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DEPARTMENT OF MINES

OTTAWA, CANADA.

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A CLASSIFICATION OF COALS FOR USE IN THE BY-PRODUCT COKING INDUSTRY.[1]

by

E. J. Burrough[2] and E. Swartzman[2]

Reviewed by

R. E. Gilmore[3]

The volatile-matter determination obtained as part of the ordinary proximate analysis is serviceable for indicating the gas-yielding qualities of coals rather than for demonstrating their relative value for the manufacture of gas. A given coal or coals will, when heated under different conditions, behave differently, with respect to decomposition into uncondensable gas, tar oil vapours, and coke or char residue. When small quantities are heated rapidly, the yields and quality of the reaction products are apt to be different from those obtained from the same coal when treated in bulk in commercial retorts or ovens, where the destructive distillation reactions are much slower. Realization of this fact, especially in the case of bituminous coals, explains the practice of relying more upon the results of actual large-scale testing than upon general description and analysis of a coal or coal mixture in order to predict the yields and quality of both gas and coke.

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1. A full account of the development and details of this coal classification scheme will be found in "Investigations of Fuels and Fuel Testing, 1930."
2. Engineer and Chemist respectively, Carbonization Section, Fuel Research Laboratories, Division of Fuels and Fuel Testing.
3. Superintendent, Fuel Research Laboratories.

During 1930 and 1931, a large number of coking tests on coals varying widely in nature were made in an experimental by-product coke oven of two-ton capacity at the Fuel Research Laboratories of the Department of Mines at Ottawa. In this oven, which is a duplicate of certain commercial units used in the industry, the different bituminous coals tested were coked alone and in admixture with one another; standard imported coals were used for blending purposes. On certain individual coals and coal mixtures, follow-up tests were made in full-size commercial ovens and the comparative results recorded. Subsequently, through the correlation of results obtained in small-scale, carbonization assay tests with those of large-scale tests, a classification scheme was devised whereby it appears possible to predict the relative value of coals for the manufacture of both gas and coke.

Specific Volatile Index

The special feature of the coal classification scheme presented herewith is what has been termed by the proposers as the "S.V.I", that is, the specific volatile index, which is to be defined as:

$$\frac{\text{Determined B.T.U. per pound of coal} - (\text{per cent of fixed carbon} \times 14{,}500)}{\text{Per cent volatile matter}}$$

In the formula just given the fixed carbon percentage is read as a decimal, while the denominator (which is the determined volatile matter percentage) is to be read as a whole number. Although originally intended to apply only to bituminous coals, it was found that the S.V.I. varied widely for different classes of coals higher and lower in rank than bituminous. For example, the S.V.I. of peat is below 80, wheres the anthracites, including semi-anthracites, are above 215, thus leaving a S.V.I. range of 135 for all coals between the lower limit of the lignitic and sub-bituminous on the one hand, and the upper limit of the semi-bituminous on the other. By plotting as abscissa the specific volatile indices against the percentage of volatile matter, the respective positions of the different ranks of coals have been illustrated graphically in Chart I. In this chart, vertical lines intersecting the S.V.I. base divide the whole range of coals into classes or groups, according to rank. Horizontal dividing lines are also drawn to show the upper and lower limits of the respective groups of coals according to their volatile-matter content.

In Charts I and II, the different rectangular areas enclosing the respective groups of coals are indicated by capital letters "A" to "K" inclusive, the typical by-product coke-oven yields of groups A to I, namely lignites to semi-bituminous coals, are shown in the legend of Chart I. In Chart II, where the specific volatile indices have been calculated to the "unit coal" basis instead of the ordinary dry and ash-free basis, 75 different coals representing all ranks are shown, and with the exception of four "cannel" coals, all come within the rectangles indicated.

For the coals in the different rectangles, certain of the nomenclature of Seyler have been indicated in brackets alongside the names under which the respective groups of coals are known in Canada, and in the United States; and the system of rectangular areas is similar to, though considered to be an improvement on, that of Parr.

Proposed Classification

For special use in the by-product coking industry the proposal is to divide coals into at least seven groups or sections, more or less in line diagonally, to which for general classification purposes two or more groups may be added to each end. These may be described under lettered sections as below, in which all volatile-matter contents, gas yields, etc., are on the dry and ash-free coal basis.

Section A - with S.V.I. limits 100 to 120 - comprises the low-rank, lignite coals that produce chars rather than coke, with fairly large yields of gas high in carbon dioxide and low in calorific value. The volatile-matter range indicated for this group is above 40 per cent on the dry ash-free basis.

Section B - with S.V.I. limits 120 to 145 - also contains low rank lignitic or sub-bituminous coals that produce a char rather than a coke and that show a lower gas yield also high in carbon dioxide. The calorific value of the gas is, however, appreciably higher than that from coals in Section A. The volatile-matter content of coals in this group range from 37 to 50 per cent.

Section C - with S.V.I. limits 145 to 154, and with the same volatile-matter range as immediately above — comprises a relatively small group of "sub-bituminous" coals which, when strongly heated as in the volatile-matter determination, slightly agglomerate or show incipient caking or coking. This section contains those coals, the coking properties of which are greatly improved by pretreatment. The volatile-matter range of the coals and the therms in the gas obtained by carbonizing these coals at high temperature are approximately the same as for those in Section B. Their tar yield is, however, appreciably higher.

Section D - with S.V.I. limits 154 to 160 - contains the so-called "pseudo" gas coals, the volatile-matter range of which is 35 to 45 per cent. When these coals are carbonized they tend to give a porous, friable, fingery coke, the structure of which is greatly improved when blended with coals in Sections F to I inclusive. The tar yield is roughly the same as for those in Section C, and although the yield of gas on the dry ash-free coal basis is slightly lower, there is a noticeable increase of therms.

Section E - with S.V.I. limits of 160 to 170 - comprises the so-called "natural gas" coals with volatile-matter contents ranging from 30 to 43 per cent. These coals are equally suitable for use in by-product ovens, either coked alone or blended with lower volatile coals to enhance coke quality. Coals falling in this section, as well as those in Section D, closely resemble or are similar in character to the para-bituminous coals in Seyler's classification.

Section F - with S.V.I. limits 170 to 185 and with volatile-matter contents on the dry ash-free basis ranging from 30 to 36 per cent — contains those coals that are seemingly most suitable for by-product oven coking; for this reason they are termed "natural by-product coking coals". Although these coals produce a gas slightly lower in therms than do those coals in Section E, they produce, when coked alone, a high quality coke with respect to structure. In addition the tar-yield average is about 10 (U.S.) gallons per short ton.

Section G - with S.V.I. limits 170 to 185 which are the same as in Section F, but with a lower volatile-matter range, namely, 23 to 30 per cent — contains what is termed the low-volatile, blending bituminous coals. When coked alone these coals exhibit noticeable non-shrinking or even slightly expanding properties, that, under certain operating conditions, make it difficult to push the coke from the oven. The coke is much harder and denser than that from coals in Section F, but the gas is appreciably lower in therms. In Seyler's nomenclature the coals of this section as well as those in Section F are termed "ortho-bituminous".

Section H - with S.V.I. limits 185 to 200 - contains coals that resemble Seyler's "meta-bituminous" class. Although in the same volatile-matter range and somewhat similar to the coals in Section G, they are higher in rank and are considered more suitable for blending purposes.

Section I - with S.V.I. limits 200 to 215, and a volatile-matter range of 14 to 25 per cent — contains the semi- or "super" bituminous coals, of which the well-known Pocahontas coal is typical. These coals are most serviceable for blending with high volatile (gas) coals for improving coke quality. They are quite unsuited for coking alone, as it is practically impossible to push their coke from the oven due to swelling. The therms in the gas and the tar yield are both appreciably lower than from coals in Sections G and H.

Section J - with S.V.I. limits 215 to 230, and

Section K - with limits from 230 to 250, are the semi-anthracite and anthracite coals respectively. The volatile-matter range on the dry ash-free basis for the semi-anthracites, (which are also known as "sub-anthracites") is from 9 to 16 per cent, whereas that of the so-called "true" anthracites is below 10 per cent.

Arrangement as to Coking and Non-coking Coals

In the charts, vertical division lines are used to differentiate between the bituminous coals in the middle portion that are suitable for coking alone in by-product ovens, and the non-coking coals in both the lower and higher S.V.I. ranges at the ends. This indeed is a commendable feature of the classification scheme proposed, and may be shown in tabular form, as below:—

S.V.I. ranges	Sections or groups of coals included.	Coking or non-coking in by-product ovens
Below 145	Lignites and sub-bituminous	Non-coking
145 to 154	"Sub-bituminous"	Agglomerating
154 to 215	Bituminous and semi-bituminous	Coking
215 to 250	Semi-anthracites and anthracites	Non-coking

In the above summary the names of the groups of coals corresponding to the different S.V.I. ranges are provisional and are used here merely to indicate the kind of coal as now generally known and predominating in the respective ranges or sections. In the appended table and its accompanying chart, No. II, the volatile-matter and fixed-carbon ranges, corresponding to eleven S.V.I. ranges, namely, Sections A to K inclusive, are shown. In the table all the criteria used are calculated to Parr's "unit coal" basis. The well-known nomenclature as used above, and the corresponding nomenclatures of Seyler and of Parr, are shown opposite the different groups or sections. The correlation of Seyler's nomenclature, as indicated in brackets in Sections D to H inclusive, was effected after plotting a number of border line coals on both his and the S.V.I. charts.

Reliability of the Volatile-matter Determination

Discussion as to the merits of the classification proposed, as outlined above, may first consider the reliability of the volatile matter on which the specific volatile index is based. The apparatus for making the volatile-matter determination of the many coals on which this proposed classification is based consists of a Chaddock gas burner and a so-called Fieldner electric furnace. This furnace and its method of operation are in accordance with the A.S.T.M. D.271 - 30, viz.: "Standard Methods of Laboratory Sampling and Analysis of Coal and Coke." Many tests on coals differing widely in rank were made in platinum crucibles of two differemt sizes, first in the Chaddock burner by the alternative gas burner method in D271-30, and then by the electric furnace method. These comparative tests indicate that for practical purposes the results by these two methods agree quite closely. Care, of course, is taken to see that the temperature during the determination is maintained as near as possible to the 950°C. specified,

and those coals (mainly the non-coking low rank coals) that are liable to spark, are given a short pre-heating before the final six-minute period as specified. In general, it is considered that with reasonable care duplicate and consistent results are obtainable by the employment of the standard volatile-matter determination as outlined above. In fact this has been confirmed by the exchange of standard samples between different government laboratories in Canada and the United States. It is to be noted that for purposes of plotting coals on the Burrough-Swartzman chart, changes of plus or minus 0.5 per cent in volatile matter causes variations in S.V.I. figures ranging from zero on the low rank lignite end to as high as 5 and 7 on the anthracite end. The variation for a typical bituminous coal near the intersection of F, G, and H is less than 1, and of course a change in the volatile-matter results of plus or minus one per cent, along the line suggested by A.C.Fieldner for border line coals, would be double the variation just stated.

Merits of the S.V.I. Classification Scheme

The charts and the classification illustrated are equally as serviceable when either the volatile matter or the fixed carbon are used as ordinates , since on the dry, ash-free and "unit coal" bases the one is the reciprocal of the other. The value of 14,500 B.T.U. per pound as the calorific value of ash-free fixed carbon was chosen after trying out other values, and after discovering it to be the average of a large number of actual determinations.

While similar to Parr's two-dimensional diagram, where calorific values are plotted against volatile matter, the S.V.I. classification scheme avoids overlapping of classes along the main axis. In this connexion it is to be noted that in the latter scheme using the "unit coal" corrections for calculating the specific volatile indices as referred to above, a straight line may be drawn through the centre of the coals plotted on Chart II, and that on Chart I, by leaving out one section, namely G, the line joining the centres of the remaining rectangles shown will be straight, or nearly so. This straightening out of the band of coal plottings in the rectangular areas avoids overlapping in the bituminous coking coal areas as is the case in the Parr chart, and it is mainly in this respect that the S.V.I. scheme is considered superior.

Further claims of the authors of the classification scheme under discussion may be summed up and commented on as follows:

(1) Simplicity, in that the results of proximate analysis and the calorific value only are required. The necessity of not having to conduct a full examination including ultimate analysis is considered both simple and desirable.

(2) By plotting a coal, the proximate analysis and calorific value of which are known, on the chart and noting its position, it is seemingly possible to predict, with a fair degree of accuracy, the characteristics of that coal with respect to its behaviour in a by-product oven, and the approximate yield of by-products to be expected.

(3) It is also serviceable for determining what mixture or blend of coals may be suitable for obtaining a certain yield of coke, gas, and other products, and for producing a desired coke quality with respect to ash content, structure, etc. However, other tests of a laboratory-and large-scale nature are desirable, and, in certain cases, necessary, to ensure that the predictions regarding the physical properties of the coke are correct.

(4) Although the possible prediction of the yield and quality of the coke is the special feature of this S.V.I. classification scheme, it may also be used, where steaming is not practised, to predict the approximate therms in the gas from a given coal or coal mixture. In this respect it may serve that part of the carbonization industry using gas retorts or vertical ovens in contrast to horizontal by-product coke ovens.

(5) This classification scheme employing the specific volatile index plotted against either the volatile matter or fixed carbon on a two-dimension chart, may serve for a purely scientific classification of coals equally as well as for a "use" classification, especially for the carbonization industry. For this purpose, that is, as a scientific classification, the calculating of all values to the "unit coal" basis before plotting is recommended.

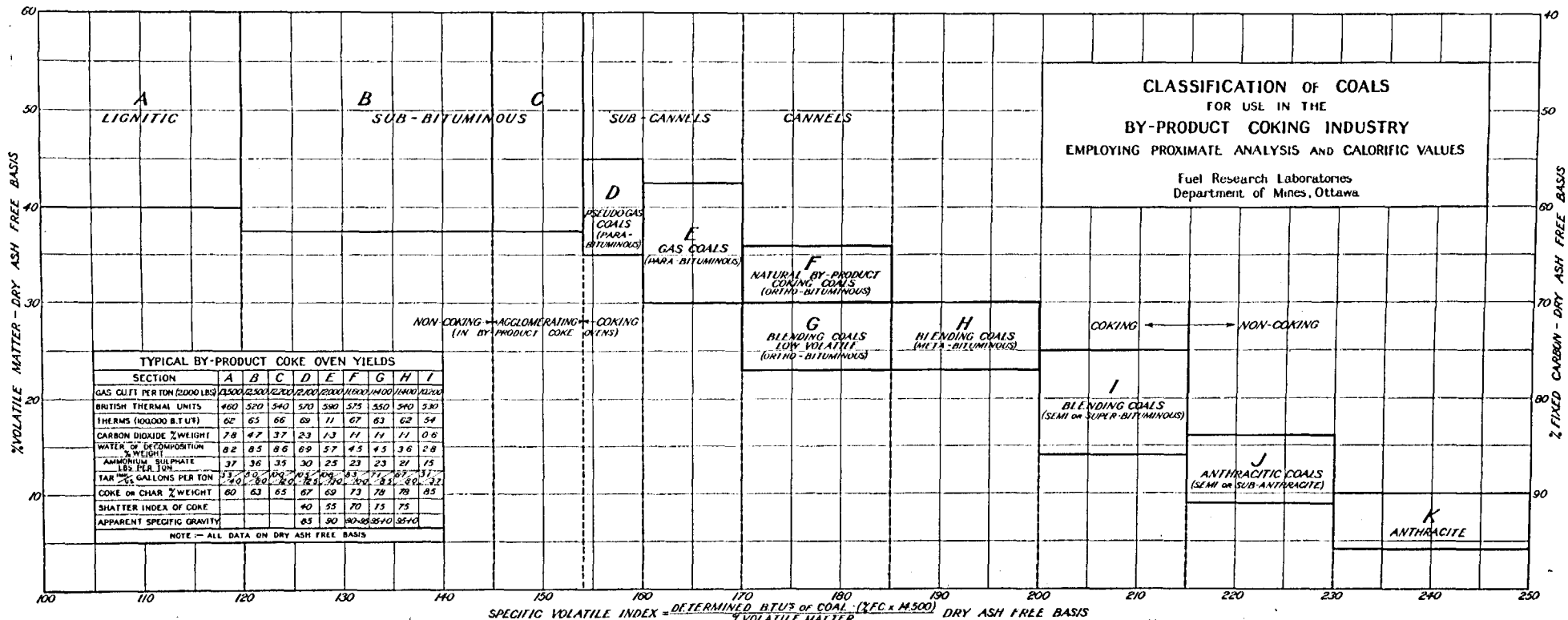
The phrase, "other tests of a laboratory- and large-scale nature are desirable" etc., in (3) above refers to supplementary small-scale coking tests and to full-size oven tests respectively, the latter varying from a two-ton scale to that in a large-size commercial oven. Of special mention is a small-scale, coke button test for the prediction of physical properties of the coke to be expected from a given coal or coal mixture, developed by the junior proposer of the classification scheme here summarized. Under the title "Estimation of Physical Properties of Coke by Laboratory Tests on Coal", a full description of the method and the results obtained will be found in "Investigations of Fuels and Fuel Testing, 1931", now in the process of publication.

TABLE

Specific Volatile Index Classification on the "Unit Coal" Basis

Section	Name of Predominating group*	S.V.I. limits	Volatile-matter range	Fixed-Carbon range	Calorific value limits; B.T.U. per pound	Parr's terminology of predominating class
A	Woods	Under 50	60 and above	Below 50	Up to 9000	
B	Peats	50 - 82	45 - 75%	50 - 70%	8500 - 11000	Peat
C	Brown lignites (lignitic)	82 - 99	40 - 70	70 - 75	10500 - 12700	Lignites
D	Black lignites (ortho-lignitious)	99 - 125	36 - 55	75 - 80	12500 - 14000	Bituminous D
E	Sub-bituminous (meta-lignitious)	125 - 160	35 - 50	80 - 84	13800 - 15100	Bituminous C
F	Bituminous (para-bituminous)	160 - 175	28 - 45	84 - 87	15000 - 15600	Bituminous B
G	" (ortho- ")	175 - 190	21 - 35	87 - 89	15300 - 15800	" B
H	" (meta- ")	190 - 210	21 - 28	89 - 91	15700 - 16000	" B
I	Semi- or "super" bituminous	210 - 230	14 - 24	91 - 93.3	15700 - 16000	Bituminous A
J	Semi- or "sub" anthracite	230 - 255	9 - 16	Over 93.3	15500 - 15800	Semi-anthracite
K	Anthracites	255 - 300	3 - 10	Over 93.3	15000 - 15700	Anthracite

* The nomenclature in brackets in this column are those of Seyler.

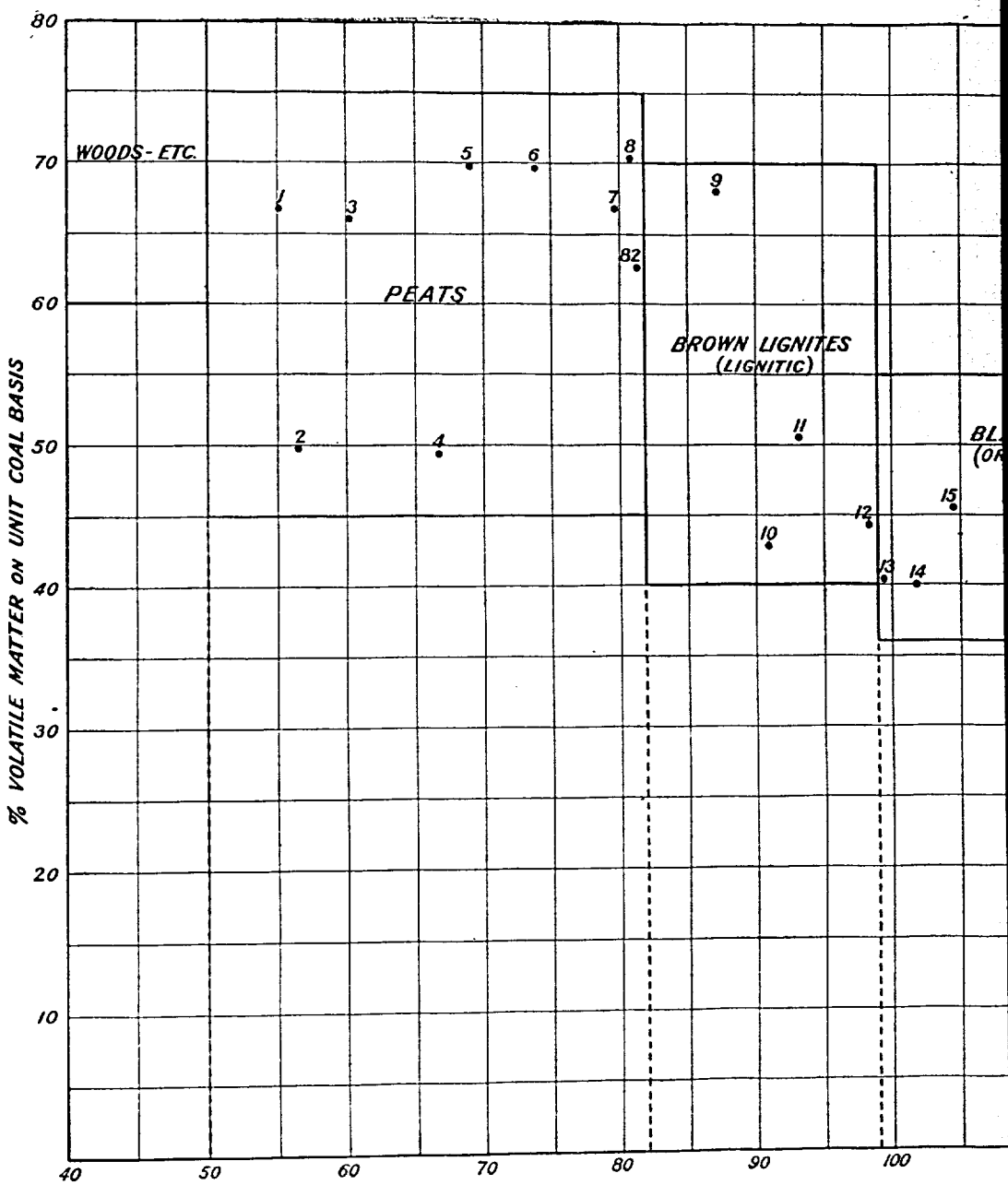


TYPICAL BY-PRODUCT COKE OVEN YIELDS

SECTION	A	B	C	D	E	F	G	H	I
GAS CU.FT PER TON (2000 LBS)	13500	12500	12200	12100	12000	11800	11400	11400	11200
BRITISH THERMAL UNITS	460	520	540	570	590	575	550	540	530
THERMS (100,000 B.T.U'S)	62	65	66	69	71	67	63	62	54
CARBON DIOXIDE % WEIGHT	7.8	4.7	3.7	2.3	1.3	1.1	1.1	1.1	0.6
WATER OF DECOMPOSITION % WEIGHT	8.2	8.5	8.6	6.9	5.7	4.5	4.5	3.6	2.8
AMMONIUM SULPHATE LBS PER TON	37	36	35	30	25	23	23	21	15
TAR IMP. U.S. GALLONS PER TON	13 to 40	8.0 to 8.0	10.0 to 8.0	10.5 to 7.5	10.0 to 7.0	8.3 to 10.0	7.1 to 8.3	6.7 to 8.0	3.1 to 3.2
COKE OR CHAR % WEIGHT	60	63	65	67	69	73	78	78	85
SHATTER INDEX OF COKE				40	55	70	75	75	
APPARENT SPECIFIC GRAVITY				85	90	90-85	85-10	85-10	

NOTE :— ALL DATA ON DRY ASH FREE BASIS

Chart I


WOODS - ETC.
PEATS
BROWN LIGNITES
(LIGNITIC)
% VOLATILE MATTER ON UNIT COAL BASIS
80
70
60
50
40
30
20
10
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
82
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10
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14
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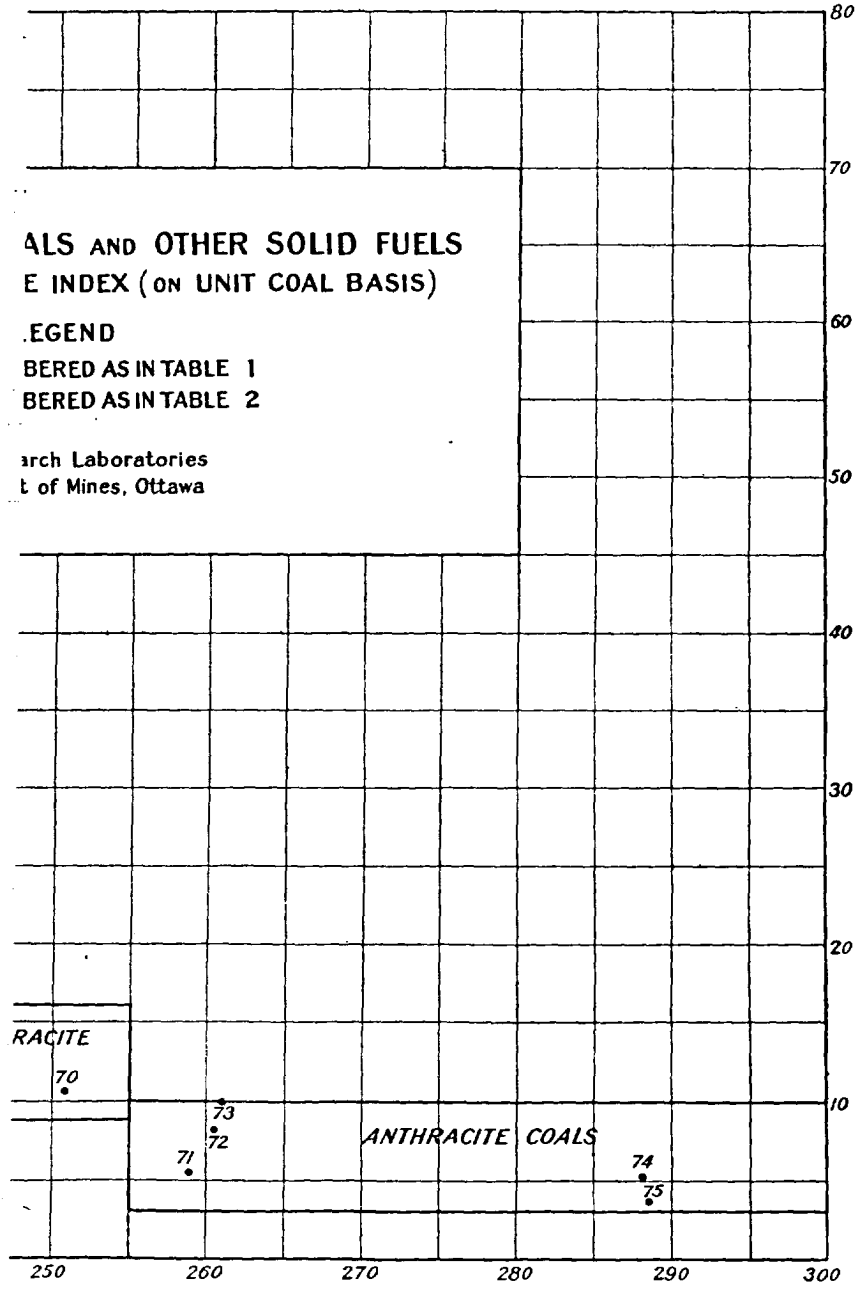

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the final report.