On a Laboratory method of testing Gas Coals
for yield of Gas and Illuminating Power.

By

George Percy Lishman.
On a Laboratory method of testing Gas Coals for yield of Gas and illuminating power.

Although a small coal testing plant is frequently attached to a large gasworks and is in many cases found useful it cannot be denied that the laboratory testing of gas coals has of late years been somewhat under a cloud. Many gas engineers look with suspicion on the results obtained from an apparatus carbonizing a few lbs of coal and even regard them as absolutely unreliable or misleading. This can be gathered from the various discussions which have taken place from time to time. Andrew Scott(1) at a meeting of the West of Scotland Gas Managers Association in May 1879 stated how published analyses were not realised in the works in the case of several shales and cannel coals. Later J. M'Grae(2) brought up the same subject stating that little heed should be paid to printed analyses. Some allowance can certainly be made for the difference between the clean sample sent to an analyst and the bulk forwarded to a works but this does not explain

(1) "Remarks on the analyses of Gas Coals"
(2) North British Association of Gas Managers July 1892 "Coal Analyses" J. M'Grae.
everything and the tone of the discussions at these and other meetings is evidently against the small scale apparatus. The Report of the 1893 Research Committee of the North British Association of Gas Managers states that "all analyses should be conducted on a thoroughly practical scale". Just previous to this the Association of German Gas-works chemists had come to a similar conclusion. J. Stellfox (Belfast) in a letter dated July 11th 1892, writes to the Journal of Gas Lighting giving the following analyses of the same coal from different sources.

<table>
<thead>
<tr>
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<th>Yield</th>
<th>Illuminating Power</th>
<th>Sperm Value</th>
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<td>C</td>
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In spite of this the continuous record of coal testing ever since the introduction of gas lighting indicates that there is and has always been a demand from practical men for information about gas coals at a less cost than that of a practical trial. In 1815 and 1819 Accum published his books\(^1\) giving lists of various coals and their yield of gas and describing the arrangement of his apparatus; though crude it was very useful in distinguishing cannel from bituminous coal. Clegg's improved form is figured

\(\text{(1) "A Practical Treatise on Gas Light," by Frederick Accum 1815}
\)
\(\text{"Process of Manufacturing Coal Gas" by Frederick Accum 1819.}\)
in his treatise\(^1\) of 1841 (p.38). On the model of the plant designed by Sugg, figured in Banister's book of 1867\(^2\) most subsequent forms of laboratory coal-testing arrangements have been designed. L.T. Wright\(^3\) put his condensers in a water tank, and Sheard\(^4\) later on described another form in which the gas after passing through a washer-scrubber spread itself over a number of vertical tubes. Clegg, Wright, Sheard and many others have used a retort carbonizing 2 or 3 lbs but coal testing has been done on all quantities from 50 grammes to the "thoroughly practical scale". Dr. Wallace of Glasgow from whose laboratory an extensive series of analyses was published in the Journal of Gas Lighting for December 18th, 1877 used 22.4 lbs. Leicester Greville\(^5\) used \(\frac{1}{160}\) of a ton in two clay retorts. T. Glover\(^6\) in 1896 described an arrangement in which

\(^1\) "Manufacture and distribution of Coal Gas," by Samuel Clegg, 1841.

\(^2\) "Gas Manipulation and Analyses" by the late Henry Banister, enlarged by W.T. Sugg. 1867.


\(^4\) Journal Gas Lighting 51.369.

\(^5\) Journal Gas Lighting 51.508.

\(^6\) J.G.L. 68.347.
two retorts were used carbonizing $\frac{1}{2}$ cwt each. Rhodin's apparatus (1) is designed to overcome the expense and inconvenience of other forms rather than to deal with the difficulties of the subject. Frequently a full-sized retort in a set has been isolated by a by-pass on the hydraulic main and the gas tested. (2)

Abroad a similar state of affairs obtains. Schilling (1863) used 160 German lbs in a $\bigcirc$-shaped retort measuring 19" x 16" x 8 feet, his apparatus including a meter and an exhauster. Stein (1858) used 20 lbs with two retorts in the same furnace, making duplicate estimations; at that time he had great difficulty in estimating illuminating power and was chiefly guided in this respect by the specific gravity. Dr. Bunte has used an apparatus similar to that of Schilling, with an exhauster. Perhaps the chief form of laboratory apparatus used abroad is that of Dr. Leybold fully described by A. Schäfer (3). Another arrangement for carbonization of one kilogramme of coal has been described by G. Jouanne (4) the purifier in this case seems much too small.

(1) J.S.C.I. 1896. 12
(2) H. Veevers, J.G.L. 35. 985.
(3) "Einrichtung und Betrieb eines Gaswerkes" p.24
E. Sainte Claire Deville has used Leybold's apparatus and also a much larger one, others (1) have attempted to base a valuation of gas coal on the estimation of volatile matter, but the estimation is not accurate.

From this it is seen that the manner of testing gas coals is by no means agreed upon; the fact is that results from the various forms of laboratory coal testing plant come out most irregularly, and when working with the same coal very considerable differences are often found between one test and the next. E. Grahn has emphasized these differences. (2) Still it seemed to the writer that there ought to be some manner of manipulating the $\frac{1}{1000}$ of a ton plant so as to obtain satisfactory results.

**Nature of the difficulties**

The cause of the trouble lies chiefly in the physical changes occurring in the condensers of the plant while coal is being distilled. Certainly if the gas is not properly purified the presence of carbonic anhydride will cause reduction of illuminating power, but this case need

(2) "Versuchanstalten für Gaskohlen" J.F.G. 1869. 59
(1) "De Gasfabrikant in het Laboratorium" A.J. van Eyndhoven. page 14.
never occur in testing. Also the retort temperature is an important factor, for a hot retort will break down heavy hydrocarbons into bodies of less carbon density and of less illuminating value, but in this case the yield of gas is increased so that the sperm value may not materially suffer. This has long been a fundamental axiom of the subject and there is no doubt that it is substantially true, but in coal testing, as will be pointed out later, conditions often arise which negative its application. With gas heating there is generally no special difficulty in keeping the retort temperature within the limits required by the process.

What is really difficult, and in the writer's case has been found impossible is to keep the condensers at a sufficiently uniform temperature for the purpose in hand. That very slight differences of condenser temperature will be liable to affect materially the quality of the gas causes no surprise when we consider on how small a percentage of coal gas the illuminating power really depends. Take away five per cent of heavy hydrocarbons and most coal gases are practically disillumined. The illuminating value of different hydrocarbons has been worked at

(1) P.F. Frankland, J.S.C.I. 1884. 271.
by Frankland and others and the following figures may be given

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<thead>
<tr>
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</tr>
<tr>
<td>Butylene</td>
<td>123</td>
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<tr>
<td>Naphthalene</td>
<td>933</td>
</tr>
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<td>Vapour</td>
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Five lbs of Naphthalene were found by Prof. Foster to be sufficient to double the illuminating power of 1000 cubic feet of 14-candle gas. Hence it is clear that the candle power of gas obtained in a coal testing plant will vary and may be expected to vary from day to day according to the external temperature.

In a continuous series of tests from a gas coal there is very little chance of getting the same results day after day. This is brought out in the table given below the results are all from the same coal tested for the most part on different days during the first six months of 1903.

(1) "The effects of specific hydrocarbons on the lighting value of combustible gas"
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<th>No. of Test</th>
<th>Yield of Gas</th>
<th>$\text{Illum}^\text{m}$</th>
<th>$\text{Illum}^\text{m}$ value per ton in lbs of sperm</th>
<th>No. of Test</th>
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</table>
The above are all tests from the coal which is used as a standard by which other coals are tested in the manner to be described. The illuminating value per ton of this coal is 580 lbs of sperm, that is, in any well equipped gas works this figure can be obtained from it. The list might be extended to several hundreds of tests made from the same coal during the last four years, but the above are sufficient to give a full idea of the variation to be expected. The differences of sperm value extend through nearly the whole range of quality of ordinary gas coals i.e. from 500 to 667 lbs per ton. The figures show however that even working with water jacketed condensers which may be assumed to be very suitable for such a purpose as this; the direct testing of gas coals is useless for comparative purposes and that any result may be obtained according to circumstances.

The idea, therefore, so frequently met with in the literature of the subject (Clegg, Wright, Newbigging, Sheard and others) that the laboratory apparatus gives results higher than those obtained in the works, but comparable to each other, is not borne out by the present investigation. There are many apparent reasons why they should be
higher, e.g. iron retorts, no loss, perfect purification, etc., but they are all overborne by the differences of condensation which occur. The temperature of the apparatus is the main determining factor in the quality of the gas. Mr. Grayson de Schodt, it may be noted, finds laboratory tests lower than those in the works.

The table will be dealt with later.

If the trouble ensuing from irregular condensation could be overcome it would end the difficulty from the point of view of the gas engineer, who has only himself to consider. For to him it does not matter whether the results are higher or lower, within limits, than those obtained in the works so long as they are reliably comparatives. This is the desideratum which, so far, has been so difficult to obtain by any method which may reasonably be called a laboratory one.

The Analytical chemist however is confronted with the further difficulty that from the same coal a better result will be obtained in one gas works than in another, this variation being caused mainly by differences of efficiency in the plant used. When steam coals are analysed the theoretical evaporative power which would

(1) J.G.L. 58. 444.
be obtained were the coal perfectly burnt and the heat entirely used for evaporation, is given. The figures obtained in this way though higher than those got in any boiler, represent an absolute property of the coal, assume nothing and are useful comparatively. But this cannot be done with gas—coal and even if it could, would not be desirable. It is not advisable because we cannot obtain on the testing scale as high results in winter weather as we do in summer or in summer have as high results as would probably be got in summer in the South of France. For testing purposes the upper limit of the sperm value is exceedingly high and long before it is reached the conditions under which we are working become quite abnormal.

Gas results it is generally agreed must be reported in terms of what could be obtained from the coal in a well equipped modern gas works.

Attempt by means of a standard apparatus —

The difficulties as above detailed fall naturally under two heads namely (1) Those connected with the temperatures of the condensers and retort and (2) that due to the difference of results found in various gas works. Keeping these in view various methods were tried
for overcoming them and finding a means of testing gas coals on the laboratory-scale. First of all Sheard's apparatus was used, then some years ago, it was thought it might be possible to produce a standard apparatus in which by warming the condensers in cold weather and by other devices the evil effects of winter days might be obviated. The condensers were water jacketed and kept always at 70°F, and sometimes sections of them were by-passed. This produced a slight improvement, but it was found that even when by-passing the whole of the condensers the action of the coal pipes and purifiers on the slowly passing gas caused much lower results to be obtained in summer than in winter. Besides this left the vagaries arising from variations of retort temperature quite out of the question. It had been hoped to get rid of these variations by means of a mercury governor on the gas supply to the retort, but the expectation was not realized; moreover, in testing, the yield of gas does not entirely depend on retort temperature but upon the age of the retort; a new retort will, at the same temperature, give more gas than an old one. It is an easy matter to lay down standard conditions which are to obtain always when tests are being made, but it has been found quite impossible to realize them
in daily work.

These experiments extending over 12 months though failing in their primary object, or rather shewing that it was unattainable were of value as indicating two points viz:- (1) That in any apparatus designed for coal testing the amount of condensation must be capable of very considerable variation indeed, and (2) that in successive tests the same coal the results are more constant when the condensation is rather heavy.

Apparatus used -

In considering the design of a coal testing plant it is necessary to bear in mind that the apparatus cannot be a model of a full-sized gas works for no two works are alike.

At the same time, we must retain the same general outlines consisting of retort, ascension-pipe, condensers, preferably a scrubber, purifiers and gas-holders. We must also use a sufficient quantity of coal to make at least 8 cubic feet of gas, as that is the least quantity with which the illuminating-power can be satisfactorily taken.

By using a standard coal as described below, to correct for varied condensation, we do away with the necessity for adhering rigidly to one particular form of apparatus, but
certain essentials cannot be neglected, particularly when work is to be done in all weathers. These may be stated as follows:

(1) The condensers must be much larger, in comparison with the retort, than those used in gas-works. They must be water-jacketed for cooling in summer, and so arranged that they may be bye-passed in sections.

(2) The purifying area must also be larger, in comparison with the retort, than is the case in gas-works, so that in a considerable series of tests approximately the same conditions as to purification may obtain throughout.

(3) Two gas-holders, conveniently each of 15 cubic feet capacity, must be in use, so that tests may follow immediately one upon the other, and the temperature of the retort may be thus maintained the same during each experiment.

(4) The whole arrangement must be placed indoors, and in summer the heat of the retort must be kept away from the rest of the plant.

(5) A good photometer and spacious photometer room are necessary. A Harcourt 10-candle pentane lamp or the Methven screen is used as the standard source of illumination, the results being calculated into, and returned in terms of, standard sperm candles.
The general arrangement of the plant at present used by the writer is shewn in Figs 1 and 2.

Routine Details of a Test

One-thousandth of a ton or 2.24 pounds of coal has been found a convenient and sufficient quantity to take for a test: about 10 cubic feet of gas are obtained, an amount which is ample for taking the illuminating power, but if the coal gives a poor yield a larger quantity may be taken. The coal is charged into the red-hot retort in a sheet-iron box, measuring 14 inches by 4½ inches by 2 inches, and the door, carrying its fire-clay luting, is screwed tight. The tap, at the entrance to the gas-holder, is immediately opened. In about 60 minutes, the gas will have ceased to come off; the volume is then measured, and the retort discharged. The gas is next passed into the other holder, being thus properly mixed, and on to the photometer to be burnt there. The retort is at once ready for the succeeding charge, which is worked into the first holder as before, the illuminating power of the gas from the previous test being taken in the meantime.

In testing a coal of unknown quality, two blank charges are first worked through the apparatus, the volume of gas
obtained in these may be noted but this gas is burnt away at the photometer without being tested. These preliminary charges are in order to secure that the pipes, purifiers, etc., of the apparatus shall at the commencement of testing be full of ordinary "endgas".

Use of a Standard Coal Seam

We have seen that it is not by any particular form of apparatus alone that Gas Coals can be satisfactorily valued. After many months work the attempt to produce a standard coal testing apparatus which could be relied on at all times and in all places to give the same results from the same coal, had reluctantly to be abandoned.

That the results given in Table I. should all have been from the same coal, tested in the best form of apparatus desirable, is sufficient evidence of the completeness of the failure. It then became evident that some correction must be applied to the results actually obtained before they could be accepted as in any sense representing the value of the coal.

In the case of coal the correction is found by using a coal of known value. A standard coal has been used before and is probably in use now in places, at any rate the idea
is by no means novel. Schilling as early as 1862 referred to the use of a stock of coal from a certain mine as a control for checking his tests; and again it is mentioned by Leybold in his 1895 paper, but from the scarcity of such references one may gather that the adoption of a standard coal is not at all general. Moreover a ton of coals may be useful as a standard for a series of tests extending over one or two months, but the coal itself will begin to change after this time, and for continuous work no standard except a standard seam can be of any value. It is well known that certain coal seams vary very considerably in quality within a short distance; this may be caused by the proximity of igneous rock. But taking top, middle and bottom coal together many seams with which the writer is acquainted are very constant over areas which can be measured by miles. It seems not unlikely that this differing of coal seams from place to place has been exaggerated and that differences of results really due to other causes may have been put down to variations in the seam. A Colliery Manager generally knows which of his seams are variable and which are not. This, combined with the writer's knowledge derived from testing led him to adopt a part of a certain seam, at the collieries at which he is engaged, as a standard
for the testing of other coals. The sperm value of this coal is fixed at a figure obtainable from it at any of the best gas works. It is stored in small stocks at a time at the laboratories so as to be always fresh. Anyone near a coal mine can with some little difficulty obtain a standard coal but it is necessary to know the coal well and to exercise care in its selection.

The results given in Table I. have all been obtained from this standard coal, it remains to be shewn how some sort of order can be extracted from that list and the manner in which the standard coal can be utilized in the valuation of others.

To begin with it may be said that all extreme results whether in yield of gas or in sperm value are rejected as standards of comparison with unknown coals; however many tests may have been made the results are in these cases rejected and the coal tested again on another day. All the results given in Table I. have been obtained from the standard coal but several have been rejected as standards of comparison. The differences in yield of gas seen in the table are caused largely by differences of retort temperature. When the retort is hottest it may happen that the condensers are also hottest as must have been the case in test 51.
then a large yield is obtained and it is ill-condensed and consequently of higher illuminating power then it would otherwise have been. Hence a high sperm value. Then again as previously stated a new retort makes all the difference, the cast iron retorts last about a month, towards the end of that time the yield of gas has begun to fall off, indeed after a week the difference is sometimes noticeable.

It has been noticed too that an especially high sperm value is obtained on a warm morning which has been preceded by some days of cold weather, hydrocarbons which have been deposited in the pipes, etc, during the cold days are picked up again by the gas. In conditions which are the reverse of the above results are obtained which are far lower than the true value of the coal. It is probably for a similar reason that on the retort becoming hotter during a series of tests, and the yield of gas greater, the illuminating power does not always immediately go down, for the gas, far from saturated with benzol etc, picks up these illuminants on its way to the holder; the larger the pipes the greater this effect will be. In testing a coal whenever there has been, between two successive tests, a notable change in the quantity of gas this effect can be looked for and it explains many an otherwise inexplicable
result, and also the frequently observed fact of the comparative uniformity of illuminating power during a day's testing.

The state of the purifiers also affects the gas.

All these things indicate how essential it is to have a check on the indications of an instrument like a coal testing apparatus. Although the sperm values in the list are highly variable they are in nearly every case explicable and very often each one just what might have been expected at the time it was obtained. Occasionally unaccountable results will come out but such are rare. If a series of tests be made from the same coal on any day the results will after the first two charges generally be fairly constant so long as the condensers are not allowed to become warm and the retort temperature remains the same. This being so the testing of an unknown coal is an easy matter. Three tests will probably suffice viz:— (1) Unknown coal (2) Standard coal, (3) Unknown coal. The two from the unknown coal will be near each other, the mean is taken and the figure corrected proportionally according as the standard coal is giving a result higher or lower than its fixed normal value.

Frequently however the case is less simple. It has
often been noticed in a series of tests during a day using the same coal, that the sperm values continue to come out higher and higher for each successive test; this is frequently owing to the condensers becoming gradually warmer. It is hopeless here to operate without a standard. In a case like this at least five tests are required to fix the unknown coal, the second and fourth being from the known. If a series of sperm values such as (1) 530, (2) 548, (3) 570, (4) 585, (5) 605 be obtained, being a rise of about 18 each time, we may safely infer that the same figures would have been obtained had the same coal been used in all the tests and that therefore the unknown coal is equal to the standard. The standard coal has a fixed value of (in the writer's case) 580 lbs. per ton therefore the unknown coal is reported as having that value although under the particular conditions of that day's testing the average result was only 568 lbs. The same result (580 lbs per ton) is obtained by taking the mean of tests (1) and (3) which makes the sperm value 550 i.e. on a par with the intervening test from the standard so that the unknown would have to be corrected up to the normal value of the standard, 580. But it is very necessary to make the five tests in order to be assured that the considerable difference
between (1) and (3) is due to a uniform rise in the sperm value and not to some other cause. When the results are rising in this manner and the unknown coal differs considerably from the standard the calculation of the unknown becomes more complicated and frequently cannot be carried out in which case the coal has to be retested at a more suitable time. Often however the quality can be gauged; the following instance is taken from the note book

\begin{table}
\begin{tabular}{|c|c|c|c|c|}
\hline
No. of Test & Sample & Yield & Illm. & Sperm \\
& & Gas & power & value. \\
\hline
1 & Unknown coal & 10700 & 13.5 & 494 \\
2 & Standard (fixed value 580) & 11050 & 14.8 & 561 \\
3 & Unknown & 10400 & 15.3 & 546 \\
4 & Standard & 10700 & 16.4 & 601 \\
5 & Unknown & 10700 & 16.4 & 601 \\
\hline
\end{tabular}
\end{table}

In this case the room was becoming warmer during the whole time occupied by the tests. There is a difference of about 100 in the sperm value between the first test taken from the unknown and the last; test 3 occupies an
intermediate position at 546. It may be gathered there is a rise of about 25 in the sperm value for each test. In order therefore to bring all to an equal footing 50 must be added to test 1 and subtracted from test 5, and 25 added to test 2 and subtracted from test 4. Then the following series is obtained.

<table>
<thead>
<tr>
<th>Test</th>
<th>Sperm value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>544</td>
</tr>
<tr>
<td>2</td>
<td>586</td>
</tr>
<tr>
<td>3</td>
<td>546</td>
</tr>
<tr>
<td>4</td>
<td>576</td>
</tr>
<tr>
<td>5</td>
<td>551</td>
</tr>
</tbody>
</table>

The standard coal is here seen to be practically at its true fixed value of 580 therefore the other coal requires no further correction and may be taken as having a value of 547 or 10500 feet of 15.2 candle gas.

It will be seen that considerable judgment is required in the interpretation of the actual results obtained from test gas-apparatus.

(1) Cf. "Gas Manufacture" W.J.R. Butterfield 1896 ed. p.18 "With judicious interpretation of the results, the tests are most useful".
This has been admitted by all operators but the grounds on which such judgment is to be based are often not gone into.

In making tests like the above the last results can nearly always be anticipated before they come out. Over and over again the same coal has been tested against the standard coal on different days and while giving totally different actual results the corrected figures are very much alike.

Sufficient has now been said to give an idea of the somewhat oblique paths by which it is necessary to proceed in order to arrive at the value of a gas coal. No doubt there are many objections to this method; its uncertainty, i.e., the possibility of working all day and obtaining nothing; possible variation in the standard coal selected, its laboriousness, cost, in time and gas are all against it. Also a standard having a sperm value of 580 is no use for testing cannel. A separate cannel standard is required for that. Nevertheless if ever it should be necessary to value gas coals as between buyer and seller it seems to the writer that in the present state of our knowledge, the only method of avoiding contention would be to adopt a common standard coal obtained from a certain
locality. The value of this once agreed upon there would be no need for differences of more than about 15 in the sperm value between different workers.

**Advantages**

(1) It will be seen that the practice of this method by introducing a check, considerably minimises the difficulties due to variable condensation.

(2) It is less difficult to keep the retort temperature constant for one day than to maintain it at the same temperature on different days.

(3) The Analyst's difficulty caused by the variety of results obtained from the same coal in different gas works is largely overcome, because the standard coal is fixed at a sperm value which can be obtained from it at our best gas works and all corrected results are statements of what can be obtained from the coal at such works.

(4) The method permits of the alterations of the form of the apparatus from time to time as improvements may be suggested, for such alterations affect only the uncorrected results.

**Summary:**

By means of proper condensation, the use of a coal
seam as a standard, and careful attention to retort heat

gas coals can be somewhat finely discriminated by a labora-
tory method; the use of a standard coal is regarded as
absolutely essential to success.

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DESCRIPTION of PLATE.

A. Retort heated by gas. The short bent pipe prevents excessive dripping of tar into the retort. Tar condensing in the ascension pipe is caught in the seal pot B.

C & D. Condensers, carrying cocks by means of which 1, 2, 3, 4, 5 or 6 tubes may be used at will or the whole by-passed. The condensers are carried in water tanks through which a constant stream of water may be kept running to secure an even temperature. This circulation is only necessary in hot weather but the tanks are always kept full of water.

The spout under the seal-pots E & F carries tar and liquor into the tar pit, G. H, Scrubber containing wet glass marbles, it can be by-passed at will and as a rule is only used in hot weather.

I & I. Purifiers, one of which only is used at a time.

J & K. Gasometers.