

freshly pulverised coal had changed to dull black. No caking together of the particles had taken place, for their fineness was the same as that of the original coal, 97 per cent. passing a 200 by 200 mesh sieve. The coking power of the dust had, however, completely departed after a duration of heating of 18 secs., although it still contained 23 per cent. of volatile matter.

At or about a temperature of 530 degs. Cent. there is, so far as the particular coal experimented with is concerned, a change in the character of the carbonisation. For at and above this temperature the particles that passed through the heated zone were spherical globules, only 10 per cent. of which passed through a 90 by 90 mesh sieve, and some of which were retained on a 10 by 10 mesh. The perfect spherical shape of even the smallest globules indicated that the dust during its passage through the heated zone had become molten.

The production of such large particles would be detrimental to the efficient working of any process devised for the production of gaseous fuel from the dust; but it could be guarded against by the destruction of the coking power of the coal before

it passed into the gasification chamber. The experiments show that, with the coal dust employed this would be effected in 18 secs. at a temperature of 420 degs. Cent., or in 12 secs. at a temperature of 500 degs. Cent. Quite a short exposure of the powdered fuel in the form of a cloud, to a low temperature (400-450 degs.) would therefore render it non-coking, and would permit the succeeding stage of producer gas manufacture to proceed with the efficiency and despatch which the use of coal in a fine state of division allows.

There are, of course, many other difficulties to be overcome in the application of the process besides that of agglomeration of the particles. Notably, the removal of the ash, which would normally appear as fine dust with the gas, would be necessary. Such difficulties are not, however, insuperable, and the process seems to us to be worthy of attention by those interested in the utilisation of fine coal—a product so hard to dispose of at most collieries.

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Coal and its Carbonisation.

By S. ROY ILLINGWORTH.

This is the first of a series of articles in which Mr. Illingworth outlines what are, in his opinion, the salient facts regarding the character of coal; and shows how knowledge of those facts can be used to regulate the commercial utilisation of coal.

THE imperative need for the most economical usage of our coal resources necessitates the forceful prosecution of a well-conceived and widespread programme of research; firstly, to elucidate the chemical nature of the various types of coal; and, secondly, to turn this knowledge to economic account. The research chemist, the technologist, the mining engineer, the commercial head of industry, must come together in a common and national interest, in order that the activities of each essential function may be co-ordinated into a general staff. We cannot hope for rapid progress if each works, unco-ordinated, in a watertight compartment.

The author has devoted himself to the comparative study of typical coals with the object of ascertaining whether or no their characteristic properties are ascribable to the presence of particular components; and with a view to determine how far variations in the properties of coals can be correlated with the relative amounts and the thermal stabilities of these components. It will be realised that the consummation of these aims is a matter of prime importance.

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Under present practice the general method of evaluating a coal for a specific purpose

is to run works scale trials, which may be costly in their results on the coal in question. It is the absence of truly scientific data as to the underlying reasons for the behaviour of a coal under given conditions that has caused works managements to decide by practical trial which variety of coal best suits their purpose. Having found one that answers more or less, then all future consignments are ordered by quoting the particular name given to the trial consignment; and that name, but not necessarily that variety of coal, is stuck to through thick and thin.

It is evident that when it becomes possible to correlate the specific behaviour of a coal under works practice with the presence of known and determinable constituents in that coal, it will be possible, by the resolution of a typical sample of any coal into its components, to state definitely what will be the behaviour of that coal under any conditions of use. Furthermore, by an extension of our knowledge of the components of coal, it should be possible so to treat any variety as to render it suitable for any service.

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Coal is the raw material from which it is potentially possible to manufacture any desired type of solid, liquid or gaseous fuel. The

full economic importance of this statement will only become manifest when a rigorous scientific basis for it has been established by the prosecution of laborious research into the chemical nature and constitution of coals of all types from widely divergent sources. Time and money expended towards this end form an investment the returns from which will of necessity be high by reason of the economies that must result from the proper selection and utilisation of our coal resources.

Let us review the main facts, so far as they are known, regarding the nature of coal, with a view to portray their significance in relation to its use. The vast amount of work that remains to be done will be only too obvious.

Coal is a mineral which, according to its nature and, more particularly, its geological age, contains varying amounts of the elements carbon, hydrogen, oxygen, nitrogen and sulphur, associated with mineral matter. A portion of the sulphur, when it occurs as "pyrites" or sulphate, for example, must be regarded as belonging to the mineral matter. The study of coal, and more particularly the comparative study of different coals, is concerned with their organic constituents; for this reason all the analytical data are calculated on what is termed an "ash-free dry" (a.f.d.) basis, a calculation readily performed by multiplying each analytical determination by the factor $\frac{100}{100-x}$ in which x is the sum of the percentages of moisture and ash in the sample. The economic importance of the ash and other impurities is judged from the known influence of varying quantities of different minerals on the properties of the "coal substance" (sometimes termed the "pure coal").

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Various schemes have been advocated from time to time with the object of correlating the amount of the elements in the coal substance of a coal with its properties. In the nature of things such schemes can only afford an approximation to the truth, for it is a well-known chemical fact that for given percentage amounts of the constituent elements two or more totally distinct compounds, with widely different properties, can exist. The determining factor as regards the properties of an organic compound is its architecture—the manner in which the atoms of the elements are arranged relative to one another in the molecule.

The more it becomes possible to resolve the conglomerate, coal, into its typical components, the easier will it be to judge as to the arrangement of the atoms in the molecules of those components. As we shall see, it is even now possible to form a fairly accurate judgment as to the quantity and character of the highly oxygenated compounds in different coals; to discriminate between the amounts of compounds rich in hydrogen; and to ascertain the concentration of certain (relatively)

stable components rich in carbon and hydrogen and unassociated with oxygen. The presence and the significance of molecules which contain the major portion of the nitrogen or the sulphur in the coal substance can also be revealed by resolution with certain solvents.

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In default, however, of definite knowledge regarding the quantities of the various chemical compounds in coal, knowledge of the quantities of the elements (carbon, hydrogen, oxygen, nitrogen and sulphur) present, and correlation of this knowledge with the properties of the coals, are steps in the right direction—towards our desideratum of a knowledge of the inner structure of coal. Amongst the earliest attempts at the classification of coals on the basis of the quantities of the elements contained in them (their "ultimate analyses"), that due to Regnault, which was the earliest of all, is the most valuable; but the recent work of Seyler, founded mainly on an examination of the coals of South Wales, has enabled him to put forward a still more advantageous classification, which should have more general usage.

Commercial practice has inclined towards the rough and ready classification of coals into lignites, bituminous coals (subdivided into house, gas and coking coals), steam coals, dry steam coals and anthracites. These types of coals merge, in their properties, gradually into one another, there exists no strict line of demarcation between them, and a rigorous evaluation of, and discrimination between, the various classes as to their suitability for specific purposes is impossible on the basis of "proximate analyses," so beloved of the trade.

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Seyler classifies coals on the basis of the percentage amounts of carbon and hydrogen that the "coal substance" contains. The main class to which a coal belongs is determined by its carbon content, each class, of which Seyler distinguishes four—the anthracitic, the carbonaceous, the bituminous, and the lignitious—being defined by certain fixed limits for the percentage of carbon in the coal substance. These limits are recorded in the subjoined table, under the names of the classes.

The coals, which belong to any particular class, that is to say, coals of which the carbon content falls within the fixed limits for that class, reveal a characteristic gradation in their properties according to the percentages of hydrogen which they contain. In every class there is a typical coal, which possesses characteristic properties, defined by its hydrogen content being between fixed limits; such a coal is termed the *normal* coal of the class. Those coals of a particular class which contain a less amount of hydrogen than the *normal* coal are given the prefix "*sub*"; they tend to be "*drier*" in their nature than the *normal*.

SEYLER'S CLASSIFICATION OF COALS.

	Anthracitic.	Carbonaceous.	Bituminous Carbon Plane.			Lignitious.
			Meta-	Ortho-	Para- East Coals.	
	C over 93.3.	93.3-91.2.	91.2-89.0.	89.0-87.0.	87.0-84.0.	84.0-80.75.
Per-Bituminous Class.	—	—	Per - Meta - Bituminous Type. North Country Steam Coals. Over 5.7 30-44	Per-Ortho-Bituminous Type. Bastard Cannel. Gas Coals. Over 5.7 Over 36	Per - Para - Bituminous Type. Cannel. Over 5.8 Over 40	Hard Steam Coals.
H. over about 5.8 Volatile over 30 p.c.						
Bituminous Class.	—	Pseudo-Bituminous Type.	Meta-Bituminous Type. Welsh Coking Coals.	Ortho - Bituminous Type. Durham Type of Coking Coals, Smithy & Gas Coals.	Para - Bituminous Type. Coking Coals and Best Gas Coals.	—
H. about 5.0-5.8 Volatile 23-40 p.c.		5.0-5.8 Over 23.	4.9-5.7 23-30	5.0-5.7 28-36	5.0-5.8 30-40 steam	
Semi-bituminous Class.	—	Ortho-semi-Bituminous 2nd Admiralty Type. Steam Coals (Coking) Higher Index blended for Coke.	Sub - Meta - Bituminous Type. Index 8-17. House Coals. Continental Coking Coals when Index high.	Sub-Ortho-Bituminous Type. Coking and Steam.	Sub - Para - Bituminous Type.	—
H. about 4.5-5.0 Volatile 16-24 p.c.		4.5-5.0 14-24	4.5-4.9 16-23	4.5-5.0 16-23	?-5.0 16-29?	
Carbonaceous Class.	Semi - Anthracitic Type. Dry (non-caking) Steam.	Ortho-Carbonaceous Admiralty Type. Welsh Smokeless Steam. Slight Caking.	Pseudo - Carbonaceous Type. Sub - Meta-Bituminous Steam Coals.	Sub-Ortho - Bituminous pseudo Carbonaceous Type.		—
H. about 4.0-4.5 p.c. Volatile about 10-16	4.0-4.5 0-15	4.20-4.45 10-14.	3.7-4.5 10-16	?-4.5	?	
Anthracitic Class.	Ortho-Anthracitic Type. True Anthracites.	Sub - Carbonaceous pseudo-Anthracitic Dry Steam (non-caking) - hard Anthracites.	Sub - Meta - Bituminous pseudo-Anthracitic Type.		Sub - Para - Bituminous pseudo-Anthracitic Type.	—
Under about H. 4.0 p.c. Volatile ... 10 p.c.	Under 4.0 5-9	Under 4.2 Under 7.7	Under 3.7 Under 10	?	Under 4.2 Under 10	

and approach in their properties the coals of the class next higher in carbon content. On the other hand, those coals which contain a higher percentage of hydrogen than the normal coal of a class (given the prefix "per") tend to become "fatter" and to resemble more closely the sub-coals of the class next lower in carbon content.

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It is evident that coals of a different ultimate composition may have very similar properties, if, as we shall see, the effect of varying quantities of different constituents is counterbalanced by variations in their thermal stabilities. The economic value of Seyler's classification becomes apparent, however, if we consider the effect of the variations of hydrogen content of coals of the same class on their properties, using the normal coal in each class as the standard for comparison.

The Normal Anthracitic Coals.—These are dry, non-caking coals. They yield no liquid by-products on carbonisation at usual (high) temperatures, but between 2,000 and 4,000 cu. ft. of gas per ton. This gas contains but little methane and much hydrogen.

The Normal Carbonaceous Coals.—These coals just verge upon the bituminous class; that is to say, they have slight caking power, yield small amounts of liquid by-products (containing but little phenolic compounds), and between 5,000 and

6,000 cu. ft. of gas per ton under ordinary gasworks practice. The gas is similar in composition to that from coals of the anthracitic class, but the proportion of methane it contains is higher.

The Bituminous Coals.—Seyler uses the term "bituminous" to signify that the coals "melt" when heated at a certain minimum temperature. He divides them into three types—*meta*, *ortho*, and *para*. The *meta* coals are less highly oxygenated than the *ortho* (which are the normal coals), and the *para* coals are more highly oxygenated. These coals all yield considerable quantities of liquid by-products. From comparative studies that the author has made, it would seem that the proportion of phenolic compounds in the liquid products is, for coals of equal contents of "volatile matter," greatest in the *para* and least in the *meta* coals. The gaseous products, under ordinary gasworks practice, vary in quantity between 8,000 cu. ft. per ton for the *meta* coals and 11,000 cu. ft. for the *para*; and the amount of carbon dioxide and water evolved, due to decomposition of the coal substance, increases as we pass from the *meta* to the *para* coals.

The Normal Lignitious Coals.—These are characterised by the large quantities of water and carbon dioxide that they evolve on heating. Their calorific value is comparatively low, and their liquid distillates contain a high proportion of phenolic substances.

If these main characteristics of Seyler's classes of coals, based on their carbon contents, are borne in mind, and the general effect of variation in their hydrogen contents is also considered, it will be understood why an accurate "ultimate analysis" of a coal is of such value in enabling a forecast to be made of its probable behaviour so that it can be selected for a specific purpose. For example, coals are being selected for use in suction gas producers. One coal is found to contain 92.60 per cent. of carbon and 4.05 per cent. of hydrogen. This, then, is a "dry" coal, yielding no liquid

distillates; it can therefore be used for suction gas producers with a simple filter. Another coal contains 91.92 per cent. of carbon and 4.34 per cent. of hydrogen. This coal is of the carbonaceous class, which borders on the bituminous, and it contains a relatively high percentage of hydrogen. One would expect it, therefore, to yield a certain amount of tar, which, in gas producer work, would necessitate the use of a scrubber.

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The Study of Mineral Matter in Coal.

By R. LESSING.

The importance of determining the character of the mineral matter, or "dirt," in coal is explained in this paper by Dr. Lessing, who has made a special study of the problem.

THE annual production and distribution in Great Britain of non-combustible mineral matter in combination with coal amounts approximately to from 25 to 40 million tons. This estimate refers to material actually despatched from the collieries to consumers or used for colliery purposes and does not include the vast quantity of rock, shale and washery refuse raised from the pits, but left on the spoil heaps. In point of comparative bulk this incombustible material ranges immediately after coal (*i.e.* pure coal) itself and is equal to about twice the tonnage of iron ore, the next largest item of our mineral products. Leaving out of consideration the potential value of iron, sulphur and building materials which may in the future be recovered from the coal minerals, the inorganic constituents of coal are worse than useless. They absorb from 10 to 15 per cent. of the whole mineral traffic of the country; lower the efficiency of heat production from the combustible portion of coal by a very considerable amount; add dust and sulphur dioxide to atmospheric pollution; and require costly and laborious disposal after conversion into ashes in industrial furnaces and domestic fireplaces. In brief, they involve the national balance sheet in a non-productive expenditure of millions of pounds.

It is therefore astonishing that the study of the nature of these impurities in coal has been lamentably neglected in the past. The percentage of "ash" is estimated for the evaluation of coal, but its composition or its chemical, physical or economic bearing on the winning and utilisation of our most valuable natural asset has failed, except in isolated instances, to attract the systematic investigation it obviously deserves.

It will therefore be useful to discuss the problems involved and the principles on which investigations should be based.

We are accustomed to speak of the "ash" of coal and actually use this term when dealing with questions relating to the constitution of coal. One need hardly stress the point that the mineral (and by this is meant the non-combustible inorganic) constituents are present in coal in a form and combination different from that in which they exist eventually in the residue resulting from incineration. The results of analyses of ashes do not therefore give a true picture of their composition. Moreover, the values for "volatile matter" and "fixed carbon" may be affected quantitatively, the former by the decomposition of carbonates or hydrates in the ash, the latter, being a difference figure, by the increase or loss in weight of the mineral residue brought about by the chemical changes during incineration.

The main constituents of coal ash are silica, alumina, ferric oxide, calcium oxide, magnesia and the alkalis. The bases may be combined with sulphuric, phosphoric or carbonic acid, and possibly with sulphuretted hydrogen and traces of arsenic. In order to get some idea as to the original compounds in the coal from which the constituents of the ash are derived, it is necessary to consider the constitution of coal.

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As early as 1848, Marsilly (*Compt. Rend.*, 1848, 46, 882) pointed out that "however pure a piece of coal may be, and however homogeneous it may appear to the eye, its different parts do not yield the same proportions of fixed residue on incineration." Until recently there were, however, very few analyses of the ash of clearly defined coal constituents on record, such as those reported by Thorpe for the "mineral charcoal" from the Better Bed and Haigh Moor seams.