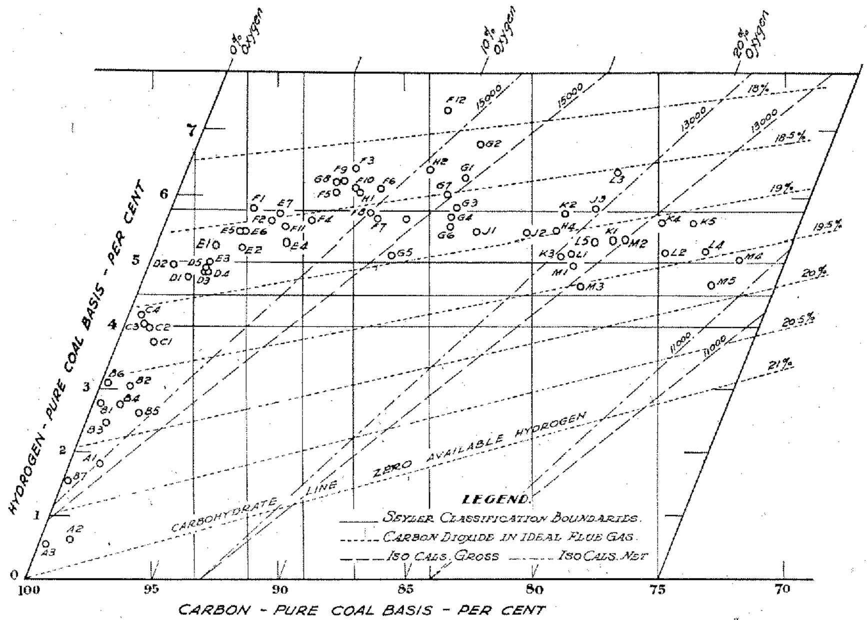


Fig. 8—Coal chart. Coals plotted on Seyler classification basis.

It should be noted that in Figs. 6 and 8 the points representing the coal samples lie along a band with a sharp bend, known as a coal band, and that the distribution along the band is somewhat similar in the two figures although the one is based on proximate, and the other on ultimate analyses.

COMBUSTION CALCULATIONS OF AIR AND FLUE GAS

Combustion calculations can be made simply and quickly by the use of molar weights as a ready means of conversion from weight to volume. The equations given below are equally applicable to the C.G.S. system and to the common units. Thus one gram-molecular weight of a gas at Standard Temperature and Pressure (S.T.P.), that is at 32°F and 29.92 inches of mercury (0°C and 760 mm.), occupies 22.412 litres, one kg-mol. occupies 22.412 cubic meters, and one pound-mol. occupies 359.0 cubic feet.

In the equations which follow, the atomic symbols C, H, O and S are each taken to represent the percentage of that element in the coal. Whole figure atomic weights have been taken for sake of simplicity, since the differences from the correct values are less than the probable errors of analysis. The nitrogen in the coal has been neglected in these equations and sulphur may be neglected in low sulphur coals. It is also assumed that air contains 21% oxygen by volume and 79% nitrogen. In the actual calculations made for this paper nitrogen and sulphur have both been taken into consideration, and the atomic weight of hydrogen taken as 1.008.

One hundred pounds of coal contains $\frac{C}{12}$ pound-atoms of carbon, $\frac{H}{1}$ of hydrogen, $\frac{O}{16}$ of oxygen, etc., and requires for its combustion $(C/12+H/4+S/32-O/32)$ pound-molecules of oxygen. This oxygen would be accompanied in the air supplied for combustion by 79/21 times its volume of nitrogen, if the theoretical or ideal amount of air were supplied. The products of combustion would be, in pound-mols., C/12 carbon dioxide, H/2 steam, S/32 sulphur dioxide and (C/12+H/4+S/32—O/32) 79/21 nitrogen. In the total flue gas the steam is considered to be present as steam, even though, for the sake of convenience, the volume is stated at S.T.P. In the dry flue gas (as analyzed) the steam is assumed condensed to water (of negligible volume) and the sulphur dioxide dissolved in the water. As the term (C/12+H/4+S/32—O/32) occurs many times it has been replaced below by the letter Z.

The following equations show the mols. (gram, kilogram, or pound) of air required, flue gas produced, etc., per 100 units of weight (gram, kg. or lb.) of coal burned. The molar values shown can be converted to litres per gram or cubic meters per kilogram at S.T.P. by multiplying by 22.412/100 or converted to cubic feet per pound at S.T.P. by multiplying by 359/100.

In equations I to V complete combustion is assumed with the theoretical amount of air, whilst equations VI to IX cover the general condition where A% of excess air is supplied.

Theoretical Air Supplied.

$$\text{Air required} = Z \times 100/21 \qquad \text{(I)}$$

$$\text{Carbon dioxide produced} = C/12 \qquad \text{(II)}$$

$$\text{Total flue gas} = C/12 + H/2 + S/32 + 79Z/21 \qquad \text{(III)}$$

$$\text{Dry flue gas} = C/12 + 79Z/21 \qquad \text{(IV)}$$

$$\text{Percent } CO_2 \text{ as analyzed} = \frac{100\ C/12}{C/12 + 79Z/21} \qquad \text{(V)}$$

Excess Air Supplied, A per cent.

$$\text{Air supplied} = \frac{(100+A)\ Z}{21} \qquad \text{(VI)}$$

$$\text{Total flue gas} = C/12 + H/2 + S/32 + \frac{(79+A)Z}{21} \qquad \text{(VII)}$$

$$\text{Dry flue gas} = C/12 + \frac{(79+A)Z}{21} \qquad \text{(VIII)}$$

$$\text{Per cent } CO_2 \text{ as analyzed} = \frac{100\ C/12}{C/12 + \frac{(79+A)Z}{21}} \qquad \text{(IX)}$$

In Table 18 the volume of air required for each coal (column 11) and the total volume of flue gas produced (column 15) were calculated in cubic feet per pound of coal by means of equations I and III. The percentage of carbon dioxide in the flue gas (column 16) was calculated by equation V.

Values were calculated for the relation between the CO_2 % of equation V and of equation IX, for three coals of widely varying proportions of carbon, hydrogen and oxygen. It was found that if A=per cent of excess air, B=per cent of CO_2 in actual flue gas, and C=per cent of CO_2 in theoretical flue gas, the following equation was correct, within the limits of experimental errors of analysis, for all three coals regardless of their different compositions:

$$A = \frac{100}{1.02}\left(\frac{C}{B} - 1\right) \qquad \text{(X)}$$

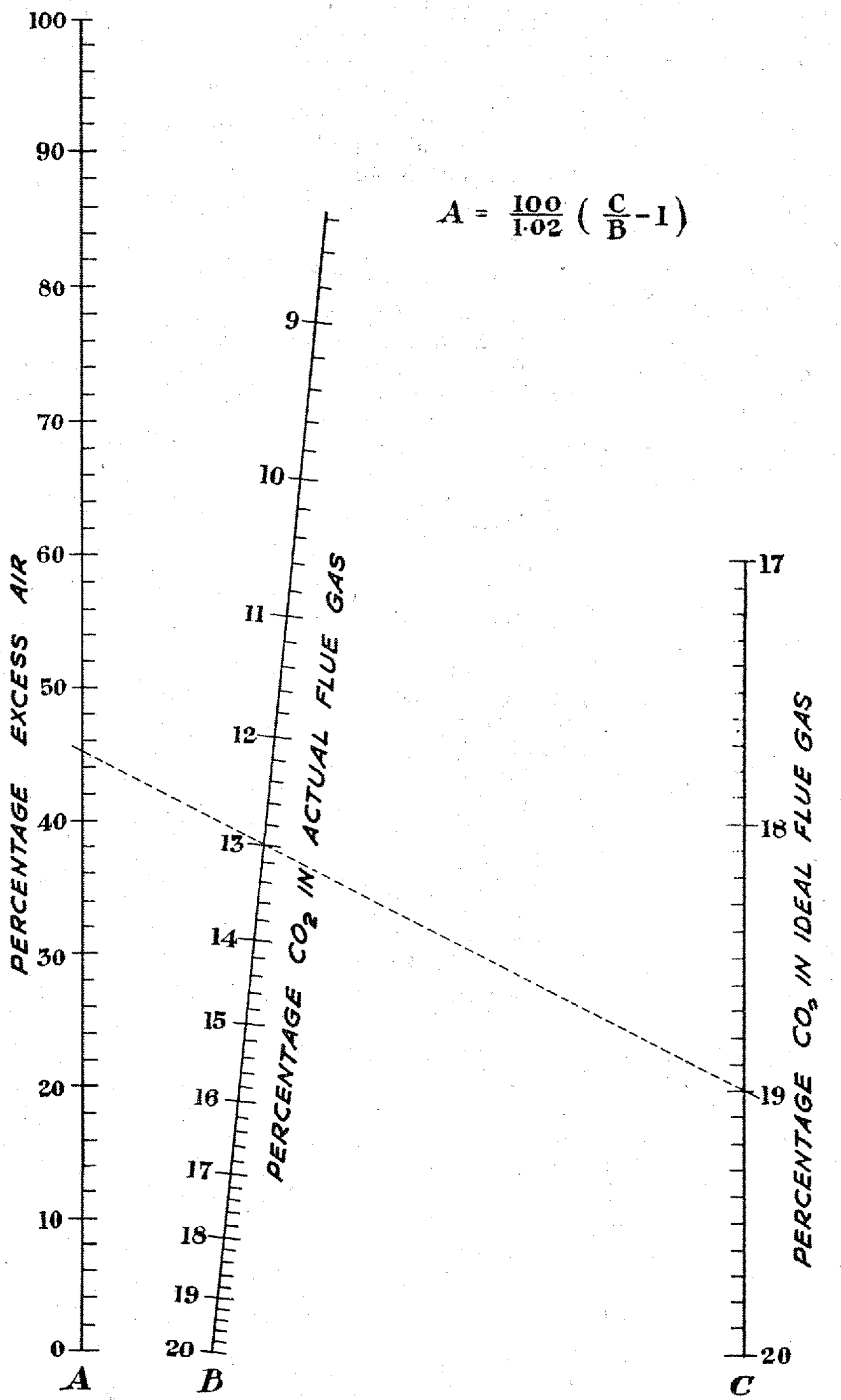


Fig. 9—Nomogram for flue gas analysis

An alignment chart, based on this equation, has been prepared by Dr. A. J. Cook, Associate Professor of Mathematics at the University of Alberta. This chart, published in 1937[7] is shown in Fig. 9. The dotted line shows, as an example of its use, that if the actual flue gas from a furnace is found to contain 13% carbon dioxide, when a coal is being burned which might give 19% were only the theoretical amount of air supplied, then the excess air actually supplied in the furnace is 45%. The theoretical carbon dioxide values for each of the coals studied can be taken from column 16 of Table 18.

VOLATILE AND NON-VOLATILE FRACTIONS OF COAL

When coal is heated in the absence of air some volatile combustible matter is driven off, and some non-volatile combustible matter is left behind. An important difference in the burning qualities of coals is found in the wide variations in the quantity of volatile matter they contain. The volatile matter driven off for any coal with heat varies with the temperature employed, and the temperature of 1740°F (950°C±20°C) employed by the fuel analyst was not selected as having any relation to boiler furnace temperatures. Nevertheless all available data are based on this temperature, and it appears quite satisfactory for the present study.

The percentages of volatile matter and of fixed carbon, as determined at the above temperature, are shown in the proximate analysis of coal and are of great value to the combustion engineer. It appears possible, however, that the relative amounts of heat produced by the burning of the volatile and non-volatile fractions, and the relative amounts of air required to burn these fractions, may be more significant. Calculations have therefore been made as shown below, and the results tabulated in columns 13 and 14 of Table 18. In addition lines showing the percentages of heat from the non-volatile fraction of coal have also been incorporated in Fig. 7.

The determined percentage of fixed carbon in any coal was multiplied by the factor of 145.4 to give the B.t.u. per pound of the non-volatile portion of the coal; and by the factor of 1.411 to give the cubic feet of air (at S.T.P.) required to burn the non-volatile portion of a pound of the coal. These values were expressed as percentages of the total heat values and of the air requirements for tabulation.

The above factors were obtained from a careful study[7] of the decomposition with heat of five typical Canadian coals and of less comprehensive tests of forty coals. The fact that two values of over 100% were found for meta-anthracites suggests that these factors are not strictly applicable to the highest rank coals.

It has not been overlooked in the above discussions of combustion of volatile and non-volatile fractions that combustion of coal in a furnace may bring in many complications. Thus the fixed carbon of a coal may be largely converted into combustible gases by partial combustion or by reaction with steam, so that its combustion is not simply combustion of a solid. It would be absurd to suggest, for example, that a determinable portion of the air should be sent through the grate to burn the non-volatile fraction and the remainder sent over the grate to burn the volatiles. Nevertheless it is suggested that experience with data along the lines suggested may show that such data is a better guide to the satisfactory com-

[7]E. Stansfield, The Eng. Jour., Vol. 20 (1937), p. 545.

bustion of a coal than are the simple percentages of volatile matter and fixed carbon of the proximate analysis.

HEAT LOSS IN FLUE GAS

When coal is burned in a calorimeter the products of combustion are cooled down to room temperatures, but when burned in a furnace the flue gases escape at a higher temperature. The available heat in the furnace is therefore always lower than the determined calorific value; Fieldner and Selvig[8] have shown that the difference between the two varies with the rank of the coal, and this difference is important in connection with the combustion value of the coal.

The heat lost includes the latent heat of the steam, unless this has already been allowed for by the use of the net calorific value, and the sensible heat of the gases above some basic temperature such as the temperature of the air entering the furnace. The latent heat loss is independent of the temperature of the flue gases or the amount of excess air. The sensible heat loss, on the contrary, increases rapidly with temperature of the flue gas and with the excess air supplied.

Column 17 of Table 18 shows for each coal the percentage of the gross heat of the coal lost when 25% excess air is supplied, and the flue gas leaves the furnace system at 572°F (300°C). The heat losses are, for simplicity of calculation, taken as above 32°F. The method used for the calculations was as follows: The latent heat in the flue gas from 1 gram of coal was taken as 91.2 B.t.u. for each one per cent of hydrogen in the coal as fired. The sensible heat was determined by multiplying the pound-mols. of oxygen+nitrogen, of carbon dioxide, and of hydrogen by their respective heats, in B.t.u. per pound-mol. at 572°F, as shown in Table 19. The calculations of the pound-mol. of these gases, from 1 pound of coal, are like those given earlier. It should be noted, however, that equations I to IX are for 100 pounds of coal. Column 6, Table 20, also shows heat losses, but these are sensible heats only, expressed as percentages of the net calorific values.

A study of the values shown in Table 18 indicated a relation between the heat losses and the fixed carbon of the coal. This has been shown in Fig. 10, in which the percentage heat losses of the different coals are plotted against the corresponding percentages of fixed carbon. As the moisture in the coal does affect the heat loss, but the mineral impurity does not, the fixed carbon percentages have been calculated to the moist, mineral-matter-free basis.

FLAME TEMPERATURES

If coal could be burned instantaneously, without loss of heat by radiation or otherwise, the products of combustion would be raised in temperature by an amount that could be calculated with fair accuracy. The rise in temperature added to the mean initial temperature of air and coal would give the final temperature or flame temperature. The combustion of powdered coal comes closest to the above ideal conditions, but combustion is never instantaneous and there must always be heat loss. The combustion of lump coal on a grate is so far removed from the ideal condition that no calculated flame temperatures would be likely to agree with determined temperatures, except by chance.

8Fuel in Science and Practice, Vol. 18 (1939), p. 76; reprinted from U.S. Bureau of Mines T.P. 586.

TABLE 19

Thermal Data and Equilibrium Constants

Employed in Calculations of Flame Temperatures and of Heat Losses in Flue Gases

Temperature °F	Sensible heat above 32°F in gases at atmospheric pressure B.t.u. per pound molecule			Sensible heat, above 32°F in Ash, B.t.u. per lb.	Equilibrium constants	
	O_2, N_2, etc.	CO_2	H_2O		K_1 CO_2	K_2 H_2O
500	3,275	4,520	3,920	....	....	....
572	3,780	5,270	4,520	....	....	....
600	3,980	5,570	4,760	....	....	....
2500	18,140	29,100	23,020	666	25,610	83,600
2600	18,940	30,440	24,150	715	13,130	46,050
2700	19,750	31,790	25,310	767	7,027	26,340
2800	20,560	33,150	26,490	823	3,910	15,580
2900	21,390	34,510	27,700	883	2,255	9,511
3000	22,220	35,870	28,930	947	1,343	5,973
3100	23,060	37,240	30,190	1,016	823.7	3,850
3200	23,910	38,610	31,470	1,091	519.2	2,542
3300	24,770	39,980	32,780	1,170	335.5	1,716
3400	25,640	41,360	34,120	1,256	221.8	1,183
3500	26,510	42,740	35,500	1,348	149.8	830.6
3600	27,400	44.130	36,900	1,445	103.1	593.7

Heats of dissociation: $CO_2 = CO + \frac{1}{2}O_2$—122,400 B.t.u.

H_2O(steam)$= H_2 + \frac{1}{2}O_2$—104,040 B.t.u.

NOTE: The above values are compiled from values in Goodenough and Felbeck (ibid.) or from Technical Data on Fuel. The sensible heat in ash values were taken from values quoted for slags in the latter, with extrapolation above 2700°F. It is stated that wide variations in the composition have but slight effect on the heat content.

TABLE 20

Effect of Coal Composition on Sensible Heat Loss and on Flame Temperature

Study of Hypothetical Coals containing only Carbon, Hydrogen and Oxygen

1	2	3	4	5	6	7
Net calorific value		Composition of coal			Sensible heat in flue gases at 572°F % of net heat	Flame temperature °F
Cals. per gram	B.t.u. per lb.	Hydrogen %	Carbon %	Oxygen %		
9,000	16,200	6.00	91.10	2.90	13.7	3466
8,000	14,400	2.00	93.91	4.09	13.8	3438
8,000	14,400	4.00	88.47	7.53	13.9	3427
8,000	14,400	6.00	83.03	10.97	13.9	3416
7,000	12,600	2.00	85.83	12.17	14.1	3376
7,000	12,600	4.00	80.40	15.60	14.2	3364
7,000	12,600	6.00	74.96	19.04	14.3	3351
6,000	10,800	3.00	75.04	21.96	14.6	3290
6,000	10,800	6.00	66.88	27.12	14.7	3268
5,000	9,000	6.00	58.81	35.19	15.4	3155
4,000	7,200	6.00	50.74	43.26	16.3	3000
3,000	5,400	7.00	39.95	53.05	18.0	2757

NOTE:

Columns 1 and 2.—Calorific values calculated from Dulong's formula—with correction to net heat.

Column 6.—Combustion with 25% excess air, and flue gases leaving at 572°F (300°C).

Column 7.—Combustion with 25% excess air. No allowance for radiation loss.

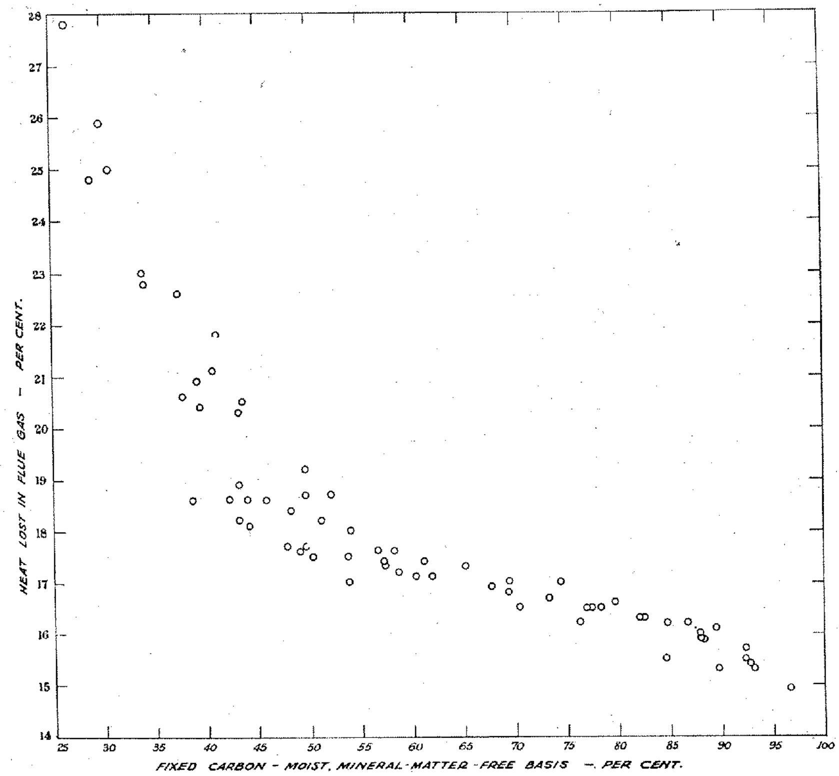


Fig. 10—Heat loss in flue gas

In spite of these difficulties it is suggested that the determination of flame temperatures of a number of coals, if made on a standard basis, does give a useful comparison of the coals. Determination of flame temperatures is clearly another method of evaluating the available heat of coals already discussed (see p. 78); the higher the available heat the higher the temperature to which the products will be raised. Furthermore, the flame temperature is important in its influence on the transmission of heat from the furnace to the boiler tubes by means of radiation. The Stefan-Boltzmann law states that radiation is proportional to the difference between the fourth power of the absolute temperature of the radiating body and the fourth power of the absolute temperature of the receiving body. A high temperature therefore gives high radiation in the furnace and a low temperature may necessitate a notable increase in boiler surface. Flame temperature is also important in relation to slag formation. The relation between the ash softening temperature and the furnace temperature is more important than the actual temperature of softening.

Flame temperatures are higher with high rank than with low rank coals; they can be raised by preheat of the air used for combustion and by avoiding the supply of unnecessary air. The temperatures shown in column 18 of Table 18 were calculated on the assumption that no heat was lost by radiation, and that 25% excess air was supplied at 32°F.

Calculations of flame temperatures are made by assuming that the sensible heat in the products of combustion, at the flame temperature, equals the heat liberated by the combustion and not lost by radiation. The sensible heat calculation is complicated by the fact that the specific heats of the gases vary with the temperature, and that the relations between temperatures and mean specific heats are far from simple. The calculation of the heat liberated by the combustion is complicated by the fact that combustion is not complete at the temperature attained. This can be stated in reverse by saying that, if the carbon dioxide and steam produced by combustion were heated to the flame temperature they would partially dissociate into carbon monoxide, hydrogen and oxygen until equilibrium was reached. This equilibrium depends on the temperature and the concentrations of the various gases, and the relation to temperature is not a simple one.

Goodenough and Felbeck[9] deal with flame temperatures and describe a method for calculating them that is necessarily laborious. Underwood[10] has developed a graphical method for simplifying the calculations. In the present work a simplified calculation has been used that could only be permissible where the excess air is considerable.

If the products of the combustion of unit weight of coal, with excess air, assuming no dissociation, are

$$a\,CO_2 + bH_2O + cO_2 + (m-a-b-c)N_2 = m$$

where a, b, c, and m are volumes of gas in mols or other units. And if x=fraction of CO_2 dissociated and y=fraction of H_2O dissociated, at any temperature, and n=volume of dissociated gas, the dissociated gas will be:

$$a(1-x)CO_2 + ax\,CO + b(1-y)H_2O + by\,H_2 + (c+n-m)O_2 + (m-a-b-c)N_2 = n$$

Also n=m+volume of oxygen from dissociation$=m+\frac{a}{2}x+\frac{b}{2}y$

Then if K_1 and K_2 are the equilibrium constants of carbon dioxide and steam at the same temperatures:

$$K_1 = \frac{1-x}{x}\sqrt{\frac{n}{c+n-m}} \quad \text{and } K_2 = \frac{1-y}{y}\sqrt{\frac{n}{c+n-m}}$$

Where c is comparatively large, as when the excess air is considerable, and where x and y are small, it can be assumed that

$$\sqrt{\frac{n}{c+n-m}} = \sqrt{\frac{m}{c}}$$

so that the above equations become:

$$K_1 = \frac{1-x}{x}\sqrt{\frac{m}{c}} \text{ and } K_2 = \frac{1-y}{y}\sqrt{\frac{m}{c}}$$

and can readily be solved for any desired temperature. When x and y are known the correct deduction of heat can be made from the calorific value of the coal burned to allow for incomplete combustion. All the values employed in these calculations are given in Table 19. It was also assumed, in order to further simplify calculations, that the sensible heat in the actual products could be calculated as though there were no dissociation. Net calorific values were employed, as this obviated calculation of the latent heat of steam in the products. Sulphur dioxide was included with the

[9] University of Illinois, Engineering Experiment Station, Bull. 139, 1924.
[10] Technical Data on Fuel, World Power Conference (1932), p. 193.

nitrogen. The sensible heats in the products and the available heats of combustion were calculated for two or more temperatures, one above and one below the actual flame temperature, and then the temperature calculated at which the two values would be identical.

Thus coal B 6 was found to give 12,217 B.t.u. of available heat per pound of coal at 3272°F (1800°C) and 12,170 B.t.u. at 3362°F (1850°C). The sensible heat in the products was found to be 11,876 B.t.u. at 1800°C and 12,260 B.t.u. at 1850°C. It can be seen that the two values will be equal at approximately 3340°F. This therefore is the flame temperature under the specified conditions. It might be noted that the above approximation in the equilibrium equations causes an error of less than 4°F.

It is customary to make a deduction for radiation loss of some percentage of the calorific value. This requires a separate calculation for each percentage deduction considered. It would be more convenient to make the deduction as a percentage subtracted from the calculated rise in temperature. No deduction has been made in the values shown.

Calculations of flame temperatures are tedious, however simplified, and it was desired to correlate them with other more easily determined values. The most obvious correlation is with net calorific value, and this is shown in Fig. 11 for the coals studied. A closer correlation might have been shown if all values had been calculated to a pure, dry basis; but coal as burned is neither pure nor dry. A study was made of the effect of coal composition and of moisture and ash on flame temperatures. The results are shown in Tables 20 and 21. In Table 20 hypothetical coals are shown that allow comparison of coals with the same heat value but with different ratios of carbon to hydrogen. It is clear that for coals of the same heat value the higher the carbon content the higher the flame tem-

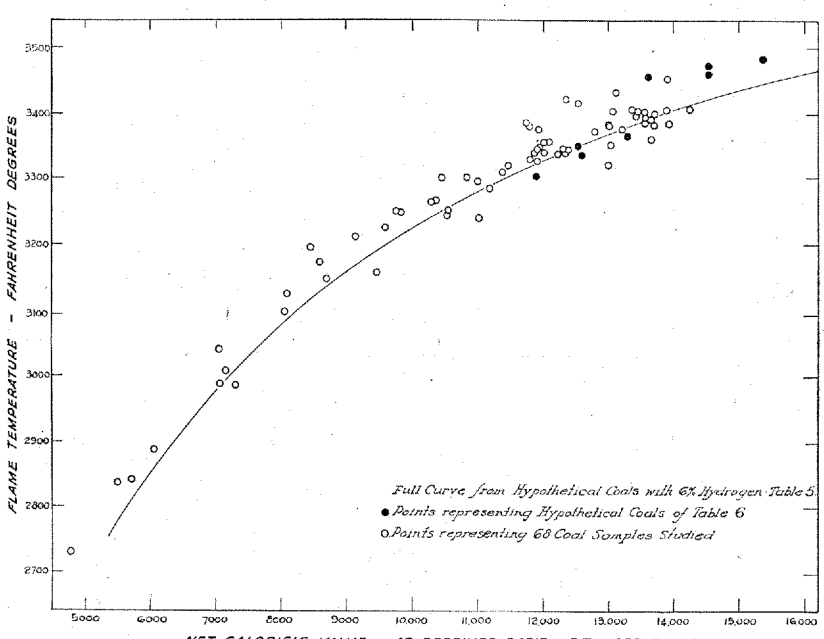


Fig. 11—Flame Temperature

NOTE: For Tables 5 and 6 in figure read Tables 20 and 21 perature. An exact correlation between flame temperature and net calorific value is therefore not possible. The curve shown in Fig. 11 is drawn through the points for pure coals, with 6 or 7% hydrogen, as shown in Table 20. Table 20 also shows the sensible heat losses of these hypothetical coals. It is interesting to note that, under the conditions specified, there is a close correlation between heat losses and flame temperatures; the higher the heat loss the lower the flame temperature.

Table 21 shows the results of a study of the effect of moisture and ash. Two typical coal analyses were taken and the flame temperature calculated for each coal both pure and dry, and after addition of specified amounts of moisture and ash. The results are not independent of the analysis of the coal, but 10% of ash (11% mineral matter) reduces the net calorific value of the coal by 11%, but only reduces the flame temperature (the rise above 32°F) by about 0.8%. Ten per cent moisture reduces the net calorific value by over 10½%, but only reduces the flame temperature by under 2%.

TABLE 21

Effect of Mineral Matter and Moisture on Flame Temperature

Study of two hypothetical coals—Combustion with 25% excess air

	Net calorific value		Flame temperature	
	B.t.u. per lb.	Reduction %	°F.	Reduction %
Coal A—Medium volatile bituminous: 88.5% C, 5.0% H, 4.5% O, 2.0% N				
Coal, pure and dry	15,384	....	3484	....
Coal with 5% ash (5.5% mineral matter)	14,537	5.5	3472	0.4
Coal with 10% ash (11.0% m.m.)	13,691	11.0	3456	0.8
Coal with 5% moisture	14,564	5.3	3457	0.8
Coal B—High volatile C bituminous: 80.0% C, 5.4% H, 13.3% O, 1.3% N				
Coal, pure and dry	13,313	....	3364	....
Coal with 5% ash (5.5% m.m.)	12,580	5.5	3349	0.4
Coal with 5% moisture	12,598	5.4	3333	0.9
Coal with 10% moisture	11,880	10.8	3301	1.9

COMBUSTION DATA AND COAL RANK

The combustion data collected in Table 18 may be considered in relation to the rank of the coal. The percentage reduction from gross to net calorific value increases with fair regularity as the rank decreases. The air required per unit weight of coal shows little variation down to the medium volatile bituminous coals, but falls through the lower ranks; the same applies to the volume of flue gas produced. The heat generated per unit of air supplied for combustion is lower for the anthracitic coals, but otherwise remains remarkably constant throughout the whole range of coals. The percentage heat from, and percentage air required for, the non-volatile fraction of the coals are high for the high rank coals and then decrease with the rank; they reach a minimum, however, with the high volatile bituminous coals and then increase slightly. This change can be seen in Fig. 7 to be due to the bend in the coal band; the cannel coals are on the outside of the bend, and have notably low values. The possible carbon dioxide in the flue gas, with ideal air supply, is also high with the high rank coals, falls to a minimum and then rises; this minimum also occurs near the bend of the coal band. This can be seen in Fig. 8.

The heat loss in the flue gas, and also the flame temperature, have been shown to be closely related to the calorific value; it is therefore natural that these should show no clear variation with rank in the higher rank coals where the calorific values, on the mm-free basis, are all over 13,000 B.t.u. per pound; but that the heat losses should increase and the flame temperatures decrease with the falling calorific values of the lower rank coals.

In Table 18 some combustion data are shown calculated to the basis of the generation of a unit of heat. The relative weight of coal burned, for the same reason stated in the last paragraph, remains fairly constant through the higher rank coals and then increases rapidly through the lower ranks. The volume of air required for combustion to produce unit heat remains remarkably steady throughout the range of coals, but does increase slightly with the low rank coals. The volume of total flue gas produced is also steady with the higher rank, low moisture coals, but increases, naturally, with the lower rank coals where the volatilised water increases the volume of flue gas.

CONVERSION FACTORS

The common units of the combustion engineer have been used almost entirely. The following factors permit conversion to the C.G.S. units of the chemist and physicist. Values with the first units can be converted to those of the second by multiplying by the factor, F.

B.t.u. to kilogram-calories, F=0.252.

B.t.u. per pound to calories per gram, or to kilogram-calories per kilogram, F=5/9.

B.t.u. per pound-molecule to calories per gram-molecule, F=5/9.

B.t.u. per cubic foot to kilogram-calories per cubic metre, F=0.8905.

Cubic feet per pound to cubic metres per kilogram, F=0.06243.

PART VI

Analytical and Technical Data by Coal Areas

For each area, for which the information and data are available, general notes are given as to the character of the coal, extent of mining operations and economic conditions. Typical analyses are shown, and equations provided for calculating modified analyses for coals with moisture or ash varying from the typical.

In many cases where the analysis of the coal varies notably from mine to mine in the area, the area has been subdivided into districts, or sub-areas, and typical analyses given for each.

The significance and interpretation of the analyses will be found in Part II, and of the special tests in Parts III and IV.

The general characterization of the coal in each area is given by the old classification still in general use; but in every case the more specific Canadian Classification of the coal is also given. This is described in Part I.

Map 12 is a key map of the areas. Maps are also given for each area, showing, first the location of mines opened and mines sampled, and second the location and approximate output of the mines operating in 1943.

The following symbols are employed in these maps:

A.—Maps of mines opened and mines sampled:

(1) A small open circle, shows that one or more mines have been opened in that section.

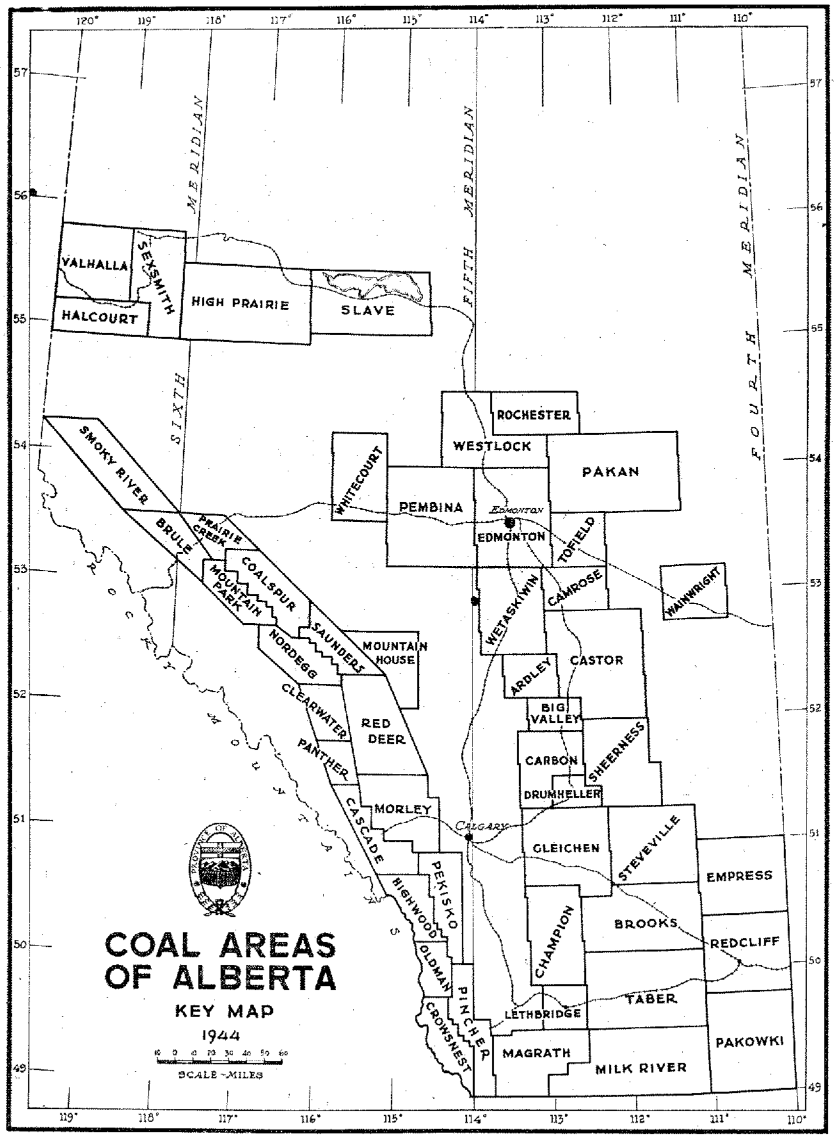
(2) A small circle half cross hatched, indicates that one or more samples have been taken from this section, by a mine inspector, and been analysed by the Research Council of Alberta.

B.—Maps of operating mines and scales of operation:

O=Low or unstated output in 1943.
I=1,000 to 10,000 tons.
X=10,000 to 100,000 tons.
C=over 100,000 tons.

Further data as to the areas and their coals, more particularly geological data, can be found in a report by Dr. J. A. Allan*.

*R.C.A. 34, Part V, 1943.



MAP 12—Key map of Coal Areas of Alberta

ARDLEY AREA

The mines produce an Alberta domestic coal—free burning and smokeless. According to Canadian classification the coal is Subbituminous B. Two seams are known and mined, both in the Edmonton horizon.

Eight mines (two stripping pits) were operated in 1943 and the output was 10,000 tons. The area is well served by the Canadian National and the Canadian Pacific railways. The largest producing mines are on a railway.

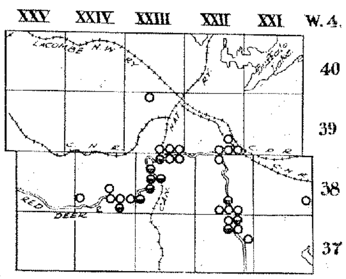
Volume Weight Relation

Solid coal as in seam

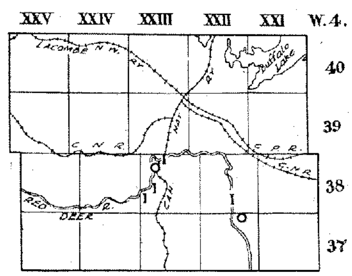
Percentage of Ash	8
Specific gravity	1.34
Tons per hundred cubic feet	4.20
Tons per acre foot	1,820

Map 13 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 14 shows the location of operating mines graded by output in 1943.



MAP 13



MAP 14

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate			Ultimate (with 19.8% moisture)		
Moisture	%	19.8	Carbon	%	55.3
Ash	%	8.2	Hydrogen	%	5.7
Volatile matter	%	28.0	Sulphur	%	0.3
Fixed carbon	%	44.0	Nitrogen	%	0.9
			Oxygen	%	29.6
			Ash	%	8.2

Fuel ratio (FC/VM), 1.55.

Calorific value, gross, in B.t.u. per lb., 9,260.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	$= 63.0 - 0.63(M+1.26A)$
Volatile matter	$= 100 - (M+A+FC)$
Calorific value, B.t.u./lb.	$= 13,000 - 130(M+1.10A)$

BIG VALLEY AREA

The mines produce an Alberta domestic coal—free burning and smokeless. According to Canadian classification the coal is Subbituminous B. At least three seams are known, all in the Edmonton horizon.

Four mines were operated in 1943 and the output was 13,000 tons. Two Canadian National Railway lines cross the area; but most of the mines are on the banks of the Red Deer River.

Volume Weight Relation

Solid coal as in seam

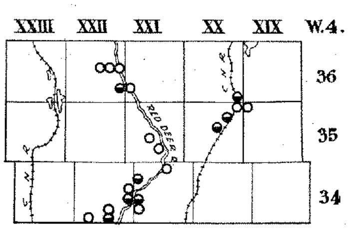
Percentage of Ash	5	10
Specific gravity	1.33	1.37
Tons per hundred cubic feet	4.15	4.25
Tons per acre foot	1,800	1,860

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: fusibility of coal ash, solubility in alkalies, coal sizing, and smithy coal.

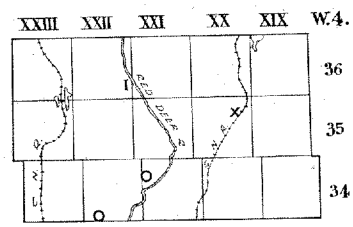
Map 15 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 16 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 15



MAP 16

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	34-36	XXI-XXII
B	34-36	XX

DISTRICT A

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 18.2% moisture)	
Moisture	% 18.2	Carbon	% 53.6
Ash	% 12.3	Hydrogen	% 5.5
Volatile matter	% 27.8	Sulphur	% 0.3
Fixed carbon	% 41.7	Nitrogen	% 0.9
		Oxygen	% 27.4
		Ash	% 12.3

Fuel ratio (FC/VM), 1.50.

Calorific value, gross, in B.t.u. per lb., 9,000.

The net calorific value of this coal is approximately 500 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	62.0 — 0.62(M+1.20A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,400 — 134(M+1.20A)

DISTRICT B

Canadian classification—Subbituminous B

Typical Analyses

Proximate			Ultimate (with 21.8% moisture)		
Moisture	%	21.8	Carbon	%	50.05
Ash	%	10.6	Hydrogen	%	5.75
Volatile matter	%	28.4	Sulphur	%	0.2
Fixed carbon	%	39.2	Nitrogen	%	0.9
			Oxygen	%	32.5
			Ash	%	10.6

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 8,550.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	58.0 — 0.58(M+1.00A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,900 — 129(M+1.12A)

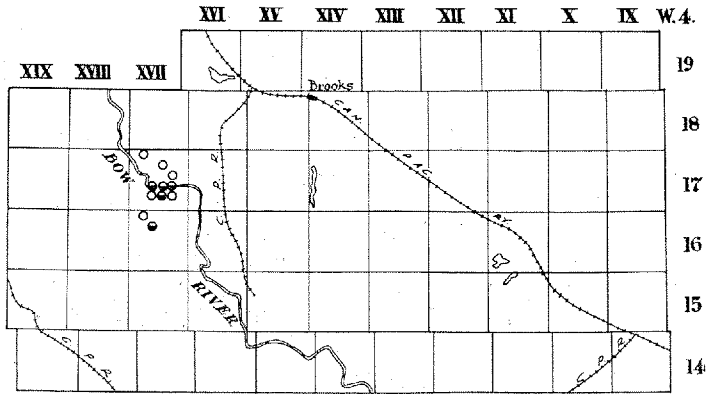
BROOKS AREA

The mines produce an Alberta domestic coal—free burning and smokeless. According to Canadian classification it is Subbituminous B.

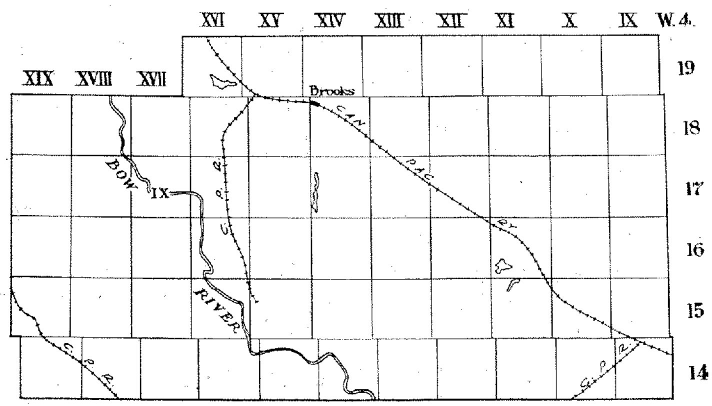
Two mines (one stripping pit) were operated in 1943 and the output was 30,000 tons. The area is served by the main line and branch lines of the Canadian Pacific Railway, but the mines opened have not been adjacent to a railway.

Map 17 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 18 shows the location of operating mines graded by output in 1943.



MAP 17



MAP 18

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate		Ultimate (with 17.4% moisture)	
Moisture	% 17.4	Carbon	% 54.65
Ash	% 11.9	Hydrogen	% 5.75
Volatile matter	% 31.1	Sulphur	% 0.7
Fixed carbon	% 39.6	Nitrogen	% 1.2
		Oxygen	% 25.8
		Ash	% 11.9

Fuel ratio (FC/VM), 1.25.

Calorific value, gross, in B.t.u. per lb., 9,280.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

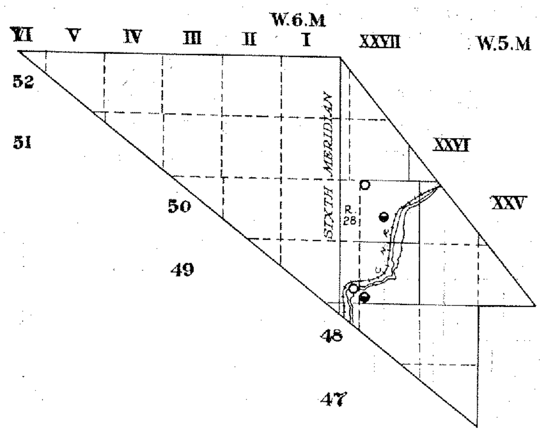
Fixed carbon = 58.0 — 0.58(M+1.20A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 13,400 — 134(M+1.12A)

BRULE AREA

No mine has operated since 1928. The coal previously mined is the type generally known as bituminous, steam coal; it is coking and weather resistant. The Canadian classification is Low Volatile Bituminous. The coal occurs in the Kootenay horizon; more than one seam has been mined.

In addition to the typical analyses given below reference has been made to coal from this area in the following sections of this report: fusibility of coal ash, coal sizing, carbonization (L.T.C.) and smithy coal.

Map 19 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.



MAP 19

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate			Ultimate (with 1.0% moisture)		
Moisture	%	1.0	Carbon	%	76.2
Ash	%	13.9	Hydrogen	%	4.9
Volatile matter	%	18.8	Sulphur	%	0.4
Fixed carbon	%	66.3	Nitrogen	%	1.2
			Oxygen	%	3.4
			Ash	%	13.9

Fuel ratio (FC/VM), 3.5.

Calorific value, gross, in B.t.u. per lb., 13,170.

The net calorific value of this coal is approximately 450 B.t.u. per lb. lower than the gross value.

CAMROSE AREA

The mines produce an Alberta domestic coal—free burning and smokeless. Two ranks of coal are mined, according to the Canadian classification; the principal output is Subbituminous C, but some Subbituminous B is also mined. Several seams are known, all in the Edmonton horizon.

Six mines (four stripping pits) were operated in 1943 and the output was 64,000 tons. The area is served by branches of both the

Canadian National and the Canadian Pacific railways. Most of the mines are close to a railway.

Volume Weight Relation

Solid coal as in seam

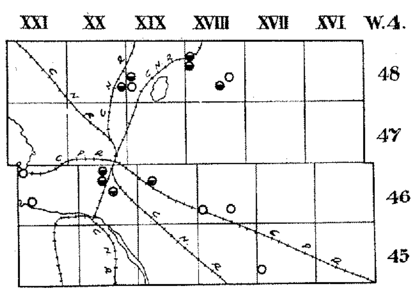
Percentage of Ash	5	10
Specific gravity	1.30	1.33
Tons per hundred cubic feet	4.05	4.15
Tons per acre foot	1,760	1,800

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: fusibility of coal ash and coal sizing.

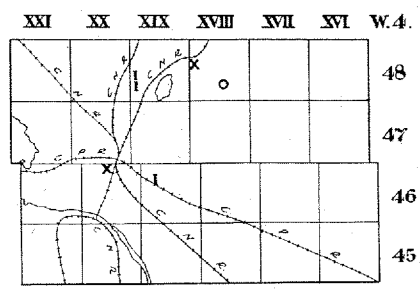
Map 20 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 21 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 20



MAP 21

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	46	XIX-XX
B	48	XIX-XX
C	48	XVIII

DISTRICT A

Canadian classification—Subbituminous C and also Subbituminous B

Typical Analyses

Proximate		Ultimate (with 25.2% moisture)	
Moisture %	25.2	Carbon %	52.4
Ash %	5.2	Hydrogen %	6.3
Volatile matter %	29.2	Sulphur %	0.3
Fixed carbon %	40.4	Nitrogen %	1.1
		Oxygen %	34.7
		Ash %	5.2

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb, 9,080.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.22A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,100 — 131(M+1.05A)

DISTRICT B

Canadian classification—Subbituminous C

Typical Analyses

Proximate			Ultimate (with 26.4% moisture)		
Moisture	%	26.4	Carbon	%	51.05
Ash	%	5.2	Hydrogen	%	6.35
Volatile matter	%	28.9	Sulphur	%	0.4
Fixed carbon	%	39.5	Nitrogen	%	1.0
			Oxygen	%	36.0
			Ash	%	5.2

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 8,680.

The net calorific value of this coal is approximately 580 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.28A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,800 — 128(M+1.13A)

DISTRICT C

This is the main producing district in this area.

Canadian classification—Subbituminous C

Typical Analyses

Proximate			Ultimate (with 28.4% moisture)		
Moisture	%	28.4	Carbon	%	50.25
Ash	%	4.5	Hydrogen	%	6.55
Volatile matter	%	28.7	Sulphur	%	0.4
Fixed carbon	%	38.4	Nitrogen	%	1.0
			Oxygen	%	37.3
			Ash	%	4.5

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 8,540.

The net calorific value of this coal is approximately 600 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	58.0 — 0.58(M+1.18A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,800 — 128(M+1.08A)

CARBON AREA

The mines produce an Alberta domestic coal—free burning and smokeless. Two ranks of coal are mined according to the Canadian classification, principally Subbituminous B, but also some Subbituminous A. Several seams are known, but production is principally from two seams. All are in the Edmonton horizon.

Thirteen mines (two stripping pits) were operated in 1943 and the output was 68,000 tons. The area is well served by the Canadian National and the Canadian Pacific railways; and most of the production is from mines on a railway.

Volume Weight Relation

Solid coal as in seam

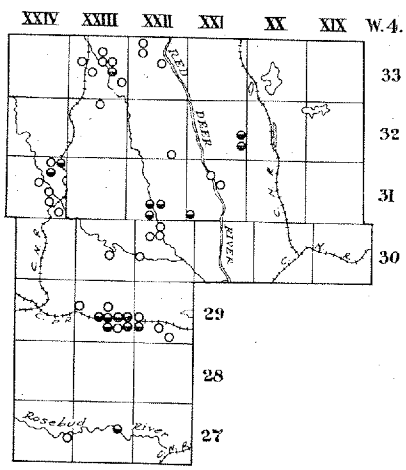
Percentage of Ash	5	10
Specific gravity	1.33	1.38
Tons per hundred cubic feet	4.15	4.30
Tons per acre foot	1,800	1,860

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), solubility in alkalies and carbonization (L.T.C.).

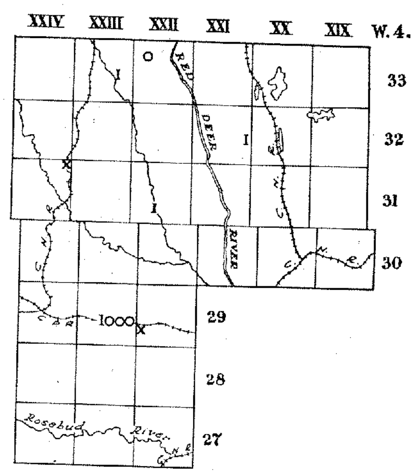
Map 22 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 23 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 22



MAP 23

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	31-33	XXII-XXIV
B	31-32	XXI
C	29	XXII-XXIII

DISTRICT A

This is the principal producing district.
Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 17.4% moisture)	
Moisture	% 17.4	Carbon	% 57.0
Ash	% 9.1	Hydrogen	% 5.6
Volatile matter	% 28.3	Sulphur	% 0.3
Fixed carbon	% 45.2	Nitrogen	% 0.9
		Oxygen	% 27.1
		Ash	% 9.1

Fuel ratio (FC/VM), 1.60.
Calorific value, gross, in B.t.u. per lb., 9,680.
The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 62.0 — 0.62(M+1.06A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 13,400 — 134(M+1.14A)

DISTRICT B

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 19.3% moisture)	
Moisture	% 19.3	Carbon	% 55.5
Ash	% 8.1	Hydrogen	% 5.9
Volatile matter	% 29.6	Sulphur	% 0.3
Fixed carbon	% 43.0	Nitrogen	% 1.1
		Oxygen	% 29.1
		Ash	% 8.1

Fuel ratio (FC/VM), 1.45.
Calorific value, gross, in B.t.u. per lb., 9,380.
The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 61.0 — 0.61(M+1.26A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 13,100 — 131(M+1.13A)

DISTRICT C

Canadian classification—the coal in this district is on the border line between Subbituminous A and Subbituminous B

Typical Analyses

Proximate		**Ultimate** (with 16.5% moisture)	
Moisture	% 16.5	Carbon	% 57.8
Ash	% 8.8	Hydrogen	% 5.7
Volatile matter	% 31.1	Sulphur	% 0.3
Fixed carbon	% 43.6	Nitrogen	% 1.2
		Oxygen	% 26.2
		Ash	% 8.8

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 9,940.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 60.0 — 0.60(M+1.24A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 13,500 — 135(M+1.13A)

CASCADE AREA

The coal mined is a short flame, bituminous, steam coal, but is also suitable for domestic use. It is smokeless, non-coking and weather resistant. Most of the coal, according to the Canadian classification, is Low Volatile Bituminous, but some Semianthracite is also mined. There are at least twelve seams, eight of importance, all in the Kootenay horizon.

Two mines were operated in 1943. The output was 343,000 tons.

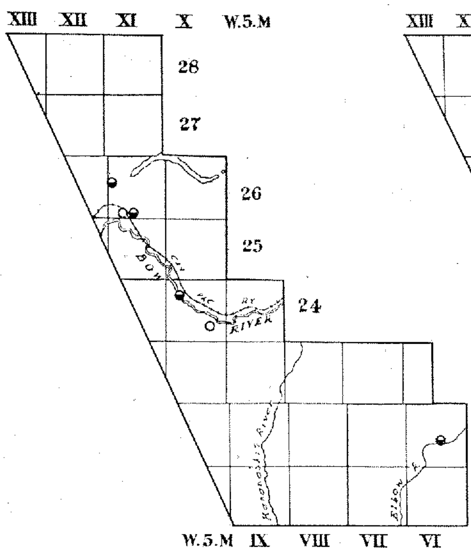
The operating mines are on the main line of the Canadian Pacific Railway. A briquetting plant is operated and 90,000 tons of coal were briquetted in 1943.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: pulverizability and grindability, fusibility of coal ash, and solubility in alkalies.

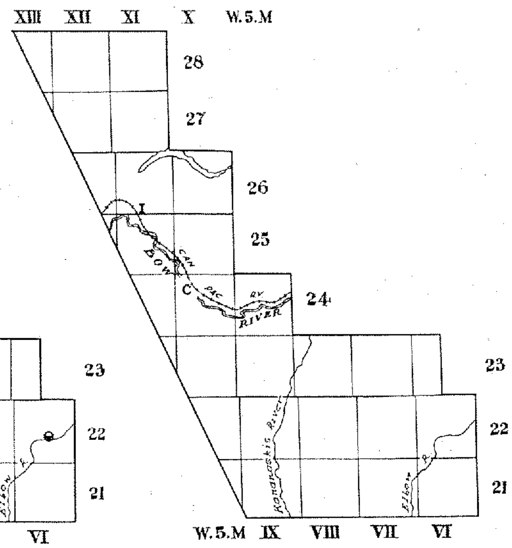
Map 24 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 25 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 24



MAP 25

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	26	XI
B	24	X
C	22	VI

DISTRICT A

The coal that has been mined—Canadian classification—is Semianthracite

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10
Specific gravity	1.36	1.42
Tons per hundred cubic feet	4.20	4.40
Tons per acre foot	1,840	1,920

Typical Analyses

Proximate			**Ultimate** (with 1.5% moisture)		
Moisture	%	1.5	Carbon	%	82.7
Ash	%	7.9	Hydrogen	%	3.8
Volatile matter	%	10.4	Sulphur	%	0.7
Fixed carbon	%	80.2	Nitrogen	%	1.2
			Oxygen	%	3.7
			Ash	%	7.9

Fuel ratio (FC/VM), 7.7.

Calorific value, gross, in B.t.u. per lb., 14,170.

The net calorific value of this coal is approximately 350 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	89.0 — 0.89(M+1.06A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,800 — 158(M+1.12A)

DISTRICT B

This is the largest producing district in the area.
Canadian classification—Low Volatile Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.34	1.39	1.44
Tons per hundred cubic feet	4.15	4.30	4.50
Tons per acre foot	1,820	1,880	1,940

Typical Analyses

Proximate			Ultimate (with 1.8% moisture)		
Moisture	%	1.8	Carbon	%	82.0
Ash	%	7.9	Hydrogen	%	4.2
Volatile matter	%	14.2	Sulphur	%	0.8
Fixed carbon	%	76.1	Nitrogen	%	1.6
			Oxygen	%	3.5
			Ash	%	7.9

Fuel ratio (FC/VM), 5.4.

Calorific value, gross, in B.t.u. per lb., 14,050.

The net calorific value of this coal is approximately 380 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	85.0 — 0.85(M+1.11A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,700 — 157(M+1.11A)

DISTRICT C

This district, remote from the railway, is not at present producing.
Canadian classification—Low Volatile Bituminous

One sample, from a mine now closed, had the following analysis:

Moisture	%	2.8
Ash	%	9.8
Volatile matter	%	16.4
Fixed carbon	%	71.0

Fuel ratio (FC/VM), 4.3.

Calorific value, gross, in B.t.u. per lb., 13,680.

CASTOR AREA

The mines produce an Alberta domestic coal—free burning and smokeless. Two ranks of coal are mined, according to the Canadian classification; the principal output is Subbituminous C, but some Subbituminous B is also mined. Several seams are known and mined, all in the Edmonton horizon.

Twenty-eight mines (three stripping pits) were operated in 1943 and the output was 60,000 tons. The area is well served by both the Canadian National and the Canadian Pacific railways, but many of the mines are on the banks of the Battle River.

Volume Weight Relation

Solid coal as in seam

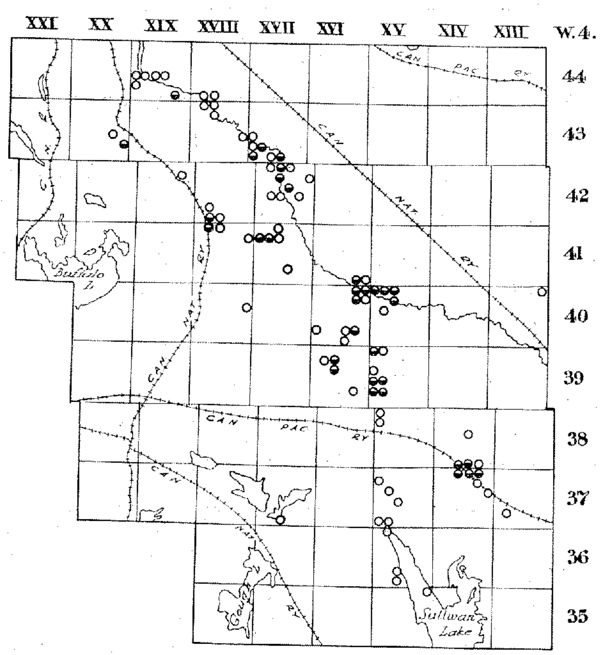
Percentage of Ash	5	10	15
Specific gravity	1.30	1.34	1.39
Tons per hundred cubic feet	4.05	4.20	4.30
Tons per acre foot	1,760	1,820	1,880

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: solubility in alkalies, carbonization (L.T.C.).

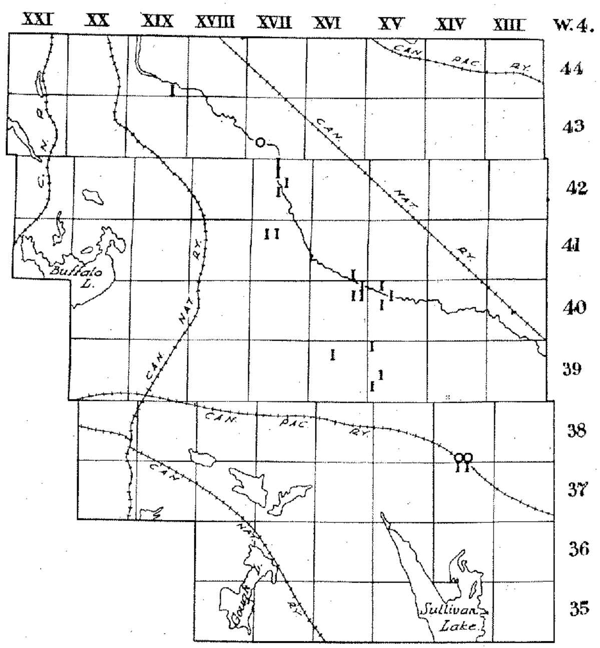
Map 26 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 27 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 26



MAP 27

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	41-44	XVII-XX
B	39-41	XV-XVI
C	37-38	XIV

DISTRICT A

Canadian classification—Subbituminous B and Subbituminous C

Typical Analyses

Proximate		Ultimate (with 25.2% moisture)	
Moisture	% 25.2	Carbon	% 50.9
Ash	% 6.7	Hydrogen	% 6.2
Volatile matter	% 29.0	Sulphur	% 0.4
Fixed carbon	% 39.1	Nitrogen	% 1.0
		Oxygen	% 34.8
		Ash	% 6.7

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 8,710.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = $59.0 - 0.59(M + 1.26A)$

Volatile matter = $100 - (M + A + FC)$

Calorific value, B.t.u./lb. = $12{,}800 - 128(M + 1.00A)$

DISTRICT B

This is the main producing district.
Canadian classification—Subbituminous C

Typical Analyses

Proximate		Ultimate (with 26.4% moisture)	
Moisture	% 26.4	Carbon	% 50.25
Ash	% 6.3	Hydrogen	% 6.35
Volatile matter	% 29.0	Sulphur	% 0.4
Fixed carbon	% 38.3	Nitrogen	% 0.9
		Oxygen	% 35.8
		Ash	% 6.3

Fuel ratio (FC/VM), 1.30.
Calorific value, gross, in B.t.u. per lb., 8,550.
The net calorific value of this coal is approximately 580 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = $58.0 - 0.58(M+1.22A)$
Volatile matter = $100 - (M+A+FC)$
Calorific value, B.t.u./lb. = $12{,}900 - 129(M+1.17A)$

DISTRICT C

Canadian classification—Subbituminous C

Typical Analyses

Proximate		Ultimate (with 29.5% moisture)	
Moisture	% 29.5	Carbon	% 47.0
Ash	% 6.2	Hydrogen	% 6.5
Volatile matter	% 28.6	Sulphur	% 0.4
Fixed carbon	% 35.7	Nitrogen	% 0.9
		Oxygen	% 39.0
		Ash	% 6.2

Fuel ratio (FC/VM), 1.25.
Calorific value, gross, in B.t.u. per lb., 7,980.
The net calorific value of this coal is approximately 590 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = $57.0 - 0.57(M+1.28A)$
Volatile matter = $100 - (M+A+FC)$
Calorific value, B.t.u./lb. = $12{,}500 - 125(M+1.07A)$

CHAMPION AREA

The mines produce an Alberta domestic coal—free burning and smokeless. Two ranks of coal are mined according to the Canadian classification, Subbituminous A and also Subbituminous B. Several seams are known, all in the Edmonton horizon.

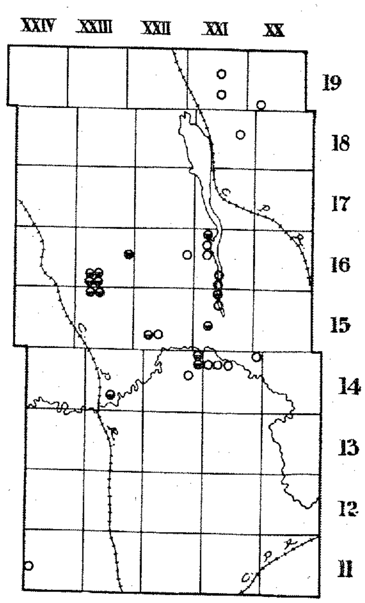
Four mines were operated in 1943 and the output was 12,000 tons. The area is served by three branches of the Canadian Pacific Railway, but none of the mines is on a railway.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: solubility in organic solvents, solubility in alkalies.

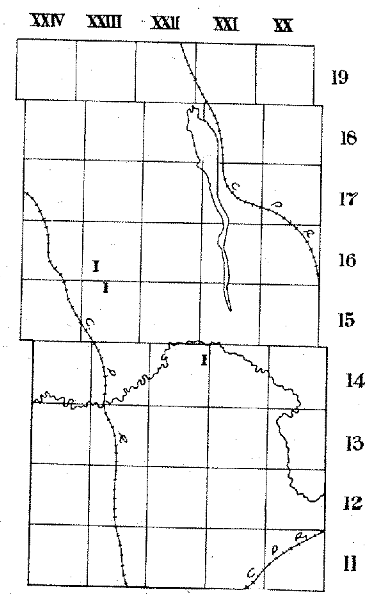
Map 28 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 29 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 28



MAP 29

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	14-16	XXIII
B	14-15	XXI-XXII
C	16	XXI

DISTRICT A

This is the largest producting district in the area.
Canadian classification—Subbituminous A

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.33	1.41	1.48
Tons per hundred cubic feet	4.15	4.40	4.60
Tons per acre foot	1,800	1,900	2,000

Typical Analyses

Proximate			**Ultimate** (with 12.7% moisture)		
Moisture	%	12.7	Carbon	%	61.5
Ash	%	7.4	Hydrogen	%	5.6
Volatile matter	%	34.9	Sulphur	%	0.5
Fixed carbon	%	45.0	Nitrogen	%	1.3
			Oxygen	%	23.7
			Ash	%	7.4

Fuel ratio, (FC/VM), 1.30.

Calorific value, gross, B.t.u. per lb., 10,690.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 57.0 - 0.57(M+1.16A)$

Volatile matter $= 100 - (M+A+FC)$

Calorific value, B.t.u./lb. $= 13{,}400 - 134(M+1.04A)$

DISTRICT B

Canadian classification—Subbituminous A

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.35	1.40	1.45
Tons per hundred cubic feet	4.20	4.35	4.50
Tons per acre foot	1,840	1,900	1,960

Typical Analyses

Proximate			**Ultimate** (with 14.9% moisture)		
Moisture	%	14.9	Carbon	%	60.2
Ash	%	7.1	Hydrogen	%	5.6
Volatile matter	%	31.9	Sulphur	%	0.9
Fixed carbon	%	46.1	Nitrogen	%	1.4
			Oxygen	%	24.8
			Ash	%	7.1

Fuel ratio (VC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 10,320.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	$60.0 - 0.60(M+1.18A)$
Volatile matter	=	$100 - (M+A+FC)$
Calorific value, B.t.u./lb.	=	$13{,}300 - 133(M+1.06A)$

DISTRICT C

Canadian classification—Subbituminous B

Typical Analysis
Proximate

Moisture	%	17.3
Ash	%	8.3
Volatile matter	%	32.1
Fixed carbon	%	42.3

Fuel ratio (FC/VM), 1.3.

Calorific value, gross, in B.t.u. per lb., 9,830.

COALSPUR AREA

The coal mined has been called Subbituminous; it is used both for power production and for domestic heating. It is free burning, slightly smoky, non-coking and weather resistant coal. According to Canadian classification it is High Volatile C Bituminous. Several seams are known, all in the Belly River horizon, but production is largely from three.

All mines opened in this area are on the Coal Branch of the Canadian National Railway. Six mines (two stripping pits) were operated in 1943 and the output was 713,000 tons. Coal cleaning plants are operated.

Volume Weight Relation

Solid coal as in seam

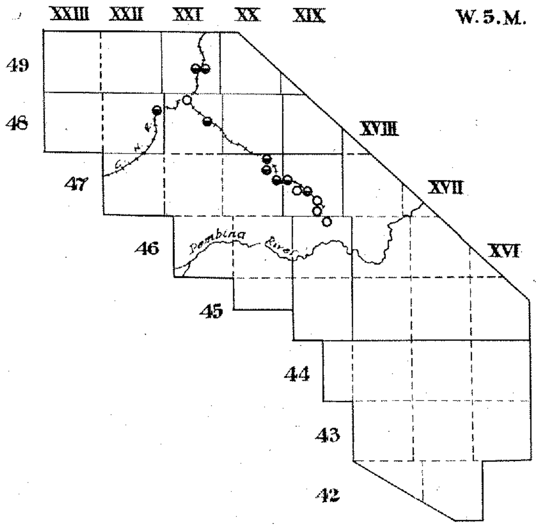
Percentage of Ash	5	10	15
Specific gravity	1.35	1.40	1.44
Tons per hundred cubic feet	4.20	4.35	4.50
Tons per acre foot	1,840	1,900	1,960

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, fusibility of coal ash, solubility in organic solvents, microstructure and spores, coal sizing, and carbonization (L.T.C.).

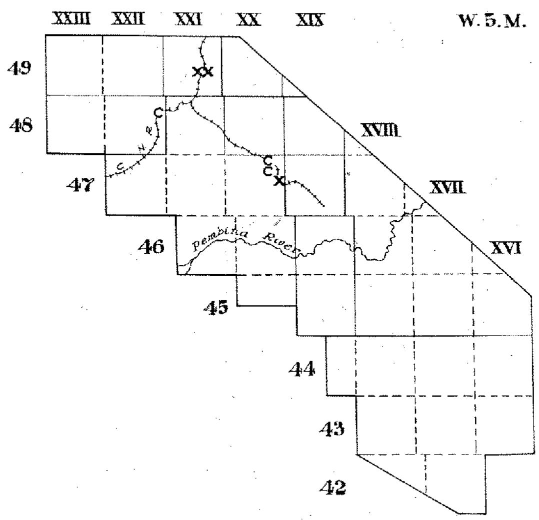
Map 30 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 31 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 30



MAP 31

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	49	XXI
B	48	XXI-XXII
	47	XX
C	47	XIX

DISTRICT A

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate		**Ultimate** (with 10.0% moisture)	
Moisture	% 10.0	Carbon	% 61.7
Ash	% 10.8	Hydrogen	% 5.0
Volatile matter	% 34.1	Sulphur	% 0.2
Fixed carbon	% 45.1	Nitrogen	% 0.5
		Oxygen	% 21.8
		Ash	% 10.8

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 10,570.

The net calorific value of this coal is approximately 460 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 59.0 — 0.59(M+1.26A)

Volatile matter = 100 — (M+A+FC)

Calorific value, B.t.u./lb. = 13,900 — 139(M+1.29A)

DISTRICT B

In this district coal cleaning plants are operated.

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate		**Ultimate** (with 8.3% moisture)	
Moisture	% 8.3	Carbon	% 65.15
Ash	% 9.2	Hydrogen	% 4.95
Volatile matter	% 34.8	Sulphur	% 0.2
Fixed carbon	% 47.7	Nitrogen	% 0.8
		Oxygen	% 19.7
		Ash	% 9.2

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 11,240.

The net calorific value of this coal is approximately 450 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 58.0 — 0.58(M+1.04A)

Volatile matter = 100 — (M+A+FC)

Calorific value, B.t.u./lb. = 13,800 — 138(M+1.12A)

DISTRICT C

The mines in this district have been closed.

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate		Ultimate (with 11.0% moisture)	
Moisture	% 11.0	Carbon	% 60.5
Ash	% 12.5	Hydrogen	% 5.0
Volatile matter	% 31.8	Sulphur	% 0.2
Fixed carbon	% 44.7	Nitrogen	% 0.9
		Oxygen	% 20.9
		Ash	% 12.5

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 10,400.

The net calorific value of this coal is approximately 460 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 61.0 - 0.61(M+1.26A)$

Volatile matter $= 100 - (M+A+FC)$

Calorific value, B.t.u./lb. $= 14{,}000 - 140(M+1.18A)$

CROWSNEST AREA

The coal mined is a bituminous, steam coal; it is coking and weather resistant. Most of the coal, according to the Canadian classification, is Medium Volatile Bituminous, but some High Volatile A Bituminous is also mined.

There are at least five seams of coal; but only three are of importance. All mines now operating are mining Kootenay horizon coal; but one small mine, now closed, mined Belly River horizon coal.

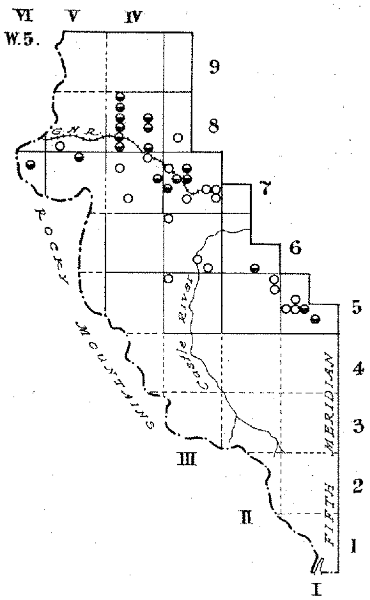
Eight mines were operated in 1943 and the output was 2,000,000 tons. The principal mines are on the Crowsnest line of the Canadian Pacific Railway. Several of these mines have coal cleaning plants, and at one mine there is a briquetting plant. At another mine a coke oven plant is operated and 101,000 tons of coal were coked in 1943.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, fusibility of coal ash, solubility in organic solvents, solubility in alkalies, coal sizing, carbonization (L.T.C.) and smithy coal.

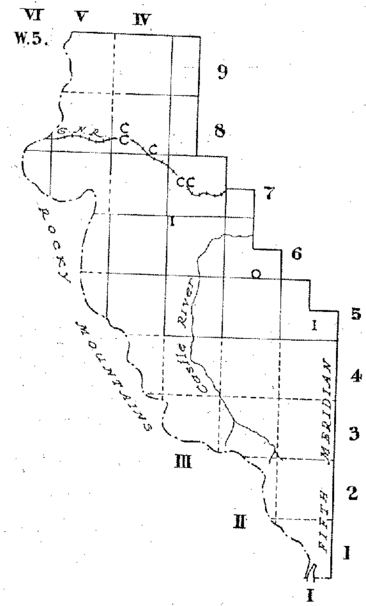
Map 32 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 33 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 4 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 32



MAP 33

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	8	IV
	7	VI
B	7	V
C	7	III-IV
	6	III
D	6	II
	5	I

DISTRICT A

This is one of the two main producing districts in the area; three seams have been mined. A briquetting plant, coke ovens, and coal cleaning plants are operated in this district.

Canadian classification—Medium Volatile Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.30	1.36	1.41
Tons per hundred cubic feet	4.05	4.25	4.40
Tons per acre foot	1,760	1,840	1,920

Typical Analyses

Proximate		Ultimate (with 1.5% moisture)	
Moisture	% 1.5	Carbon	% 73.6
Ash	% 14.3	Hydrogen	% 4.4
Volatile matter	% 23.6	Sulphur	% 0.5
Fixed carbon	% 60.6	Nitrogen	% 1.1
		Oxygen	% 6.1
		Ash	% 14.3

Fuel ratio (FC/VM), 2.6.

Calorific value, gross, in B.t.u. per lb., 12,860.

The net calorific value of this coal is approximately 400 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 74.0 — 0.74(M+1.16A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 15,700 — 157(M+1.16A)

DISTRICT B

No mine at present operating in this district.

Canadian classification—High Volatile A Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.30	1.34	1.39
Tons per hundred cubic feet	4.05	4.15	4.30
Tons per acre foot	1,760	1,820	1,880

Typical Analyses

Proximate		Ultimate (with 4.0% moisture)	
Moisture	% 4.0	Carbon	% 67.65
Ash	% 13.9	Hydrogen	% 5.15
Volatile matter	% 35.5	Sulphur	% 1.2
Fixed carbon	% 46.6	Nitrogen	% 2.0
		Oxygen	% 10.1
		Ash	% 13.9

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 12,100.

The net calorific value of this coal is approximately 470 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 57.0 — 0.57(M+1.02A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 15,000 — 150(M+1.10A)

DISTRICT C

This is one of the two main producing districts in the area; three seams have been mined. Coal cleaning plants are operated in this district.

Canadian classification—Medium Volatile Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.29	1.36	1.42
Tons per hundred cubic feet	4.00	4.25	4.40
Tons per acre foot	1,760	1,840	1,920

Typical Analyses

Proximate			**Ultimate** (with 1.5% moisture)		
Moisture	%	1.5	Carbon	%	72.8
Ash	%	14.3	Hydrogen	%	4.6
Volatile matter	%	24.2	Sulphur	%	0.5
Fixed carbon	%	60.0	Nitrogen	%	1.1
			Oxygen	%	6.7
			Ash	%	14.3

Fuel ratio (FC/VM), 2.5.

Calorific value, gross, in B.t.u. per lb., 12,830.

The net calorific value of this coal is approximately 420 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	$71.0 - 0.71(M+1.18A)$
Volatile matter	=	$100 - (M+A+FC)$
Calorific value, B.t.u./lb.	=	$15{,}500 - 155(M+1.10A)$

DISTRICT D

This is a relatively unimportant district, and the mines are distant from the railway.

Canadian classification—High Volatile A Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.33	1.37	1.42
Tons per hundred cubic feet	4.15	4.25	4.40
Tons per acre foot	1,800	1,860	1,920

Typical Analyses

Proximate		Ultimate (with 3.3% moisture)	
Moisture	% 3.3	Carbon	% 72.8
Ash	% 10.2	Hydrogen	% 5.0
Volatile matter	% 31.3	Sulphur	% 1.7
Fixed carbon	% 55.2	Nitrogen	% 1.0
		Oxygen	% 9.3
		Ash	% 10.2

Fuel ratio (FC/VM), 1.75.

Calorific value, gross, in B.t.u. per lb., 12,940.

The net calorific value of this coal is approximately 460 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	64.0 — 0.64(M+1.03A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,200 — 152(M+1.14A)

DRUMHELLER AREA

The mines produce an Alberta domestic coal—free burning and smokeless. This is by far the most important area for the production of such coal, both for home and outside markets. According to the Canadian classification the coal is Subbituminous B. Numerous seams are known, all in the Edmonton horizon, and five seams have been mined. A full description of this area can be found in Research Council of Alberta Report 4 (1921) and also in Report 34 (1943), part V, page 188.

Twenty-seven mines were operated in 1943 and the output was 1,839,000 tons. The area is well served by the Canadian Pacific and Canadian National railways. The mines are adjacent to a railway, and a considerable portion of the market for this coal is outside the Province.

Volume Weight Relation

Solid coal as in seam

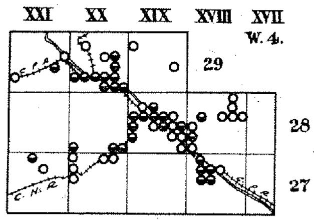
Percentage of Ash	5	10	15
Specific gravity	1.32	1.36	1.40
Tons per hundred cubic feet	4.10	4.25	4.35
Tons per acre foot	1,800	1,840	1,900

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, fusibility of coal ash, solubility in organic solvents, solubility in alkalies, coal sizing and carbonization (L.T.C.).

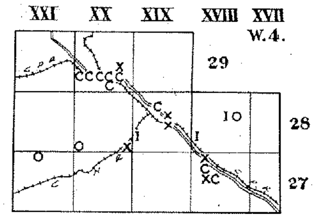
Map 34 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 35 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 34



MAP 35

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Seam	Township	Range
A_1	1	29	XX-XXI
A_7	5 & 7	29	XX-XXI
B_1	1	28	XVIII-XX
		27	XXI
B_2	2	28	XVIII-XX
		27	XXI
C	......	27	XVIII

DISTRICT A—Seam 1 or Lower Seam

Canadian classification—Subbituminous B

Typical Analyses

Proximate		**Ultimate** (with 18.0% moisture)	
Moisture	% 18.0	Carbon	% 57.6
Ash	% 6.6	Hydrogen	% 5.7
Volatile matter	% 31.2	Sulphur	% 0.4
Fixed carbon	% 44.2	Nitrogen	% 1.2
		Oxygen	% 28.5
		Ash	% 6.6

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, B.t.u. per lb., 10,020.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	$= 60.0 - 0.60(M+1.26A)$
Volatile matter	$= 100 - (M+A+FC)$
Calorific value, B.t.u./lb.	$= 13{,}400 - 134(M+1.10A)$

DISTRICT A—Seams 5 and 7 or Upper Seams

Canadian classification—Subbituminous B

Typical Analyses

Proximate		**Ultimate** (with 18.8% moisture)	
Moisture	% 18.8	Carbon	% 57.1
Ash	% 6.1	Hydrogen	% 5.8
Volatile matter	% 30.3	Sulphur	% 0.4
Fixed carbon	% 44.8	Nitrogen	% 1.2
		Oxygen	% 29.4
		Ash	% 6.1

Fuel ratio (FC/VM), 1.50.

Calorific value, gross, in B.t.u. per lb., 9,870.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	60.0 — 0.60(M+1.08A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,400 — 134(M+1.24A)

DISTRICT B—Seam 1 or Lower Seam

Canadian classification—Subbituminous B

Typical Analyses

Proximate			Ultimate (with 18.8% moisture)		
Moisture	%	18.8	Carbon	%	56.7
Ash	%	6.9	Hydrogen	%	5.9
Volatile matter	%	31.3	Sulphur	%	0.5
Fixed carbon	%	43.0	Nitrogen	%	1.3
			Oxygen	%	28.7
			Ash	%	6.9

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 9,780.

The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.20A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,300 — 133(M+1.11A)

DISTRICT B—Seam 2 or Upper Seam

Canadian classification—Subbituminous B

Typical Analyses

Proximate			Ultimate (with 19.6% moisture)		
Moisture	%	19.6	Carbon	%	56.7
Ash	%	6.0	Hydrogen	%	5.9
Volatile matter	%	30.2	Sulphur	%	0.4
Fixed carbon	%	44.2	Nitrogen	%	1.2
			Oxygen	%	29.8
			Ash	%	6.0

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, B.t.u. per lb., 9,730.

The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	60.0 — 0.60(M+1.12A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,300 — 133(M+1.20A)

DISTRICT C

Canadian classification—Subbituminous B

Typical Analyses

Proximate			Ultimate (with 20.2% moisture)		
Moisture	%	20.2	Carbon	%	54.5
Ash	%	7.6	Hydrogen	%	5.9
Volatile matter	%	30.1	Sulphur	%	0.5
Fixed carbon	%	42.1	Nitrogen	%	1.2
			Oxygen	%	30.3
			Ash	%	7.6

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 9,280.

The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	60.0 — 0.60(M+1.28A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,100 — 131(M+1.18A)

EDMONTON AREA

The mines in this area produce an Alberta domestic coal; but the coal is also largely used for power production. It is free burning and smokeless. Two ranks of coal are mined according to the Canadian classification—Subbituminous B and Subbituminous C. Ten seams are known, all of them in the Edmonton horizon.

Twenty-nine mines were operated in 1943 and the output was 457,000 tons. The area is served by the Canadian National, the Canadian Pacific and the Northern Alberta railways. The principal producing mines are adjacent to a railway.

Volume Weight Relation

Solid coal as in seam

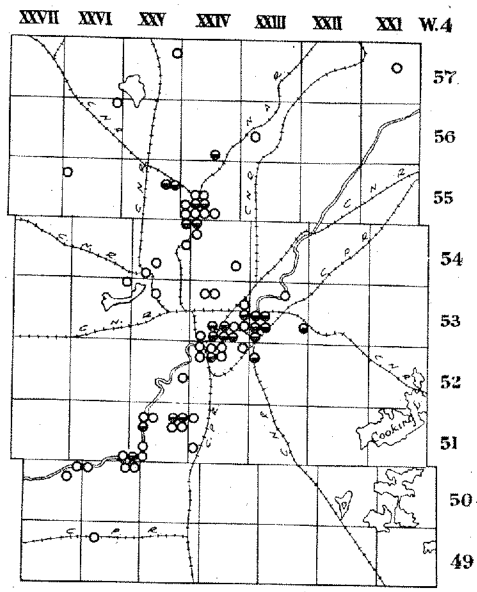
Percentage of Ash	5	10	15
Specific gravity	1.31	1.35	1.38
Tons per hundred cubic feet	4.10	4.20	4.30
Tons per acre foot	1,780	1,820	1,880

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), fusibility of coal ash, solubility in organic solvents, coal sizing, and carbonization (L.T.C.).

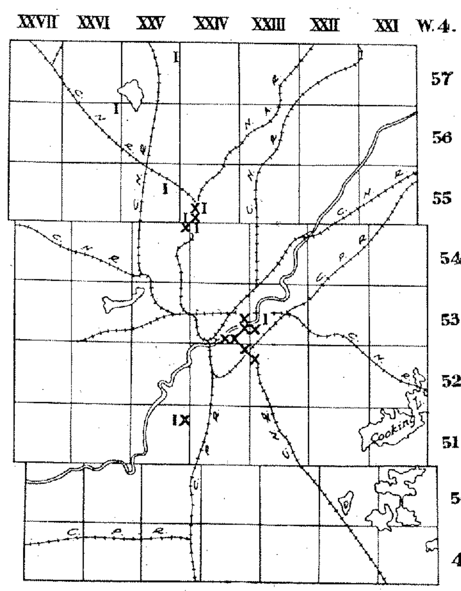
Map 36 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 37 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 36



MAP 37

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	54-56	XXIV-XXV
B	52-53	XXIII-XXIV
C	50-51	XXV-XXVI

DISTRICT A

Canadian classification—Subbituminous C and also Subbituminous B

Typical Analyses

Proximate		Ultimate (with 25.3% moisture)	
Moisture	% 25.3	Carbon	% 50.25
Ash	% 7.1	Hydrogen	% 6.15
Volatile matter	% 28.6	Sulphur	% 0.3
Fixed carbon	% 39.0	Nitrogen	% 1.0
		Oxygen	% 35.2
		Ash	% 7.1

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 8,640.

The net calorific value of this coal is approximately 560 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	60.0 — 0.60(M+1.36A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,800 — 128(M+1.02A)

DISTRICT B

This is the principal producing district in the area.

Canadian classification—Subbituminous B and Subbituminous C

Typical Analyses

Proximate		Ultimate (with 25.0% moisture)	
Moisture	% 25.0	Carbon	% 51.6
Ash	% 6.2	Hydrogen	% 6.2
Volatile matter	% 28.4	Sulphur	% 0.3
Fixed carbon	% 40.4	Nitrogen	% 1.0
		Oxygen	% 34.7
		Ash	% 6.2

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 8,860.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	60.0 — 0.60(M+1.24A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,900 — 129(M+1.02A)

DISTRICT C

The mines in this district are not as close to a railway as those in the other two districts.

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 23.3% moisture)	
Moisture	% 23.3	Carbon	% 53.5
Ash	% 6.5	Hydrogen	% 6.1
Volatile matter	% 28.5	Sulphur	% 0.3
Fixed carbon	% 41.7	Nitrogen	% 1.1
		Oxygen	% 32.5
		Ash	% 6.5

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 9,160.

The net calorific value of this coal is approximately 560 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

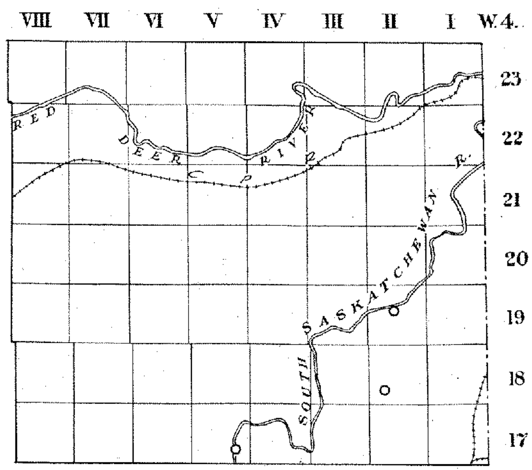
Fixed carbon $= 60.0 - 0.60(M + 1.10A)$

Volatile matter $= 100 - (M + A + FC)$

Calorific value, B.t.u./lb. $= 13{,}200 - 132(M + 1.12A)$

EMPRESS AREA

Map 38 shows the location of three recorded mines opened. No samples have been obtained.



MAP 38

Scale: 20 miles to 1 inch. For symbols see page 93.

GLEICHEN AREA

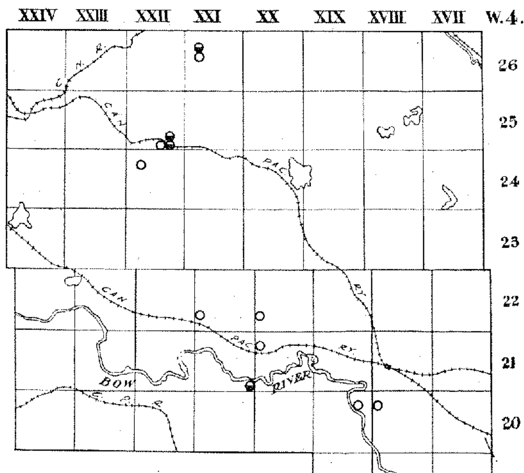
The mines produce an Alberta domestic coal, free burning and smokeless. According to the Canadian classification the coal is Subbituminous B. Three seams are known, all in the Edmonton horizon.

Five mines were operated in 1943 and the output was 21,000 tons. The area is served by the main line, and several branch lines, of the Canadian Pacific Railway, and one branch line of the Canadian National Railway.

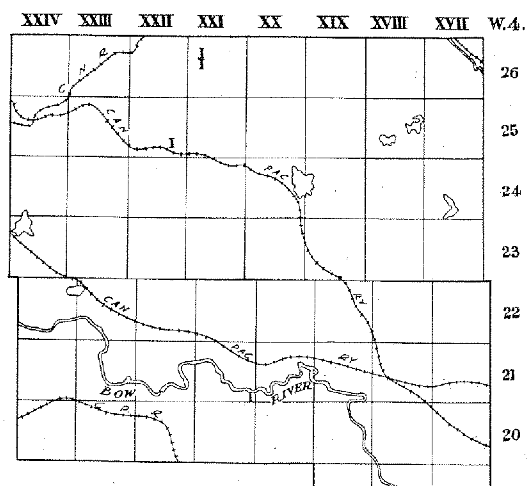
In addition to the typical and modified analyses given below reference has been made to coal from this area in the following section of this report: solubility in organic solvents.

Map 39 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 40 shows the location of operating mines graded by output in 1943.



MAP 39



MAP 40

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate		Ultimate (with 17.6% moisture)	
Moisture	% 17.6	Carbon	% 55.25
Ash	% 9.5	Hydrogen	% 5.75
Volatile matter	% 31.0	Sulphur	% 0.3
Fixed carbon	% 41.9	Nitrogen	% 1.1
		Oxygen	% 28.1
		Ash	% 9.5

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 9,570.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	61.0 — 0.61(M+1.44A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,400 — 134(M+1.16A)

HALCOURT AREA

The coal has so far been developed for the domestic market, but it could also be used for power production. The coal is an Alberta domestic; it is free burning, weather resistant and only slightly smoky. Two ranks of coal are mined, according to the Canadian classification—High Volatile C Bituminous from the west and Sub-bituminous B from the east of the area.

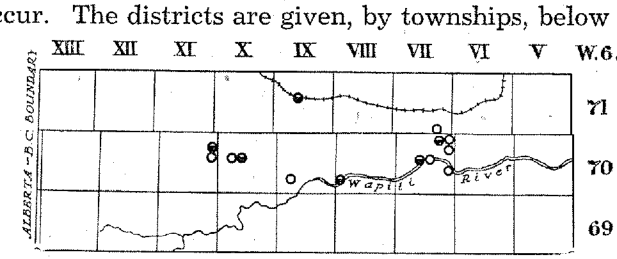
Several seams are known, but no thick seam has yet been found. These seams are all in the Belly River horizon. Five mines (two stripping pits) were operated in 1943 and the output was 1,900 tons. The Northern Alberta Railway Co. serves this area, but the operating mines are not on the railway.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following section of this report: storage (oxidation).

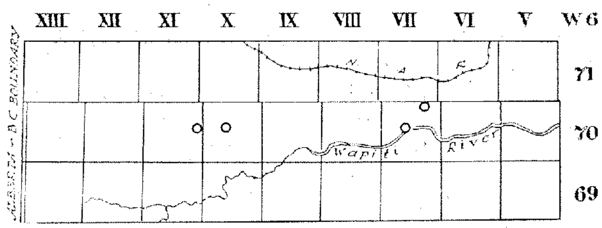
Map 41 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 42 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 41



MAP 42

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	70	VIII, X-XI
B	71	IX
	70	VII

DISTRICT A

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate			**Ultimate** (with 13.0% moisture)		
Moisture	%	13.0	Carbon	%	64.1
Ash	%	7.0	Hydrogen	%	5.8
Volatile matter	%	32.9	Sulphur	%	0.4
Fixed carbon	%	47.1	Nitrogen	%	1.4
			Oxygen	%	21.3
			Ash	%	7.0

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 11,290.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.04A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	14,100 — 141(M+1.00A)

DISTRICT B

Canadian classification—Subbituminous B

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.31	1.35	1.39
Tons per hundred cubic feet	4.10	4.20	4.35
Tons per acre foot	1,780	1,840	1,880

Typical Analyses

Proximate

Moisture	%	15.5
Ash	%	8.5
Volatile matter	%	30.7
Fixed carbon	%	45.3

Ultimate (with 15.5% moisture)

Carbon	%	60.6
Hydrogen	%	5.8
Sulphur	%	0.4
Nitrogen	%	1.3
Oxygen	%	23.4
Ash	%	8.5

Fuel ratio (FC/VM), 1.50.

Calorific value, gross, in B.t.u. per lb., 10,600.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = $60.0 - 0.60(M+1.06A)$

Volatile matter = $100 - (M+A+FC)$

Calorific value, B.t.u./lb. = $14{,}000 - 140(M+1.04A)$

HIGHWOOD AREA

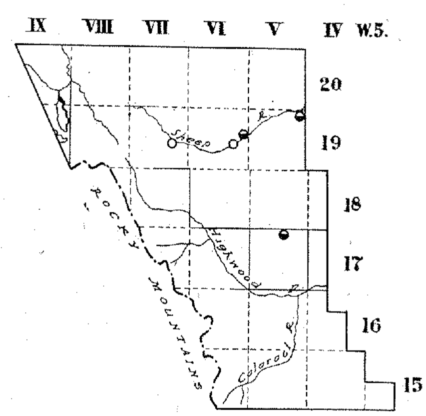
This area has so far been little developed, but if given railway connection to the Calgary-Macleod branch of the Canadian Pacific Railway might become an important producer.

The coal is a short flame, bituminous, steam coal; weather resistant. It is, according to Canadian classification, Low Volatile Bituminous.

Data with regard to the seams, and locations of prospects, are given in Research Council of Alberta Report No. 34 (1943), Part V, page 171.

No mine was operated in 1943.

Map 43 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.



MAP 43

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate		Ultimate (with 1.8% moisture)	
Moisture %	1.8	Carbon %	77.3
Ash %	12.3	Hydrogen %	4.1
Volatile matter %	16.3	Sulphur %	0.6
Fixed carbon %	69.6	Nitrogen %	1.1
		Oxygen %	4.6
		Ash %	12.3

Fuel ratio (FC/VM), 4.3.

Calorific value, gross, in B.t.u. per lb., 13,360.

The net calorific value of this coal is approximately 370 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 81.0 - 0.81(M + 1.00A)$

Volatile matter $= 100 - (M + A + FC)$

Calorific value, B.t.u./lb. $= 16{,}000 - 160(M + 1.20A)$

LETHBRIDGE AREA

The coal is an Alberta domestic coal, but it is similar to the coals of certain other areas that have been regarded as Subbituminous. It is free burning, weather resistant and slightly smoky. This coal is widely used for domestic heating and for power production. According to the Canadian classification it is High Volatile C Bituminous.

Several seams are known, but only one seam is extensively worked. All seams are in the Belly River horizon. Nine mines were operated in 1943 and the output was 579,000 tons. The area has good railway facilities. These include the Crowsnest line, and several branch lines of the Canadian Pacific Railway. This area ships a large tonnage of coal outside the Province.

Volume Weight Relation

Solid coal as in seam

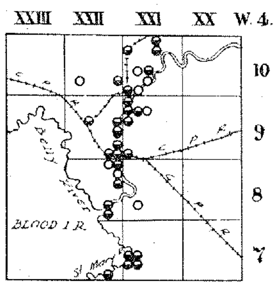
Percentage of Ash	5	10	15
Specific gravity	1.33	1.37	1.41
Tons per hundred cubic feet	4.15	4.25	4.40
Tons per acre foot	1,800	1,860	1,920

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), fusibility of coal ash, solubility in organic solvents, solubility in alkalies, microstructure and spores, and coal sizing.

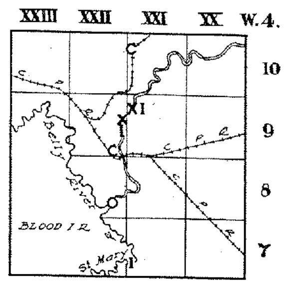
Map 44 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 45 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 44



MAP 45

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	9	XXI
	10	XXI-XXII
B	8-9	XXII
C	7	XXI-XXII

DISTRICT A

This is the main production district in the area.

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate			Ultimate (with 11.7% moisture)		
Moisture	%	11.7	Carbon	%	61.3
Ash	%	9.7	Hydrogen	%	5.5
Volatile matter	%	33.6	Sulphur	%	0.6
Fixed carbon	%	45.0	Nitrogen	%	1.5
			Oxygen	%	21.4
			Ash	%	9.7

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 10,680.

The net calorific value of this coal is approximately 500 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	$59.0 - 0.59(M + 1.24A)$
Volatile matter	=	$100 - (M + A + FC)$
Calorific value, B.t.u./lb.	=	$13{,}800 - 138(M + 1.12A)$

DISTRICT B

This is also a large production district.

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate		Ultimate (with 10.7% moisture)	
Moisture	% 10.7	Carbon	% 62.55
Ash	% 9.8	Hydrogen	% 5.55
Volatile matter	% 34.7	Sulphur	% 0.5
Fixed carbon	% 44.8	Nitrogen	% 1.5
		Oxygen	% 20.1
		Ash	% 9.8

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 10,960.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.36A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	14,100 — 141(M+1.18A)

DISTRICT C

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate		Ultimate (with 10.5% moisture)	
Moisture	% 10.5	Carbon	% 60.1
Ash	% 13.0	Hydrogen	% 5.4
Volatile matter	% 34.9	Sulphur	% 0.7
Fixed carbon	% 41.6	Nitrogen	% 1.3
		Oxygen	% 19.5
		Ash	% 13.0

Fuel ratio (FC/VM), 1.20.

Calorific value, gross, in B.t.u. per lb., 10,620.

The net calorific value of this coal is approximately 490 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	57.0 — 0.57(M+1.28A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	14,000 — 140(M+1.05A)

MAGRATH AREA

The coal mined is an Alberta domestic coal, but it is similar to the coals of certain other areas that have been regarded as Sub-bituminous. It is free burning, weather resistant and slightly smoky. Most of the coal, according to the Canadian classification, is High Volatile B Bituminous, but some High Volatile C Bituminous also has been mined.

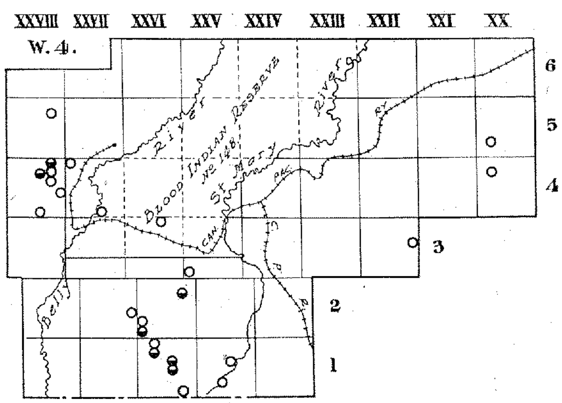
Coal production has been from thin seams in the Belly River horizon; but seams of younger age are known to occur. No mine operated in 1943. The area is served by branch lines of the Canadian Pacific Railway.

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.33	1.37	1.42
Tons per hundred cubic feet	4.15	4.25	4.40
Tons per acre foot	1,800	1,860	1,920

Map 46 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.



MAP 46

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate		Ultimate (with 7.0% moisture)	
Moisture %	7.0	Carbon %	65.65
Ash %	11.2	Hydrogen %	5.25
Volatile matter %	35.8	Sulphur %	0.7
Fixed carbon %	46.0	Nitrogen %	1.7
		Oxygen %	15.5
		Ash %	11.2

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 11,670.

The net calorific value of this coal is approximately 480 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	58.0 — 0.58 (M+1.22A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	14,300 — 143 (M+1.02A)

MILK RIVER AREA

The mines produce an Alberta domestic coal. It is free burning but slightly smoky. Two ranks of coal are mined, according to the Canadian classification, Subbituminous A and Subbituminous B.

Several thin seams occur. All seams are in the Belly River horizon. Two mines were operated (one a stripping pit) in 1943 and the output was 2,600 tons. This area is served by two branch lines of the Canadian Pacific Railway, but the operating mines are distant from the railway.

Volume Weight Relation

Solid coal as in seam

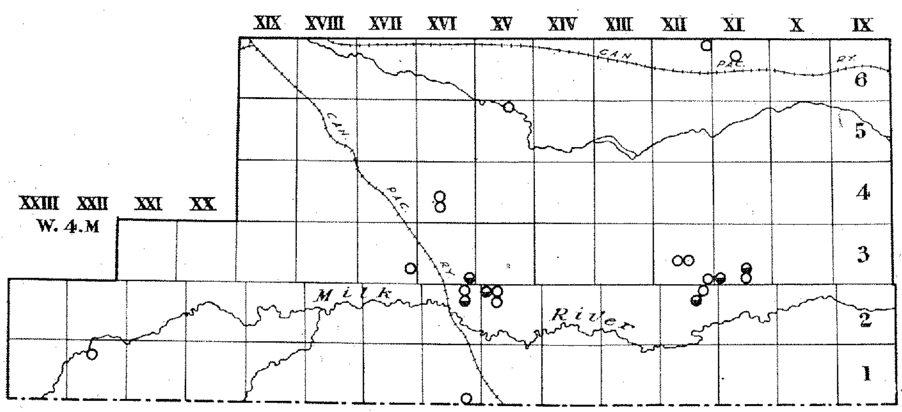
Percentage of Ash	5	10	15
Specific gravity	1.33	1.37	1.42
Tons per hundred cubic feet	4.15	4.25	4.40
Tons per acre foot	1,800	1,860	1,920

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following section of this report: storage (oxidation).

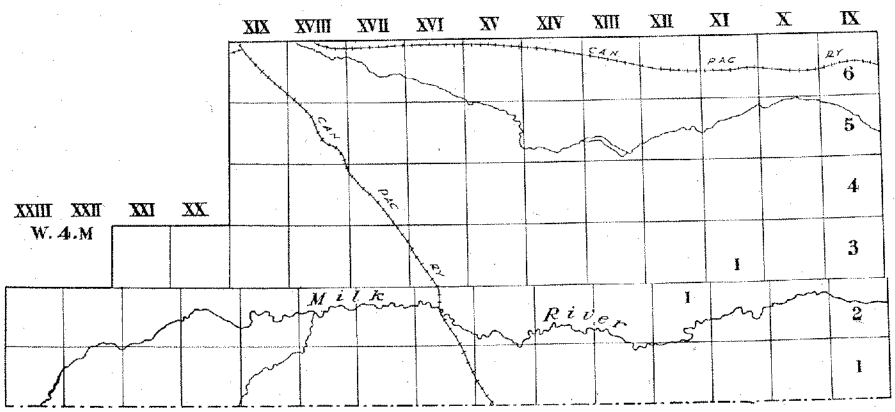
Map 47 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 48 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 47



MAP 48

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	2-3	XV-XVI
B	2-3	XI-XII

DISTRICT A

No mines listed as operating in this district.
Canadian classification—Subbituminous A

Typical Analyses

Proximate		**Ultimate** (with 14.0% moisture)	
Moisture	% 14.0	Carbon	% 57.25
Ash	% 12.0	Hydrogen	% 5.35
Volatile matter	% 30.2	Sulphur	% 0.9
Fixed carbon	% 43.8	Nitrogen	% 1.4
		Oxygen	% 23.1
		Ash	% 12.0

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 10,000.

The net calorific value of this coal is approximately 490 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 61.0 - 0.61(M + 1.18A)$
Volatile matter $= 100 - (M + A + FC)$
Calorific value, B.t.u./lb. $= 13{,}700 - 137(M + 1.08A)$

DISTRICT B

All coal mined in 1943 was from this district.
Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 19.8% moisture)	
Moisture	% 19.8	Carbon	% 55.3
Ash	% 8.8	Hydrogen	% 5.8
Volatile matter	% 29.3	Sulphur	% 0.7
Fixed carbon	% 42.1	Nitrogen	% 1.1
		Oxygen	% 28.3
		Ash	% 8.8

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 9,420.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

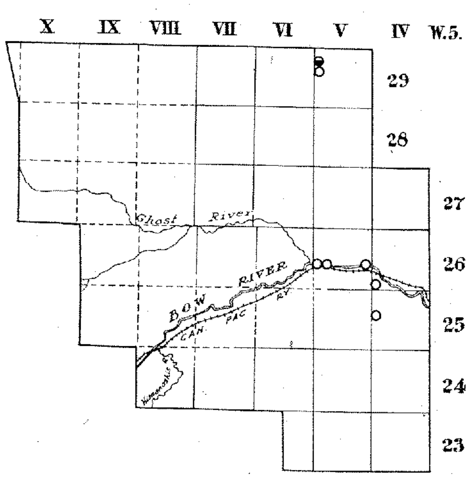
The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	$= 59.0 - 0.59(M+1.00A)$
Volatile matter	$= 100 - (M+A+FC)$
Calorific value, B.t.u./lb.	$= 13{,}500 - 135(M+1.18A)$

MORLEY AREA

This area, traversed by the main line of the Canadian Pacific Railway, had no producing mines in 1943; the seams occur in the Belly River horizon.

Map 49 shows the location of all recorded mines opened, and also indicates a mine from which a sample has been obtained.



MAP 49

Scale: 20 miles to 1 inch. For symbols see page 93.

The Canadian classification for sample (1) is High Volatile B Bituminous and for sample (2) from Morley Indian Reserve, location not shown on map, is High Volatile A Bituminous.

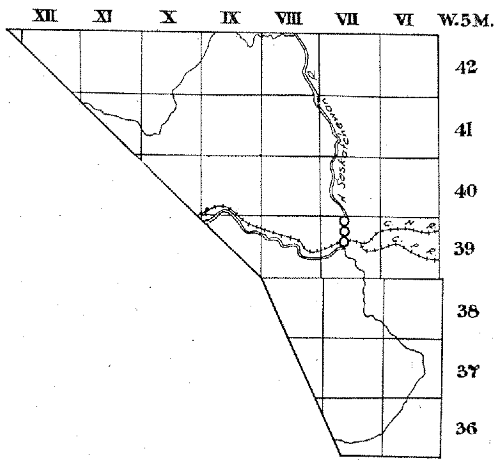
Two samples received had the following analyses:

Proximate

		(1)	(2)
Moisture	%	7.3	3.2
Ash	%	12.2	11.8
Volatile matter	%	33.3	36.3
Fixed carbon	%	47.2	48.7
Fuel ratio (FC/VM)		1.4	1.35
Calorific value, gross, in B.t.u. per lb.		11,290	12,770

MOUNTAIN HOUSE AREA

Map No. 50 shows the location of three recorded mines opened. No samples have been obtained.



MAP 50

Scale: 20 miles to 1 inch. For symbols see page 93.

MOUNTAIN PARK AREA

All mines operating are mining bituminous steam coal; it is coking and weather resistant. According to the Canadian classification, two ranks of coal are mined—Medium Volatile Bituminous and High Volatile A Bituminous.

There are several seams of coal being mined, all in the Kootenay horizon. Four mines were operated in 1943 and the output was 843,000 tons.

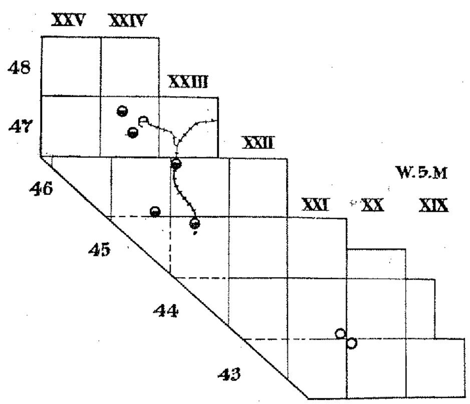
All the mines are on the Coalspur line of the Canadian National Railway. Coal cleaning plants are operated at three mines.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, solubility in organic solvents, coal sizing, and carbonization (L.T.C.).

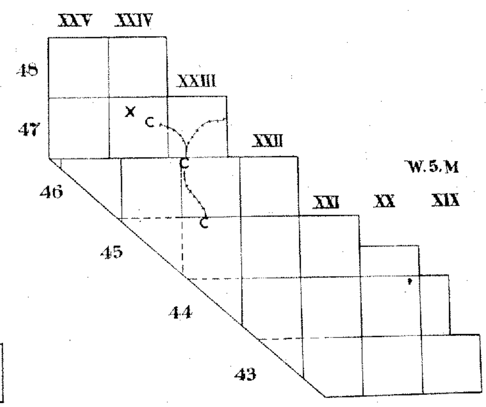
Map 51 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 52 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 51



MAP 52

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	47	XXIV
B	46	XXIII
C	45	XXIII

DISTRICT A

The coal mined in this district, according to Canadian classification, is mainly Medium Volatile Bituminous, but some High Volatile A Bituminous was mined from one entry.

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.31	1.38	1.45
Tons per hundred cubic feet	4.10	4.30	4.50
Tons per acre foot	1,780	1,880	1,960

Typical Analyses

Proximate

Moisture	%	1.6
Ash	%	12.8
Volatile matter	%	20.7
Fixed carbon	%	64.9

Ultimate (with 1.6% moisture)

Carbon	%	76.35
Hydrogen	%	4.35
Sulphur	%	0.3
Nitrogen	%	1.1
Oxygen	%	5.1
Ash	%	12.8

Fuel ratio (FC/VM), 3.1.

Calorific value, gross, in B.t.u. per lb., 13,310.

The net calorific value of this coal is approximately 400 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	76.0 — 0.76(M+1.02A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,900 — 159(M+1.15A)

DISTRICT B

Canadian classification—High Volatile A Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.29	1.35	1.41
Tons per hundred cubic feet	4.00	4.20	4.40
Tons per acre foot	1,740	1,840	1,920

Typical Analyses

Proximate

Moisture	%	1.8
Ash	%	10.8
Volatile matter	%	28.3
Fixed carbon	%	59.1

Ultimate (with 1.8% moisture)

Carbon	%	77.1
Hydrogen	%	4.7
Sulphur	%	0.3
Nitrogen	%	1.1
Oxygen	%	6.0
Ash	%	10.8

Fuel ratio (FC/VM), 2.1.

Calorific value, gross, in B.t.u. per lb., 13,500.

The net calorific value of this coal is approximately 430 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	69.0 — 0.69(M+1.16A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,700 — 157(M+1.13A)

DISTRICT C

Canadian classification—High Volatile A Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.29	1.33	1.38
Tons per hundred cubic feet	4.00	4.15	4.30
Tons per acre foot	1,740	1,800	1,860

Typical Analyses

Proximate		Ultimate (with 2.0% moisture)	
Moisture	% 2.0	Carbon	% 75.8
Ash	% 10.8	Hydrogen	% 4.8
Volatile matter	% 26.0	Sulphur	% 0.5
Fixed carbon	% 61.2	Nitrogen	% 1.2
		Oxygen	% 6.9
		Ash	% 10.8

Fuel ratio (FC/VM), 2.4.

Calorific value, gross, in B.t.u. per lb., 13,490.

The net calorific value of this coal is approximately 440 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	71.0 — 0.71(M+1.10A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,600 — 156(M+1.07A)

NORDEGG AREA

The one mine operating is mining a short flame, bituminous, steam coal. This coal may coke when fired but is not used for making coke; it is weather resistant. The Canadian classification of this coal is Low Volatile Bituminous.

There are at least five seams in this area, but only two are now being mined, both in the Kootenay horizon.

The mine in the area is on the Brazeau branch of the Canadian National Railway. The output for 1943 was 321,000 tons. A coal cleaning plant and a briquetting plant are operated; 118,000 tons of coal were briquetted during 1943.

Volume Weight Relation

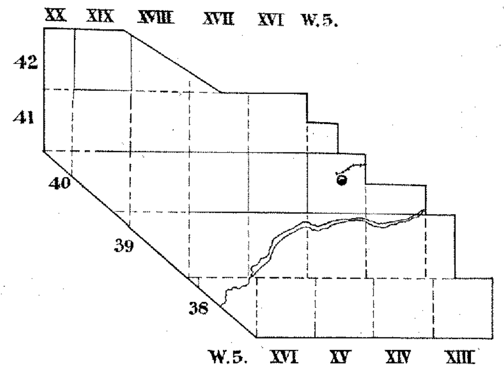
Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.32	1.36	1.41
Tons per hundred cubic feet	4.10	4.25	4.40
Tons per acre foot	1,780	1,840	1,900

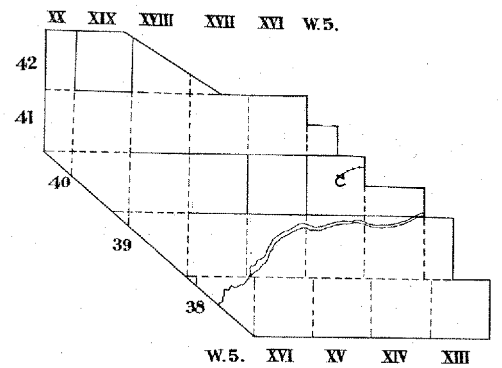
In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, fusibility of coal ash, solubility in organic solvents, and solubility in alkalies.

Map 53 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 54 shows the location of operating mines, graded by output in 1943.



MAP 53



MAP 54

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate			**Ultimate** (with 1.5% moisture)		
Moisture	%	1.5	Carbon	%	80.5
Ash	%	9.4	Hydrogen	%	4.3
Volatile matter	%	15.6	Sulphur	%	0.5
Fixed carbon	%	73.5	Nitrogen	%	1.2
			Oxygen	%	4.1
			Ash	%	9.4

Fuel ratio (FC/VM), 3.7.

Calorific value, gross, in B.t.u. per lb., 14,030.

The net calorific value of this coal is approximately 390 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	83.0 — 0.83(M+1.06A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	15,900 — 159(M+1.10A)

OLDMAN AREA

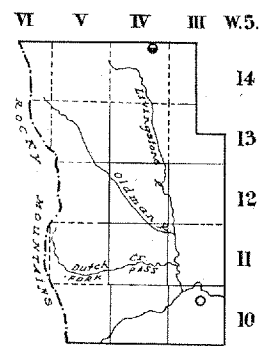
There are no operating mines in this area. The coal is a bituminous steam coal, weather resistant. According to the Canadian classification it is Medium Volatile Bituminous. There are no railways serving the area.

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10
Specific gravity	1.29	1.33
Tons per hundred cubic feet	4.05	4.15
Tons per acre foot	1,760	1,800

Map 55 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.



MAP 55

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate

Moisture	%	3.9
Ash	%	11.5
Volatile matter	%	22.4
Fixed carbon	%	62.2

Ultimate (with 3.9% moisture)

Carbon	%	74.2
Hydrogen	%	4.5
Sulphur	%	0.7
Nitrogen	%	1.0
Oxygen	%	8.1
Ash	%	11.5

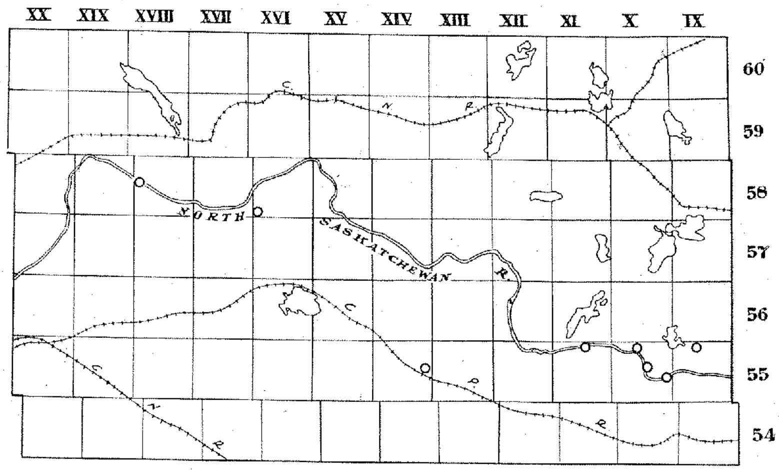
Fuel ratio (FC/VM), 2.8.

Calorific value, gross, in B.t.u. per lb., 13,000.

The net calorific value of this coal is approximately 410 B.t.u. per lb. lower than the gross value.

PAKAN AREA

Map 56 shows the location of all recorded mines opened. No samples have been obtained.



MAP 56

Scale: 20 miles to 1 inch. For symbols see page 93.

PAKOWKI AREA

The coal mined is an Alberta domestic coal. It is a free burning, smokeless coal, used locally for domestic heating. Two ranks of coal are mined according to the Canadian classification, Subbituminous C and Lignite.

Several seams are known, most of them in the Belly River horizon. One seam in the Cypress Hills, in the N.E. corner of the area, however, is in the Edmonton horizon. Three mines were operated in 1943 and the output was less than 500 tons. A branch line of the Canadian Pacific Railway crosses the area, but the mines opened have been distant from the railway.

Volume Weight Relation

Solid coal as in seam

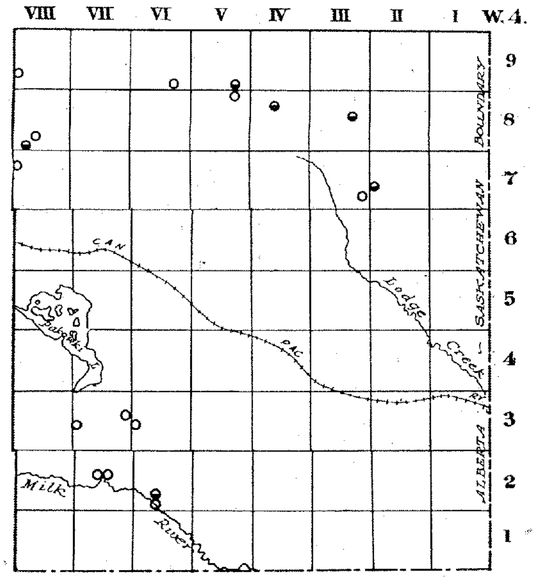
Percentage of Ash	5	10
Specific gravity	1.31	1.35
Tons per hundred cubic feet	4.05	4.20
Tons per acre foot	1,780	1,820

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: solubility in organic solvents, solubility in alkalies.

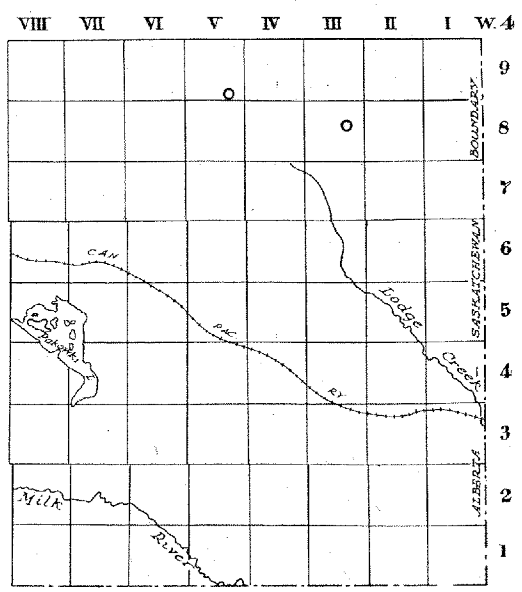
Map 57 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 58 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 57



MAP 58

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	8	VIII
	2	VI
B	9	V
	8	IV
C	8	III
	7	II

DISTRICT A

Canadian classification—Subbituminous C

Typical Analyses

Proximate		Ultimate (with 24.5% moisture)	
Moisture	% 24.5	Carbon	% 49.8
Ash	% 9.1	Hydrogen	% 6.0
Volatile matter	% 28.9	Sulphur	% 0.7
Fixed carbon	% 37.5	Nitrogen	% 1.0
		Oxygen	% 33.4
		Ash	% 9.1

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 8,440.

The net calorific value of this coal is approximately 550 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 57.0 - 0.57(M+1.07A)$
Volatile matter $= 100 - (M+A+FC)$
Calorific value, B.t.u./lb. $= 12{,}700 - 127(M+1.00A)$

DISTRICT B

Canadian classification—Subbituminous C and Lignite

Typical Analyses

Proximate		Ultimate (with 29.1% moisture)	
Moisture	% 29.1	Carbon	% 43.6
Ash	% 8.5	Hydrogen	% 6.2
Volatile matter	% 29.6	Sulphur	% 0.4
Fixed carbon	% 32.8	Nitrogen	% 0.8
		Oxygen	% 40.5
		Ash	% 8.5

Fuel ratio (FC/VM), 1.10.

Calorific value, gross, in B.t.u. per lb., 7,320.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 54.0 - 0.54(M+1.20A)$
Volatile matter $= 100 - (M+A+FC)$
Calorific value, B.t.u./lb. $= 12{,}400 - 124(M+1.40A)$

DISTRICT C

Canadian classification—Lignite

Typical Analyses

Proximate		Ultimate (with 33.6% moisture)	
Moisture %	33.6	Carbon %	40.8
Ash %	8.3	Hydrogen %	6.7
Volatile matter %	28.4	Sulphur %	0.2
Fixed carbon %	29.7	Nitrogen %	0.6
		Oxygen %	43.4
		Ash %	8.3

Fuel ratio (FC/VM), 1.05.

Calorific value, gross, in B.t.u. per lb., 6,870.

The net calorific value of this coal is approximately 610 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 53.0 — 0.53(M+1.26A)

Volatile matter = 100 — (M+A+FC)

Calorific value, B.t.u./lb. = 11,900 — 119(M+1.04A)

PEKISKO AREA

The coal mined has been called subbituminous; it is largely used locally for domestic heating, but is also suited for power production. It has coking tendencies and is weather resistant. According to Canadian classification it is High Volatile B Bituminous.

Several seams are known, all in the Belly River horizon. Two mines were operated in 1943 and the output was 12,000 tons. No railway enters this area.

Volume Weight Relation

Solid coal as in seam

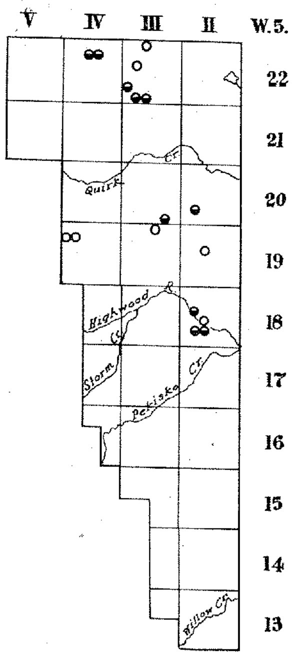
Percentage of Ash	5	10
Specific gravity	1.31	1.36
Tons per hundred cubic feet	4.10	4.25
Tons per acre foot	1,780	1,840

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following section of this report: storage (oxidation).

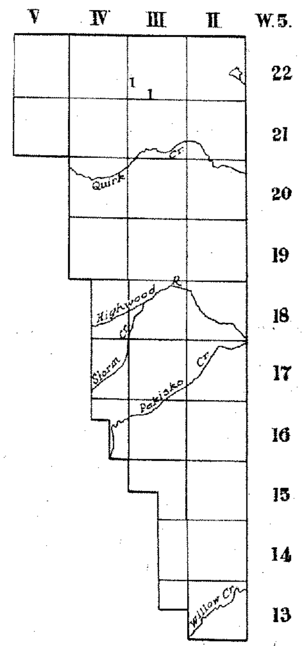
Map 59 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 60 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 59



MAP 60

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	20-22	III-IV
B	18-20	II

DISTRICT A

This district includes all mines now operating.

Canadian classification—High Volatile B Bituminous

Typical Analyses

Proximate		
Moisture	%	5.8
Ash	%	7.1
Volatile matter	%	36.8
Fixed carbon	%	50.3

Ultimate (with 5.8% moisture)		
Carbon	%	71.1
Hydrogen	%	5.6
Sulphur	%	0.6
Nitrogen	%	1.7
Oxygen	%	13.9
Ash	%	7.1

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 12,750.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon $= 58.0 - 0.58(M+1.06A)$

Volatile matter $= 100 - (M+A+FC)$

Calorific value, B.t.u./lb. $= 14{,}700 - 147(M+1.06A)$

DISTRICT B

Canadian classification—High Volatile B Bituminous

Typical Analyses

Proximate			Ultimate (with 8.0% moisture)		
Moisture	%	8.0	Carbon	%	67.25
Ash	%	9.2	Hydrogen	%	5.55
Volatile matter	%	36.1	Sulphur	%	0.6
Fixed carbon	%	46.7	Nitrogen	%	1.8
			Oxygen	%	15.6
			Ash	%	9.2

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 12,060.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59 (M + 1.40A)
Volatile matter	=	100 — (M + A + FC)
Calorific value, B.t.u./lb.	=	14,800 — 148 (M + 1.14A)

PEMBINA AREA

The mines produce an Alberta domestic coal; it is free burning and smokeless. According to the Canadian classification the coal is Subbituminous B. Two or more seams have been mined, all in the Edmonton horizon.

Six mines (two stripping pits) were operated in 1943 and the output was 54,000 tons. The area is crossed by three Canadian National railway lines. The principal production is on the main line of the C.N.R.

Volume Weight Relation

Solid coal as in seam

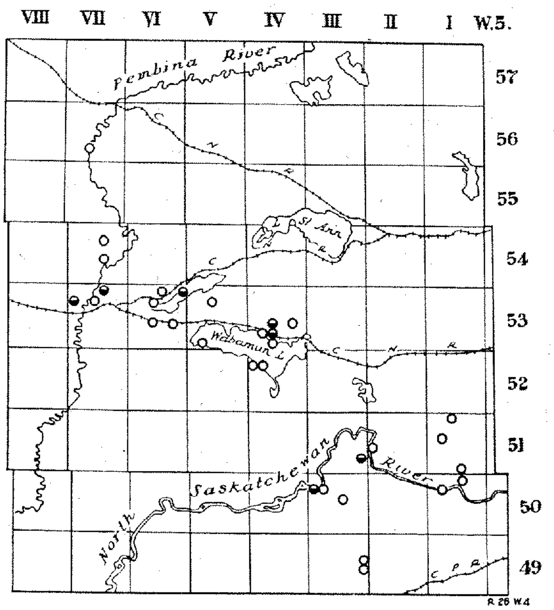
Percentage of Ash	5	10	15
Specific gravity	1.34	1.39	1.44
Tons per hundred cubic feet	4.15	4.30	4.45
Tons per acre foot	1,820	1,900	1,960

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following section of this report: coal sizing.

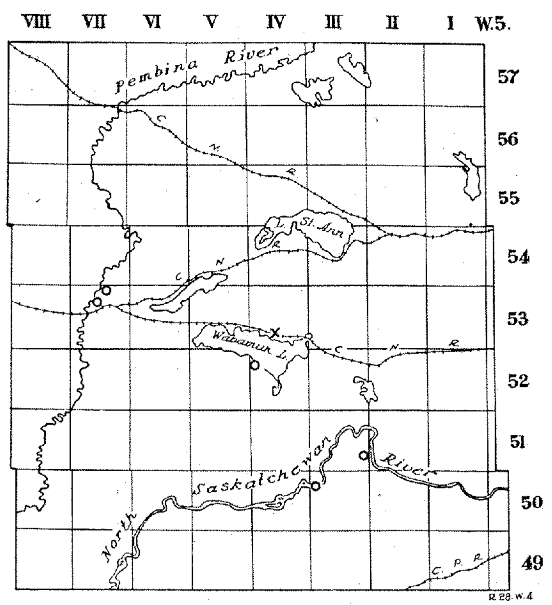
Map 61 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 62 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 3 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 61



MAP 62

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	53	VII
B	53	IV
C	50-51	III

DISTRICT A

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 19.3% moisture)	
Moisture	% 19.3	Carbon	% 53.8
Ash	% 10.3	Hydrogen	% 5.4
Volatile matter	% 26.7	Sulphur	% 0.2
Fixed carbon	% 43.7	Nitrogen	% 0.8
		Oxygen	% 29.5
		Ash	% 10.3

Fuel ratio (FC/VM), 1.65.

Calorific value, gross, in B.t.u. per lb., 9,070.

The net calorific value of this coal is approximately 490 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 63.0 — 0.63(M+1.10A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 13,000 — 130(M+1.06A)

DISTRICT B

This is now the main producing district.

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 21.4% moisture)	
Moisture	% 21.4	Carbon	% 53.0
Ash	% 8.0	Hydrogen	% 5.7
Volatile matter	% 28.3	Sulphur	% 0.8
Fixed carbon	% 42.3	Nitrogen	% 0.7
		Oxygen	% 31.8
		Ash	% 8.0

Fuel ratio (FC/VM), 1.50.

Calorific value, gross, in B.t.u. per lb., 8,920.

The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 62.0 — 0.62(M+1.30A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 12,900 — 129(M+1.18A)

DISTRICT C

This district is remote from a railway.
Canadian classification—Subbituminous B

Only two samples tested; an average analysis follows:

Proximate

Moisture	%	20.5
Ash	%	6.3
Volatile matter	%	28.7
Fixed carbon	%	44.5

Fuel ratio (FC/VM), 1.55.
Calorific value, gross, in B.t.u. per lb., 9,500.

PINCHER AREA

The coal mined has been called subbituminous; it is sold locally for domestic heating. It is a fair coking coal and is weather resistant. Three ranks of coal occur according to Canadian classification; the present production is High Volatile A Bituminous but High Volatile B, and High Volatile C Bituminous have also been mined.

Several seams are known, all in the Belly River horizon; but only two of these are of workable thickness. One mine was operated in 1943 and the output was 500 tons. This mine lies on the Crowsnest Branch of the Canadian Pacific Railway.

Volume Weight Relation

Solid coal as in seam

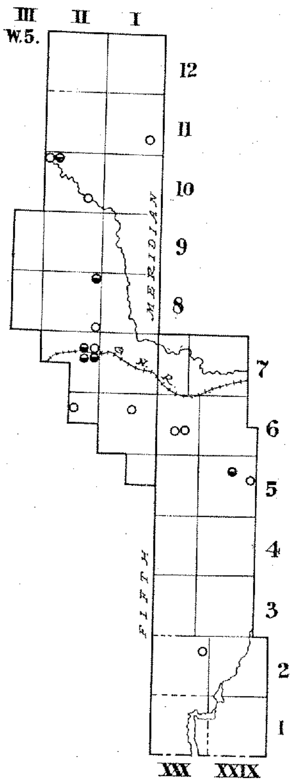
Percentage of Ash	5	10	15
Specific gravity	1.30	1.34	1.38
Tons per hundred cubic feet	4.05	4.15	4.30
Tons per acre foot	1,760	1,820	1,860

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: solubility in organic solvents, solubility in alkalies.

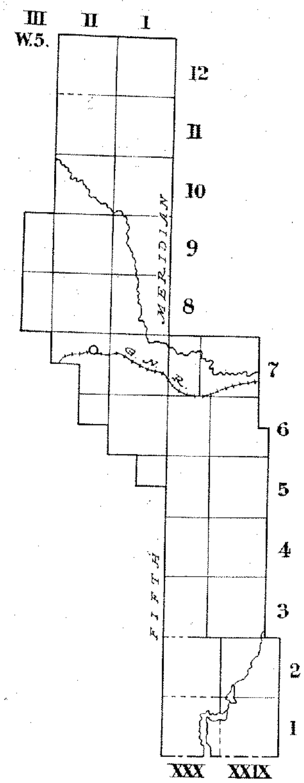
Map 63 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 64 shows the location of the operating mine graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 63



MAP 64

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range	Meridian
A	7-10	II	W 5
B	5	XXIX	W 4

DISTRICT A

The production now is from this district.

Canadian classification—High Volatile A Bituminous and High Volatile B Bituminous

Typical Analyses

Proximate		Ultimate (with 6.0% moisture)	
Moisture %	6.0	Carbon %	65.35
Ash %	14.6	Hydrogen %	5.25
Volatile matter %	35.2	Sulphur %	0.8
Fixed carbon %	44.2	Nitrogen %	1.7
		Oxygen %	12.3
		Ash %	14.6

Fuel ratio (FC/VM), 1.25.

Calorific value, gross, in B.t.u. per lb., 11,700.

The net calorific value of this coal is approximately 480 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	= 58.0 — 0.58(M+1.22A)
Volatile matter	= 100 — (M+A+FC)
Calorific value, B.t.u./lb.	= 15,000 — 150(M+1.10A)

DISTRICT B

Canadian classification—High Volatile C Bituminous

Only one sample has been received from this district, with analysis as follows:

Proximate

Moisture	%	7.5
Ash	%	14.6
Volatile matter	%	33.8
Fixed carbon	%	44.1

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 10,830.

PRAIRIE CREEK AREA

The mines are on the main line of the Canadian National Railway and the coal is sold for railway use. The coal is known as sub-bituminous; it is weather resistant. Two ranks of coal have been mined, according to Canadian classification, High Volatile B Bituminous and High Volatile C Bituminous. The seams occur in the Belly River horizon.

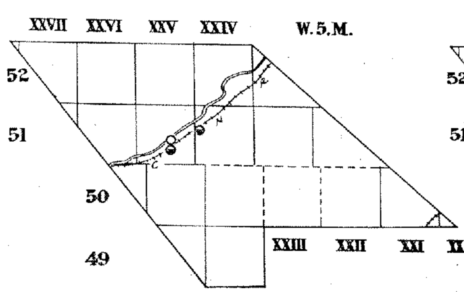
One mine was operated in 1943. The output for 1940 was 100,000 tons, and for 1943 was 1,900 tons.

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability.

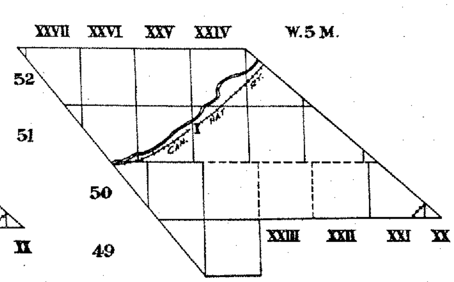
Map 65 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 66 shows the location of the operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 65



MAP 66

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	51	XXV
B	51	XXIV

DISTRICT A

This coal has coking tendencies

Canadian classification—High Volatile B Bituminous

Volume Weight Relation

Solid coal as in seam

Percentage of Ash	5	10	15
Specific gravity	1.31	1.35	1.39
Tons per hundred cubic feet	4.05	4.20	4.35
Tons per acre foot	1,780	1,820	1,880

Typical Analyses

Proximate

Moisture	%	7.0
Ash	%	10.7
Volatile matter	%	35.3
Fixed carbon	%	47.0

Ultimate (with 7.0% moisture)

Carbon	%	66.85
Hydrogen	%	5.35
Sulphur	%	0.3
Nitrogen	%	1.3
Oxygen	%	15.5
Ash	%	10.7

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 11,850.

The net calorific value of this coal is approximately 490 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 58.0 — 0.58(M+1.12A)

Volatile matter = 100 — (M+A+FC)

Calorific value, B.t.u./lb. = 14,900 — 149(M+1.26A)

DISTRICT B

Canadian classification—High Volatile C Bituminous

Typical Analyses

Proximate

Moisture	%	8.4
Ash	%	10.4
Volatile matter	%	34.2
Fixed carbon	%	47.0

Ultimate (with 8.4% moisture)

Carbon	%	64.7
Hydrogen	%	5.2
Sulphur	%	0.2
Nitrogen	%	0.8
Oxygen	%	18.7
Ash	%	10.4

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 11,200.

The net calorific value of this coal is approximately 470 B.t.u. per lb. lower than the gross value.

REDCLIFF AREA

The mines produce Alberta domestic coal, free burning and smokeless. According to the Canadian classification it is Subbituminous C coal.

The coal is mined from one seam in the Belly River horizon. Two mines were operated in 1943 and the output was 28,000 tons. The main line of the Canadian Pacific Railway crosses this area, and both mines are adjacent to the railway.

Volume Weight Relation

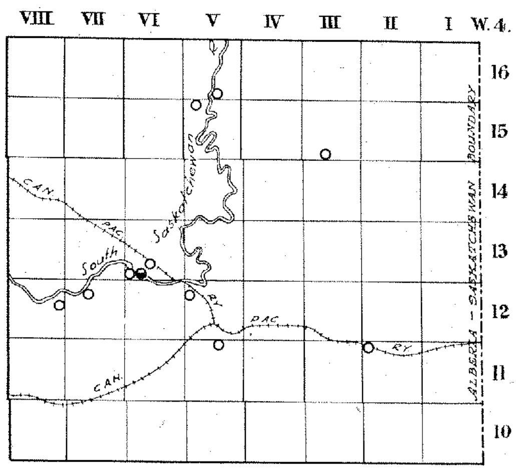
Solid coal as in seam

Percentage of Ash	5
Specific gravity	1.32
Tons per hundred cubic feet	4.10
Tons per acre foot	1,780

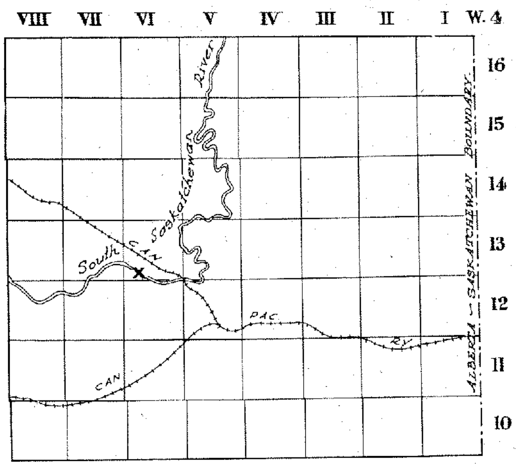
In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), and solubility in alkalies.

Map 67 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 68 shows the location of operating mines graded by output in 1943.



MAP 67



MAP 68

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate

Moisture	%	25.8
Ash	%	7.0
Volatile matter	%	27.8
Fixed carbon	%	39.4

Ultimate (with 25.8% moisture)

Carbon	%	50.5
Hydrogen	%	6.2
Sulphur	%	0.5
Nitrogen	%	0.9
Oxygen	%	34.9
Ash	%	7.0

Fuel ratio (FC/VM), 1.40.

Calorific value, gross, in B.t.u. per lb., 8,540.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

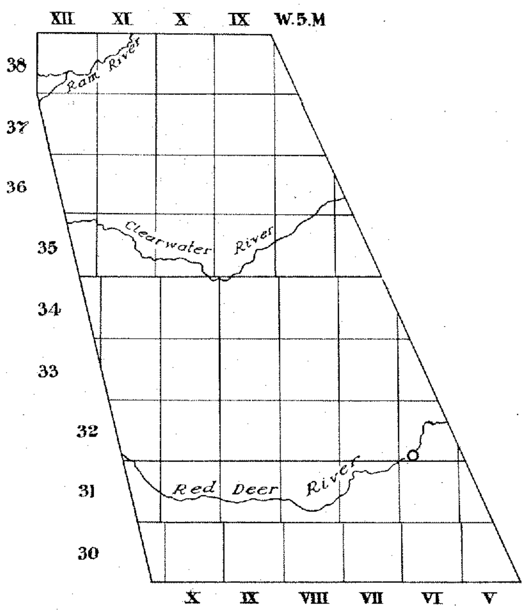
Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	$59.0 - 0.59(M+1.06A)$
Volatile matter	=	$100 - (M+A+FC)$
Calorific value, B.t.u./lb.	=	$12{,}900 - 129(M+1.14A)$

RED DEER AREA

Map 69 shows the location of the recorded mine opened. No samples have been obtained.

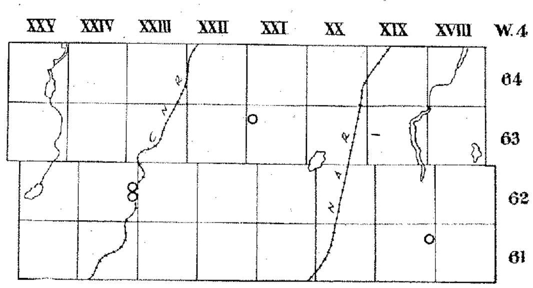


MAP 69

Scale: 20 miles to 1 inch. For symbols see page 93.

ROCHESTER AREA

Map 70 shows the location of four recorded mines opened. No samples have been obtained.



MAP 70

Scale: 20 miles to 1 inch. For symbols see page 93.

SAUNDERS AREA

The coal mined has been called subbituminous; it has been used principally for domestic heating. It is free burning, non-coking, weather resistant and slightly smoky. According to Canadian classification it is High Volatile C Bituminous. Several coal seams occur, all in the Belly River horizon.

The principal mines are on the Brazeau Branch of the Canadian National Railway. Two mines were operated in 1943 and the output was 65,000 tons.

Volume Weight Relation

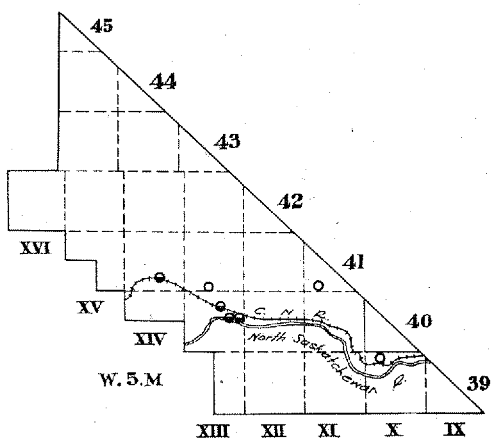
Solid coal as in seam

Percentage of Ash	5	10
Specific gravity	1.34	1.38
Tons per hundred cubic feet	4.15	4.30
Tons per acre foot	1,820	1,880

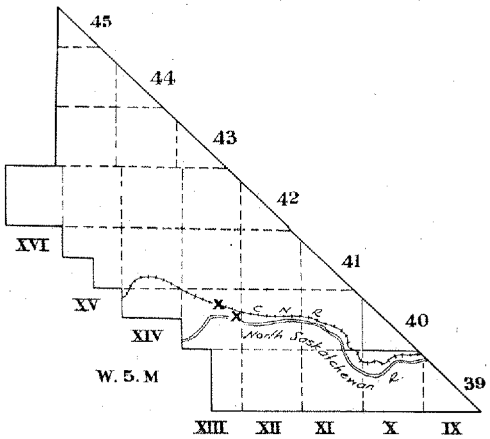
In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), pulverizability and grindability, fusibility of coal ash, solubility in organic solvents, solubility in alkalies, microstructure and spores, coal sizing, carbonization (L.T.C.) and smithy coal.

Map 71 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

May 72 shows the location of operating mines graded by output in 1943.



MAP 71



MAP 72

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate		
Moisture	%	9.7
Ash	%	6.8
Volatile matter	%	33.2
Fixed carbon	%	50.3

Ultimate (with 9.7% moisture)		
Carbon	%	66.7
Hydrogen	%	5.3
Sulphur	%	0.4
Nitrogen	%	1.0
Oxygen	%	19.8
Ash	%	6.8

Fuel ratio (FC/VM), 1.50.

Calorific value, gross, in B.t.u. per lb., 11,550.

The net calorific value of this coal is approximately 480 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

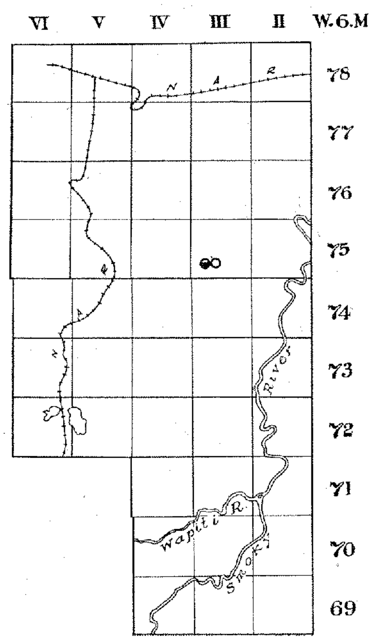
Fixed carbon	=	61.0 — 0.61(M+1.16A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	14,200 — 142(M+1.32A)

SEXSMITH AREA

The coal is an Alberta domestic coal; free burning and smokeless. According to the Canadian classification it is Subbituminous C. Seams are known, in both the Belly River and Edmonton horizons, but all are thin.

No mines were operated in 1943. Branches of the Northern Alberta Railway serve the area.

Map 73 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.



MAP 73

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analysis
Proximate

Moisture	%	29.6
Ash	%	6.9
Volatile matter	%	27.2
Fixed carbon	%	36.3

Fuel ratio (FC/VM), 1.3.
Calorific value, gross, in B.t.u. per lb., 8,090.

SHEERNESS AREA

The mines produce an Alberta domestic coal, free burning and smokeless. According to the Canadian classification the coal is Subbituminous C. Several seams are known, all in the Edmonton horizon. A description of this field can be found in Report 33, Research Council of Alberta (1935), p. 31.

Eight mines (seven stripping pits) were operated in 1943 and the output was 59,000 tons. The area is served by branches of the Canadian National Railway and the largest producing mines are on a railway. A considerable portion of the market for this coal is outside the Province.

Volume Weight Relation
Solid coal as in seam

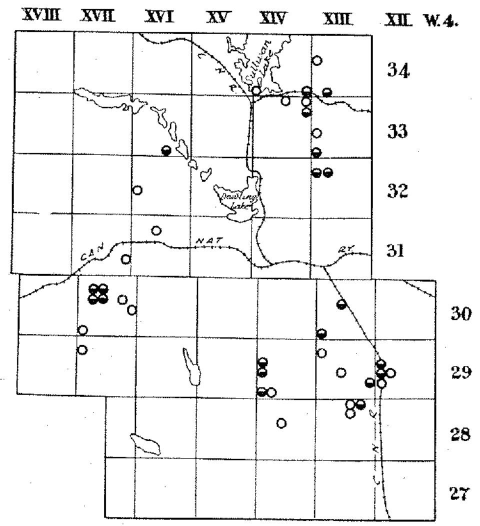
Percentage of Ash	5	10	15
Specific gravity	1.31	1.36	1.38
Tons per hundred cubic feet	4.10	4.25	4.30
Tons per acre foot	1,780	1,840	1,880

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), fusibility of coal ash, solubility in organic solvents, solubility in alkalies, and carbonization (L.T.C.).

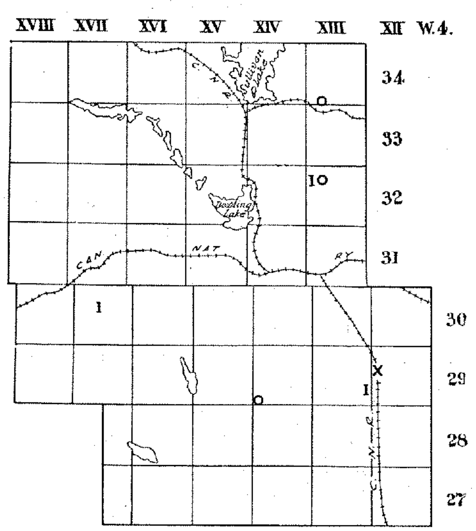
Map 74 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 75 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 5 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 74



MAP 75

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	33	XVI
B	32-34	XIII-XIV
C	30	XVII
D	29	XIV
E	28-30	XII-XIII

DISTRICT A

No mines operated in 1943.
Canadian classification—Subbituminous C

Typical Analysis

Proximate

Moisture	%	25.9
Ash	%	7.4
Volatile matter	%	27.4
Fixed carbon	%	39.3

Fuel ratio (FC/VM), 1.45.
Calorific value, gross, in B.t.u. per lb., 8,150.

DISTRICT B

Canadian classification—Subbituminous C

Typical Analyses

Proximate			Ultimate (with 28.8% moisture)		
Moisture	%	28.8	Carbon	%	45.6
Ash	%	8.2	Hydrogen	%	6.4
Volatile matter	%	28.0	Sulphur	%	0.4
Fixed carbon	%	35.0	Nitrogen	%	0.9
			Oxygen	%	38.5
			Ash	%	8.2

Fuel ratio (FC/VM), 1.25.
Calorific value, gross, in B.t.u. per lb., 7,730.
The net calorific value of this coal is approximately 580 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 57.0 — 0.57(M+1.20A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 12,500 — 125(M+1.14A)

DISTRICT C

Canadian classification—Subbituminous C

Typical Analyses

Proximate			Ultimate (with 24.3% moisture)		
Moisture	%	24.3	Carbon	%	49.95
Ash	%	8.7	Hydrogen	%	5.95
Volatile matter	%	27.6	Sulphur	%	0.3
Fixed carbon	%	39.4	Nitrogen	%	0.8
			Oxygen	%	34.3
			Ash	%	8.7

Fuel ratio (FC/VM), 1.45.
Calorific value, gross, in B.t.u. per lb., 8,370.
The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	61.0 — 0.61(M+1.28A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,500 — 125(M+1.00A)

DISTRICT D

Canadian classification—Subbituminous C

Typical Analyses

Proximate		Ultimate (with 25.4% moisture)	
Moisture	% 25.4	Carbon	% 51.2
Ash	% 6.0	Hydrogen	% 6.3
Volatile matter	% 29.3	Sulphur	% 0.5
Fixed carbon	% 39.3	Nitrogen	% 1.0
		Oxygen	% 35.0
		Ash	% 6.0

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 8,720.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	58.0 — 0.58(M+1.14A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,700 — 127(M+1.00A)

DISTRICT E

This is the principal producing district in the area.

Canadian classification—Subbituminous C

Typical Analyses

Proximate		Ultimate (with 27.5% moisture)	
Moisture	% 27.5	Carbon	% 49.0
Ash	% 5.9	Hydrogen	% 6.3
Volatile matter	% 28.8	Sulphur	% 0.4
Fixed carbon	% 37.8	Nitrogen	% 0.9
		Oxygen	% 37.5
		Ash	% 5.9

Fuel ratio (FC/VM), 1.30.

Calorific value, gross, in B.t.u. per lb., 8,180.

The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

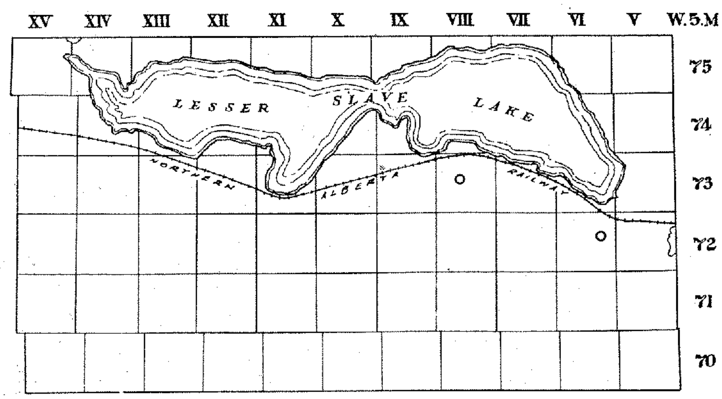
Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	57.0 — 0.57(M+1.04A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,600 — 126(M+1.04A)

SLAVE AREA

Map 76 shows the location of two recorded mines opened. No samples have been obtained.



MAP 76

Scale: 20 miles to 1 inch. For symbols see page 93.

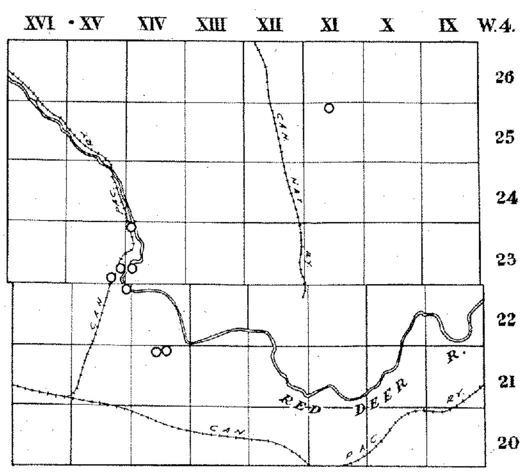
SMOKY RIVER AREA

No operating mines have been recorded. The seams that have been prospected are of bituminous steam coals and occur in the Kootenay horizon.

A description of this area is given in "Smoky River Coal Field", James McEvoy, Geological Survey No. 2055, Department of Mines, Ottawa, 1922.

STEVEVILLE AREA

Map 77 shows the location of all recorded mines opened. No samples have been obtained.



MAP 77

Scale: 20 miles to 1 inch. For symbols see page 93.

TABER AREA

The mines produce an Alberta domestic coal. It is free burning and smokeless. Two ranks of coal are mined according to the Canadian classification, Subbituminous A and Subbituminous B.

Numerous seams of coal occur, all in the Belly River horizon.

Seven mines (four stripping pits) were operated in 1943 and the output was 21,000 tons. The area is well served by the Canadian Pacific Railway.

Volume Weight Relation

Solid coal as in seam

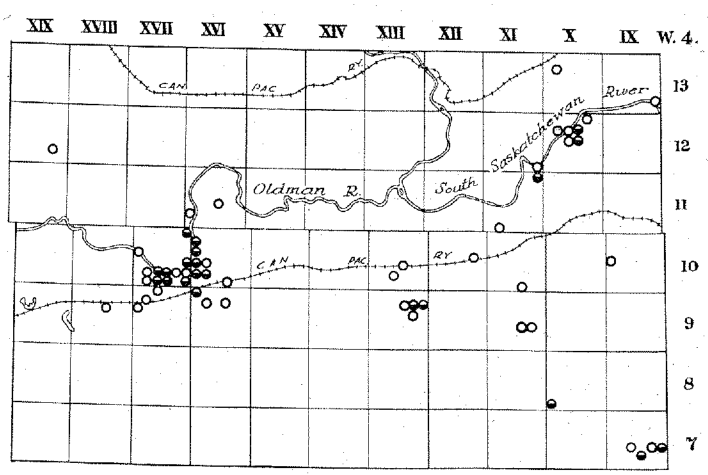
Percentage of Ash	5	10	15
Specific gravity	1.33	1.37	1.42
Tons per hundred cubic feet	4.15	4.25	4.40
Tons per acre foot	1,800	1,860	1,920

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: storage (oxidation), solubility in alkalies, and carbonization (L.T.C.).

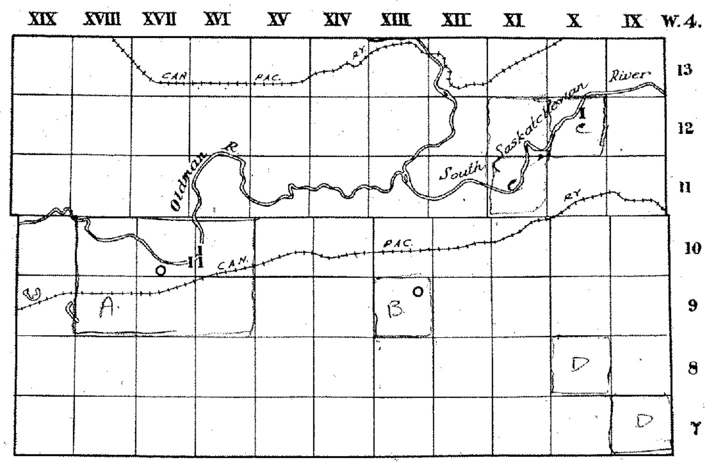
Map 78 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 79 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 4 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 78



MAP 79

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	9-10	XVI-XVIII
B	9	XIII
C	11	XI
	12	X
D	8	X
	7	IX

DISTRICT A

This was the main producing district in 1943.

Canadian classification—Subbituminous A

Typical Analyses

Proximate			**Ultimate** (with 15.3% moisture)		
Moisture	%	15.3	Carbon	%	56.8
Ash	%	10.2	Hydrogen	%	5.6
Volatile matter	%	31.5	Sulphur	%	1.2
Fixed carbon	%	43.0	Nitrogen	%	1.4
			Oxygen	%	24.8
			Ash	%	10.2

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 9,580.

The net calorific value of this coal is approximately 510 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.16A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,600 — 136(M+1.08A)

DISTRICT B

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 18.5% moisture)	
Moisture	% 18.5	Carbon	% 54.6
Ash	% 9.4	Hydrogen	% 5.8
Volatile matter	% 30.8	Sulphur	% 1.1
Fixed carbon	% 41.3	Nitrogen	% 1.1
		Oxygen	% 28.0
		Ash	% 9.4

Fuel ratio (FC/VM), 1.35.

Calorific value, gross, in B.t.u. per lb., 9,440.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	58.0 — 0.58(M+1.09A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,300 — 133(M+1.12A)

DISTRICT C

Canadian classification—Subbituminous B

Typical Analyses

Proximate		Ultimate (with 22.5% moisture)	
Moisture	% 22.5	Carbon	% 53.35
Ash	% 7.4	Hydrogen	% 5.95
Volatile matter	% 28.7	Sulphur	% 0.6
Fixed carbon	% 41.4	Nitrogen	% 1.0
		Oxygen	% 31.7
		Ash	% 7.4

Fuel ratio (FC/VM), 1.45.

Calorific value, gross, in B.t.u. per lb., 9,060.

The net calorific value of this coal is approximately 540 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	59.0 — 0.59(M+1.00A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,200 — 132(M+1.20A)

DISTRICT D

No operating mines listed.
Canadian classification—Subbituminous B

Typical Analysis

Proximate

Moisture	%	22.5
Ash	%	10.1
Volatile matter	%	29.5
Fixed carbon	%	37.9

Fuel ratio (FC/VM), 1.30.
Calorific value, gross, in B.t.u. per lb., 8,700.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	57.0 — 0.57(M+1.10A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	13,100 — 131(M+1.10A)

TOFIELD AREA

The mines produce an Alberta domestic coal, free burning and smokeless. According to the Canadian classification the coal is Subbituminous C. Several seams are known, all in the Edmonton horizon, but only the top seam is mined.

Four mines (two stripping pits) were operated in 1943 and the output was 85,000 tons. The area is served by several lines of the Canadian National Railway, and the mines are adjacent to a railway. A considerable portion of the market for this coal is outside the Province.

Volume Weight Relation

Solid coal as in seam

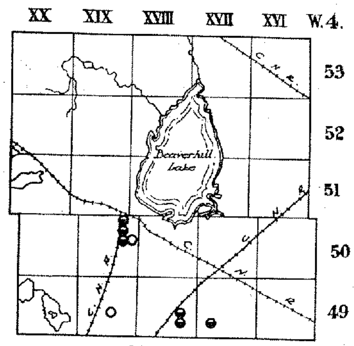
Percentage of Ash	5
Specific gravity	1.30
Tons per hundred cubic feet	4.05
Tons per acre foot	1,760

In addition to the typical and modified analyses given below reference has been made to coal from this area in the following sections of this report: fusibility of coal ash, coal sizing, and carbonization (L.T.C.).

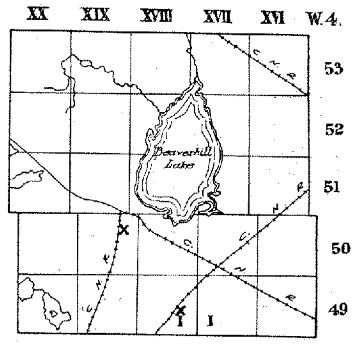
Map 80 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 81 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 80



MAP 81

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range
A	50	XIX
B	49	XVII-XVIII

DISTRICT A

This is the main producing district in the area.
Canadian classification—Subbituminous C

Typical Analyses

Proximate		
Moisture	%	28.1
Ash	%	5.4
Volatile matter	%	28.0
Fixed carbon	%	38.5

Ultimate (with 28.1% moisture)		
Carbon	%	49.6
Hydrogen	%	6.4
Sulphur	%	0.4
Nitrogen	%	0.9
Oxygen	%	37.3
Ash	%	5.4

Fuel ratio (FC/VM), 1.40.
Calorific value, gross, in B.t.u. per lb., 8,520.
The net calorific value of this coal is approximately 580 B.t.u. per lb. lower than the gross value.

Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon = 58.0 — 0.58(M+1.04A)
Volatile matter = 100 — (M+A+FC)
Calorific value, B.t.u./lb. = 12,700 — 127(M+1.00A)

DISTRICT B

Canadian classification—Subbituminous C

Typical Analyses

Proximate		
Moisture	%	28.4
Ash	%	7.5
Volatile matter	%	27.9
Fixed carbon	%	36.2

Ultimate (with 28.4% moisture)		
Carbon	%	47.3
Hydrogen	%	6.3
Sulphur	%	0.6
Nitrogen	%	0.9
Oxygen	%	37.4
Ash	%	7.5

Fuel ratio (FC/VM), 1.30.
Calorific value, gross, in B.t.u. per lb., 8,070.
The net calorific value of this coal is approximately 570 B.t.u. per lb. lower than the gross value.

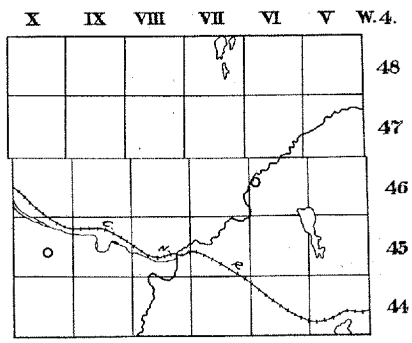
Modified Proximate Analysis

The following equations are provided to enable operators to tender on coals with moisture or ash differing from those of the typical analysis. See page 28 for method of use.

Fixed carbon	=	57.0 — 0.57(M+1.07A)
Volatile matter	=	100 — (M+A+FC)
Calorific value, B.t.u./lb.	=	12,700 — 127(M+1.07A)

WAINWRIGHT AREA

Map 82 shows the location of two recorded mines opened. No samples have been obtained.



MAP 82

Scale: 20 miles to 1 inch. For symbols see page 93.

WESTLOCK AREA

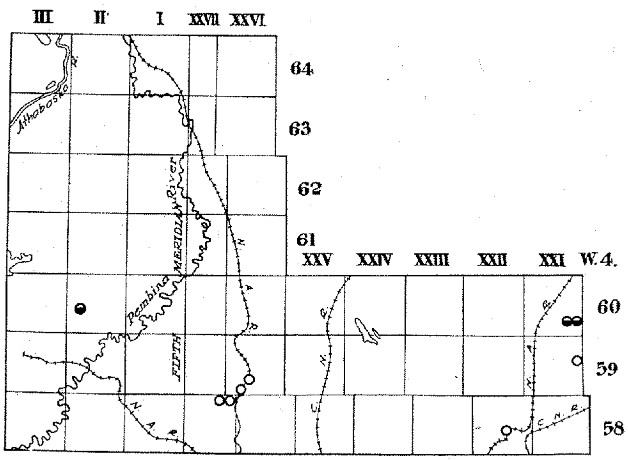
The coal is an Alberta domestic coal, free burning and smokeless. According to the Canadian classification it is Subbituminous C. Seams are known in both the Belly River and Edmonton horizons, but production has been from the former only.

Two mines, both stripping pits, were operated in 1943 and the output was 7,000 tons. The area is well served by the Northern Alberta and the Canadian National railways.

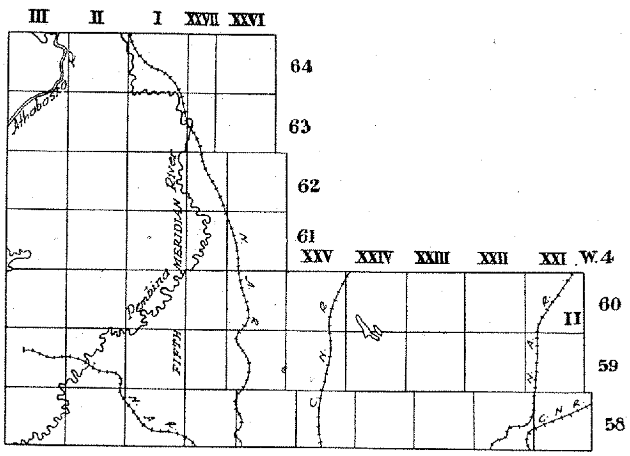
Map 83 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 84 shows the location of operating mines graded by output in 1943.

Because of wide differences in analyses of coals from separate points, the area has been subdivided into 2 districts wherein similar coals occur. The districts are given, by townships, below the maps.



MAP 83



MAP 84

Scale: 20 miles to 1 inch. For symbols see page 93.

District	Township	Range	Meridian
A	60	II	W 5
B	60	XXI	W 4

DISTRICT A

Canadian classification—Subbituminous C

Typical Analysis

Proximate

Moisture	%	26.5
Ash	%	4.6
Volatile matter	%	29.7
Fixed carbon	%	39.2

Fuel ratio (FC/VM), 1.3.

Calorific value, gross, in B.t.u. per lb., 8,730.

DISTRICT B

Canadian classification—Subbituminous C

Typical Analyses

Proximate		**Ultimate** (with 31.3% moisture)	
Moisture	% 31.3	Carbon	% 45.9
Ash	% 7.0	Hydrogen	% 6.6
Volatile matter	% 26.9	Sulphur	% 0.4
Fixed carbon	% 34.8	Nitrogen	% 0.9
		Oxygen	% 39.2
		Ash	% 7.0

Fuel ratio (FC/VM), 1.3.

Calorific value, gross, in B.t.u. per lb., 7,730.

The net calorific value of this coal is approximately 600 B.t.u. per lb. lower than the gross value.

WETASKIWIN AREA

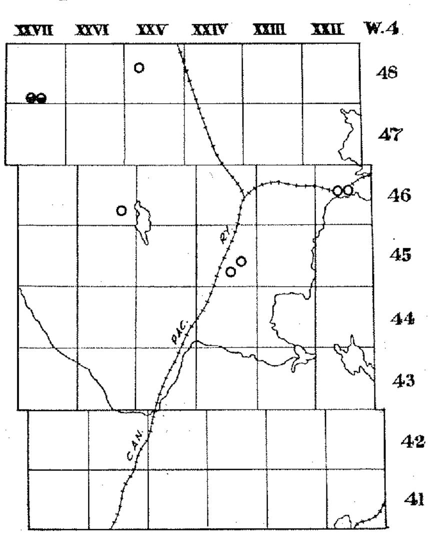
The mines produce an Alberta domestic coal, free burning and smokeless. According to the Canadian classification the coal is Subbituminous B. A number of seams are known, all in the Edmonton horizon.

One mine was operated in 1943 and the output was 3,000 tons. The area is crossed by two branches of the Canadian Pacific Railway. The mines are not on a railway.

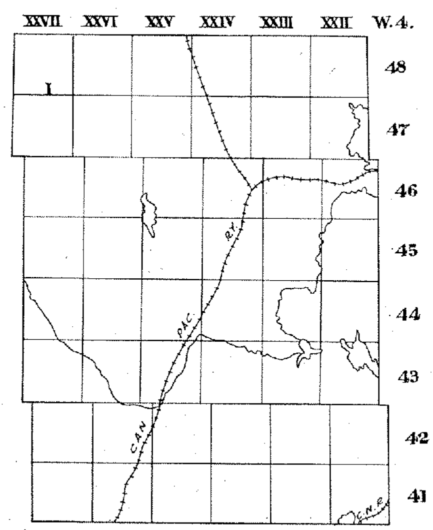
In addition to the typical analyses given below reference has been made to coal from this area in the following section of this report: storage (oxidation).

Map 85 shows the location of all recorded mines opened, and also indicates the mines from which samples have been obtained.

Map 86 shows the location of the operating mine graded by output in 1943.



MAP 85



MAP 86

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate

Moisture	%	20.0
Ash	%	7.6
Volatile matter	%	28.0
Fixed carbon	%	44.4

Ultimate (with 20.0% moisture)

Carbon	%	55.8
Hydrogen	%	5.8
Sulphur	%	0.2
Nitrogen	%	0.8
Oxygen	%	29.8
Ash	%	7.6

Fuel ratio (FC/VM), 1.60.

Calorific value, gross, in B.t.u. per lb., 9,520.

The net calorific value of this coal is approximately 530 B.t.u. per lb. lower than the gross value.

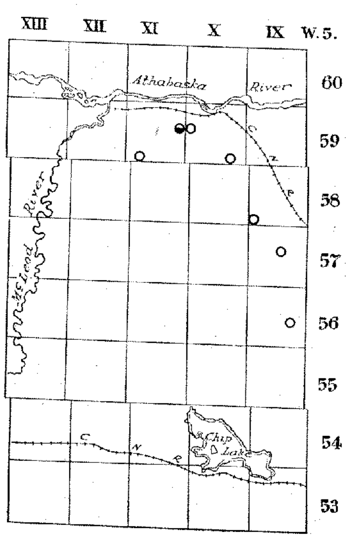
WHITECOURT AREA

The mines produce an Alberta domestic coal, free burning and smokeless. According to the Canadian classification the coal is Subbituminous B. The seams are all in the Edmonton horizon.

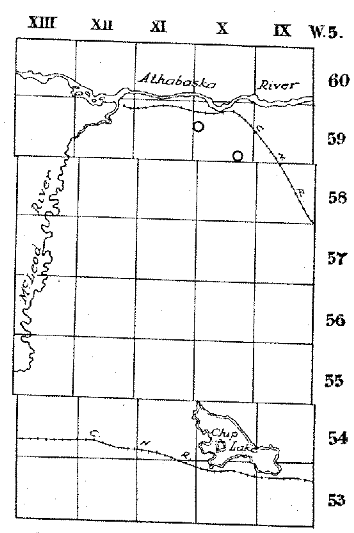
Two mines, both stripping pits, were operated in 1943 and the output was less than 200 tons. The area is crossed by the main and one branch line of the Canadian National Railway.

Map 87 shows the location of all recorded mines opened, and also indicates the mines from which a sample has been obtained.

Map 88 shows the location of operating mines graded by output in 1943.



MAP 87



MAP 88

Scale: 20 miles to 1 inch. For symbols see page 93.

Typical Analyses

Proximate

Moisture	% 22.6
Ash	% 12.2
Volatile matter	% 24.8
Fixed carbon	% 40.4

Ultimate (with 22.6% moisture)

Carbon	% 52.6
Hydrogen	% 5.7
Sulphur	% 0.3
Nitrogen	% 0.8
Oxygen	% 28.4
Ash	% 12.2

Fuel ratio (FC/VM), 1.6.

Calorific value, gross, in B.t.u. per lb., 8,670.

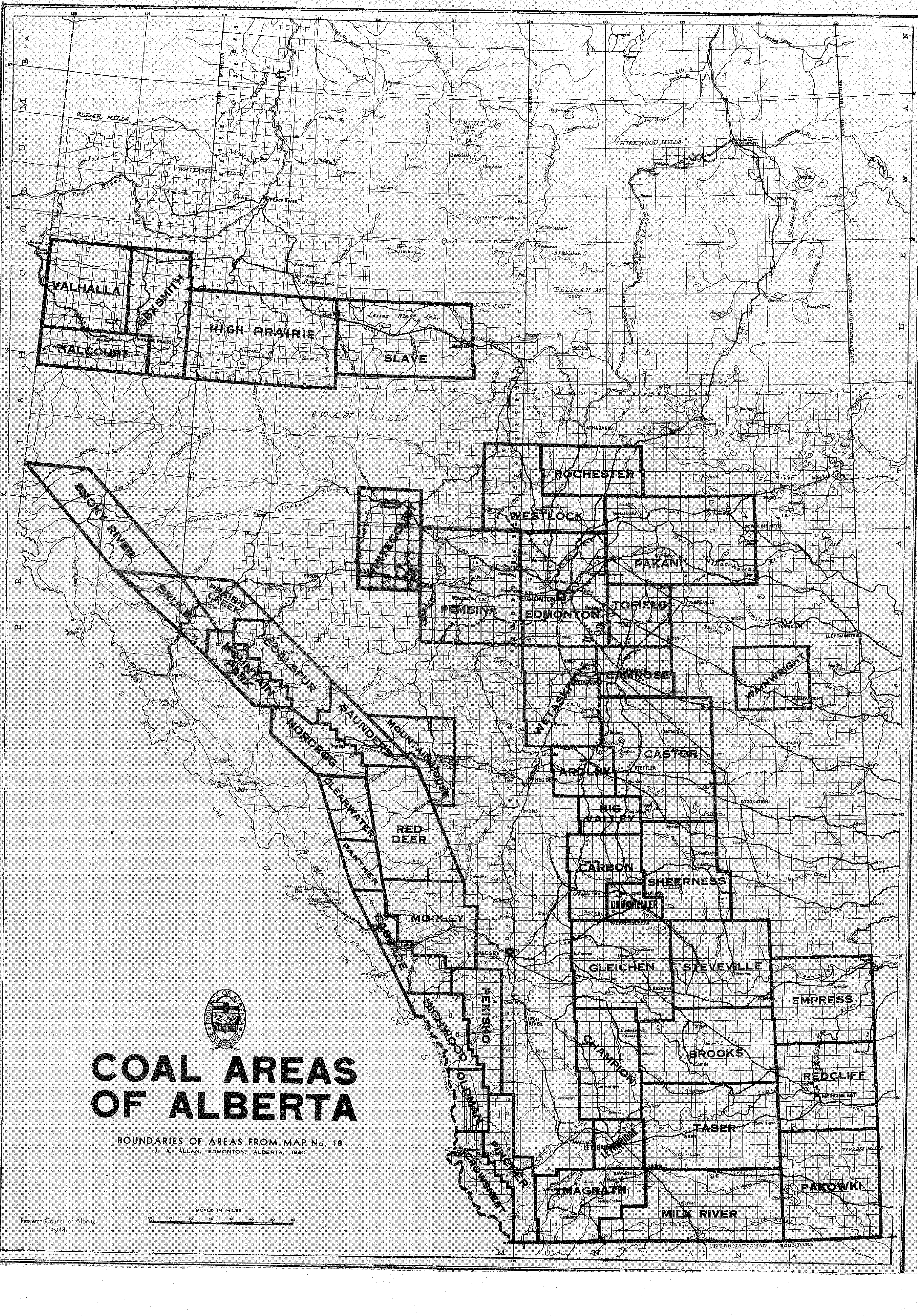
The net calorific value of this coal is approximately 520 B.t.u. per lb. lower than the gross value.

TABLE 22

Fusion Data for Ash of Alberta Coals

Area	District	Softening Temperature Low, °F	High °F	Softening Interval °F	Flowing Interval °F	Samples Tested
Ardley		2030	2410	80	120	14
Big Valley		2190	2460	70	140	7
Brooks		2130	2370	70	160	3
Brule		+2600	....	....	.....	1
Camrose		1980	2380	90	70	15
Carbon		1970	2400	70	140	22
Cascade	A	2550	+2770	....	.....	3
	B	2140	+2770	120	150	11
Castor		2010	2360	70	80	20
Champion		1900	2180	50	50	8
Coalspur	A	2050	2170	40	130	7
	B	2090	2450	70	100	20
Crowsnest	A & C	2630	+2770	....	.....	35
Drumheller		1850	2370	60	110	69
Edmonton		1970	2470	60	120	34
Gleichen		2010	2370	60	110	6
Halcourt	A	2460	2600	180	130	2
	B	2200	2460	100	160	4
Highwood		+2600	.....	....	.....	4
Lethbridge		2060	2420	80	140	23
Magrath		2190	2280	90	70	2
Milk River		1960	2200	90	190	6
Mountain Park		2280	+2700	140	130	21
Nordegg		2600	+2800	....	.....	11
Pakowki		1920	2300	50	60	8
Pekisko		2150	2550	90	150	11
Pembina		2280	2460	70	110	12
Pincher	A	2330	+2600	80	170	4
Prairie Creek	A	2150	2340	80	160	6
	B	2100	2120	50	230	2
Redcliff		1880	2120	80	80	7
Saunders		2010	2260	60	80	12
Sexsmith		2070	....	60	70	1
Sheerness		1980	2320	50	70	17
Taber	A & B	2100	2490	60	90	11
	C	1870	2380	60	130	3
Tofield		2050	2270	50	60	7
Westlock		2050	2240	60	100	2
Wetaskiwin		2030	2420	90	100	3
Whitecourt		2180	....	90	190	1

Explanation of terms given on page 42.


COAL AREAS
OF ALBERTA
BOUNDARIES OF AREAS FROM MAP No. 18
J. A. ALLAN, EDMONTON, ALBERTA, 1940
Research Council of Alberta
1944
SCALE IN MILES
PROVINCE OF ALBERTA
VALHALLA
SEXSMITH
HALCOURT
HIGH PRAIRIE
SLAVE
ROCHESTER
WESTLOCK
PAKAN
WHITECOURT
SMOKY RIVER
BRULE
PRAIRIE CREEK
COALSPUR
MOUNTAIN PARK
PEMBINA
EDMONTON
TOFIELD
CAMROSE
WAINWRIGHT
WETASKIWIN
SAUNDERS
NORDEGG
MOUNTAIN HOUSE
CASTOR
ARDLEY
BIG VALLEY
CLEARWATER
RED DEER
PANTHER
CARBON
SHEERNESS
DRUMHELLER
MORLEY
CASCADE
GLEICHEN
STEVEVILLE
EMPRESS
HIGHWOOD
PEKISKO
CHAMPION
BROOKS
REDCLIFF
OLDMAN
TABER
LETHBRIDGE
PINCHER
CROWSNEST
MAGRATH
MILK RIVER
PAKOWKI
CLEAR HILLS
SWAN HILLS
THICKWOOD HILLS
PELICAN MT
TROUT MT
Peace River
Lesser Slave Lake
INTERNATIONAL BOUNDARY
M O N T A N A