

case of oxygen; there are, however, two other agencies which also come into play, and tend to diminish the illuminating power; these are—firstly, dilution of the gas with the inert nitrogen (this factor is wholly absent in the case of the oxygen above); and secondly, more rapid oxidation of the illuminating material. The two latter factors produce, however, an effect greater than the first, so that, on the whole, the illuminating power is reduced, although until the air is present to the extent of about 50 per cent., the intrinsic luminosity remains unaffected, but as the proportion of air increases beyond that, its prejudicial effect approaches that of nitrogen, which it equals at the point of complete disillumination. It has, moreover, been experimentally shown that the reduction in the temperature of the flame by dilution with atmospheric air, gradually approaches that which is caused by dilution with nitrogen.

Of what practical value to the gas manufacturer are the experimental facts and theoretical considerations which have been discussed above?

In the first place, we see that neither is the proportion of heavy hydrocarbons in coal-gas, nor the equivalent in ethylene of these hydrocarbons, a definite measure of the illuminating power of the gas. For the same amount of light may be yielded by a small proportion of a heavy hydrocarbon, like benzene, as is yielded by a proportion of a lighter hydrocarbon, equivalent to more ethylene than the benzene. Thus the London gas of the Gas Light and Coke Company, with its heavy hydrocarbons, equivalent to between six and seven per cent. of ethylene, gives as much light as the same gas with these hydrocarbons exchanged for 13 per cent. of ethylene. Thus by increasing the density of the hydrocarbons, the same light can be obtained by means of a much smaller proportion of hydrocarbons, so that if the heavy hydrocarbons present in any given gas (which, as the analyses show, are nearly wholly olefines), could be converted into hydrocarbons of the acetylene and benzene series, the illuminating power of that gas would be greatly increased, without importing into it any *foreign* illuminating constituents. Unfortunately we are at present still very much in the dark as to the precise conditions of temperature, etc., influencing the conversion of hydrocarbons from one series to another.

In the second place, as to the combustible diluents with which the hydrocarbons are mixed, it is obvious from my experiments that marsh-gas is the one most fitted for developing the illuminating power; and, indeed, when an Argand burner is used, it cannot be regarded as a diluent only, but must be classed with the illuminating constituents of the gas. It must, however, be remembered that marsh-gas also possesses disadvantages as a diluent, for it consumes four times as much oxygen as does the same volume of hydrogen, and produces three times as much heat, besides producing its own volume of CO_2 , so that it tends to vitiate the atmosphere of the room in which the gas is burnt. From my experiments, it also appears that hydrogen is a more advantageous diluent than carbonic oxide.

Lastly, as regards the incombustible diluents which are present in gas, it appears that these should be conspicuous by their absence; for although oxygen itself increases the illuminating power, yet in gas it is always present, with an excess of nitrogen over and above that required for the proportion in atmospheric air, so that its presence can only be accompanied by loss of light. Of the incombustible diluents, carbonic anhydride is the one which is most, and atmospheric air least prejudicial to the illuminating power, whilst water-vapour and nitrogen

are intermediate in their action. Carbonic anhydride is now fortunately almost banished from the gas supplied to many of our large towns, whilst nitrogen is allowed to exist, sometimes in no small proportion.



SOME NEW PHASES IN PHOTOMETRICAL PRACTICE.

BY W. J. DIBDIN, F.I.C., F.C.S., CHEMIST TO AND SUPERINTENDENT OF THE GAS AND GAS METER TESTING DEPARTMENT OF THE METROPOLITAN BOARD OF WORKS.

THE attention which has been paid within the last few years to the improved illumination of open spaces and large areas generally, and the introduction of the electric light, and gas burners of high power, has inevitably led to a reconsideration of the methods in use for estimating the value of the various systems adopted.

It was formerly considered sufficient to estimate the intensity of the luminous rays in a horizontal direction only, irrespective of the value of those rays which are actually utilized in practice. Such a system was doubtless useful in those cases in which burners of similar primary construction were employed; but with the various forms of burners and lanterns recently introduced to the public, such a system is entirely erroneous, and can only afford results of a misleading character.

In order to ascertain the true value of a luminous agent, it is necessary to determine the power of those rays falling at angles, varying from the horizontal to the vertical, or more strictly, through the whole of the semi-circle, from the vertical line above to the vertical line below the point of illumination, thus—



For this purpose the ordinary form of photometer is altogether unsuitable, and can only be employed after considerable modification, and with an expenditure of time and labour, which is all but out of the question. I have therefore devised an instrument of entirely different construction to the usual form, which renders the testing of the angular rays both easy and rapid.

Before proceeding to the description of this photometer, it will be advisable to discuss the principles adopted, and the reasons for them.

When the Committee of the Gas Section of the International Gas and Electric Exhibition, held at the Crystal Palace last year, invited Prof. William Foster and myself to report upon the various burners exhibited, one of the first points considered by us, at the request of the committee, was the estimation of the angular rays emitted from the various burners submitted to our examination. For this purpose we employed a small portable photometer designed by Mr. F. W. Hartley, and termed by him the "Universal" photometer. The instrument consists of a light narrow table, 11 inches wide, 2 feet 6 inches high, and 5 feet 6 inches in length. The scale is divided into inches and tenths, and is 21 inches in length. It is fitted into, and capable of being shifted and fixed at any position within a groove in the table top, which has a long slot along its centre, below which slot is a brass socket connected by wire cords passing over pulleys to the winch handle, similar to the arrangement in the Evans photometer for moving the candles, and serving the same purpose, viz., the movement of the standard. The disc carrier is supported on a stand, the base of which is fitted with a pointer or index coinciding with the vertical line of the disc. The

by CDC^1D^1 . By drawing the circumference of a circle whose radius is CC^1 , and finding the cosine CE , it is at once seen that the section of the rays CF , which impinge upon the disc, is in exact proportion to the cosine of the angle of incidence CE .

When the light is raised throughout a quadrant, the number of rays impinging upon the vertical disc will be *nil*, and thus, although the burner may be one of high illuminating power, such a system of photometry would fail to record any value for it.

Another important point in connection with the vertical disc must not be overlooked, and that is, that when the rays of light impinge upon a surface at an oblique angle, a considerable loss of light occurs by reason of the increase of reflection and absorption, which preponderates over the loss incurred when the angle of incidence forms a right angle. This loss increases with the increase of the angle, and seriously vitiates any results obtained.

Table I shows the results of some tests made in this manner.

TABLE shewing the Illuminating Power of *Angular Rays* when tested with the Photometer Disc fixed in a vertical position, and when it is arranged so that the angles of incidence are identical:—

RAYs FROM BURNER 22.5° WITH HORIZONTAL LINE.

Readings with Disc Vertical.	Corrected for Cosine of angle = .9239.	Readings with Disc arranged for equal angles of incidence.	Loss % by estimation with Vertical Disc, due to reflection.
38.7	41.9	44.1	4.9
205.0	222.0	245.0	9.4
453.5	491.0	519.5	5.5
27.0	29.2	29.7	1.6
326.0	353.0	352.0	—
62.8	68.0	68.8	1.1
26.5	28.7	30.8	6.8
140.5	152.1	162.2	6.1
Average			4.4

RAYs FROM BURNERS 45° WITH HORIZONTAL LINE. COSINE = .7071.

Readings with Disc Vertical.	Corrected for Cosine of angle = .9239.	Readings with Disc arranged for equal angles of incidence.	Loss % by estimation with Vertical Disc, due to reflection.
20.2	28.6	34.9	18.0
282.5	400.0	491.5	18.6
20.6	29.2	34.2	14.6
47.5	67.2	87.3	22.0
23.7	33.6	38.4	12.5
49.4	70.0	85.8	18.4
42.5	60.2	67.1	10.3
15.6	22.1	25.2	12.3
81.0	114.8	136.5	15.9
124.1	176.0	186.9	15.8
104.2	147.8	161.9	8.7
15.7	22.2	25.1	11.6
88.2	125.0	144.0	13.2
14.5	25.5	25.7	0.8
9.2	13.0	12.7	—
129.3	183.0	207.0	11.6
9.0	12.7	12.6	—
52.2	74.0	86.5	14.5
Average			12.15

RAYs FROM BURNER 67.5° WITH HORIZONTAL LINE. COSINE = .3827.

Readings with Disc Vertical.	Corrected for Cosine of angle = .9239.	Readings with Disc arranged for equal angles of incidence.	Loss % by estimation with Vertical Disc, due to reflection.
55.3	144.5	378.0	61.8
82.8	216.5	920.0	76.5
Average			69.1

After correction for the diminished number of rays impinging upon the disc at the different angles, the value obtained is deducted from that found by estimation with the disc arranged for equal angles of incidence, and the difference between the two results calculated into percentages. By this means I find that when the burner is at an angle of 22.5° above the horizontal, the average loss due to reflection from the vertical disc is 4.4 per cent.; at 45° it is 12 per cent.; and at 67.5° 69 per cent.

It is obvious, therefore, that the method of estimating the illuminating power of angular rays by means of a vertical disc is erroneous.

By arranging the disc so that the angle of incidence is equal on either side, thus:—

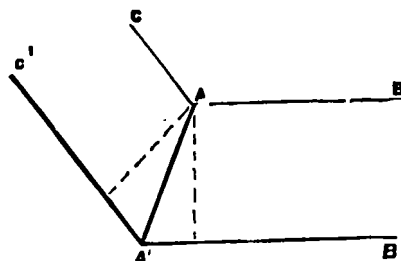


Fig. 3.

Disc AA' . Horizontal rays $ABA'B'$. Angular rays $CAC'A'$.

we equalise both the proportionate number of rays impinging thereon, as well as the loss due to reflection. Determinations thus made possess all the value of those made with a vertical disc and horizontal rays on either side in the usual manner.

For the purpose of comparison with the "Radial" photometer, as I have termed my design, I append the following woodcut of a portable photometer, made by Messrs. Sugg & Co., which embraces all the essential points of the most approved pattern of the ordinary bar photometer. It is easily taken to pieces and packed in a box for conveyance and is readily fitted up for use, with a little practice, in five minutes.

The principle involved in the construction of the Radial photometer is very simple, viz.: that the light under examination should be rigidly fixed in one position while the estimations of the value of the angular rays emitted from the horizontal to the vertical, either above or below, are being made, thus ensuring perfect steadiness of the burner, or other luminous point.

The apparatus consists of two vertical supports, one of which is permanently fixed to the base-board or foot, while the one on the right hand travels on rollers on the base-board in such a position that it will run in front of the fixed support.

The two uprights are connected by a bar, the ends of which work upon trunnions, or axles, attached to blocks which travel in the grooves of the uprights. These blocks can be clamped in any desired position. One end of the bar is attached to the front of the fixed upright, while the other end is attached to the travelling upright at the back, so that when the two uprights are in juxta-position the bar is perpendicular between them. The centres

of the trunnions correspond in position with the centres of the two graduated dial plates in front of the uprights. The distance between the centres of these dial plates is 50 inches. It is therefore evident that whatever position the bar may be in, the distance from the centre of one dial to that of the other must be constant. In front of the dial plate on the travelling upright the screen or disc-holder is fixed, so that its centre is coincident with the centre of the dial.

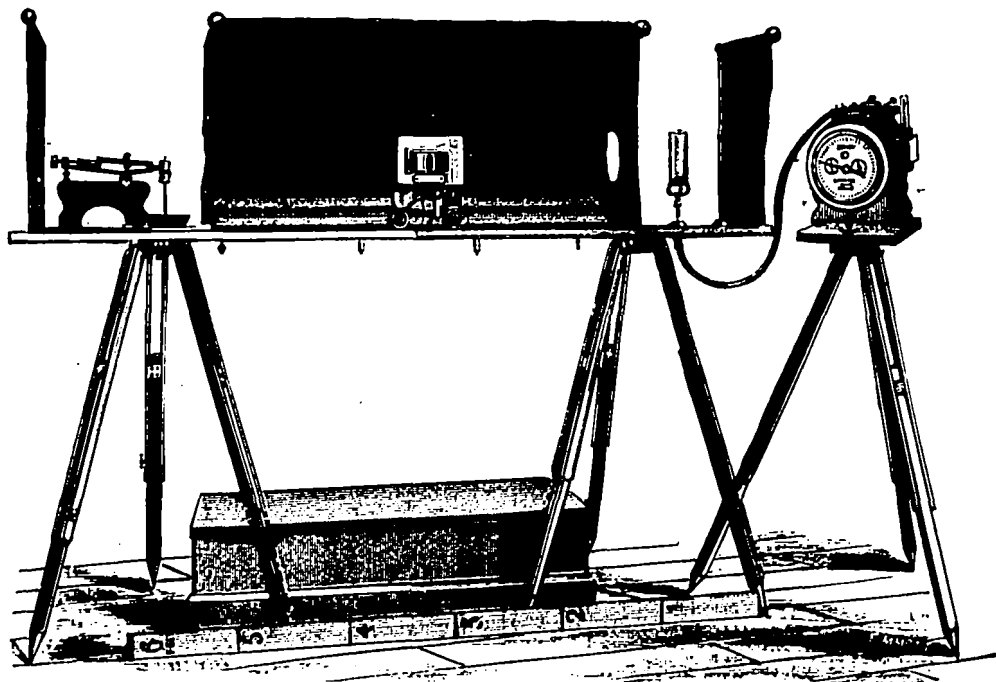


Fig. 1.

Attached to the block in the groove of the travelling upright support is the horizontal bar carrying the standard.

The standard is supported in front of the horizontal bar by a travelling carriage, working on rollers, and is moved by a cord and winch, conveniently placed on the right-hand side of the graduated dial on the support. Attached to the block carrying the photometer disc is a brass rod, which is brought well forward and then curved round for the purpose of carrying a velvet curtain to screen off extraneous light when readings are being taken.

The two dial plates are graduated; the larger one on the fixed support in degrees, and the smaller one on the travelling support in half degrees, which are numbered as whole degrees for the purpose of facilitating the setting of the disc for equal angles of incidence, so that when the bar is set, say, at 40 degrees, the disc-pointer is to be set at 40, it will then be in the proper position, viz., 20 degrees. The disc may be arranged to work automatically with the movement of the bar by means of a simple mechanical appliance, so that whatever may be the position of the bar, the disc will be at the correct angle.

A brass rod is provided for adjusting the position of the burner, &c., to be tested. It has to be pushed through the centre of the block and trunnion on the fixed upright support, and will then be at right angles with the plane of the dial, and project exactly through its centre, by which means it is easy to fix the exact position of the flame in front of the apparatus. The light to be tested may be brought forward to the full

extent which can be attained by the disc and standard, which, obviously, can be regulated as desired, so that the size of the burner or lantern—which may be tested with this apparatus—is practically unlimited, due regard being paid to the length of the bar and the power of the light.

When a test is commenced the light to be examined is fixed on the support attached to the block in the fixed upright, and accurately centred with the dial plate, which is to be lowered to the bottom of the groove in the support. The block in the travelling support has next to be raised, which operation will bring it immediately over the burner, the travelling upright being in front of the fixed support, and the pointer on the bar indicating 90° on the large dial plate. The photometer disc is to be arranged for equal angles of incidence, by turning it until its pointer is at 90, when a reading can be taken. The clamp holding the top block in position is then loosened, and the handle working the rack and pinion of the travelling support turned until the bar is at an angle of 80°, the block must then be clamped, the disc adjusted to 80°, and so on for each degree or ten degrees as desired, until the horizontal rays are estimated. The block supporting the light is then to be raised to the higher position, and the bar adjusted for the desired angle below the horizontal, and a second series of readings taken until the downward vertical rays are estimated.

The following wood-cut shows the instrument arranged for testing the rays thrown downward at an angle of 45°

The Bunsen, or greased disc, under ordinary circumstances, with lights of equal colour, is all that can be desired; but when used for testing the electric light or gas burners of the recuperative class, it is very unsatisfactory, and at times useless, in consequence of the great difference in tint between the light emitted from the standard and that of the burner under examination. I have, therefore, abandoned its use for these purposes, and use a modified form of the Leeson or "Star" disc. As originally designed, this disc was unsatisfactory, in consequence of the "cockling" of the two thin papers on either side of the perforated stout paper. To such an extent was this fault found to interfere with the readings, that the Gas Referees, some time back, disallowed its use at the Metropolitan gas testing stations under their charge.

Finding that the Bunsen disc did not answer all the purposes required, I modified the Star disc by pressing together the three papers, of which it is formed, with very thin starch water, and drying the moist disc under pressure. This treatment effectually prevented "cockling," and the use of the disc in its present form is sanctioned by the Gas Referees.

The great advantage of this form of disc is that very sharp readings are readily obtained, with totally different coloured lights; red and blue lights are compared with the greatest ease, an advantage which no words of mine can enhance.

It is to be hoped that in future all comparative tests of the value of various burners will be so conducted as to shew the actual work done by them, not only in one direction, but in all directions. With argand and other circular burners, this can be done

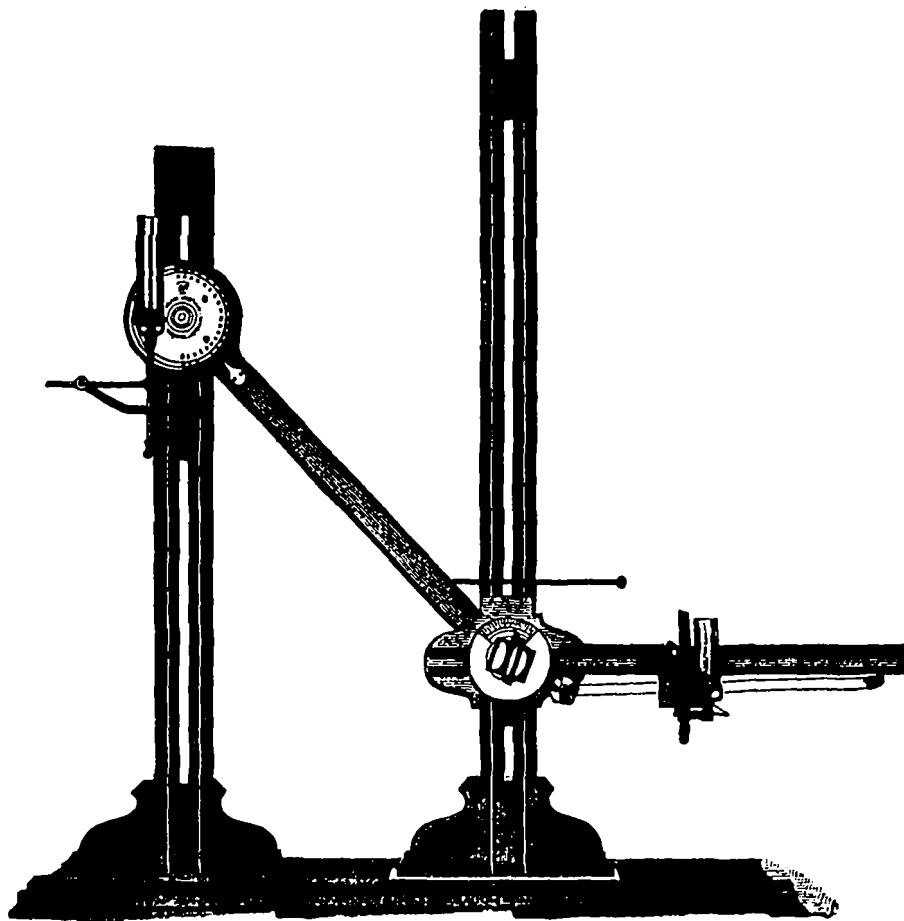


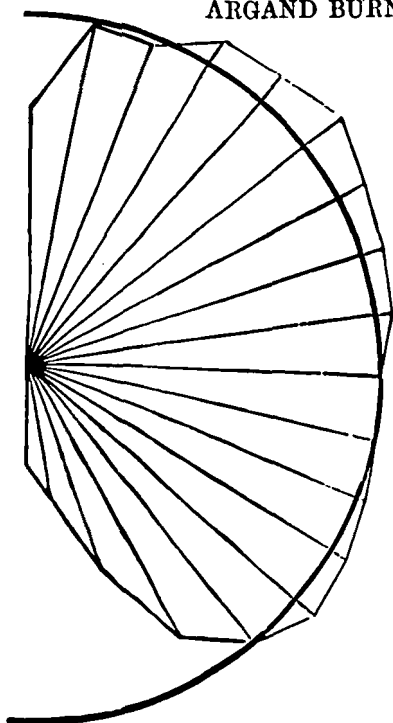
Fig. 5.

by making one series of tests from the vertical above to the vertical below, at every 10 degrees. But in the case of flat-flame burners, it is necessary that this series should be made in duplicate, one with the flame flat, or at right angles to the bar of the photometer, and one with the flame placed with its edge to the bar. An extensive series of experiments on this point has shewn that very considerable differences exist between the quantity of light emitted from the flat surface and from the edge of various burners; this difference varying from 10 to 35 per cent. of the light emitted from the flat surface. Therefore, it is very necessary that the two series of tests should be made

and an average taken, which should be held to represent the value of the burner.

For the purpose of facilitating comparison, I have drawn the following diagrams, representing the quantity of light emitted in the different directions, by which it will be seen that the ordinary method of testing burners does not give really comparative results of any value, as the horizontal rays in each case are curiously less in illuminating power than the angular ones, both above and below them; therefore horizontal testing only is unfair to the burner, and in all competitive trials should be supplemented in the manner I have described.

ARGAND BURNER.



The thick line represents the circumference of a circle whose radius equals the value of the light thrown from the burner horizontally.

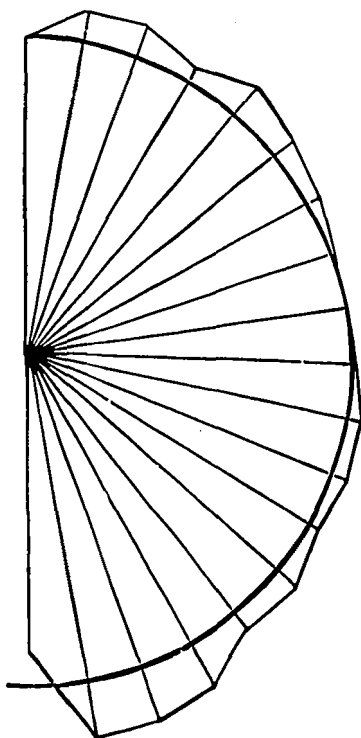
I am aware that I am proposing a complete revolution in practical photometry, but, having shown a full justification for it, I venture to hope that those experienced will readily agree with me, that the sooner the old erroneous methods are abandoned the better.

By means of the radial photometer, and the improved Leeson's disc any light can be readily tested in a most satisfactory manner, and results obtained which will fully repay the small amount of additional work expended in their production.

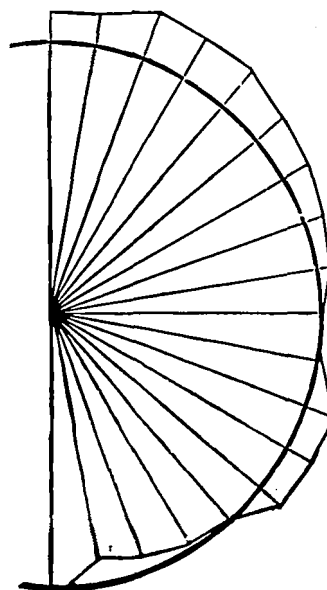
The importance of a reliable standard of light is admitted by all experts in photometry, and a great deal of work has been done by various investigators with the view of obtaining something of a more definite character than candles. It is to be hoped that before long a change from the present parliamentary standard will be authorised, and one or more of the proposed substitutes for candles made legal.

Enough has been done to prove that the Pentane test of Professor A. Vernon Harcourt, and the screen of Mr. Methuen possess all the requirements of practical standards; and where expense is no object in the one case, or gaseous fuel is obtainable in the other, and a small degree of illumination is desirable, little objection can be made to them. But where gaseous fuel is not at hand, and when a standard of light of higher illuminating power is desired, no better standard can be advised than the sperm oil lamp of the late Mr. T. W. Keates, which was fully described by him in the *Journal of Gas Lighting* of March 16, 1869. At that time the lamp was arranged to give a light equal to 10 candles, but since then it has been improved so as to yield a light equal to 16 candles, which can be modified, when desired, to give a light of two, five, or ten candles, by simply cutting off

FLAT FLAME BURNER No. 1..

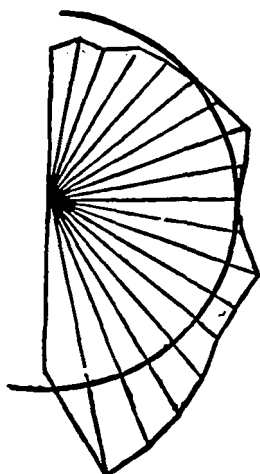
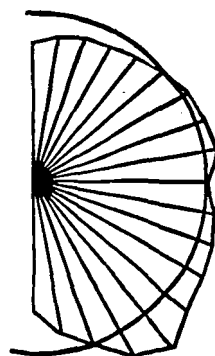


Flame at right angles to Photometer Bar.



Flame to the edge with Photometer Bar.

FLAT FLAME BURNER, No. 2.

Flame at right angles to
Photometer Bar.

Flame with the edge to Photometer Bar.

portions of the flame by means of a suitable screen; in which case sufficiently accurate results for ordinary purposes can be obtained without weighing the oil.

In raising this question of the lamp, I am perfectly aware that many will think that I am "thrashing a dead horse." In answer to those who do so, I will ask for any systematic tests made with this lamp which shall prove its unreliability. The objection that the lamp is used with a wick I hold to be utterly unscientific and unworthy of consideration in the face

of the fact that, when properly used, the lamp yields a light which is practically constant. In proof of this statement, I would point to the following series of tests of a gas flame arranged to yield a steady column of light, 3 inches in height, by cutting off the light from the top of the flame with a screen, so as to exclude errors, as far as possible, arising from slight variation of consumption or quality of the gas.

Table II. shews the results of some preliminary tests made in this manner.

TABLE II.

Shewing the results of tests of the angular rays emitted from an argand, and from two flat flame burners of different construction. The photometer disc was arranged so that the angle of incidence was equal on either side. Results stated in percentages of maximum intensity.

Rays from Burner.	Argand.	Flat Flame, No. 1.		Flat Flame, No. 2.	
		Flame at right angles to Photometer Bar.	Flame with the edge to Photometer Bar.	Flame at right angles to Photometer Bar.	Flame with the edge to Photometer Bar.
90° above horizontal	64.2	84.8	79.6	56.0	50.0
80° " "	94.3	94.2	79.6	60.0	52.0
70° " "	86.4	95.0	84.0	60.0	55.0
60° " "	96.5	92.7	84.0	64.0	56.0
50° " "	97.1	95.6	83.2	66.0	58.0
40° " "	100.0	91.3	79.6	68.0	60.0
30° " "	97.1	87.0	70.8	72.0	62.0
20° " "	96.5	84.0	75.3	74.0	63.0
10° " "	95.0	84.0	74.0	70.0	63.0
Horizontal	90.0	84.8	71.0	68.0	60.0
10° below horizontal	90.0	89.1	71.6	72.0	65.0
20° " "	92.0	89.1	76.8	78.0	68.0
30° " "	94.3	87.0	76.8	76.0	69.0
40° " "	97.1	94.2	76.0	78.0	72.0
50° " "	91.5	93.5	69.5	84.0	76.0
60° " "	81.5	98.5	68.1	88.0	70.0
70° " "	57.2	100.0	66.7	94.0	60.0
80° " "	36.5	90.2	63.8	100.0	56.0
90° " "	26.4	74.0	72.1	62.0	45.0

TABLE III.

Shewing the results of tests made with Keates' lamp, of a flame 3 inches in height, the light from portions above that height being cut off by means of a screen.

	Light given by Standard Lamp, corrected for consumption of Sperm.	Ascertained value of Gas Flame.
1st day	16.55	18.03
"	16.82	17.85
"	16.89	18.07
2nd day	15.50	17.99
"	16.21	17.94
"	16.75	17.82
"	16.38	18.32
"	17.02	18.21
3rd day	16.48	18.06
"	16.68	18.11
4th day	16.10	17.93
"	16.50	18.13
"	17.08	17.93
5th day	16.46	17.88
"	17.00	17.92
"	16.52	18.05
"	17.00	18.06

71% of the tests were within 0.1 candle of the mean.

The tests were made at intervals, and on various days, during which, practically, no variation was found in the illuminating power of the gas used. The results may, therefore, be taken as fairly representative of the work done by the lamp.

The conditions under which the lamp must be burnt, are very simple, viz., clean oil and a clean wick. For particulars regarding the oil I cannot do better than refer to Mr. Keates' paper above mentioned. What he said there holds true now, and will hold true so long as there are sperm whales to be caught, and a temperature of 40° F. obtainable.

The only objection of any moment which can be made to the use of the lamp, is that it requires a certain interval of time to elapse between the first lighting and its readiness for use, but as this interval is only about thirty minutes, I do not see that this objection should have weight with those who are desirous of obtaining correct results from an operation which requires such an exercise of patience as photometry admittedly does. It is proverbial that impatient operators make bad photometrists.

The great advantages to be derived from a 16-candle standard, which is ready for use at all times and in all places, are obvious.

In the first instance, the advantage of using a standard which approximates more nearly to the power of the light under examination, must be perceptible to the most superficial observer, as by this means the errors due to the multiplication of the readings by 8, 16, etc., are eliminated, and more correct results obtained.

In the second place, the colour of the standard lamp is almost identical with that of the ordinary 16-candle gas flame, and, therefore, readings with the disc rendered easier.

In the third place, the use of the 16-candle lamp enables estimations to be made of the value of high power gas burners and electric lights, with far greater facility and exactness than can possibly be the case with standards of lower power; with the further advantage of shortening the photometer bar.

I have thus shewn enough to point out the chief advantages of the lamp. The objection that "the lamp will not burn," is so utterly at variance with all the facts, and the results of hundreds of tests made with it, that I pass it over without further comment.

In conclusion, I may state that I do not claim to have settled the many vexed questions arising in photometric practice. On the contrary, the radial photometer was designed to assist in their investigation, and it is to be hoped that its systematic use will throw considerable light on many points connected with the construction of gas burners and other illuminating agents, which at present rest in obscurity. If my endeavours to provide a workable instrument, which shall assist in their solution, meet with any degree of success, I shall be more than satisfied.

DISCUSSION.

The CHAIRMAN said the meeting had to thank Dr. Percy Frankland and Mr. Dibdin for their most interesting papers on very important subjects. It was very encouraging to see so many representatives of gas manufacturing industry present; because, the operations concerned acted and reacted upon other branches of chemical industry. Reference to the pages of the Journal would show how that fact was recognised, and how frequently the subject was touched upon. One could not help feeling that chemistry had not yet done all it could for the gas industry; and he believed that in the future they would owe a great deal more to its products, besides getting the advantages of the light, for the gas industry had not yet arrived at the perfection which it would some day reach. Then it was wonderful to see how the art of photometry had kept pace with the necessities of the changing lights of the present time; and the points to which their attention had been called were useful, not merely from a photometrical point of view, but also from a practical one. They could not help thinking that it was exceedingly probable a good deal of the complaints of the efficiency and economy of gas-lighting might be owing, in no small degree, to the detestable quality of the burners used, while at the same time it was no doubt possible to use a good burner in such a way as to get a bad result from it. He would, with these preliminary observations, invite remarks from the meeting upon the papers which had been read.

Mr. F. W. HARTLEY said that being an old photometrist he wished to make a few remarks. He believed that he was among the first of those who showed the importance of testing the powers of gas flames at more than one angle; and in the articles which he furnished to the *Journal of Gas Lighting* in January, 1881, he described the photometric arrangement which he used. That arrangement was developed in the "Universal," which was before them, which instrument was employed by Mr. Dibdin and Professor Foster as stated, after the arrangement for the disc to be set at any desired angle had been made. That modification and improvement was entirely due to the gentlemen named; and he hoped that the system of placing the disc at a mid-angle between the unit light and any other which was opposed to it, would be universally adopted, as thereby the true relations in powers were found. He so used the photometer in its later improved state. In his earlier experiments he had, however, sought to ascertain the amount of light which would be received on a perpendicular plane, such as a wall, for instance, where the disc was fixed vertically, as it should be for such purpose, inasmuch as it was clear that the walls of a room could not be turned or twisted to accommodate a light in the ceiling. The angle-screen method was the scientific one; and Messrs. Dibdin and Foster were entitled to the credit of devising it. He was somewhat surprised to hear that when the rays of light fell at an acute angle on the disc, so large a number were, as it were, rendered insensible to the eyes of the observer, seeing that the intensity of

illumination was judged of from the images of the disc in mirrors; but he had no doubt but that Mr. Dibden's statement was quite correct. As regards flat-flames it was the fact that much less light was delivered from their edges than from their surfaces. He had determined the difference with very many gas and paraffin oil flames. If, however, a curved reflector were placed behind a flat flame the horizontal light would be found to be greatest when the edge of the flame was presented to the photometer disc; because, for one thing, the wide flame covered more of the reflector, and prevented it from so fully acting. He regretted that he had not yet worked with Mr. Keates' lamps. That gentleman's lamented death prevented him obtaining it when he had opportunity to try it, and since, he had been too much occupied to find time. He hoped, however, to be able to fully try it presently; but he must differ from the opinion of Mr. Dibdin that a powerful standard of light was necessary, his (Mr. Hartley's) personal experience being that with a unit not exceeding two-candles light the eyes were not so distressed and wearied as when the unit light was powerful; a matter of importance when operations extend over seven or eight hours. With a two-candle unit he had tested lights up to a 1000 candles' power. During the past four months Mr. Heisch and himself had been engaged in investigations on photometric light units, but lamps with wicks were, by instructions, excluded from the inquiry. Mr. Dibdin had shewn them a novel and very beautiful instrument, and he hoped that its employment would lead to the development of many interesting and valuable facts in photometry.

Dr. E. FRANKLAND had been much interested in the paper which had been brought before the Society by Mr. Dibdin. He was not aware before how great the difference could be in the light emitted by argand and fish-tail burners in different directions. It was quite obvious that photometric readings of this kind were absolutely essential if anything like a true result was to be arrived at, and he thought the apparatus which Mr. Dibdin had contrived could be easily worked, and it was obviously susceptible of the attainment of accurate results. He had not quite understood the remarks of Mr. Hartley with regard to the reflection from the paper, but it might be well to bear in mind that the reflection of light from a surface of paper was very different indeed from the reflection of a metallic surface; the reflection from paper increased continually in amount as the angle of incidence formed by the rays and the paper diminished, so that at last, when the rays made a very small angle, a very large proportion of them indeed would be reflected; but how far that would affect the appearance of the disc he was not prepared at the moment to say. Such a photometer would be of essential service in determining the ratio of the illuminating power between the arc lights, which had never yet been properly tested, and he hoped by the help of this instrument they would obtain more trustworthy results than hitherto. With regard to his son's paper, and the experiments he had brought before the notice of the Society, he had not many remarks to offer. It was obvious, as had been pointed out, that there was a very marked difference in the proportion of what might be termed excess-nitrogen in the gases of the different periods mentioned, which might require some explanation. In his own experiments of 1851, it would be seen that the nitrogen was but very slightly in excess of that required by the quantities of oxygen which were also present, whilst the subsequent experiments shewed that the proportion of nitrogen to oxygen had been constantly increasing. He spoke subject to correction by the practical men who were present, but it occurred to him that the fol-

lowing might be the explanation: In 1851, gas was made almost exclusively in iron retorts, and those retorts were much more gas-tight or air-tight than the earthenware retorts since employed. At that time, no doubt the exhaustion was carried on much as it was now—he did not know whether the exhaustion was now greater than it was then—but, at that time, the super-exhaustion, though it would not have the effect of drawing air into the retorts themselves, would draw it in through leaky joints and insufficient seals. There would thus be drawn in the proportions of oxygen and nitrogen contained in the atmosphere. But all the air drawn into a leaky retort would be almost instantaneously deprived of its oxygen, so that if there were a leaky retort into which the furnace gases were drawn, nitrogen, without the corresponding proportion of oxygen, would become mixed with the gas. He hoped the results his son had obtained, in ascertaining the hydrogen density of the illuminating hydrocarbons, would eventually lead to a really trustworthy method of determining chemically the illuminating power of gas. As soon as the intrinsic illuminating power of the different illuminating hydrocarbons, and especially the acetylene, had been determined, he thought a formula might be devised, which would enable the illuminating power of a gaseous mixture to be calculated from the carbon of hydrogen densities with greater accuracy than could be attained by photometric methods. Although it was a method which could never, perhaps, be brought into daily practice, still it would be found very useful to submit gases from time to time to that crucial test. It was not impossible that an apparatus could be contrived, so that by, say, a weekly analysis of the gas of a town, the average quality of that gas could be determined. If a small holder were made to receive a current of the gas, proportional to the amount being supplied at any moment, and then the contents submitted to a weekly analysis, probably a fairly good average would be arrived at, provided they could devise a working formula for the determination of the true illuminating power from the chemical composition.

Mr. DAVID SUGG said:—With regard to placing the discs used in photometry in relative positions to receive the light from the standard and that from the light to be tested equally on both sides, he would quote an instance when his father was engaged making experiments on the Thames Embankment. For this purpose a Richie disc (in the form of an equilateral triangle) was employed. The side towards the standard was fixed, the other made movable, so that it could be elevated into position, making the angles of incidence equal. The images of the discs were received upon a mirror placed above, and at an angle of 45°. It is curious to note, as compared with the results obtained by Mr. Dibdin with his radial photometer, that the observations made by Mr. Sugg with the disc firstly in its normal position and then elevated—making the angles of incidence equal—the readings remained unaltered. This was due, no doubt, to the fact that the same beam of light was received upon the disc, the only difference being the respective angles at which the lights infringed upon it. When short-bar photometers are employed it may be found necessary to have the means of adjusting the disc.

Mr. W. LANT-CARPENTER said it had been pointed out very clearly that some of the remarkable results obtained with regard to the illuminating power of gas, as compared with its chemical composition, were to be explained by the temperature of the flame resulting from the burning of the gas; and he would like to ask whether that line of inquiry had been at all followed out in the direction of investigating the

temperature resulting from the combustion of gas of known compositions. This was an important point, when the constantly increasing use of gas for heating purposes and in gas engines was considered, and it also bore upon the proposal of the late Sir W. Siemens to partially separate the gaseous products of coal distillation into heating gas (the first and last portions) and lighting gas.

Mr. OTTO HEHNER, as one who had to spend a considerable part of his time daily in testing and examining gas, was very glad to hear Mr. Dibdin say that there was every prospect of the present standard of measuring illuminating power being speedily abandoned. There had been much talk of change for a long time past, but we now apparently might hope that not many months would elapse before it was realised. Candles, in fact, were not standards at all—every gas examiner could not but feel that. Could one feel any confidence in the accuracy of the results of one's testing if three successive tests of the same gas, on the same evening, but with different candles, could indicate 15, 16, and 17 candle-powers respectively, when, doubtless, the gas itself had remained practically the same. He did not mean to say that such widely discrepant results were the rule, but still they did occur, and made one feel very diffident in certifying to any slight deficiency in illuminating power of any given gas supply, when one considered that the certificate would probably form the basis of a prosecution against the Gas Company. This absence of a standard worthy of the name made one inclined to regret that Dr. Percy Frankland had bestowed so large an amount of labour in comparing the chemical composition of gas with the nominal illuminating power. If ever a really good standard were obtained, it would be quite impossible to re-calculate Dr. Frankland's results upon that new standard.

Dr. ARMSTRONG remarked that the statements of Dr. P. Frankland afforded conclusive evidence on the subject they were discussing. Professor Frankland had on more than one occasion pointed out what a very bad article the public were supplied with by the gas companies, and he was glad to see his son following in his footsteps and again pointing out the very low quality of the gas supplied to the Metropolis in reference to its illuminating constituents. At the same time his observations indicated the direction in which gas manufacturers must proceed in order to give the public a gas which would satisfy requirements, and be worthy of the present condition of chemical knowledge. He had pointed out, amongst other things, what a great effect a small amount of benzene has upon the illuminating power. They heard on all hands that they were going to recover a very large quantity of benzene and other hydrocarbons which were at present lost in coking coal, and there was little doubt that if they did recover all that was anticipated the hydrocarbons would become drugs in the market. The direction indicated in which they must proceed was perfectly clear, for it was obvious that gas manufacturers might develop their industry to render the gas of sufficient illuminating and heating power by the introduction of volatile hydrocarbons.

Professor FOSTER desired to say a few words with reference to the points which Mr. Hartley and Dr. Frankland had referred to. Mr. Dibdin and himself were rather at a disadvantage on the present occasion; but he had in his hands a report, which had been printed since last November, where the first principles relating to this subject were very fully and fairly discussed, and that discussion, when published, would enable those who took an interest in the matter to better understand the reasons for this new depart-

ture of theirs. The method of obtaining an equality of angle had never, he thought, been adopted before, and there were some points in connection with it to which he would allude. With reference to the use of the disc, light was absorbed, transmitted, and reflected. By so arranging the disc that it makes equal angles with both sources of light, the disposition of the light falling on each side is similar, whatever be the laws with regard to it. That was a fundamental point; and whatever might be the co-efficient of reflection, &c., they would be sure of having trustworthy results by arranging the disc symmetrically with regard to both the lights compared. But he need not now discuss the matter further, because there was no very ready way of understanding what the co-efficient of reflection would be. Mr. Hartley had made an observation about the reflection from the disc, but he had failed, apparently, to notice that the incidence of the reflected rays on either side of the disc would be in the same plane, and that any reflected light as supposed would pass in the way shewn [describing by a diagram]. Mr. Hartley had, therefore, fallen rather into an error in that matter. Whatever the law of reflection might be, the disc was really illuminated and viewed under precisely like conditions on either side.

REPLY.

Dr. PERCY FRANKLAND, in reply to the remarks made, said Mr. Foster had spoken of the carbonic oxide and nitrogen, and there certainly did appear to have been some leakage from the large proportion of carbonic acid found. On that point, Prof. Pedler, of Calcutta, had told him the previous week that he had examined the Calcutta gas and found it contained, not only 10 per cent. like the Ipswich and Birmingham gas, but 17 per cent.; so that he supposed the Calcutta gas manufacturers appreciated the advantages of the introduction of air even more than it had been suggested that some of the gas manufacturers in England appreciated it. (Laughter.) Mr. Otto Hehner had regretted that he had unfortunately taken so much trouble with these analyses, when there was no reliable standard of illuminating power; but, of course, he was obliged to be content with what he could get, and no doubt if he had had some of Mr. Dibdin's more reliable standards they would have been of more value. With regard to Mr. Carpenter's remarks on the temperature of flames, he had not investigated them himself, but there were a number of data on the subject, and as far as they were known they coincided very closely with the results he had obtained. For instance, in the case of the combustible diluents the amount of heat produced by marsh-gas was very much in excess of either carbonic oxide or hydrogen. The temperature was mostly reduced by admixture with carbonic anhydride; it was next most reduced by nitrogen, and it was least reduced by atmospheric air; but the reduction in temperature by the admixture of nitrogen and atmospheric air became more and more approximate as the proportion of those diluents increased. As the proportions of nitrogen and atmospheric air increased their illuminating power converged, whilst the reduction in temperature effected by the carbonic anhydride became more than by nitrogen and the atmospheric air. There was a complete accordance, therefore, between the flame temperatures and the illuminating power, so that this matter of the temperature appeared to be the most important of all.

Mr. DIBDIN, in reply, said: With regard to Mr. Hartley's remarks on the high power standard that he had used such a standard and had found a certain amount of strain upon the eyesight from the increased power of the standard, but he himself had worked a

great deal with the 16-candle standard, and though it might be that there was a difference between the eyesight of himself and Mr. Hartley, he must say that after a long day's work with the 16-candle lamp he felt less exhausted than after a similar day's work with the candles; the readings were sharper upon the screens, they took less time to observe, and there was consequently much greater relief for the eyes. On account of the time occupied in trying to balance the position of the disc, when a low power standard was used, one's eyes were tired before the reading could be obtained; but with the 16-candle standard the reading could be taken in a moment; it was as sharp as could be, and the eyes were rested until the next test had to be taken. He had had a great deal of experience with the 16-candle lamp, and he was bound to say that he did not agree with the experience of Mr. Hartley. Mr. Helmer spoke as if he had understood him to say they would actually have another standard of light very shortly, but he was sorry to have given him that impression, as it was, of course, not in his power to determine what the standard should be; that was a matter for Parliament. No doubt many people desired it, but there was a great deal of difference of opinion on the subject of standards, and until it was settled, which was the best, Parliament would probably not do anything. It had been suggested that two or three should be allowed by the Board of Trade, to be used if found suitable for the purpose, instead of the present arbitrary rule that only candles should be used. Dr. Frankland had remarked on the subject of the reflection of the light impinging upon the screen at a greater or less angle. He must confess he had felt a little puzzled on that point, and it really required a great deal of work to elucidate the question thoroughly. Until he had this photometer, the testing of the angular rays was a matter of very great difficulty and labour, as at every alteration of the angle the distance had to be calculated and measured, the burner re-adjusted, the photometer scale re-arranged, fresh readings taken of the meter, and in fact each test had to be started *de novo*. It was the anxiety and labour attending all that which induced him to turn his thoughts to such a design as this radial photometer, and he had shewn that by it it was possible to obtain readings at any angle; only one reading of the meter was required, and two settings of the burner—one for the rays above and one for the rays below the horizontal. After the first adjustment only one movement of the burner was required during the whole of the tests from the vertical above, and to the vertical below; and, consequently, the readings taken would be perfectly reliable throughout the whole series, as the consumption could not possibly be affected. He must express his sincere thanks to Messrs. W. Sugg and Co., who had made the instrument for him, for their kind assistance, and the care they had taken in producing the design.

Professor FOSTER resuming, said with reference to the results of Dr. Percy Frankland, the figures as to the illuminating value were more important than some other incidental matter; and still he would like to make a few remarks upon the latter. Some years ago it struck him that the fact of the diminution of carbonic oxide, as shewn by the more recent analyses, might be due to the more perfect methods of closing the retorts. He was not prepared to say whether that was the case or not. Dr. Frankland had alluded to the possibility of air being introduced through the medium of imperfections in the retorts. He (Mr. Foster) might say that he thought there was something underlying the system of purification at Birmingham and Ipswich, where the proportions of nitrogen were shown to be so large, which was slightly different from that adopted

in the majority of cases. He believed that some gas engineers, after the gas had passed out of the hydraulic main, allowed a certain amount of atmospheric air to be introduced. It assisted the purification. It was difficult to understand the 10 per cent. of nitrogen getting into the gas in any other fashion. How could it be understood as the result of the temporary closing of the lid of the retort? He did not know whether they had patent lids at Birmingham or those of the ordinary form. He spoke with the greatest deference on the subject, but there was the 10 per cent. of nitrogen, and those figures were quite exceptional. He certainly believed that it did assist the purification in some instances to admit a certain amount of atmospheric air. The oxygen, as shown in all the analyses had practically disappeared. What became of it? The fact of the ready absorption of oxygen in gas purification had struck him very much some years ago in the course of some works on which he was then engaged. Sulphide of calcium, as it exists in the ordinary lime purifier, was a very powerful absorbent of oxygen; and there was no cheaper or better way of getting rid of it than by such means. Sulphide of iron would, no doubt, act in a similar way. Really, therefore, the free oxygen of atmospheric air was never found in the finished gas owing to these circumstances. The report he had already alluded to would throw some light on the subject of the illuminating power of hydrocarbons. Mr. Dibdin and himself had worked it out very carefully for naphthalene, the values for which were expressed in grains per candle power per hour. The results were valuable in themselves, though he was afraid they had not been working on quite the same line as Dr. Frankland. He had no doubt that their figures, imperfect as they might be, would throw some light upon the subject. One very curious point in connection with the burning of the naphthalene, as was done in the alcohocarbon apparatus, was that the illuminating power, due to the naphthalene itself, worked out wonderfully closely for widely different rates of consumption of naphthalene. The figures all through the series were very concordant, though he regretted that it was not then in his power to publicly state what they were.

Liverpool Section.

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Vice-Chairman: Prof. J. Campbell Brown, D.Sc.

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E. W. Parnell.
C. Symes.
H. Tate, jun.
G. T. J. Wells.

Hon. Sec.: E. G. Ballard, Queen's Park, St. Helens.

Notices of papers and communications for the meetings to be made to Edward George Ballard, Queen's Park, St. Helens.

UNIVERSITY COLLEGE, ASHTON STREET, LIVERPOOL.

Wednesday, May 7th, 1884.

MR. MUSPRATT IN THE CHAIR.

ON THE ACTION OF NITRATES UPON IRON AND SULPHIDES IN THE PRESENCE OF CAUSTIC ALKALI.

BY G. LUNGE.

The *Journal of the Society of Chemical Industry* (1884, p. 138) contains a paper by Mr. E. W. Parnell, in