BRITISH ASSOCIATION OF GAS MANAGERS.

Incorporated gas institute.
Transactions.

British Association of Gas Managers.

REPORT OF PROCEEDINGS

OF THE

SEVENTH ANNUAL MEETING,

HELD

AT THE SOCIETY OF ARTS' ROOMS,

JOHN STREET, ADELPHI, LONDON.

JUNE, 1870.

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BRITISH

ASSOCIATION OF GAS MANAGERS.

REPORT OF PROCEEDINGS,

&c. &c.

The Seventh Annual General Meeting of this Association was held at the Rooms of the Society of Arts, John Street, Adelphi, London. MAGNUS OHREN, Esq., A.I.C.E., Vice-President, occupied the chair.

TUESDAY, JUNE 7, 1870.

The first sitting was held this morning, when the chair was taken at eleven o'clock.

The HONORARY SECRETARY (Mr. W. H. Bennett) read the minutes of the sixth annual meeting, held last year at Liverpool, which were approved.

The annual financial statement of the association having been previously printed and circulated among the members, was taken as read, and was received and adopted.

The HONORARY SECRETARY read the following list of applications for membership which had been submitted to the committee.

Barrett, W.	Accrington.
Beale, F.	Hackney.
Blanchett, E. R. . . .	Calcutta.
Bower, F.	Low Moor, Bradford.
Child, F.	Sheffield.
Clark, H.	Imperial Gas Company, Shoreditch.
Clark, J.	Imperial Gas Company, St. Pancras.
Clift, J. E.	Redditch.
Cornish, J. H. . . .	Bridgwater.
Cross, S.	Abergavenny.
Doughty, F.	Margate.
Drew, T. A.	Crewe.
Duff, W.	Morecambe.
Eldridge, H. O. . . .	Richmond.
Evans, E.	Peterborough.
Evans, F. J.	Chartered Gas Company, Westminster.
Farrand, C.	Croydon.
Fish, R.	Hornsey.
Foulis, W.	Glasgow.
Gill, R.	Bridgnorth.
Goodwin, J.	Rotherham.
Harris, R.	Great Central Gas Company, Bow.
Hastings, P. W. . . .	Pinner.
Helps, G.	Bath.
Humphreys, W. C. . .	New Barnet.
Hunt, Charles . . .	Nine Elms.
Jones, H. M. L. . . .	Westminster.
Jowett, J.	Leeds.

B

Kitto, C. W.	Tunbridge.
Kitt, A.	Chartered Gas Company, Curtain Road.
Lawson, J. W.	South Shields.
Littlehales, Thomas	Wormwood Scrubbs.
Methven, John	Gravesend.
Middleton, J.	Wandsworth.
Moir, John	Shotley Bridge.
Murray, J.	Scotswood.
Niven, R. J.	Kettering.
North, W.	Stourbridge.
Osborn, J. H.	Bromley.
Padfield, W. A.	High Wycombe.
Paterson, R. O.	Cheltenham.
Pontifex, S.	New Barnet.
Pritchard, W.	St. Helen's.
Rowan, J.	Colchester.
Scott, G.	Tunbridge Wells.
Severs, —	Birstall.
Smith, H. W.	Seaham Harbour.
Smith, T.	Wigan.
Studholm, S.	Whitehaven.
Trewby, G. C.	Chartered Gas Company, Westminster.
Vanheson, G. B.	Rochester.
Wilson, W. P.	Strand.
Wright, C.	Saffron Walden.

It was unanimously resolved that the gentlemen whose names had just been read be elected ordinary members of the association.

The Honorary Secretary read the names of several gentlemen who had expressed a desire to become extraordinary members of the association, under the provisions of rule 4.

The President said the committee were quite of opinion that the list of extraordinary members was being somewhat unduly increased, and that it was a question which the association would do well to consider. The rule 4 provided that extraordinary members should consist of gentlemen taking an interest in matters connected with gas manufacture, who should only be admitted on being elected by a majority of two-thirds of the members present at an annual meeting, and they were required to pay an admission fee of £5 in addition to the ordinary subscription. With reference to the gentlemen whose names had been read by the secretary, it was perhaps rather too late to raise the question on the present occasion, but it was important that the association should act with caution in the future.

Mr. G. Livesey said he hardly liked to raise the question at that time whether it was advisable to continue to admit extraordinary members according to rule 4, under which "gentlemen taking an interest in matters connected with gas-works" were eligible, and in the remarks he should offer on the subject he should speak as an individual member, and not at all as representing the committee. Nearly every member of the committee, including himself, had either proposed or seconded one or more of the gentlemen whose names had been read, as, under the rules, they were bound to do. From conversation he had had with several of the members, he thought it was desirable that an opportunity should now be given for the expression of opinion on the subject, now that the question of electing extraordinary members was before the meeting, so that the committee might know how to act, and what recommendations to make for future guidance. The rule of the association was a very vague one. Under it they began by electing manufacturers, now they were coming to manufacturers agents, and it would require great prudence on their part, or they would drift into that which would damage the association.

The Honorary Secretary, in reply to an inquiry as to the proportion of extraordinary members to ordinary members, said the number of extraordinary members was 9, and of ordinary members 250.

Mr. Warner (South Shields) said as he was the first to raise an objection to the admission of extraordinary members, he felt bound now to say that, in his opinion, having created that class of membership, they ought to continue it. There were many manufacturers who took as deep an interest in the progress of gas lighting as any gas manager could do, and had a far greater personal interest in the subject than some of them had. As the members of the association had the matter always in their own hands, and could reject by their votes any candidate whose fellowship they might not desire, no harm could come by retaining the present rule.

Mr. BROADHEAD (Great Grimsby) said he objected at the second meeting to the creation of extraordinary members, as he was apprehensive the association would be made use of for trade purposes. In those early days, however, there were reasons for the course then adopted, but now the association could afford to give it up.

Mr. A. WILLIAMS thought the prejudice to extraordinary members arose from the name. It was singular that those who might fairly be supposed to know least about the subjects discussed at these meetings should be called "extraordinary," and those who were the most thoroughly and practically acquainted with them should be merely "ordinary." He was in favour of continuing the existing rule.

Mr. G. ANDERSON could see no difficulty in connexion with the subject. The rule provided that gentlemen interested in gas matters were eligible as extraordinary members. This did not mean "interested" in a pecuniary sense, but interested intellectually, and likely, by the part they would take in the discussions of the association, to instruct and interest the other members. It was clearly unadvisable to allow persons who had a mere money interest in these matters to join the association, otherwise there would be the danger of it becoming a canvassing society for trade purposes, and the liberty of gas managers would become fettered thereby. To give the committee the opportunity of reconsidering the question, he would move that the election of extraordinary members be postponed until the following day.

Mr. D. CLARK seconded the motion.

Mr. BARTHOLOMEW (Glasgow) pointed out what he feared would be a hardship in some cases. He, for one, and Mr. Sharp, of Southampton, were not now connected with the manufacture of gas, and if the rule which admitted to extraordinary membership were expunged thev would be cut off from connexion with the association.

The PRESIDENT said that Mr. Bartholomew, having already become a member, would continue so as long as he pleased. He did not see any objection to the postponement of the question, that the committee might take it again into consideration.

The motion was put and carried.

The PRESIDENT then delivered the following

INAUGURAL ADDRESS.

Gentlemen,—You are aware that our friend Mr. Esson was at our last meeting elected president of this association, and Mr. George Anderson and myself vice-presidents. You have been informed of the severe illness which has deprived you this day of the services of a gentleman whom you did the honour to elect to a position that, had he been present, would have justified the high opinion you had of him. I am sure that you feel with me deep regret at the cause of his absence, and that, although absent, our sympathies are with him and his family, and our earnest wish is that he may be soon restored to health. When our secretary heard that Mr. Esson's medical advisers had prohibited him from taking any part in the proceedings at this meeting, a special committee was convened to take the subject into consideration, as it became necessary that one of the vice-presidents should at once be elected to carry out the important duties of president, that the association should not suffer by the loss of your president's services, to this office I was proposed by my brother vice-president, Mr. George Anderson, and as the committee were unanimous in their approval of that proposition, and as the vice-presidents were elected to perform that very office, should occasion require it, I felt bound to accept the trust and carry out the duties to the best of my ability. It is under these circumstances that I preside over you this session, and it is therefore my province to deliver an address to the members of this association upon gas matters in general, but particularly to draw attention to any new subject which may have an interest to gas managers, or conduce to the interests of the companies with which we all are connected.

I make the attempt with great pleasure, but, at the same time, with great diffidence, surrounded as I am by so many members of the gas fraternity, whose attainments and general knowledge of gas engineering far better qualify them for the duties which it has fallen to my lot to perform; yet, however unworthily those duties may be discharged, when compared with those of the gentlemen eminent in their profession who have addressed you before—I mean the past presidents of this association—let me assure you that any failure on my part will not be from want of perseverance or attention to the duties I have undertaken.

I think the first thing I should direct your attention to is, the stability and prosperity of this association, for I conceive that if I can present to you a prosperous state of affairs it will relieve your minds of all doubt as to the solid foundation on which the association stands, and on that point, I may congratulate you, we are working with good will and harmony, not only in committee, but amongst the members generally, and the number of members is, consequently, steadily increasing.

Before our June meeting of last year, we had on our books 214 members of all classes (honorary, extraordinary, and ordinary members); at that meeting we added 52 members to our number, making it 266, and you have just elected 52 new members, bringing our number up to 318. There are, I know, many members who are most anxious on this subject—the financial position and prosperity of the association—their great desire being to create a gas managers benefit-fund. Well, the committee go with them in that very laudable desire, but with all their desire to establish such a fund, they consider that the time has not quite arrived; nevertheless, there is a notice of motion on the subject by Mr. Warner, and all I can say is, that if the members think that the present strength of the association will warrant the starting of such a fund, every member of the committee will exert himself to establish it on the best possible foundation.

The subscriptions for 1867 amounted to £140, and left a balance in the hands of the treasurer of £6 odd; last year the subscriptions amounted to £210, with a balance in hand of £63; and this year, to the 30th of April, we have a balance in hand, after meeting our liabilities, of £135; so that we have now in this association the germ of prosperity.

Now how has this prosperity been arrived at, and how is it to be maintained? Why, by the amount of benefit members receive and impart by the interchange of opinions and ideas, and by the large amount of useful information to be gleaned at our meetings. Such being the case, you will be pleased to learn that we have no fewer than twelve papers promised for this session for reading and discussion on important subjects. The first paper on my list is on the "Setting and Working of Retorts," by Mr. Cathels, and whatever light may be thrown on this subject, to my mind, the "setting and working of retorts" is one of the greatest importance, and I make no doubt much good will result from Mr. Cathels's paper, and the discussion which such an important subject is sure to elicit; for, remember, low-priced gas, dividends, and last, though not least, fees and salaries, are produced from the retort, a residual product so to speak of good carbonizing.

The next thing of importance, after making the gas in good productive *quantity*, is *quality*. Gas can be made practically free from impurities, and it is but right that the consuming public should have pure gas to burn, especially now that chemical science has shown us the way to free our gas from those impurities which 30 years ago we supplied with the gas, because we had not then the knowledge required to grapple with those difficulties. About that time, with gas at 10s. per 1000 cubic feet, I remember perfectly well, when testing the gas for sulphuretted hydrogen by means of acetate of lead—the only test for sulphur known to gas engineers of that day—I often found the test of a shade which, if found in the gas of the present day, would make Dr. Letheby's hair stand on end with horror at the amount of impurity. Mind, I am giving you my experience of 30 years ago, when I was a pupil of the engineer of one of the London gas companies. Chemical science has, however, made vast strides since then, and the case is very different in the present day. Gas can now be, and should be, sent out to the public free from visible sulphuretted hydrogen and ammonia; and, further, no well-regulated gas establishment should now send out gas of a less illuminating power than 12 standard sperm candles, burning 120 grains, when compared with 5 feet of gas burnt through the Letheby London burner, nor less than 13½ candles burnt through the gas referees' or Sugg's new "London" burner, and I believe the consumers have no cause to complain that this is not done. Gas managers are constantly trying new inventions to improve the purity and illuminating power of gas, and when thoroughly proved the members are always willing to impart the knowledge so gleaned, and there is scarcely a meeting of this association but we have a paper on purification in some of its branches, showing the proper importance that members attach to this subject. On the present occasion we have two such papers, one by Mr. Upward, of the Chartered Gas Company, on purification; and one by Mr. George Livesey, of the South Metropolitan Gas Company, on scrubbers. I trust we shall also be favoured by some remarks from Mr. F. C. Hills, of Deptford; Mr. J. B. Paddon, of Hove; and Mr. J. W. Pollard, of Mincing Lane (one of our new members), embracing their views on the subject of which those papers treat. I must, however, particularly draw your attention to scrubbers. Of all apparatus in general use upon a gas factory, probably no portion is so uncertain and unsatisfactory in its operation as the ordinary coke scrubber. Care is taken, in designing this purifier, to provide scrubbing surface of proper proportion to the gas made, but the maintenance of this proportion is a question of time, and often of very little time. Under very favourable conditions, as regards the kind of coal used and the condensing apparatus through which the gas has previously passed, the scrubber may perform the duty for which it was intended; but almost always when a scrubber is opened it is found that there is just sufficient room in the centre to pass the volume of gas for the time being, all other openings being filled with deposit. Some admirable arrangements for distributing liquor are in use, but no mode of distribution of water or liquor that I know of can prevent or dislodge this deposit. Steam has been successfully used to prolong the life of the material, and save the cost of changing it; but any force the water may possess is exhausted by the upper strata of scrubbing material, and it simply finds its way to the central apertures through which the gas ascends. My brother, Mr. John Ohren, the engineer-in-chief of the Rio de Janeiro Gas Company, substituted plates of iron for trays of coke, and with good effect; and Mr. George Livesey will explain in his paper an admirable arrangement by means of thin boards placed edgeways tier above tier, which he has used at his works, and which, he says, is very effective, never gets out of order, and never wants changing. Well, so far, we seem to be arriving at a point of perfection in scrubbers; but then we find we have arrived at the same time at a knowledge that the scrubber is, after all, not the friend to gas managers it was supposed to be. We know that scrubbing is very effective in taking out the ammonia from the gas, and it having been found necessary to reduce the amount of sulphur compounds contained in the gas, to comply with the conditions required by the Metropolis Gas Act of 1860, that gas should not contain more than 20 grains of sulphur in every 100 cubic feet, the ingenuity of gas managers and gas chemists became taxed to devise means to this end. Amongst other experiments, the washing of the gas in the scrubbers, more particularly with ammoniacal liquor, was found to be beneficial in removing sulphur, and it was supposed that the greater the scrubbing surface the greater the amount of sulphur removed; but to the present time we have no reliable data to go upon. From careful testings of the gas for sulphur compounds, before and after entering the scrubber, to ascertain the full effect of the working of that part of the purifying apparatus, we find that the amount of sulphur in the gas varies from day to day in a remarkable manner, and from causes not yet ascertained.

The board of gas referees have to determine a maximum for the sulphur compounds, and therefore their proceedings are of extreme importance to the London gas companies. Averages are of little use here, for the London Gas Acts of 1868·9 require that the maximum shall, under heavy penalties, be observed for each single day. The referees have not yet issued any public report on the subject, but I learn that experiments on a manufacturing scale—the only ones reliable—have been made, and are still in progress, under the instructions of the referees, which unquestionably will throw much light on this difficult point. Among others, a systematic series of experiments is being made to ascertain the efficiency of each separate part of the various purifying processes employed in gas-works. My successor in office will be in a position to comment upon these experiments at the next annual meeting of the society. For myself, judging from the information given to me by the engineers conducting those experiments, I must say that the idea entertained in many quarters of trusting to increased scrubbing power as a means of lessening the amount of sulphur in the gas is wholly contradicted by the result of those experiments, so far as they have gone. I may add, that if the referees properly and wisely discharge the important duties devolving from time to time upon them, the result cannot fail to be of much use to the science of gas manufacture; for they have, what none of us have had before, the means of instituting careful experiments, upon a uniform plan, in each of the large gas-works under their supervision, and thereby combining and bringing to a focus the knowledge of the able engineers of the several companies, and sifting out the truth in a practical and reliable manner.

I cannot quit this subject without calling your attention to a new apparatus which the gas referees have devised for the testing of gas for sulphur compounds other than sulphuretted hydrogen. I have obtained from Mr. Sugg a specimen of this apparatus. The main difference between it and the Letheby apparatus is twofold—firstly, instead of a large empty cylinder, the referees use a small upright cylinder filled with glass balls, a sort of scrubber, in fact; secondly, a careful adjustment has been made in order to ensure a good draught. The bottom of the Letheby apparatus is left open, and also the area of the lower end of the "trumpet-tube" is considerably larger than that of the upper end; accordingly the instrument, besides requiring to be carefully guarded against side draughts, is liable to this drawback, that the external air, although drawn up by the heat to the height of the burner, cannot all pass upwards through the narrow orifice above, and consequently is liable to regurgitate and escape again at the lower end; in the referees instrument this is prevented by covering the lower end of the trumpet-tube, and narrowing the admission of air in such a way as to improve the draught, which at the same time protects the lower end of the instrument from the action of external currents. From experiments made with the two instruments, I find that the amount of sulphur obtained by the referees test is as 30 grains against 24 grains obtained by the Letheby apparatus. I need hardly say that the adoption of this more efficient test for the sulphur compounds must, in justice to the gas companies, be properly taken into account by the referees before they fix the maximum of sulphur to be allowed in the gas of the companies placed under their supervision by the recent Acts of Parliament.

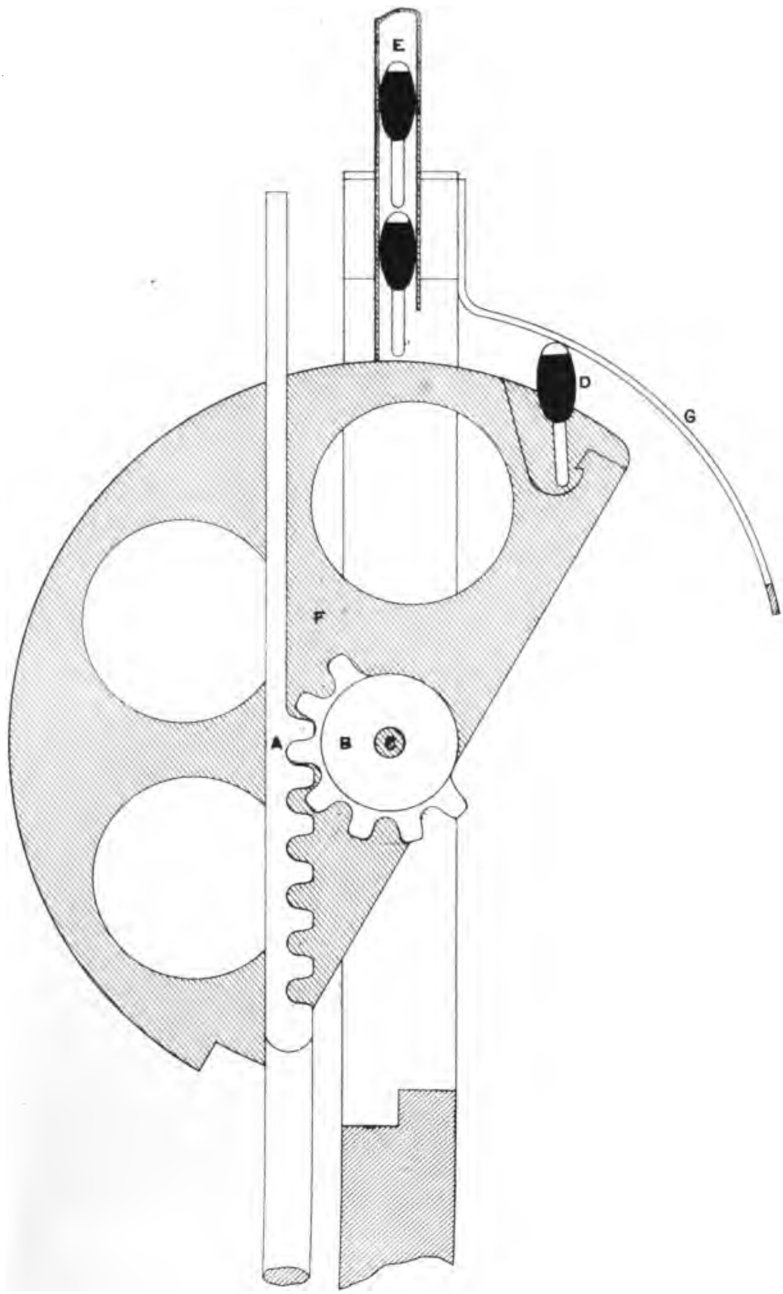
The next paper sent to the committee is by Mr. Somerville, of Dublin, who will give his additional experience of the working of Best and Holden's iron stoker. I have seen the one at Dublin at work, and I would draw the attention of gas managers to the subject, more especially managers of foreign works. In places where labour is scarce, and consequently expensive, and particularly in hot climates, an iron stoker, simple in its working arrangements and management, would be of great advantage. From what I have seen of Best and Holden's iron stoker, I have no doubt that it is very costly, and a large number of retorts must be worked to make it remunerative to the company, and then, bear in mind, the retorts are built to suit it, and not it to suit the retorts, so that it would not do for general use; but let the iron stoker be found to be useful and remunerative, and it will be constructed to suit beds of retorts as at present built. We have only to direct the attention of engineers to the want of a machine, and if it is at all likely to pay them for their trouble and expense in designing and perfecting it, they will never tire until that want is supplied. Of this fact we have evidence in the iron stoker produced by Messrs. Dunbar and Nicholson for drawing and charging single retorts. The want was felt, and to a great extent has been supplied, and I make no doubt that that firm, as well as others, are now at work on plans all tending to that end—the production of a machine perfect in its working adapted to suit all sorts of setting.

Another example of a want being supplied is shown by the production of the "iron lamplighter." It was found that an "iron lamplighter" was wanted, as well as an "iron stoker," and the result has been the production of some ingeniously contrived apparatus, of various sorts, to effect the object required.

Mr. Price, whose apparatus was described at the last annual meeting, deserves credit for his step, which is in the right direction. His regulator (the controlling apparatus) is an ingenious adaptation of the "Cathels district main governor," and it appears to answer equally well on a small scale as on large district mains.

Since our last meeting we have two additional "iron lamplighters"—the hydraulic lamplighter and the pneumatic lamplighter, the first designed by

HUNTER'S IRON LAMP-LIGHTER



Litho by Whiteman & Bass, London.

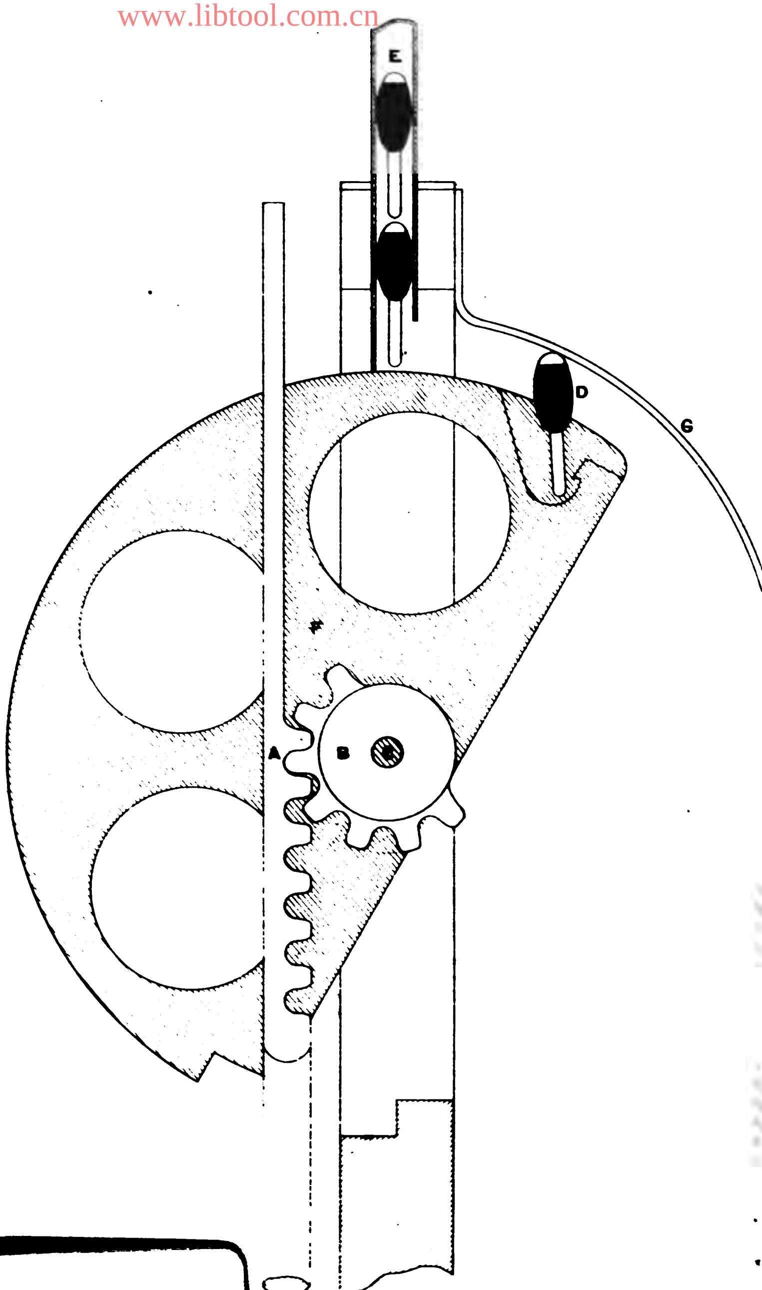
Mr. Hunter, an engineer, but not connected with gas-works. He has produced an apparatus to be worked by hydraulic power. The peculiar feature is that by one operation the tap is opened, a match struck, and the gas lighted. A service-pipe is to be laid throughout the district to be lighted, with branches to each lamp. The pipes are charged with water, and the pressure required is given and maintained from a tank placed at the required elevation. Inside each lamp-post is to be placed a small cylinder, to the piston of which is attached a rod, A. The top of this rod is serrated, and gears into a toothed wheel, B, attached to the plug of the lamp-tap, C, which is turned round and opened as the rod rises. A small fusee, D, drops from a reservoir, E, and is carried by a swivel-plate, F, to a piece of roughened spring, G, on which it is rubbed and ignited. It is then carried round past the burner, the gas is lighted, and the fusee drops to the bottom of the lantern. In the morning, when the gas is to be extinguished, the pressure of water is taken off the cylinders and an escape-tap opened, the pistons drop with the weight of the rod, and the taps are turned off. It is proposed that, as the lamps are cleaned weekly, the lamp-cleaner shall supply the reservoir with a week's supply of matches.

Now, up to this point all is satisfactory. I have tried the model apparatus repeatedly, and found it to work well, the only exception to the general plan, as worked by the model, being the ignition of the matches, as they occasionally fail; but this is a difficulty of little moment, as good matches can easily be procured. My great objection was, that in a hilly district the pressure of water could not be taken off the cylinders; therefore the pistons in the lamps on the side of a hill would be kept up by the pressure from the top of the hill, and as it would be out of the question to take the water out of the pipes every morning, and recharge them before night for relighting, the lamps would continue burning. Mr. Hunter, when I discussed the matter with him, thought to get over this difficulty by weighting the rods, and varying the size of the cylinder; but he took my advice not to commence in a hilly district, and he is prosecuting his operations at Southport. Another greater difficulty I foresee is the freezing of the water in the pipes in winter, which, I fear, will curtail his richly deserved reward for his beautiful invention. One hint I may throw out for his consideration—the use of sea water. It is not only at the sea-side that this can be got, but, as a company is forming to supply sea water in London at a cheap rate, the London gas companies can be supplied with sea water for their iron lamplighters, unless it be superseded by the pneumatic lamplighter, the second invention mentioned, the patentees of which, Messrs. Stephenson, Bartholomew, and King, have no doubt foreseen the difficulties I have spoken of. Their "iron lamplighter" is worked with air instead of water, and from all I at present see will prove a success. There is a model working apparatus on the table, and members will not only have a chance of seeing the working of it, but have an explanation, if time will permit.

Since writing the foregoing, I have heard from Mr. Hunter. He says: "I am happy to say the apparatus works well. All through the last winter it has been entirely uneffected in its working by frost; the lamps light in rapid succession, so that the cylinders are not all required to be filled at the same moment, consequently a small water-pipe will answer the purpose."

We speak of "iron stokers" and "iron lamplighters" that may serve us by-and-by, but in the meantime let us all remember that the stoker of the present day is flesh and blood—one of ourselves; let us not forget that while we enjoy the blessing of rest from our labours on the seventh day, the stoker of the period must be at his post on that as well as on other days. It gives me great pleasure to find that the subject has been taken up by Mr. Morton, of the London Gas Company, and that he will read a paper on Sunday labour. This subject was introduced, I believe, by Mr. Livesey, of the South Metropolitan Gas Company. He commenced by giving his men a Sunday holiday once a month. It was also introduced at my company's works some years ago, and has been continued ever since; in fact, we have lately given the men one Sunday out of every three instead of every four, to carry out the desire of the directors of my company to reduce Sunday labour as much as possible. I do not know how Mr. Livesey progresses with the Sunday question, but I trust we shall have his own views thereon during the discussion on the subject. I think that directors of companies will only want it made clear to them by their managers, that the men can be to a great extent dispensed with on that day, to restrict Sunday labour to its lowest possible limit. The men work hard, and it is a duty of humanity, even

HUNTER'S IRON LAMP-LIGHTER



Lith. by Whiteman & Bass, London

if we take no higher ground, for persevering in carrying out this most desirable object. It is very possible that Mr. Morton will speak of the labour of the stoker. There can be no doubt about the work being hard, and in the summer time very oppressive. I once made an experiment to ascertain what amount of heat the men were exposed to. The thermometer at my office stood at 65° at seven o'clock in the evening, in the month of September, when the men commenced taking off the retort-lids.

At 7.15	the thermometer	rose to	70°.
„ 7 25	„	„	80°.
„ 7.30	„	„	88°.
„ 7.35	„	„	90°.
„ 7.40	„	„	99°.
„ 7.50	„	„	105°.

And this was the highest point.

At 7.55	it fell to	99°.
„ 8	„	97°.
„ 8.5	„	90°.

The men had then finished their draw, and left the retort-house; at 8.15 the thermometer fell to 70°, and I left. The retort-house is large and well ventilated. The men were in fine healthy condition, and some of them had been a long time in the employ of the company, and none of them had suffered illness from heat; nor do I remember regular stokers being incapacitated from excessive heat, except in a few cases of men green from the country on their first employment, more especially in hot weather. Circumstances, of course, alter cases; my remarks apply to the Crystal Palace District Gas-Works. After Mr. Morton's paper is read we may get the experience of others. But I think it will be readily admitted that the stokers, as a body, are hard-working men.

The next paper is by Mr. T. H. Methven, of Bury St. Edmunds, on "Tar Pavements." We all long for the luxury of tar pavements along our country roads, and I make no doubt the system would be largely adopted if the material could be made hard and durable, so as to save us, in summer weather, from sticking to the pavement, like flies in treacle. I hope that Mr. Methven's system is satisfactory on this point; for myself, I consider it necessary to boil the tar, to drive off the light oils and water, otherwise the material will not set firmly, or at least until the sun has done the work that should have been done previously. If, then, it becomes necessary to remove the light oils, I consider they should be removed by distillation and utilized, instead of being boiled off in the open air, to the great nuisance of the neighbourhood where the operation is performed; for remember, in those oils, which would be lost in open air boiling, we have benzole, &c., from which aniline is made—the base of those beautiful colours, magenta and mauve—so fully reported upon at the last annual meeting by the president for that session, Mr. Goddard.

Mr. W. T. Fewtrell gives us a paper connected with tar—on "Artificial Alizarine;" or, chemically speaking, on alizarine artificially produced from a base obtained from coal tar oils, called anthracene; this is, however, not made from the *light* oils before alluded to, but is obtained from the last of the *heavy* oils, commonly called creosote, which comes over just previous to the tar becoming *hard* pitch.

While on the subject of tar, I may state that another important use that tar is likely to be put to is in the manufacture of gas. As tar contains a large quantity of rich hydrocarbons, it has engaged a large share of the attention of gas managers, who for many years have, by various means, endeavoured to convert the valuable fluids which it contains into permanent gases. Their attempts, however, have not been attended with anything like success—principally because it was found that solid deposits and naphthaline caused obstructions in the mains and pipes, and carbon on the retorts, without the anticipated increased quantity of gas. An improvement has, however, been introduced at Cork, by Messrs. Still and Lane, and although the new process has been in operation there over a year, no deposits have been observed in either the manufacturing or distributing apparatus.

The essential difference in their process, which, by-the-by, they have patented, consists in the thorough amalgamation, by suitable machinery, of the tar with a portion of the coal which is to be carbonized. From 30 to 40 gallons of tar are mixed and ground up with three-quarters of a ton of coal and a quarter of a ton of breeze; the proportion to be used is 25 per cent. of the total quantity of coal to be carbonized.

The advantages claimed for the process are a large yield of gas, increased illuminating power, and reconversion of breeze into coke, its particles being cemented together by the pitch of the tar. It is said that inferior Welsh coal treated under this patent can be made to yield 15-candle gas, tested by the old London burner. The theory of the process appears to be this—that while in former experiments the tar was merely distilled, in this process it is in a great measure decomposed, and the poorer gases coming from the coal while in their nascent state combine with the rich hydrocarbons of the tar, which are thus converted into permanent gases, instead of condensing and forming obstructions in the apparatus. The patentees have given a long trial to the process before endeavouring to get it adopted by other companies. Some trials have been made in Dublin, extending over several weeks, which have resulted, it is reported, in considerable economy of manufacture. If further experience confirms these results, gas companies—particularly where the iron stoker is in use—will no doubt adopt the process, and as a consequence, tar will rise in price, as a great quantity will be withdrawn from sale. Gas managers will do well to bear this in mind in making their contracts for the sale of tar.

We have next a paper by Mr. D. Clarke, of the gas-works at Brymbo, on "Stoppage in Ascension-Pipes"—a capital subject to ventilate—and your attention should be closely given to this paper, and the views arising therefrom freely discussed. It is useless to have good retorts and good settings, if the gas does not pass freely from the retort when generated; the loss that occurs in many places while the so-called "jumping" process is being performed is most distressing to witness.

I hope Mr. Clarke will throw new light upon this subject. If he advocates large ascension-pipes and capacious hydraulic main, not too close in contact with the retort-beds, he will be in the right track; but I will not anticipate his views, I desire only to give a direction to the discussion on the subject after the paper is read.

And the subject analogous to this, "The Scurfing of Retorts," is, I believe, to be brought forward by Mr. Cockey, who has an apparatus for scurfing retorts. Like the stoppage in ascension-pipes, the deposit of carbon on the retort results from pressure, or the want of relieving the retort from the gas as generated, and the aim of gas managers should be, not to devise apparatus to remove carbon, but to prevent the formation of it. It is a known fact that although a gas-exhauster, working at level gauge, draws off a considerable portion of the gas produced in a retort, still a pressure is maintained in the retort equal to the seal of the dip-pipe, and that, if that pressure is not removed, a large portion of gas is destroyed in the retort; this is particularly the case where through-retorts are used, if the dip, and consequently the pressure, on one side is greater than on the other. About ten years ago I had experience of this fact. The sinking on one side of some through-retorts caused an increase in the seal of the dip-pipes on that side, consequently the whole of the gas generated passed off at the other side, the pressure there being lightest. To remedy this defect, I invented an apparatus, which I called a "moveable disc," by which the liquor in the hydraulic main could be regulated, and the pressure equalized, allowing the gas to pass off at each end; when this was done the carbon ceased to accumulate on the retorts, and the make of gas and illuminating power were increased. If any gas manager finds himself in the same difficulty that I did, and would like to try the effect of the apparatus, I refer him to Mr. Sugg, of Westminster, who made the apparatus for me, and has, no doubt, the patterns by him.

We have a paper by Mr. Goddard, of Ipswich, on the "Application of Gas to the Generation of Steam." Any application of gas to the uses of man must be a benefit to the gas producer as well as to the gas consumer, and therefore the application of gas to the generation of steam, whether for machine power or for cooking, if effective, must cause an increase in the sale of gas. That gas can be used for cooking with advantage is a fact known to many of us. Mr. Somerville, of Dublin, introduced cooking-stoves at Maidstone, and so satisfied were the consumers with the use of his stoves, that they were taken faster than he could make them, and his summer consumption of gas was largely increased thereby. I believe he has also introduced them at Dublin, and I have no doubt with good results. Hitherto the great drawback to cooking-stoves has been the smell, but by using stoves made with glazed tiles and atmospheric burners, there is no smell, and they can be fixed in any part of the house, as they require no chimney. The benefit to be derived from the use of these stoves in small houses during the summer months is self-evident. From experiments made by myself, I have found that the cost of gas for cooking a joint is very much less than coal, if the fire has to be made for that purpose only. These stoves have just been introduced to our consumers; they cost the company £5 5s. each, and we let them out at a rental of 2s. 6d. per quarter. I recommend gas managers to consider this subject, with a view to increase their summer consumption.

GAS COOKING-STOVE EXPERIMENTS.

GAS.

Date. 1869.	Joint.	Weight.	Time.	When Cooked.	Dripping.	Loss.	Gas Used.	Cost of Gas at 4s. 5d.
		lb. oz.	h. m.	lb. oz.	lb. oz.	lb. oz.	ft.	d.
Sept. 22	Leg of mutton....	8 1½	2 20	7 5	.. 5	.. 7½	41	2·17
„ 25	Rib of beef.......	10 14	2 37	9 10¾	.. 5¼	.. 14	46	2·43
„ 30	Leg of mutton....	9 7	2 30	8 6	.. 7½	.. 9½	42	2·22
Oct. 6	Rib of beef.......	11 ..	2 45	9 13	.. 4½	.. 14½	48	2·54
		39 6½	.. ..	35 2¾	1 6¼	2 13½	177	9·36

COAL.

Date. 1869.	Joint.	Weight.	Time.	When Cooked.	Dripping.	Loss.	Coal Used.	Cost at 22s. per Ton.	Wood	Total Cost.
		lb. oz.	h. m.	lb. oz.	lb. oz.	lb. oz.	lbs.	d.		d.
Sept. 22	Leg of mutton	8 1½	2 50	7 ¾	.. 8	.. 7¾	28½	3·36	0·50	3·86
„ 25	Rib of beef...	10 14	2 45	9 10¾	.. 5	.. 14¼	29	3·42	0·50	3·92
„ 30	Leg of mutton	9 12	2 30	8 ..	.. 10	1 2	28	3·30	0·50	3·80
Oct. 6	Rib of beef...	13 2	2 50	11 13	.. 6	.. 15	30	3·53	0·50	4·03
		41 13½	.. ..	36 8½	1 13	3 7	115½	13·61	2·00	15·61

The following experiment was made by the maker of these stoves, and verified by subsequent trials:—

A leg of mutton . . .	8½ lbs.	Three tarts	2¼ lbs.
Gooseberry pie . . .	3 lbs.	Potatoes	3 lbs.
Baked rice pudding . .	4½ lbs.		

The rice, being baked unboiled, took longer to cook than the other things; the potatoes were cooked over one of the top burners, and the gas consumed for the whole was only 56¼ feet, costing about 3d.

There are three top burners, so that soup and fish could have been cooked at the same time.

Mr. W. J. Warner, of South Shields, will give us a paper on "Gas-Meters." My own opinion respecting meters is, that in the "Sanders and Donovan's" patent wet meter, as now manufactured by the Gas-Meter Company, we have a perfect wet meter, and I look for improvements in the dry meter. The best description of dry meter I have used is that commonly called "Croll and Glover's meter," but there are still improvements to be made in it to ensure accuracy of registration after having been at work for three or four years, and although those in error bear only a small per centage to the meters made, we look for improvements to reduce even that small per centage of error, which is very annoying to the company and the consumer when it does occur.

The measure of the illuminating power of the gas follows next. Mr. Hartley will read a paper on "Photometry." Mr. Warner's is an important subject, the measurement of gas fairly and justly between the company and the consumer, and of almost equal importance is the measurement or determination of its quality, for unless the system in either case be of such a nature as to ensure accuracy of result, the relations between the seller and the buyer of gas can never stand on a satisfactory footing; hence any new system by which our measures may be improved, or any modification of the present system which appears to be an improvement or is put forward as such, claims the attention of gas managers.

Among the novelties of photometry is the apparatus designed by Mr. F. W. Hartley, of Westminster. The apparatus consists of three photometers converging to a common centre, which is occupied by one candle, so that three operators may determine the illuminating power of any one of three gases compared with one and the same candle. Fortunately the days are passing away when two or more gas companies were allowed to supply gas in the same street, generally resulting in a waste of the shareholders money, and a loss to the consumer, otherwise this photometer would have been useful to try one company's gas against another, but now I do not see the object to be obtained. I can understand three operators testing the gas at one time, and then comparing their results. I believe they would be nearer the truth than three separate testings by a single burner; not that I put much faith in the report of difference in human vision. I believe the difference to be in the candle, not in the vision; and I am led to infer, if this be so, that Mr. Hartley's instrument would be more perfect if his gas were in the centre, and the candles placed at the three points. The difficulty that I have experienced most in photometry is the variation in the amount of light given by different sperm candles, and even different parts of the same candle, and under different temperatures; and I conceive that the more we multiply the candles the nearer we arrive at a correct average. Supposing, then, we have three pairs of candles, two at each point, by this means any variation in one pair of candles will be checked by the other two pairs; for, although not impossible, yet I think it hardly likely that all the candles would err exactly in the same way; at any rate a certain number of experiments must necessarily end in a more perfect result than at present obtained with the single apparatus, and this fact I believe was maintained by Mr. Kirkham in a paper read by him at the Institution of Civil Engineers last year. A lecture is to be delivered by him and Mr. Wm. Sugg this evening, on "Photometry as Applied to the Estimation of the Value of Coal Gases," and as a matter of course the "cross photometer" will be exhibited and explained; so that, with Mr. Hartley's paper and Messrs. Kirkham and Sugg's lectures, members will have a history of photometry to the present day, and will be able to judge the merits of each apparatus.

I find, connected with this subject, that we are to have a paper by Mr. Charles Heisch, the gas examiner to the Corporation of London, "On the Method of Testing the Illuminating Power of Gas, with special reference to Burners."

I take this opportunity to direct your attention to a report made to the Board of Trade by the referees appointed under the City of London Gas Act, 1868. One of the questions addressed to the referees was to determine the burner to be employed in testing the gas for illuminating power. As appears from the report, the referees carefully examined the various kinds of burners in use, and also some new ones, and the result of their inquiries was the adoption of a burner submitted to them by Mr. Wm. Sugg, now known as "Sugg's New London Burner"—in all respects a beautiful instrument, superior to any hitherto invented.

In the referees report, the burners in use by the consumer are commented upon. How often has this subject been commented upon, and the unfortunate consumer, after trying burner after burner, drags on his life in a state of semi-darkness? He has gone past complaining, and has a belief that the fault is in the *gas*, not the burners, and that he is being victimized by the gas company.

It is therefore a matter of rejoicing to gas managers that the gas referees have probed this sore point—with a desire to heal it. Their inquiries revealed in an extraordinary manner the badness of the burners in common use; their investigations, as detailed in their report, show that some of the burners give barely 20 per cent. of the real illuminating power, and on inspecting various large establishments, the burners in use gave only 55 per cent. of the illuminating power obtainable from the gas. These facts prove in a remarkable manner how groundless has been the bitter outcry on the part of the public against gas companies. They show that the fault has really lain with the consumers themselves, who have been in the habit of wasting the gas supplied to them, and throwing away very large sums annually, by the use of shamefully bad burners. This is a point of great importance to the public, and it is to be hoped that one result of the publicity given to this report by the Board of Trade will be to lead consumers to adopt better burners, a change which will be greatly in their own interest, and which ought certainly to lead to a cessation, or, if that be hopeless, at least to a diminution of the outcry against the gas companies. At the same time let me point out to gas managers that it is their duty to assist consumers to a selection of burners. For years past I have done this, and we recommend Sugg's steatite burner and the slit fishtail as far preferable to the 2 hole fishtail. In a paper read by Mr. Sugg at our last meeting, on burners, the Brönner burner was mentioned as giving an illuminating power of 12 candles, with a consumption of 5 feet per hour. I have made some experiments with this burner, and am pleased with the results. These burners are all split or bat's-wing burners, and glasses are made to suit that description of burner. They are made of various sizes, from 1 to 8 feet. Mr. Greene, of King William Street, London Bridge, is the London agent for these burners, and they have given great satisfaction in places where they have been fixed. Mr. Sugg has also a new burner which contains in the socket a regulator, by this means you can with four sizes effect the same object as the Brönner burner with eight or nine sizes. A sample of both burners will be before you for inspection.

The last paper on my list is by Mr. Davis, introduced by Mr. E. White, of Birmingham, "On a New Form of Gas-Exhauster." The subject of gas-exhausters was discussed in committee, and it was thought that a practical trial of the working of the various known exhausters should be made, and that members should have ocular demonstration of the working. I think this was a step in the right direction. I am sorry the committee had not time to carry it out, but it may be borne in mind.

I believe I have now exhausted my stock of papers if I have not your patience, and I shall but just glance at two or three new introductions in the shape of valves. Who is there so fortunate as not to have been plagued with leaky valves, and what mischief have they not caused? I hope next session we shall have a paper on valves, and I would draw attention to Messrs. C. and W. Walker's new patent for improvements in centre-valves, "Cathels and Terrace's" patent four-way disc gas-valves, Mr. George Livesey's water-valve, Thorneloe and Co.'s patent flexible valves, and C. and W. Walker's slide-valves for large sizes. Messrs. Walker are manufacturing the centre-valves for the Beckton works. They state that centre-valves hitherto made were liable to leak from settlements of naphthaline and dirt upon their surface facings. Some of these deposits were of a slippery nature, so that the valves in turning slid over them, instead of throwing them off, and became leaky. Messrs. Walker's improvement overcomes this difficulty by means of casting surfaced bars, or covering facings, in the valve, which do not interfere with the passage of the gas, but always cover the surfaced facings of the partitions of the body, thus protecting that part from injury of every kind, and rendering the valve perfectly tight. A gentleman will be in attendance wth a model and drawings for the inspection of members; he will also exhibit a drawing of the new wedge-valve. The valve itself is no longer a disc plate with a spring behind, but a rigid solid wedge of cast iron, having two perfectly surfaced facings fitting the facings inside the body casting; it is worked by a powerful screw, and is said to be perfectly gas-tight. Messrs. Cathels and Terrace's are improvements on their well-known four-way gas-valves, and consist of a simplified arrangement of the gas-ways through the valve, reducing it in size and weight, the ports being now all on one level, the disc being actuated by one movement, instead of two, as formerly; and last, though not least, by the impossibility by this arrangement of accidentally shutting back the gas, because the closing of one gas-way simultaneously opens another. The principle will be easily understood by an inspection of a model of the valve on the table. Mr. Livesey's water-valve differs entirely from the old water-valve. It is very simple, but no doubt very effective. It has no facing, springs, or wedges to get out of order, and is easily worked. I hope Mr. Livesey will have a drawing of it with him to explain it. I look upon it as a valuable invention. Messrs. Thorneloe's valve appears to be an adaptation of the principle of Morton's retort-lid, and will, no doubt, do very well for small mains.

A few words in conclusion. I make no apology for the length of my address, feeling, as I do, that I have only touched upon those points which seemed to demand your attention and my recognition; and however dry to our visitors some of the subjects may be, they are all of importance to gas managers, whose duty and interest it is to perfect themselves in every department, to keep alive to all new inventions or improvements, so as to secure any benefits which may arise therefrom to their respective companies. If I have failed to condense the matter I have laid before you, that I grant is a fault, although, perhaps, a fault more honoured in the breach than the observance; for I would much rather repeat myself than fail to convey to you my full meaning; but, under any circumstances, I cannot but express to you my thanks for the kind attention you have bestowed on my remarks. It leads me to hope that they have not been destitute of merit, and if so, I trust some little good may result from them.

GAS MANAGERS BENEVOLENT FUND.

Mr. Warner moved the following resolution, of which he had given notice:— " That a gas managers benefit-fund be formed for the relief of deserving members who may be incapacitated by old age or sickness from discharging their duties; and that a sub-committee, consisting of the president, ex-president, and president for the coming year, be appointed to consider the best means of giving effect thereto, and to report to the next annual meeting upon the formation of such a fund." In doing so he said that while he deeply regretted the painful circumstances under which the association was deprived of the services of Mr. Esson on this occasion, he felt gratified in having to submit his motion to a meeting presided over by a gentleman whose name appeared as one of the contributors to the benevolent fund of the Institute of Civil Engineers. He trusted that he should be able to show, in the few remarks he was about to offer, that it was a matter of great importance such a fund should be established in connexion with this association. The subject had frequently been brought under the attention of gas managers, not only at the annual meetings of the members of the association, but in the pages of the Journal of Gas Lighting. As a body they were behind their subordinates in the creation of a benefit-fund, and he might mention that some time back, being desirous to establish such a provision for the sick and infirm among his own workmen, he found that nearly all of them were members of some society having that object in view. Among professional men, too, the necessity of a benevolent arrangement, such as he hoped the gas managers would feel it their duty to undertake, was extensively recognized, and amongst solicitors and civil engineers two such organizations had for some years been successfully in operation.

Mr. Goddard said the subject brought under the attention of the meeting by Mr. Warner was a very important one, and fully deserved the consideration of the association. But, looking at the short time available for discussion at these annual assemblies, it was scarcely possible to go fully into it. He thought the better course would be to refer the question to a committee to go into the details, and bring up a report to the next meeting.

Mr. G. Livesey seconded this proposition, and

Mr. Warner assenting, it was resolved—" That a committee, consisting of Messrs. G. Livesey, Morton, Brothers, Malam, Wood (Bury), and Wood (Hastings), be appointed to consider the subject, and report thereon to the next annual general meeting."

Mr. Cathels read the following paper:—

ON SETTING AND WORKING RETORTS.

" On the proper mode of setting the retorts the prosperity of a gaslight establishment mainly depends." Thus wrote Mr. Peckstone, in his treatise on the manufacture of gas, 30 years ago, and even now, after the additional experience of all that time, Mr. Peckstone's penetrative assertion is as applicable as ever; for in the somewhat multifarious duties of a gas manager there are certainly none more important than the setting and working of the retorts. When it is borne in mind that the expenses directly connected with this part of the process of manufacture—viz., coals, and labour carbonizing them, fuel, and retorts, absorb on an average from 60 to 75 per cent. of the whole cost of manufacture and distribution, and that the amount of each of these items depends to a considerable extent on the attention given to and the degree of skill exercised in the retort-house arrangements, the necessity for a manager being thoroughly efficient in this essential part of his duties is sufficiently obvious. Indeed, I think it may be accepted as an axiom, that (other things being equal) as are the retort-house qualifications of the manager, so will be the success of the concern with which he is connected. But whether this be agreed with or not, the question is, at any rate, of sufficient importance to profitably engage the attention of this association.

I shall not presume to occupy the time of the meeting by attempting to enumerate the difficulties experienced with the retorts in the early days of gas lighting, owing to the inconvenient modes at first practised of setting them, before the method was ultimately adopted of placing them horizontally in arches or ovens, or of the various fantastic and more or less impracticable schemes that have since those days from time to time been proposed, or tried and abandoned; because the ingenuity displayed in this direction—sometimes with valuable results, but far oftener otherwise—is pretty familiar to all of us, and is, at any rate, beside the purpose of the few observations here offered, which are to briefly bring the subject before the meeting, with the object chiefly of eliciting the views of such of the members as may favour the meeting with their experiences, so that instruction and benefit may result from the discussion thus provoked.

Cast iron was at first the only material available for retorts, but their rapid destruction, from being exposed unprotected to the direct action of the fire, must have been such a costly matter, that the necessity of protecting them in some way seems soon to have forced itself on those engaged in struggling to overcome the difficulties incidental to this entirely new branch of industry.

Fire-clay tiles were then introduced with great advantage as guards for the retorts, and the number of retorts in a setting or bed was gradually increased to five, which seems to have been generally regarded as the most advantageous. From fire-clay bricks and lumps being used in setting the retorts, the next thing that was likely to suggest itself was the building the retort itself of these materials. And this decided step in advance was taken by Mr. Grafton in the construction of his fire-clay oven, patented just half a century ago. But the substitution of fire-clay for iron retorts was but a slow and gradual process. Nor is this to be wondered at when it is considered that iron retorts, although a costly item, through their requiring to be frequently renewed, had the immense advantages over those of fire-clay, of being absolutely gas-tight, which the latter in their then comparatively imperfect state of manufacture were far from being. And the irons had the further advantage of not filling up with carbon to anything like the same extent as the clays, consequent on their porosity, roughness of finish, and the head of water against which they had to work for want of an exhausting apparatus. But now, when the pressure is removed by exhaustion, and when the manufacture of clay retorts has attained to such a superior state of finish, the advantages are, I think, wholly and indisputably on their side. As regards first cost, a properly constructed clay setting is less than half that of an iron one of retorts of equal size. The durability of a clay retort is—or ought to be—never less than at least twice that of an iron one; while the fuel account for equal productions of gas is quite as favourable with clay as with iron settings. The life of iron retorts, when worked at a proper temperature, may be taken at about ten to twelve months. By working with low heats they might be made to last a few months longer, but the additional longevity obtained would be at the expense of their usefulness. They would make no more gas—and I will venture to say no better gas—in the longer than in the shorter time with better heats and heavier charges. I have been favoured with the results of iron settings in a well-managed works—the manager being a member of this association—where iron retorts were used until within the last few years. The settings were five D retorts 20 inches wide by 12½ inches high, and 8 feet long in a bed. They were set on as good a principle, I think, as could have been adopted, and were altogether a very favourable specimen of iron settings. The total average production of each retort was a little under a million and a half cubic feet, but if we take the production in round numbers at that quantity, we shall have, I believe, iron settings working under the most favourable conditions, and with the best results; because less than two-thirds of that quantity has been generally found to be the extent of their productive power. In addition to the rapid perishability of iron retorts at temperatures that do not injuriously affect clay ones, there used to be the further disadvantage—especially in the case of the width of the retort being larger in proportion to its height—of the crown "dropping in;" but this evil has been obviated, I understand, by the strengthening ribs introduced a few years ago by Mr. Fraser, of Colchester, and iron retorts so improved have since their introduction been, I am informed, used to a considerable extent both at home and abroad.

But although the almost universal experience of the gas world has emphatically pronounced against iron retorts as set in the usual way by themselves (except in some few special cases, such as very small works, where the retorts cannot be charged regularly, or kept at a uniform heat, and where, therefore, iron ones are perhaps more suitable than those of clay), they have for many years been used in combination with clays; sometimes in the same arch or oven with the clays, and in other instances set by themselves in a separate arch, but always arranged for the clays to receive the first of the heat. In this application the iron retorts are not usually protected by any covering, and if the principle be not carried too far—that is, if the number of iron retorts be not out of proportion to the clays—they may be entirely heated, or at any rate materially assisted, by the waste or partly spent heat, after leaving the clays, and before passing to the main flue. In these settings the irons require to be so arranged that their outside surfaces can be cleaned with facility, and this I found, from seven to eight years experience of the system, requires to be done about once a week. This combination seems to have been first adopted by the late Mr. George Lowe, who, according to the drawing in "Clegg," had the two bottom retorts of iron in a bed of five, the other three being of clay. The retorts were so set that the irons could be renewed without disturbing the clays. Messrs. Robinson, of Leicester, appear to have worked a somewhat similar system for many years, their arrangement being a bed of six D retorts, the two top ones only being clay, and the other four iron, the sides of the irons next the furnaces being protected in the usual way of ordinary iron settings. There appears from the drawing (also given in the last edition of "Clegg") to be the same facility for renewing the irons without interfering with the clays, as in Mr. Lowe's arrangement. But in this case the number of iron retorts are so disproportionate to the clay ones, that the spent heat of what would be sufficient for the latter alone can have but an inappreciable effect in heating them. They otherwise, too, so closely resemble an ordinary setting of iron retorts as to be fairly regardable as such, rather than a combination of iron with clay retorts, as usually understood, for the purpose of utilizing the waste heat from the clays. Mr. Croll also, as is well known, worked a combination of clay and iron retorts, which he patented so far back as 1844. He had three different arrangements to suit works of different sizes. The arrangement for the smallest sized class of works for which the combination was suitable consisted of four or five retorts set in a 6 feet wide arch. The furnace was placed at one side, over which there were two clay retorts, through which the heat first played, and was then drawn down through two or three iron ones, and passed to the main flue by a flue under the bottom retort. To suit the next larger class of works there were nine retorts—viz., four clays and five irons, set in an arch about 11 feet high, the clays being all above the irons, and worked from one floor level (in which the furnace was set), while the irons were worked from a lower floor at the back of the arch, the mouthpieces of the clays being at the front, and of the irons at the back of the arch. The heat, after leaving the clays, passed down through the irons to the main flue, under the floor of the arch. The system again for the largest class of works, as is well known from the publicity given to it at the time of the establishment of the Great Central Gas-Works, and the extensive application of it both there and at the Surrey Consumers Gas-Works, during the time of Mr. Croll's connexion with both concerns, was the double arch with stage system, except that the lower arch was set with iron retorts instead of being empty, and merely carrying the arch and retorts above, as in the ordinary application of the stage principle. The furnace was on the stage line in the usual way, and like the modifications already described, the gases generated in the furnace, after playing through six or seven clay retorts, descended through nostrils in the crown of the lower arch, and then through seven or eight iron retorts, finally passing under two or more of the bottom retorts to the main flue, placed in this, as in the other cases, under the bench. In each case the clay retorts were circular in section, and 15 inches in diameter, and the iron ones were of the D shape, 12½ inches by 12½ inches, and set without any protecting tiles, to enable them to get the full benefit of the partly spent heat. These settings were, in my opinion, open to the same objection as those of

Messrs. Robinson—viz., that there were too many iron retorts in proportion to the clays to secure the economy sought, and being through or double-length retorts, there was not sufficient room for an ascension-pipe at both ends of each retort, involving the serious objection of causing the gas generated near the end, without the exit-pipe, to pass along the whole length of the retort before escaping. There was also the further objection of not being able to separate the clay from the iron bed, so that the letting down of the irons required the clays to be let down too.

Mr. George Anderson's applications of the combined principle have certainly been the most successful, the reason chiefly being, in my opinion, that he subordinates the iron retorts to the clay ones. The number of irons are but half those of clay, instead of being an equal or even greater number, as in Mr. Croll's system. There is also in each of his modifications the power of shutting off the iron retorts when required with facility, by merely altering the dampers of the iron and clay beds. For the smallest sized works, three retorts are set over each other in a narrow arch, so arranged that only two or all the three can be worked as required. For larger works the arrangement consists of setting nine retorts in an arch from 7 feet 6 inches to 8 feet 6 inches wide, according to the size of the retorts. The six retorts that surro und the furnace are of clay, the remaining three, placed at one side of the arch, being of iron. The heat from the furnace acts first on the clays and then on the irons, in the usual way of such combination. For the largest sized works, again, the retorts are set in three separate but adjoining ovens, the two outside ones being set with clay retorts, and having a furnace each (one of which is usually, though not necessarily, a tar fire), and the middle one with irons without a furnace. Each bed is provided with a separate flue, which enables the bed of irons to be heated or not as desired.

I, also, for some years worked an arrangement whereby the waste heat of each bed of seven clay retorts passed through, among, and effectually heated the retorts in an adjoining oven without a furnace, containing three retorts placed over each other. This oven was 30 inches wide, and was at first set with three iron retorts of the D shape, 15 by 13 inches, with rounded corners, the bottom one being set on a close floor of fire-tiles, and each of the upper two simply carried by four 12-inch wide tiles, placed at equal distances apart, and supported by corbels springing from the side walls of the oven. But it was found the bottom retort burned out before the other two, notwithstanding its being protected by the fire-tiles. A clay retort was, therefore, set in the bottom instead, the upper two only being of iron. As there was a direct communication from each bed of clays with the main flue, in addition to that with the bed of irons, it was only necessary to shut the damper of the iron, and open that of the clay setting, in order to shut the bed of irons off. The arrangement worked very satisfactorily, but the gentleman who has now charge of the works in which I had these double settings erected, has considered it better to dispense altogether with the iron retorts, and to substitute clay ones, still heating them from the adjoining bed. He informs me that he has no difficulty with them.

The important question of utilizing the waste heat from clay retorts by means of blank iron settings is one that I am not prepared to argue very strongly one way or the other. There are so many things to be taken into consideration, that what might be the proper course to adopt in one place, and under one set of circumstances, might be injudicious if carried out in another place, and under totally different conditions. The question resolves itself into whether the value of the fuel saved outweighs the loss of the somewhat diminished production of gas in the iron retorts, and the cost of their more frequent renewal. But in estimating the relative costs, the greater durability of iron retorts in this arrangement than when set over a fire, owing to the absence of cutting draughts, must not be lost sight of. My opinion is that where the demand for coke is good, and the price per ton obtainable averages, say, not less than three-fourths the cost per ton of coal carbonized, iron retorts may be used advantageously, combined with those of clay, as set in the ordinary and often imperfect way. This advantage would hold good to a greater degree, I think, when the retorts happen to be built of bricks, and more so still where brick ovens are used. Wherever this combination is adopted there is an entire absence of flame from the chimney-top, which is too frequently to be seen on a winter night from gas-works chimneys, often resembling more a smelting-furnace than what a retort-house chimney should be, and representing, one is afraid to say what value of fuel utterly and literally thrown to the winds.

But when the retort-house arrangements are efficiently conducted, there is, I think, but little need for supplementary iron retorts. If the art of retort setting and working be properly understood, and carried into effect, not only will the spent furnace gases that pass to the chimney be but of inappreciable value, so far as further retort heating is concerned, but the retorts, by obtaining the maximum effect of the heat generated in the best possible way, will produce a great deal more gas during the time they are in action than is usually obtained, with a very important saving over the average fuel accounts.

But whether the spent heat from good clay settings be sufficient or not for heating iron retorts, it is at any rate amply sufficient for generating steam, where there are, say, four or five beds in action. Utilizing it thus is no new idea, but I am not aware that the application has ever been so entirely successful as Mr. Upward, of the Chartered Gas Company, has made it. That gentleman has employed the system in several places very successfully. The arrangement is perfectly simple and manageable, and could be advantageously adopted even in small works, because the want of sufficient heat during the summer months would be no inconvenience, steam not being then required; but in the winter time when it is needed the greater number of retorts in action would supply the required heat.

Of the three kinds of fire-clay vessels used in gas-works—viz., brick ovens, brick retorts, and ordinary retorts in whole lengths, or in convenient lengths for jointing together—their efficiency, I think, may be taken in the inverse order here given. Brick ovens, if justifiable at all, can only be so, it seems to me, where coals are very cheap, and coke valueless. They are beyond all doubt the most inefficient appliances for gas-making, and although highly creditable to the inventor, as being a great advance on the processes then in use by introducing fire-clay as a substitute for iron, are surely inexcusable now. Everything is against their use except durability, which might have been some plea in their favour when retorts cost from 10s. to 12s. per foot run, but now when they can be obtained, in a greatly improved condition to what they were in those days, at less than half these prices, it seems to me that this, their only recommendation, is obtained at a ruinous price. They do not make so much gas per ton of coal carbonized as retorts do; they do not produce the same quantity of gas in the same retort-house floor area that good settings do; they are wasteful in drawing and charging; and the fuel required to get at all a satisfactory production of gas from the coals is enormous. I do not think there will be any exaggeration in saying that the oven system requires at least 25 per cent. more coke for fuel than suffices for retorts in fairly average settings, to produce an equal quantity of gas, and I have heard of cases where considerably more even than that was used. But taking the extra coke required for an oven over a bed of retorts at but 20 per cent. by measure, and assuming that such a setting of retorts requires a chaldron of coke per 12 hours, equal to 24 sacks—say 25 cwt. per 24 hours—and reckoning the selling price of coke at but 10s. per ton, there is a loss in money value of 17s. 6d. per week, sufficient to renew a bed of seven retorts at £6 per retort every eleven months; so that apart from the other serious evils of the oven system, this economy of duration theory utterly breaks down. In this comparison I have taken fair average settings, and, I believe, put everything favourable for the ovens. If the comparison be made with settings that make more gas per retort, and with a considerably greater economy of fuel than here given, the case is, of course, still worse for the ovens. Nobody who wants to generate steam quickly would now think of applying heat merely to the outside of a boiler of large diameter. To attain that object flues are made through the boiler, so that the mass of water to be acted on is broken up and brought into more direct contact with the heat applied, and one would think that a little reflection would show that the same principle should be applied to the vessels used for the generation of gas. The oven is the boiler without flues; a bed of retorts is the boiler having a number of flues. In the one case the flues heat in the surrounding medium, in the other they are heated by the surrounding medium; and it seems to me that using ovens for distilling coal is only less absurd in degree than would be the employment of an old-fashioned waggon boiler for generating steam quickly.

Next in order, and in my opinion occupying an intermediate place in utility between the antiquated brick oven and the modern clay retort, comes the brick-built retort. The advocates of these retorts, like those of the ovens, fairly claim for them a greater durability than the ordinary retort; but when this has been conceded, it seems to me that nothing more can be said of their superiority, while in some points they are certainly inferior to the ordinary retorts. The question is not merely whether a setting of brick retorts lasts longer than a setting of the ordinary clay ones, but which of them, all things considered, are on the whole the more advantageous. The first cost of a setting of these brick retorts, and the annual cost of repairs, are as nearly as possible the same as for the setting of ordinary retorts of the same number and capacity, but their duration (with the renewal of the retort over the fire in a bed of seven) extends, I am informed, to four years, or a little over, contrasting favourably in this respect with ordinary clay retorts. The production of a D-shaped retort, 15 by 13 inches, and 9 feet 9 inches long, or 19 feet 6 inches from mouth to mouth of a through retort, is 5000 cubic feet per mouthpiece per 24 hours from Newcastle coals with the usual admixture of cannel. These particulars have been given to me for this paper by a member of this association, who is the engineer of very large works where these retorts are used; and you may take it that his results are the most favourable possible with this class of retorts, because the establishment with which he is connected is one of the best managed and most successful in the kingdom. The objectionable thing about these settings—viz., the fuel they require—outweighs, in my opinion, the advantage of their greater durability. They require 28 to 30 per cent. of fuel, as usually reckoned, or, in other words, every 100 tons of coal carbonized requires the consumption of 28 to 30 chaldrons of coke. But this is about 8 to 10 per cent. more than is in some works found necessary for similar settings of ordinary retorts, and at least twice what suffices for settings of seven oval retorts arranged as shown on the drawings exhibited, and which in the ordinary every-day way of working produce from 10 to 15 per cent. more gas than the brick retorts do. Now, assuming the extra fuel required over settings of ordinary retorts to be but three sacks of coke for each fire per 12 hours = six sacks per 24 hours, there is thus for each through bed an extra consumption of a chaldron per 24 hours. This, at say 7s. 6d. per chaldron, amounts to £2 12s. 6d. per week—sufficient to renew the retorts every eight months. Or, taking the life of ordinary retorts at two years, the saving in fuel alone in that time would not only pay for the renewal of the entire setting, but would leave a surplus in addition of £189, being nearly £100 per annum per through bed of retorts. In this estimate I believe the disadvantage in this respect of the brick retort system to be rather understated than otherwise, but if only half the above amount be taken as correct, there would, over and above renewing the retorts, be still a loss for fuel alone over ordinary clay retorts of about £50 per through bed per annum. It is true that in many places the fuel for ordinary settings is as heavy, and in some instances even heavier, than that here given for brick retorts, but that only denotes want of time, or attention, or skill on the part of those having the management of the carbonizing. In these cases the evil can be cured, if the proper means be adopted; but with settings of brick retorts I do not think any appreciable improvement can be made on the above results.

The degree of success in carbonizing with clay retorts depends on several conditions, but chiefly on the following—viz., on the quality of the retorts, on their form, on the degree of skill exercised in setting them, and on the way in which they are worked and used. That "the best is the cheapest" is a maxim especially applicable to a retort, and it is hardly necessary to say that its worth depends both on the quality of the clay of which it is made and on the mode of manufacture. I prefer a well-burnt retort, even although it may detract a little from its finished appearance. Retort manufacturers are often sadly pushed for time in the execution of the orders sent to them, and it is hardly, therefore, to be wondered at if retorts are sometimes delivered in but a semi-baked condition, requiring the gas companies that use them to do work that should be done before being delivered, thus giving the makers additional kiln room, and lessening their fuel and labour accounts. The form of the retort is a material element as regards both its durability and the facility of working it. The nearer the circular, the greater the strength; the less unequal is the expansion and contraction; the less injuriously is the retort affected by the furnace flame; and the greater ease is there in drawing the charge. Next to the square or oblong section, the D shape—for which there seems to be an unaccountable preference, especially in country gas-works—is the very worst. The unequal contraction and expansion, owing to the corners of the retort, is alone sufficient to condemn it. But even that is unimportant compared with the rapid destruction of retorts of this form owing to the corners getting burnt away. This evil effect is so obvious that it hardly requires mentioning, and I hope this meeting will be favoured with some more satisfactory reason for continuing their use than has hitherto been advanced. The natural result of the use of this kind of retort is seen in the recently published "Gas Manager's Handbook," by Mr. Newbigging, where the duration of an ordinary D clay retort is given as equal to the production of about a million and a half cubic feet of gas. Now, if this statement is anything like reliable, and I see no reason to doubt its accuracy, I have no hesitation in saying that such working is simply playing at gas-making. Respecting the facility of drawing and charging, any stoker who has worked round or oval and D retorts will tell you that he would as soon draw three of the former as two of the latter. In the round or oval shapes the coke slides into the centre of the retort and to the drawing-rake, whereas with retorts of the D shape a portion falls away into the corners, requiring the more frequent insertion of the rake, and consequently additional time and labour. In addition to the form of the retorts and the arrangement of their setting, a good deal depends, both as regards the economy of fuel and the duration of the retorts, on the way they are worked and managed. The minimum draught requisite to keep them sufficiently hot must be ascertained by gradually opening or closing the damper until the proper draught be ascertained, and this should not afterwards be exceeded. Again, a good deal depends on the skill in repairing the retorts. I have seen retorts condemned as worn out that might have been easily repaired by a little contriving, such as the shifting, or adding, of an arched ring or two to form a backing against the bad places, that could have been done at a trifling cost, and would have made the retorts equal to another season's work.

In the arrangements for working the retorts it used to be customary to draw and charge a whole bed at once. I do not know whether this is still done anywhere; if so it would be found advantageous to abandon the practice. The result is the lowering of the temperature of the retorts to a greater degree than when only a part of the setting is charged, and this, too, at the time it is most required to be kept up. A convenient way is to reciprocally charge half the number of retorts in the bed when the charge in the others is half off. There not being then such a rapid absorption of the heat by the retorts containing the half-spent charge, the fresh charged ones get the benefit, and thus a kind of self-acting adaptation of the heat to the condition of the charge is effected, and better results, both as to quantity and quality of the gas, produced. It is true that the injurious effect of charging a whole bed at once does not hold good to the same extent with clay as with iron retorts. Still it is an evil, and is just one of those apparently unimportant details, the due attention to or neglect of which go far towards accounting for the greater or less success of any industrial pursuit. There is the less reason, too, for this custom, because its abandonment entails no additional labour or inconvenience, but is, on the contrary, especially where the scoop is used, a matter of convenience and comfort. I have understood that Mr. Kirkham, when engineer-in-chief to the Imperial Gas Company, was the first to abandon the old and defective system of working retorts.

There are three conditions in retort-setting essential for their successful working—viz: First, to so arrange the course of the furnace gases that heat will be imparted, not only to all the retorts in the bed, but also to the whole length of each retort as nearly as possible alike; second, that the brickwork be so contrived as to give the required support to the retorts at the greatest number of points, with as little actual covering of the retorts as possible, and without interfering with the free play of furnace flame; and, third, that the retorts be set sufficiently close together. When these conditions are thoroughly understood, Newcastle gas coal may be carbonized without any difficulty, with an expenditure of coke for fuel not exceeding from 10 to 15 per cent. in the usual way of computing such account, and with the production of from 38,000 to 40,000 cubic feet of gas per 24 hours on a retort-house floor of 81 feet super., including division walls between the ovens in which the retorts are set; or, in other words, in an arch 7 feet 6 inches wide by 9 feet long, with 18-inch division, or party wall. Round and oval retorts need not, and ought not, to exceed 3 inches in thickness; and I may here parenthetically observe that this is one of the advantages of having retorts of these forms. When the strength or resisting power of the retorts is diminished by their having angles, it is usually found necessary to have them made 4 inches or even 4½ inches thick. The retorts I prefer are 3 inches thick, with an additional inch at the swell or flange at the mouth, for the mouthpiece bolts, and they are set with the flanges touching all round, which leaves 2-inch flue spaces between them. By this means the furnace gases are, so to speak, squeezed into a thin sheet, and are thus elongated in the lengthway of the retorts, and, spreading over and rubbing against the retorts, are readily deprived of their caloric. It is often considered one of a gas manager's chief difficulties to keep his retorts hot, and not without reason as retorts are sometimes set. They do not get a chance of heating with an ordinary consumption of fuel. In cricket parlance, the stumps are set so wide apart that there is no getting the bails off, and unnecessarily large balls have to be resorted to in consequence. As one having paid some considerable degree of attention to this question of retort-setting, I would respectfully counsel "wide-stumped" gentlemen, should there be any present, just to make one trial of moving their "stumps" a little closer. The products of the furnace, like those of the retorts, will pass where there is least resistance, and the great bulk will find their way to the chimney unused if the retorts are too far apart, so that one of two things must happen—either the retorts are not properly heated, or an excessive volume of furnace gases must be passed through the bed to effect that end, requiring, of course, an unnecessary consumption of fuel. As to the way in which these products pass through the bed, it will be found that making them pass alternately up and down is more effectual than what is called a "running heat," that is, playing longitudinally. Where there is a retort placed over the furnace, as in some of the drawings exhibited, it is sometimes found difficult to prevent the protecting arch from dropping. This is a difficulty that need never occur if bricks be used that will stand the heat. The reason is simply bad workmanship—too thick joints and the bricks not properly rubbed together. This, at any rate, ought to be an unknown difficulty where the red Ewell bricks are used, because, being as friable as a household bath brick, they can be easily rubbed surface to surface, and the arch built without the employment of any cement at all, if preferred, and being composed largely of silica, they are infusible by the greatest furnace heat.

It is considered a matter of great importance with some gentlemen that all the coals delivered into the retort-house be wheeled over a weighing-machine and weighed; and I have heard it referred to with evident self-satisfaction, as being the proper thing to do—as being, in fact, a cleverly devised kind of tell-tale for keeping the stokers up to their work. There is a given weight to go into each retort per 24 hours, and therefore the coals weighed into the house must be equal to such given weight per retort, multiplied by the number of retorts in action, multipled by the number of charges. Now, I am sorry to have to say anything disrespectful about such a (generally) harmless hobby as this; but truth compels me to observe that I think its utility is on a par with the other innocent amusement of peeping into the bed through cast-iron boxes with moveable lids built in the front wall for that purpose, the ostentible object, I presume, being to enable the manager to ascertain if the heats of the retorts are satisfactory. This perennial peeping observance is discharged by some of its devotees with a scrupulousness worthy of a better cause, and highly suggestive of fire-worshipping, or, at any rate, of conviction that it is essential for the proper and conscientious performances of one's duties. Well, I cannot say I am sceptical as to this doctrine, because I have no doubts on the matter. I know (and I have already endeavoured to explain why) that wherever there is room between the retorts for indulging in these playthings, there is unquestionably something radically wrong with the construction of the setting; and I have almost invariably found that their concomitant is the presence of rich hydrocarbon vapours in the neighbourhood of the tar well. But it is an ill wind that blows nobody good. These same sight-boxes are worth, I was going to say, their weight in gold to the fortunate tar distiller. I have a strong conviction that all this coal-weighing and sight-seeing is, to say the least of it, supererogant. A manager can always satisfy himself, by a glance at the production per retort in the carbonizing book every morning, whether things are going on satisfactorily in the retort-house; and this part of his duties, at any rate, ought not to be omitted. If there has been a proper make per mouthpiece for the preceding 24 hours he may rest quite satisfied; if otherwise, looking through a sight-hole, at any rate, will not mend matters. The public, we all know, have a settled conviction that the meter goes round by itself, apart from any consideration of the motive power of the gas—that it is, in fact, a disagreeable kind of solution of the perpetual motion problem; but gas managers, being more enlightened, ought to have faith in the fact that the retorts will not make the desired quantity of gas, unless there be sufficient coals put therein, and the heat be equal to its distillation.

It is scarcely necessary to discuss the question of stage *versus* ground-floor for working the retorts from, because the stage system is almost exclusively confined to London and its neighbourhood. The advantages claimed for this system are, as far as I understand, that the barrowmen do not require to go out of the high temperature of the retort-house, in cold or wet weather, in wheeling out the coke, that the coke drops down out of the stoker's way in drawing, and that extra storeage for it is obtained. But, if I may have the temerity to say so, these advantages are so dearly bought, and are so equally balanced by disadvantages, that it seems to me that the system is only justifiable where sufficient yard room is not procurable. The question of the barrowmen's comfort could easily be met, if desired, by covering in the coke-ground with an open shed. As to the additional storeage room obtained, it would, even if the whole space could be filled up to the stoking-floor, be but a mere bagatelle in cubic capacity. But that cannot be done, or anything like it. Indeed, the whole of the floor cannot even be covered with coke, and on no part of it can there be such a depth as to sensibly affect the yard storeage. And to obtain these nominal advantages the retort-house walls and chimney, or chimneys, have to be carried the additional height of the stoking from the ground floor, with more expensive foundations. There is the extra cost of the stage or stoking-floor, while the number and consequent cost of the arches or ovens is just doubled—that is to say, for each effective arch set with retorts there is another one of equal size built for the express purpose of supporting the former, and which is otherwise almost useless. Nor is this serious and otherwise avoidable first outlay the only disadvantage. The coke is unnecessarily smashed in falling so far, and, after all, it has to be handled quite as much, if not more than if it were drawn out of the retort into a barrow, and wheeled on to the coke heap in the yard at once. Men have to be kept below to quench and remove it out of the way of the next charge; after that they fill it into sacks, and in some places actually carry it outside to the vans. And over and above all this, practical men, like those I have the honour of addressing, will readily understand that with a space of more or less width between the front of the stage and the retort-bench, and with the furnace-bars usually below the stage level, there cannot be the same facility in working as on the ground floor. Again, the proportion of the coke required for fuel must either be prevented from falling on to the floor below in drawing, or it must be carried back again. So that, all things considered, I for one fail to see any appreciable advantage in the stage system.

As to the question of furnace combustion, which plays such an important part in gas-making, I have left myself but little time to speak. Moreover, it is a question of sufficient importance for a separate paper, and one that I hope some member of this association will take up and treat at next year's meeting. Where coke is used as retort fuel, there is comparative immunity from trouble with this question, but it is otherwise where coal or tar is used for that purpose. In the former case complete combustion is easily ensured, because not only is there but one element to be dealt with, but from the coke being in large pieces the fire-bars can be set wide enough apart to give ample area for the admission of air, while the portion of the coke next the furnace-bars, by its open porous nature, acts as an admirable filter or sieve, breaking up the air into finely divided threads, and so bringing each atom of carbon into immediate contact with its equivalent of oxygen. But where coal is used, especially small coal or slack, requiring the furnace-bars to be kept very close, perfect combustion becomes a much more difficult matter, because the elements into which the coal is resolved require each its own equivalent of air. To quote an extract from Wye Williams, "Each pound of good coal will give out 5 cubic feet of gas, and require for its special use 50 to 60 cubic feet of air, according to the quality of the gas; while the remaining coke, being about 50 to 60 per cent. of gross weight of the coal, will require about 100 to 120 cubic feet. The products from each hundredweight, then, in round numbers, will be as follows:—

Hydrogen	5 lbs.
Carbon in combination with the hydrogen, and forming gas	20 „
Carbon remaining as coke.	60 „
Nitrogen, sulphur, oxygen, and ashes . . .	15 „
Total	100

We here distinguish the three bodies into which the coal is resolved, and each requiring its own special equivalent of air—viz., the coke, the hydrogen, and the carbon of the gas. Now, the whole question of perfect or imperfect combustion—the utilization of all the elements of the coal, and obtaining their relative and entire calorific effect will be determined exclusively and absolutely by the facilities afforded these three bodies in obtaining their respective contact and quotas of the air supplied. It will not be enough, therefore, for engineers to look to the naked fact that each pound of coal will require 150 cubic feet of air, and to expect that all the contingencies of combustion will be satisfied if they provide that quantity. So far from that being the case, it is exclusively on the special application of these 150 cubic feet to these three separate portions of each pound of coal as above described that success will depend. For if the air be taken up by the incandescent coke (and to which it first finds access) more rapidly, or in greater quantities, than the gaseous matter can simultaneously be supplied with its own due quantity, the entire operation in the furnace will be deranged. In a word, the gas should have its own equivalent of air, and enter into combustion as rapidly as it is generated, and in due relation to the combustion of the coke in equal times." It will be thus seen that it is absolutely necessary to provide means for an adequate supply of air, in addition to what is drawn through between the furnace-bars, to obtain the full calorific effect of the fuel, and that the finer the supplementary supply of air is divided and commingled with the gaseous products of the coal the more perfect will be the combustion. And this is as indispensable for the proper combustion of tar as it is for coal. An efficient and convenient mode of burning tar is represented in the drawing of the six-retort setting exhibited. It is a copy of Mr. Anderson's tar fire, with the addition of a furnace below the sloping table, on which the stream of tar falls for the purpose of keeping it hot, so that the tar may be volatilized directly it comes in contact with it. Mr. Anderson effects this by means of the combustion in a chamber below of the resultant fine breeze from the tar itself. But I have found that the addition of the furnace saves a good deal of trouble in attending to the fire at the cost of but an insignificant consumption of breeze. It will be observed that finely perforated plates with sliding doors are built into the front wall for the purpose of regulating the admission of air. Tar cannot be burnt without destroying the retort placed over the fire before the others are worn out as they are usually set, but when arranged as in the setting of six circulars illustrating the tar fire, and also shown in one of the settings of seven ovals, this difficulty is entirely obviated, and tar can be burnt without undue destruction to the retorts, and without the production of smoke. I have burnt tar produced from both Newcastle and inland coals off and on for a good number of years, and the result of my experience is that, when consumed under proper conditions, it does the work of just about twice its weight of coke, or, in other words, five gallons of tar are equal in heating properties to a sack of coke. But whether coal or tar be used as fuel, there is no difficulty in ascertaining whether they are doing their work properly. The condition of the retorts will speedily show that, and there is in addition the tell-tale of the chimney-top. If there be an absence of smoke by day and flame by night, it may be taken for granted that the furnace combustion is satisfactory. In the larger gas-works in Scotland, the residue of the tar after distillation is used in a liquid state as retort fuel, sometimes in addition to coke, and sometimes by itself. I have seen it so used very efficiently both at Perth and Dundee. Mr. Whimster, of the Perth Gas-Works, has for many years burnt tar very successfully without any special furnace. It is merely run in over an ordinary coke fire by means of a small iron trough, in the old-fashioned way, the regulation of the air admitted by finely perforated iron plates above the furnace frame effecting complete combustion.

Mr. Siemens's regenerative gas-furnaces, which have been found to be so efficient and economical in fuel in some branches of manufacture where great heat is required, have been tried for heating gas-retorts, but I am not aware how far the application has been successful. Mr. White has tried it, I believe, to a limited extent, at the Windsor Street station of the Birmingham Gas Company, and I understand it is in operation on a rather extensive scale at the Paris Gas-Works. Like steam stoking, the process, I apprehend, is only applicable in large works. The apparatus is rather costly, requires a good deal of room, and is somewhat complicated. The late Professor Faraday, in his last public lecture at the Royal Institution, described these furnaces in the following terms:—

"The gaseous fuel is obtained by the mutual action of coal, air, and water, at a moderate red heat. A brick chamber, perhaps, 6 feet by 12 feet, and about 10 feet high, has one of its end walls converted into a fire-grate—*i.e.*, about half-way down it is a solid plate, and for the rest of the distance consists of strong horizontal plate bars where air enters, the whole being at an inclination such as that which the side of a heap of coals would naturally take. Coals are poured, through openings above, upon this combination of wall and grate, and being fired at the under surface they burn at the place where the air enters; but as the layer of coal is from 2 feet to 3 feet thick, various operations go on in those parts of the fuel which cannot burn for want of air. Thus the upper and cooler part of the coal produces a large body of hydrocarbons; the cinders or coke which are not volatilized approach, in descending, towards the grate; that part which is nearest the grate burns with the entering air into carbonic acid, and the heat evolved ignites the mass above it; the carbonic acid, passing slowly through the ignited carbon, becomes converted into carbonic oxide, and mingles in the upper part of the chamber (or gas producer) with the hydrocarbons. The water, which is purposely introduced at the bottom of the arrangement, is first vaporized by the heat, and then decomposed by the ignited fuel, and rearranged as hydrogen and carbonic oxide; and only the ashes of the coal are removed as solid matter from the chamber at the bottom of the fire-bars.

"These mixed gases form the gaseous fuel. The nitrogen, which entered with the air at the grate, is mingled with them, constituting about a third of the whole volume. The gas rises up a large vertical tube, for 12 or 15 feet, after which it proceeds horizontally for any required distance, and then descends to the heat regenerator, through which it passes before it enters the furnaces. A regenerator is a chamber packed with fire-bricks, separated so as to allow of the free passage of air or gas between them. There are four placed under a furnace. The gas ascends through one of these chambers, whilst air ascends through the neighbouring chamber, and both are conducted through ports at the end of the furnace, where mingling, they burn, producing the heat due to their chemical action. Passing onwards to the other end of the furnace, they (*i. e.*, the combined gases) find precisely similar outlets down which they pass; and, traversing the two remaining regenerators from above downwards, heat them intensely, especially the upper part, and so travel on in their cooled state to the shaft or chimney. Now the passages between the four regenerators and the gas and air are supplied with valves and deflecting plates, which are like four-way cocks in their action; so that, by the use of a lever, these regenerators and air-ways, which were carrying off the expended fuel, can in a moment be used for conducting air and gas into the furnace, and those which just before had served to carry air and gas into the furnace, now take the burnt fuel away to the stack. It is to be observed that the intensely heated flame which leaves the furnace for the stack always proceeds downwards through the regenerators, so that the upper part of them is most intensely ignited, keeping back, as it does, the intense heat; and so effectual are they in this action, that the gases which enter the stack to be cast into the air are not usually above 300° Fahr. of heat. On the other hand, the entering gas and air always pass upwards through the regenerators, so that they attain a temperature equal to a white heat before they meet in the furnace, and there add to the carried heat that is due to their mutual chemical action.

"Thus the regenerators are alternately heated and cooled by the outgoing and entering gas and air, and the time for alteration is from half an hour to an hour, as observation may indicate. The motive power on the gas is of two kinds: a slight excess of pressure within is kept up from the gas producer at the bottom of the regenerator, to prevent air entering and mingling with the fuel before it is burnt; but from the furnace downward through the regenerator the advance of the heated medium is governed mainly by the draught in the stack or chimney."

After describing the convenience and advantage of the process to various manufactures—such as glass-works, &c.—Professor Faraday concludes his lecture with the following figures:—

"Carbon burnt perfectly into carbonic acid in a gas producer would evolve about 4000° of heat, but if burnt into carbonic oxide it would only evolve 1200°. The carbonic oxide, in this fuel form, carries on with it the 2800° in chemical force, which evolves, when burning in the real furnace, with a sufficient supply of air. The remaining 1200° are employed in the gas producers in distilling hydrocarbons, decomposing water, &c. The whole mixed gaseous fuel can evolve about 4000° in the furnace, to which the regenerator can return about 3000° more."

The difference between heating retorts by this and the ordinary mode appears to be that by this plan a mass of coal is distilled or carbonized in a separate brick-built pit, the resultant smoke being consumed as fuel, any excess of air beyond what is required for their distillation being excluded; that the gases evolved are conveyed to the retort-oven (which in this application of the invention is the so-called furnace) by one passage or flue; that the proper proportion of air simultaneously enters by another flue, and that they there commingle and burn, instead of the requisite quantity of air for efficient combustion entering the ordinary furnace at once in the usual way.

But, in addition to this, a second part of the process, as has been already described, consists in the gases from the producer and the entering air being made to pass upwards to the furnace through the regenerators or chambers filled with chequered walls of fire-brick, which alternately take up the surplus heat from the used or departing, and give it up again to the entering gases or air.

Now I will not presume to offer an opinion as to the advantage or otherwise of the first part of the process—viz., the separate distillation of the coal and subsequent mixing of the gas therefrom with air, when applied to gas-works where, from special reasons, it is found to be more advantageous to burn coal than coke as retort fuel; but I think when the cost of the additional apparatus and having to purchase coal for the purpose are taken into consideration, it will not be thought an improvement where coke is used instead of coal. And as respects the second or regenerative part, looking at it theoretically, it does not appear to be worth all the extra cost or trouble in any gas-works. In applications where intense heat is required, and which do not materially lower its temperature, this mode of arresting the surplus and using it over again is, of course, of the highest importance. But the application to gas-retorts is very different; there heat of only a certain temperature is desirable or proper, and its enormous absorption by the retorts in converting their contents from the solid to the gaseous form, if properly utilized, reduces the temperature to about the same as it leaves the regenerators.

I have to apologize for having occupied so much of your time. If I have gone too much into detail in some of the matters touched on, my excuse must be my sincere conviction that no more important subjects than these same questions of setting, working, and heating retorts could engage our attention.

As respects the working of the retorts, I am glad that the remarks here offered are going to be supplemented by a paper on such an interesting question as the result of the application of steam machinery for that purpose, and that we are also to be favoured by another paper bearing closely on the subject in hand—viz., on the prevention of stoppages in the retort exit-pipes.

Of the drawing exhibited, containing thirteen different settings of retorts, from one to nine in a bed, suitable for all sized gas-works, I hope it will not be considered egotistical when I say that thay are not mere fancy plans that have never been tested, but are the selected settings of years of close observation and experiments, all of which have, therefore, been successfully proved. Although they are differently arranged to suit different sized works, it will be observed that one general principle pervades the whole. Part of this principle —viz., the particular mode in which the heat acts on the bottom retorts—I deem it proper to acknowledge to be similar to, and copied from, Mr. George Anderson's settings.

In conclusion, I may just further add that I am now working settings of seven 21 by 15 inch ovals, 19 feet long, set in a 7-feet 6-inch wide oven as per the drawings, and that they have produced, ever since they have been at work, an average of 11,400 cubic feet per 24 hours, with six-hour charges, equal to 5700 per mouthpiece, in the ordinary way of working, with an expenditure of fuel under 15 per cent. by measure as usually reckoned. These settings will produce during the life of the retorts an average of 5500 cubic feet per mouthpiece of 24 hours, and a total production per mouthpiece of 4½ millions, with an expediture of fuel not exceeding the per centage above named.

Mr. GODDARD said he had been very much interested in the paper just read, which he thought reflected great credit on the writer, who had gone very carefully into the question, and shown a number of instances in which the use of clay retorts could be advantageously adopted. The plan which he (Mr. Goddard) had followed at his own works was to have settings of seven retorts, partly oval and partly circular, set upon the principle recommended by Mr. Cathels. With regard to the plan of heating by Siemens's process, he believed it had been tried in various gas-works, but the amount of attention required in altering the current of air from one chamber to another, rendered it highly objectionable for general use.

Mr. G. LIVESEY said it was known to many of the members that at his works (South Metropolitan) brick retorts were used exclusively. He was bound to say that the writer of the paper had given the meeting very fairly and honestly a statement of all that had been done with respect to different methods of working, and when he brought forward the charge that brick retorts ran away with the fuel, it was difficult to contradict him. In fact, the 28 per cent. was a figure given by himself, but he did not think this was wholly due to this kind of retort, and he hoped in the settings he was now introducing to be able to reduce that amount of fuel down to 22 per cent. One point with respect to brick retorts Mr. Cathels did not mention, and that was not so much the question of their greater durability as to the time they lasted, but their non-liability to crack and become leaky. This was the principal reason why at the South-Metropolitan works they were exclusively used. It was found that they stood more rough usage in the matter of letting down and missing than other retorts. He was aware that during the last ten years, since they had discontinued the use of clay retorts, great improvements had been made both in the setting and working. Ten years ago they would only last eighteen months; now they might be made to last two years and a half of actual working time. At his works he had taken out eight brick retorts this year; the shortest duration of any of them was 47 months, and the longest 55 months, and these retorts had produced on an average 5000 feet of gas per mouthpiece. The heats were rather great, as they had been getting 10,000 feet per ton. To do that there must be an expenditure somewhere, and he found it better to have an excess of fuel than to lose 200 or 300 feet per ton in gas.

Mr. DUNNING said he was glad to hear Mr. Livesey's remarks, as he had not been aware that any London company were using brick retorts exclusively. At Middlesborough brick retorts had been used almost exclusively for the last fifteen years—there had been only one setting of fire-clay—and he could bear out all that Mr. Livesey had said. He believed that if gas managers would turn their attention more to brick retorts than they had done they would find great advantage from it. There were retorts of that class now at work in Middlesborough which had been in use for ten years, and were still turning out more than 5000 feet per mouthpiece, and doing their work well. They were repaired year by year at a comparatively trifling cost. The total make last year was 85 million feet, and the cost for repairs, taking into account the fire-clay and labour employed, was not more than £240.

Mr. G. ANDERSON said that, taken as a whole, he approved of the paper, but there were just two or three points in which he could not agree with the writer. He was an advocate for the use of clay retorts, brick retorts, or iron retorts, according to the circumstances in which they were employed. For a number of years he had used a setting which was almost identical with that shown in Mr. Cathels's drawings. When Mr. Cathels was manager for him at Dover he worked a setting of that kind, and that setting had been continued until a year or two ago. There were two large oval retorts on the level with the furnace, four circulars over, and three circulars on the top. The two circular retorts immediately over the furnace it was found very difficult to keep in position, because the fire shrank the brickwork, and sometimes melted it, and the retorts came down. He therefore took out those two retorts, and put in one brick retort, which made as much gas as the two together. The bottom arch of this retort was made the top of the furnace, without any protecting arches. This had been in action four or five years, and beyond the mechanical action of the coal and the rakes, it was nearly as good now as it was originally. To put an arch under would be a loss of material and of heat. One benefit in the use of brick retorts was the facility with which they could be repaired. Twelve months previously he took the bottom out of one and put in another without inconvenience. The first bottom was made of inferior bricks, which he removed, and put in Stourbridge. In taking out old settings of this class, many of the bricks could be advantageously employed again, not being liable as new ones to shrink. One point of importance which had not obtained the attention it deserved in Mr. Cathels's paper was the firing of the red-hot coke. It was not a new thing; it was well understood, but not generally practised, especially in large works, where some retorts were drawn at one time and some at another. He thought they should, as much as possible, take the coke from the retorts and put it in the furnaces. To throw the coke on the floor and quench it with water was absurd, and not creditable to their intelligence. By that means they filled the pores of the coke with water before putting it into the furnace to be cooked again, and it was not till the water had evaporated and a red heat was obtained that it began to do its work. The effect was to rob the furnace of a great amount of heat during the time. Mr. Cathels seemed to have come to the conclusion that there was no benefit from the heating of iron retorts after the clay. In that he thought Mr. Cathels was wrong, though he knew that clay retorts could not be heated at the minimum temperature at which iron could be heated for the simple reason that clay was a bad conductor.

Mr. Burgess for a number of years had been working brick retorts exclusively, and found their duration more like fourteen years than four. He had some brick retorts now being repaired at Huddersfield which had been thirteen winters at work, and they seemed, to all intents and purposes, as good as at the commencement of their term. Mr. Cathels said he could not get more than two-thirds as much gas from brick retorts as he could from clay; but he (Mr. Burgess) found he could get as much from the one as the other. He was making 9500, and sometimes 10,000, feet per ton of coal; but he admitted that the expenditure of fuel was excessive, although he thought it arose, to some extent, from the mode of setting. In the Manchester Gas-Works they formerly used iron exclusively, then they used clay, and now they adopted brick retorts exclusively. They were setting them with two small retorts over the furnace, a large one over these two, and another large one above, and he believed they were economizing fuel very considerably.

Mr. Kelsall said he could confirm what had been said by Mr. Dunning and Mr. Burgess as to the use of brick retorts. At Ashton they had been used exclusively for the last sixteen or eighteen years, and some were now being rebuilt which had been at work for fourteen winters. He did not think the expenditure for repairs, including both tile and bricks, as well as men's wages, exceeded ·39d. per 1000 feet. They had four-hour charges, and were obtaining 10,000 feet of gas per ton, but to some extent that might be accounted for by the use of cannel. His own opinion was that the small cost for repairs would far more than compensate the extra cost for heating. There were many advantages from the use of brick retorts in large works, and he could only account for their not being introduced into London gas-works by the want of ground room in consequence of the high price of land.

Mr. Douglas (Newcastle) said his experience was against the system of repairing retorts altogether. He never could make as much gas out of an old retort as out of a new one; and therefore at the end of two years, if a retort lasted so long, he would take it out and replace it with a new one. He would never think of having a retort for fourteen years, nor even four years, on the premises. His opinion was more in favour of D retorts than round ones, and he believed in thick strong retorts (4 inch), and new ones every year.

Mr. Warner said he believed that brick retorts had been used at the Chartered Gas-Works, and he had heard that in the London Company the consequence of the use of brick retorts had been to reduce the value of the shares from £100 to £5.

Mr. Mead (Reigate) said he was certainly very much surprised at the remarks made by Mr. Douglas, and to hear him express a preference for D retorts, as modern experience generally had satisfactorily proved that they were much weaker than the round or oval shapes. He could bear out Mr. Cathels in his observations with reference to Siemens's regenerative furnaces. He had tried it for gas-making, and as far as he had gone it was a failure; but this he attributed to the want of attention on the part of the men. The furnace itself was one of the most beautiful of inventions, but the necessity for changing the direction of the air every half hour presented a great difficulty to its use, as it was almost impossible to find men who would periodically attend to a matter of this kind without constant supervision. As to the material employed in the construction of retorts, he had tried them all, and in his opinion there were many situations in which iron retorts were still of great service. He had to do with many small works where in the summer season they were still found valuable; but in large works they were scarcely worth the room they occupied.

Mr. Broadhead said for the last eighteen years he had worked clay retorts entirely. They were D retorts, 7 feet 6 inches internal, 17 by 13, and he was satisfied if they produced 3000 feet per mouthpiece. The coal used was South Yorkshire (Silkstone), and with six-hour charges he obtained 8500 feet of gas per ton, of an illuminating power of 15 candles. The retorts were worked for two seasons—seven months one season, and twelve months the next—and when they were let down they were properly scurfed and pointed up ready for next season, so that he got two years regular working out of each retort. He had had nothing to do with brick ovens, and he had no exhauster. His heaviest gasholder gave a pressure of 4 inches at least, and he worked with about 1½ inch extra pressure in the winter season. He admitted that he made a fair share of carbon; but this was not all loss, as he formerly obtained 15s., and now 20s. a ton for it. No doubt the question of retorts had to do with the question of dividends; and as the Grimsby Company, of which he was manager, had been able to pay 10 per cent. up to the present time, while giving satisfaction to the public in every way, he thought the preference he had given to clay retorts was justified.

Mr. Craven (Dewsbury) said it was now ten years ago since he commenced to use iron retorts, and not being satisfied with the working of them, he tried clay and brick ovens, and ultimately entirely adopted clay. One cause why the brick retorts did not answer so well was that they were made too thick—5 inches instead of 3. He now obtained 4300 feet of gas per mouthpiece. He agreed with Mr. Douglas that clay retorts should not be kept in more than two seasons; and as a proof of this he might state that he had two which were going on for the third season, and he found his make of gas drop down from 22,000 feet in 12 hours to 14,000. He therefore pulled them out and replaced them by others, when his make again went up to 22,000.

Mr. Dunning wished to add, with respect to the working of brick retorts, that he was in the habit of charging a double set—*i. e.*, six mouthpieces, two D retorts at each side of the fire, and one on each side above—with 15 cwt. of coal six times in 24 hours—*i. e.*, 4½ tons, all weighed in—and the produce on the average was between 40,000 and 42,000 feet of gas per 24 hours, or about 9200 feet per ton of coal carbonized. He could even do a little more than that, but he preferred to stop there, as he had to keep up the illuminating power to 15½ candles. This was done with 10 per cent. cannel of the district, and the rest Durham coal.

Mr. Woodall said with reference to stage *versus* floor his personal experience was but a short one, but he believed that all those who had worked stage-work would be unanimous in saying that it was cheaper and better in every respect than floor-work, especially in large retort-houses, where it frequently happened that there was more than one gang of men at work at the same time, and where the running out of the barrows must be a considerable hindrance and annoyance. There was also the advantage attending it of keeping the men within the walls of the retort-house, and the great saving of labour in not having to remove the coke. He disagreed with Mr. Cathels as to the duration of retorts, and believed that with ordinary attention a clay retort might be made to last for 700 or 750 days without any loss of gas.

Mr. Morton said the London Gas Company, to which he belonged, had been referred to by a previous speaker. He was happy to say that the shares of that company were in a far different state now to what they were at the period alluded to. The reason of their little value at that time was not the use of brick retorts, but of large ovens, for the manufacture of gas and coke together. With regard to stage-work and ground-work, he made a calculation some time ago, at the request of a member of the association, of the difference in the cost of the two systems—he had both stage and floor work in his establishment—and he found it to be 3½d. per ton of coals in favour of stage-work.

Mr. JABEZ CHURCH agreed with Mr. Cathels in the importance of the subject dealt with in his paper. There was no doubt that dividend or no dividend, so far as the manufacture of gas was concerned, must come from the retort-house, and therefore the proper setting of retorts was a most essential element. As far as his experience went he found that clay retorts could be worked successfully for about two years, and he believed it was a mistake to work them for a longer time. They might by patching and close attention be made to last longer, but the leakage more than counterbalanced the saving effected in deferring the cost of resetting. The cost of setting a clay retort was not a large item, and in the long run it would be found to be more economical to pull out old retorts after they had been in use for the period mentioned. He had had some experience with brick ovens, and he was convinced that ovens of the character of those formerly used at the London works were altogether a mistake. The object there was more a matter of coke-making than gas manufacture. It was sought to make coke which would be suitable for locomotive engines and foundry purposes, and such coke was double the value of gas coke. His father devoted many years to the manufacture of coke, and he knew from observation that ovens as set at the London works were a failure. He had seen those in use at Mr. Livesey's works, and could testify that, set on that principle, they were a perfect success. With reference to clay-retorts, it was idle to attempt to work a large number without an exhauster. The cost of clay retorts was about half that of iron; the cost had not varied much since their first introduction. Twelve years ago he had the honour to read a paper before the Institute of Civil Engineers, on the comparative value of clay and iron retorts, and he thought that was about the estimate he then gave.

Mr. CATHELS said there had been many beliefs expressed by the various speakers, but he should like to have heard their opinion backed up in some way by statistics. Mr. Douglas omitted to tell the meeting why he abandoned round and oval, and adopted D retorts. He did not think Mr. Douglas would get a D retort to do anything like what he had stated in his paper. With reference to Mr. Anderson's remarks, he could only say that he never had an arch drop. Such an accident could only result from bad workmanship, and not rubbing the bricks well together. Some of the speakers had spoken of the quantity of gas obtained per ton, but they did not say what kind of coal they used. They might, perhaps, be using coal which would give off the same quantity of gas in four hours as could be obtained from Newcastle slack in six hours.

Mr. JOHN SOMERVILLE read the following paper:—

ON TWELVE MONTHS EXPERIENCE WITH BEST AND HOLDEN'S RETORT DRAWING AND CHARGING MACHINES AT DUBLIN.

It is proposed in this paper to give the meeting, as briefly as possible, an account of the results of twelve months working of the "steam stoker," as the machine is technically termed; and, as a paper on the same subject was read at the last meeting of the association, describing these machines, and giving some account of their working, by Mr. G. Anderson, I will begin where he left off, expressing some doubts as to the commercial advantages to be derived from the use of these machines, and I trust that that gentleman, if he is present, will be better satisfied on that important point by the time I get to the end of this paper.

It is unfortunate, in more respects than one, that Dublin is divided from England by 65 miles of water, as it is a considerable barrier to the free intercourse which otherwise exists between insular cities and towns; and those who would wish to witness the action of the machines, so as the more accurately to judge of their performance, are debarred, unless at considerable sacrifice of time and convenience. To obviate this in a small degree, I have had made, and brought over with me, a working model, that you may see more clearly than by any description I can give, their working and action.

This model is a little different to what the machines really are. The action of some of the parts is changed. The principle remains the same, and, as you see, consists of a strong framework running on four wheels on rails laid upon the stage of the retort-house. This framework carries an upright boiler with engine attached, which acts upon and drives two pitch chains, to which are geared the three rakes and three scoops; above the scoops, and supported by columns, is the hopper carrying the coals, and a small water-tank. It also moves along the rails, adjusting itself to any position opposite the retorts, and the manner of working it is as follows:—

One machine on either side of the range of benches (the same as two gangs of stokers) takes its supply of coals—about three tons—into the hopper, and a supply of water into a tank for feeding the boilers and cooling the rakes. Three doors, or nine retorts, are opened, the machine advances in front of them, sends in the three rakes, draws out the coke, which falls to the stoke-hole into waggons placed to receive it below, and is there cooled in the usual manner; the machine is then moved on to the other open retorts, draws out the coke, and then returns to the retorts it first discharged; then the scoops, ready filled from the hopper, are sent in, turned half round, and withdrawn inverted; then the machine proceeds to the next, and in like manner to the others, and charges them, two men trimming the coals into the measures in the hopper, and one man guiding, by means of a shoot, the coals from the hopper to the scoops. The man who attends the rakes, in drawing the coke out, now closes the door as the machine moves away, and follows it to the next bench. This goes on till the whole section is finished, when the machine stops, takes in three tons more coals from the upper hopper and water for the boiler and rakes, and proceeds through the other sections until the whole of the retorts for that hour are both drawn and charged; then the machine returns to its standing-place and gets a little cleaning up, while the men sweep up the stage and rest for 20 minutes, until the next hour strikes, when the same operation is repeated, and so on from hour to hour.

A system of signals, given by a steam-whistle attached to each machine, regulates their action in drawing and charging; so that as soon as the rakes of one machine have taken hold of the charge of coke it signals to the other, which in its turn enters and takes hold of the coke, as the centre of the retorts is clear for the rakes to go down. The same is the case when the scoops of the No. 1 machine are turned over, the signal is given, and the scoops of No. 2 enter and discharge the coal. By this means collision between the rakes and scoops is avoided, and it leads to no delay, as the No. 2 machine keeps a little behind the No. 1.

This work has been done at the rate of 72 retorts per hour, the usual rate being 60 per hour, or one retort per minute. The greatest number of mouthpieces that have been worked this last winter with the machines was 20 benches, of nine retorts each, or 360 mouthpieces. These were charged 60 every hour, and were usually done in from 25 to 30 minutes; the quantity of coal put in each charge being 3 cwt. per mouthpiece, more or less, according to the state of the heats, the men filling the measures regulating the quantity. The average, however, is 12 cwt. per mouthpiece for 24 hours; so that the quantity put into the retorts by two machines in 24 hours was 216 tons, or 1512 tons a week. One week in January, 1708 tons were put in, but it was exceptional, the former figures being the average of the whole work while the number of retorts were in action.

The cost of doing this work consisted of—

4 engine-drivers, at 26s.	£5	4	0
4 rakesmen, at 25s.	5	0	0
4 chainmen, at 22s.	4	8	0
8 hoppermen, at 21s.	8	8	0
A total per week of	£23	0	0

which gives 3·65d. per ton of coals carbonized. During the week in which the greatest quantity of coal was carbonized the wages were 3·23d. per ton.

Next winter I hope to have the whole of the house, containing 516 mouthpieces, in action, and expect to carbonize 2200 tons per week, at a cost of 2½d. per ton.

The coke is removed from the stoke-hole in waggons, at present by manual labour, and the usual number of men are required to attend to the furnaces, ash-pans, &c.

The arrangement with the patentees who undertook the working is that they provide the four machines at their own cost, and keep them in repair and proper action, and do the work of drawing and charging for 3d. per ton of coals put into the retorts, but should the wages exceed this amount, one-half of it is to be borne by the company; thus, if the actual wages per ton amounted to 3½d., the company pay ¼d. per ton more than 3d., and another agreement is that the company pay a royalty of 6d. per ton for licence to use the machines; thus the 6d. has to be added to the 3·65d., making 9·65d., then ·325d. has to be deducted for half excess of 3d. per ton, so that the patentees charge a total to the gas company for work done in carbonizing, repairs, maintenance, fuel, oil, wear and tear, interest, royalty, &c., 9·325d. per ton of coals carbonized.

It will be seen, therefore, that a considerable saving is effected by these machines, and there are also other advantages attending their use when compared with hand labour—such as the regularity with which the work is done, the absence of carbon in the retorts, the rakes being so shaped as to scrape the sides of the retorts, thus keeping the accumulation down, and enabling them to take the full quantity of coals throughout the whole winter without once requiring to be let down for a day or two, as is usual, and the consequent heavy wear and tear is avoided.

In connexion with the machine system it was found necessary that the coaling should also be done by machinery, as great difficulty and expense were experienced at their introduction in coaling by manual labour, which cost 8d. per ton; so last year a new arrangement has been carried out for coaling the machines, which is shown in section here.

There is a steam lift or hoist on either side of the retort-house, lifting 30 cwt. of coal in a waggon, which is run in upon a 3-ft. gauge railway, and turned on turn-tables, then run along a line of rails carried the length of the retort-house on brackets secured to the walls. This railway is above the hopper or stores of coals, from which the hopperman receives his supply by opening a door by means of a rack and pinion at the finish of each section as he moves with the machine.

On the line of rails two men on either side keep these hoppers always full, receiving the full waggons from the lift and returning the empty ones. These lifts are in direct communication with our coal-stores, the grinding-mill, where Mackenzie's patent compound, the mixing of oil and coal, is carried on, and also in connexion with our two lines of railway from the quay and the docks; so that the coals come direct from the steamer up the lifts, fall into the upper hoppers, from there into the hoppers of the machines, from the hoppers into the scoops, so into the retorts, without being touched by hand; or, in other words, the coal is taken from the steamer, conveyed into the retorts, converted into gas and coke, and in the space of six hours deposited on the ground, all by machinery.

In connexion with the system it is found to be absolutely necessary that there should be a quick method of closing the retorts. This is at present done by means of one door or lid, planed on the face, closing three retorts at once, the mouthpiece covering three retorts, and having one ascension-pipe, also with a planed surface, and the two being brought close together are supposed to be gas-tight. When they were taken from the planing lathe it is possible they might have been tight, but my last winter's experience proves that they are very far from being so now.

This has been indeed almost the only source of trouble in the whole system. The door being 7 ft. long and 2 ft. 3 in. wide, made of ⅝-inch wrought iron, with a strong angle iron round the edge, expands and contracts unequally, and the heavy blows given to the wedges, in bringing the surfaces together, tend to warp and twist the door, so that we have determined upon abandoning them, retaining the chamber part, and intend fitting on each chamber three mouthpieces, with Morton's patent lid and Holman's patent fastener, which I trust will overcome the difficulty.

Another great difficulty was the constant stopping of the ascension-pipes, and even the hydraulic main. The heat from the mass of ironwork was so great, and the main so close set upon the top of the benches, that it might not inappropriately have been termed a still for distilling tar. Frequently the pitch had to be taken out by means of pinch-bars, and the pipes were nearly half their time being cleared out. This has been remedied by raising the main 5 feet above the benches, and by fixing a flame-plate or fender above the mouthpieces, at such an angle as to throw the flame issuing from the open retort

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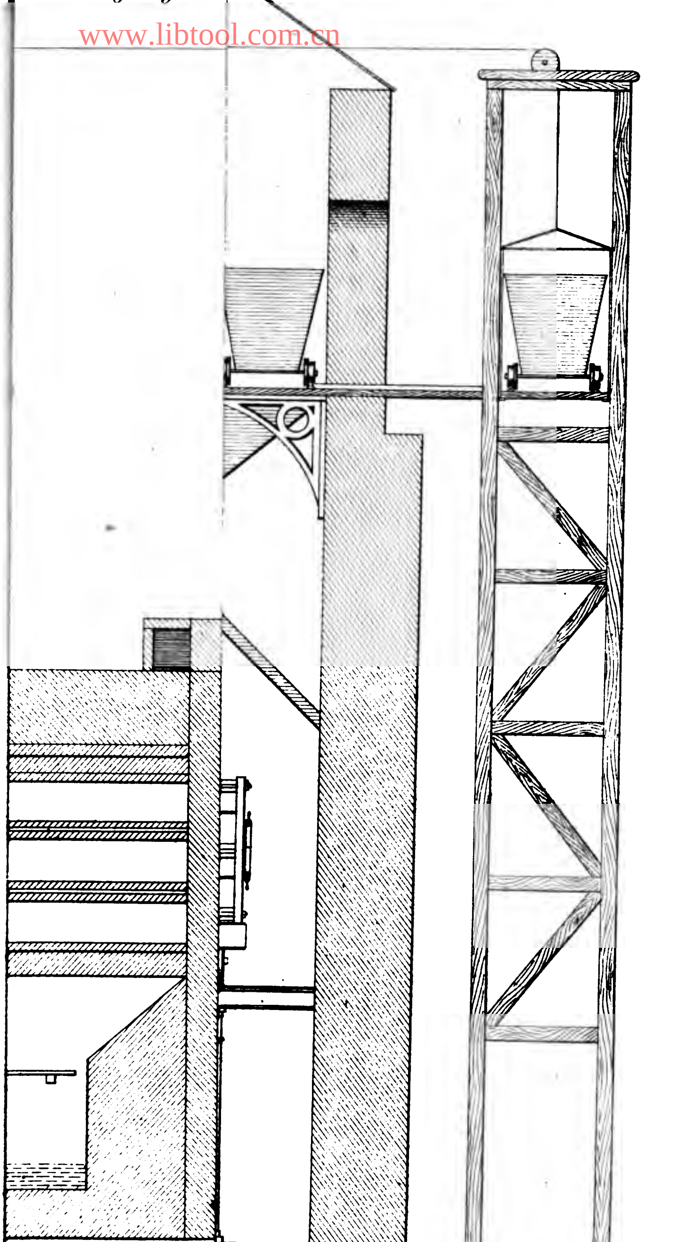


Whiteman & Bass, London.

several feet from the ascension-pipes. These experiments have proved so successful that we have not had one stopped pipe all the winter.

In passing, I would recommend all who are troubled with stopped pipes to adopt this remedy as a complete cure.

Wih respect to the machine itself, unquestionably it is a step in the right direction, and will eventually tend greatly to cheapen the production of gas, especially in large works where it can be worked to advantage. It is, in my opinion, not quite suited in its present form to a work having less than 300 mouthpieces in use during six months of the year; but for works employing that number and upwards, two of these machines will be found not only advantageous in many particulars, but decidedly economical.

It may be said they are only in their infancy, and not yet fully developed, but doubtless year by year experience will suggest new applications in their parts or simplicity in their construction, which may add more and mo re to their efficiency and completeness.

Several improvements have been made during the last year, and others will be applied this year. For instance, the scoops are now being made wider, to enable them to put more coals into the retorts, and also to prevent the coals from spilling over the edges when being let down from the hopper. A self-acting arrangement (as shown here), instead of the bottom falling out, will convey the coals from the hopper to the scoops. By this means two men on each machine will be dispensed with, and a self-acting disc at the end of the scoop is added, so that when the scoop is turned over in the retort the disc flies open, and assumes the shape of the scoop, and does not draw the coals out of the retort like the fixed disc. A spring is also substituted for the weight in turning the scoops over. This will reduce the weight of the machines considerably. These and other improvements will doubtless be added as they suggest themselves.

The machine, as a whole, is a great triumph of engineering contrivance, and exhibits in a striking manner what may be accomplished in the way of substituting machinery for manual labour—in this case labour of a nature calculated to shorten human life. Let us not, therefore, regard these machines as mere innovations; let us rather welcome them as harbingers of the "good time" when gas-making shall become not only an interesting operation, but altogether one of pleasantness, and even one of salubrity.

Mr. Woodall confessed that he did not see where the great saving by this machinery was effected. He thought the experience of most managers would be that an ordinary workman did three tons in the course of 24 hours, and, as he took it, that would come to about 10½d. or 11d. per ton. By this machinery the cost was 9·6d., which was but a very slight difference.

Mr. Morton read the following paper:—

ON SUNDAY LABOUR.

During the past twelve months a few of the gas managers in and around London have met together from time to time to discuss the subject of labour in gas-works on the Lord's Day. These discussions have led to the belief that a great deal may be done towards lessening that labour, and that the difficulties, which we were all more or less inclined at first sight to think insuperable, were really to a great extent more theoretical than practical, more imaginary than real.

I have been requested to bring the question before this meeting, with a view to having these difficulties or objections more fully ventilated, and, if possible, overcome; and I think it will be far from creditable to us as a body of professional men if we cannot devise some means, and as Christian men, if we do not use these means, so that our stokers may enjoy a much greater immunity from Sabbath labour than they do under existing arrangements. I say stokers, and I must be understood throughout this paper to refer only to carbonizing work, for I look upon all other as perfectly unnecessary, although it is a fact, and a fact very much to be regretted, that some managers do permit a considerable amount of such work to be carried on, not exceptionally, but as a rule. I think such gentlemen stand very much in their own light by so acting.

I believe that if we were all more alive to our *duty* to our men, difficulties would not appear so formidable, and that till we are thus alive they will not be dispassionately considered.

I do not believe that there is any one here who will deny that, even on the low ground of expediency, it is good policy to allow workmen to rest one day in the week, and when I put it to you from the higher ground of God's command that man should rest, I give a double reason why you should not turn from the consideration of this subject with impatience, or as unworthy your notice.

It is said, and to a large extent said truly, that the men would rather work than lose their pay. I would ask, who is responsible for this low state of morality? Who but ourselves, who have created or continued the bad custom, which, like every other bad habit, is very difficult to break off.

It is said again, that to cease working will materially affect the profits of the concern. This has been gone into carefully, and I am satisfied that the loss has been much over-estimated; but assuming for a moment, and for argument's sake, that there is a loss, I hold that it is not such as ought to deter us from at least taking a step in the direction indicated, and I am glad to say that several of us here have been encouraged by our directors to run the risk of any loss, so that it may be seen whether the end may not be attained.

In answer to queries sent to some 400 gas managers by the gentlemen referred to at the beginning of this paper, several managers say want of storeage room prevents them. As that difficulty can only apply to a part of the year, I would ask those whether they take advantage of the ample storeage they have in summer, and curtail their Sunday labour then?

In some cases I find this argument cuts the other way, and, where storeage is small, the gas made on Sunday is of necessity very much less than on week days, the consumption, as a general rule, being much smaller than on week days.

The questions of damage done to retorts by being left out of action; the risk of bad gas getting into the holders; the waste of fuel in maintaining the heats; the waste of gas when the retorts are first charged after having been left off, will doubtless be brought forward. I am far from saying there is nothing in them; but as the object of this paper is not to anticipate but rather to elicit discussion, I simply state them as points to be debated, and leave anything I may have to say regarding them till afterwards.

Having thus briefly introduced the subject, and believing it to be one well worthy your consideration, I trust you will thoroughly discuss it, and I believe the discussion will lead many to give more heed to it than they have hitherto done, and I am sure much good practical benefit will be the result.

Mr. Methven said he was very glad Mr. Morton had brought forward this subject, and hoped it would further the desire which many felt to give the stokers the day of rest they had not hitherto enjoyed. He knew there were serious difficulties in the way; the want of storeage in many works was not everything, and that might be overcome. Some one had said that a little experience was worth a great deal of theory. His own experience in this matter was that he could give his stokers one Sunday in three during the winter, and every other Sunday during the summer. The difficulty he had in the winter was that, though the amount of labour in the retort-house was reduced as much as possible, it was necessary to have some relays, and where to get them he could not tell, as there were not always stokers out of employ to put on the work. In many small works in various parts of the kingdom the directors never seemed to think of giving the stokers a Sunday to rest; they were anxious about their dividends, and nothing else. They paid the men for working seven days in the week, and never made any inquiry into their condition. He was convinced that gentlemen occupying the position of consulting engineers to gas companies might help forward this work considerably, and if they would take a little trouble in the matter many of the difficulties surrounding the question would be removed. Managers of large metropolitan works would find it more difficult to deal with than managers in the country, but if there were an earnest desire to accomplish the object, it could be done to a greater extent than at first sight might be supposed.

Mr. Parlby (Aylesbury) rejoiced that the subject had been mooted, for he was persuaded that the question of Sunday labour could not be too seriously considered by the members of the association. In the autumn of last year a number of inquiries were made by certain persons connected with metropolitan gasworks, in order to elicit information respecting it. At the time he received their circular he was the manager of some gas-works in Wales, where a small number of stokers was employed. From his experience there he found it extremely difficult, in the winter season, to carry out any efficient arrangement so as practically and materially to reduce the amount of Sunday labour. This arose from the limited and inadequate storeage resources. The greatest demand for gas was on the Saturday night, when the increase in stock from the week's manufacture was nearly distributed. This involved the necessity of Sunday labour, with little or no diminution, in order to make up the loss of stock to meet the requirements of the following week. In such a case there appeared to be no remedy, except by increased storeage room and additional carbonizing power. In most instances, an enlargement of the works under such circumstances directors would not be willing to undertake, and therefore the men must toil away on Sunday with the same—if not with greater—energy than was required every week day. But where the grievance could not be remedied, gas managers were discharged from responsibility in the matter. In the town where he was now engaged the difficulties were not so formidable, and he was able to give his men the greater part of the Sunday. To a large extent, he feared, the chief difficulty, in many works, arose from the little importance attached to the right observance of the Sabbath; but he hoped, the subject having been brought so directly under the consideration of gas managers, it would receive from them that attention which it deserved.

Mr. G. Livesey said the question was one which eminently deserved the attention of the association. The point they had to consider was the nature and the extent of the obligation laid upon them. He was afraid it was too much the habit with some of them to regard this matter as one in which no action was practicable, and that things must take their course, and go on in the same miserable way they had done for many years. If the conviction arose that it was their duty to do all in their power to ameliorate the condition of the men, no doubt means would be found to give effect to the purpose. The meetings held in London during the past year had disclosed this fact. A great number of difficulties had been started in the circulars, but the replies received had shown how many of those difficulties had been overcome. One manager would suggest a difficulty which the reply of another proved could be, and had been surmounted. In the case of the metropolis, one of the companies supplying the City had very little demand for gas from Friday night till Monday morning, and in that case they were actually compelled to cease working to a great extent. If the men came to work there would be no work for them to do, and therefore they were obliged to shut off the retorts, and means were taken by the engineer to prevent the possible deterioration of the retorts. The objection raised that the men would rather work than lose a day's pay might easily be dismissed. In his own works the Sunday holiday movement was said to have been started. He did not know whether such was really the fact; if so, the credit was due to his father. At those works they first gave the men a holiday once a month—not stopping the works, but getting other men in to take their place. This, of course, was not stopping Sunday labour at all. They afterwards went further, and gave the men a holiday once a fortnight, part of the men being away on the Sunday and part on the Monday. But it did not work well; for those who were away on the Monday would stop away on the Tuesday. They then stopped the holidays, and gave the men 4s. 6d. instead, telling them that if they took the holiday they must lose the day's pay. There was a difficulty in asking directors to pay men when they did not work. The yard men were not paid on the Sunday, nor was it considered that they had any claim to it. One day's rest in seven was a Divine institution, as old as the creation; and if it was a duty to take means to secure that rest, the men must be content to forfeit the day's pay. The Evangelical Society asked permission to hold religious service at the works with which he was connected. That permission was given, and work was suspended for two hours during the Sunday, for the purpose. The men appreciated the opportunity thus afforded them; but, after all, this was a poor substitute for a Sabbath Day's rest. In works where clay retorts were used it was not easy to arrange for suspending work on Sunday, but where, as in the case of the South Metropolitan Company, brick retorts were used, the work could be stopped and resumed without losing the greater part of the gas at the next charge.

Mr. Dunning said before the circular was received at Middlesborough a custom like that just described had grown up, not from any organized system, but the men had been told to make enough gas for Monday, and then to take all the rest they could. Their money was paid them for the week's work, and the consequence was that only about half of the men were there on the Sunday. They made a long shift on Saturday night, and until six o'clock on Sunday morning, and the men who were there on the Sunday made a little gas, kept the retorts going, the fires being banked up, and, generally speaking, there was no outcry about the hardship of Sunday labour. He agreed with Mr. Livesey that the use of brick retorts would help them considerably in this matter. If managers would make a little effort, and were willing to allow their stock to run a little low for Monday morning, they might, by working the men up to six o'clock on Sunday morning, be able to give some of them the whole of the daytime for rest. He had not much fear that the men would abuse the privilege, though, of course, there was a danger that some of them would get out drinking; but if the men, though resting, were supposed to be on duty, and in readiness to be called upon if necessary, a check would be put upon the evil thus apprehended.

Mr. WARNER was glad to find that the consideration of these social questions was not ignored by the members of the association. He suggested that the subject should be referred to the committee to whom the propriety of forming a benevolent fund had been remitted, with instructions to make inquiries and report to the next meeting whether the thing was practical.

Mr. DOUGLAS did not think there would be any difficulty in the retorts standing for some time; the real difficulty was in the extra expenditure which the abolition of Sunday labour would involve.

Mr. MARTIN (Ormskirk) said the principle was a right one, that the men were entitled to their Sabbath rest, and if it occasioned extra cost, that must be borne by the consumers.

Mr. SIMPSON (Rugby) said he had had the management of works for years, and never had the least difficulty in giving his stokers a half holiday on Sunday. Nor had he ever had any difficulty with the men in reference to stopping their money; the men were always glad when it was their turn to be off. He supplied 110,000 cubic feet of gas on Saturday nights, and though he had only 60,000 feet of storeage, he hadnever any difficulty on Monday morning, the demand during Sunday being very small. In many gas-works it was the rule to employ the Sunday in putting to rights anything which had gone wrong on the works; but with him it was the rule not to increase his ordinary manufacture nor to do special work on that day.

Mr. SOMERVILLE seconded the motion made by Mr. Warner with great pleasure, because the subject was one which he thought should be well ventilated. Gas managers were often called over the coals about Sunday labour, and certainly for many reasons it would be desirable if it could be abolished or reduced. The last summer he was at Maidstone he did it for six months, and he fully believed that in works of that size (120 retorts in winter and 60 in summer) there should not be the least difficulty in the matter. The arrangement he made was that if the stokers produced the quantity of gas required for the six days of the week, he would give them the seventh day to themselves, without decreasing their wages. The men took care to make the gas, and, with the exception of one man to look after the fires, the rest had the holiday. He never found anything wrong with the retorts; they were not burnt out, and he had no bad gas on the Monday. The retorts were a little duller in heat, and the men had to come a little earlier to attend to them. The coals were kept in during the whole 24 hours, and one advantage was that all the carbon was burnt off the retorts.

Mr. HODGSON JONES asked whether there was a gas-tester in the town.

Mr. SOMERVILLE said there was, and rather a severe one.

Mr. JOHN METHVEN: Did you stop the exhausters?

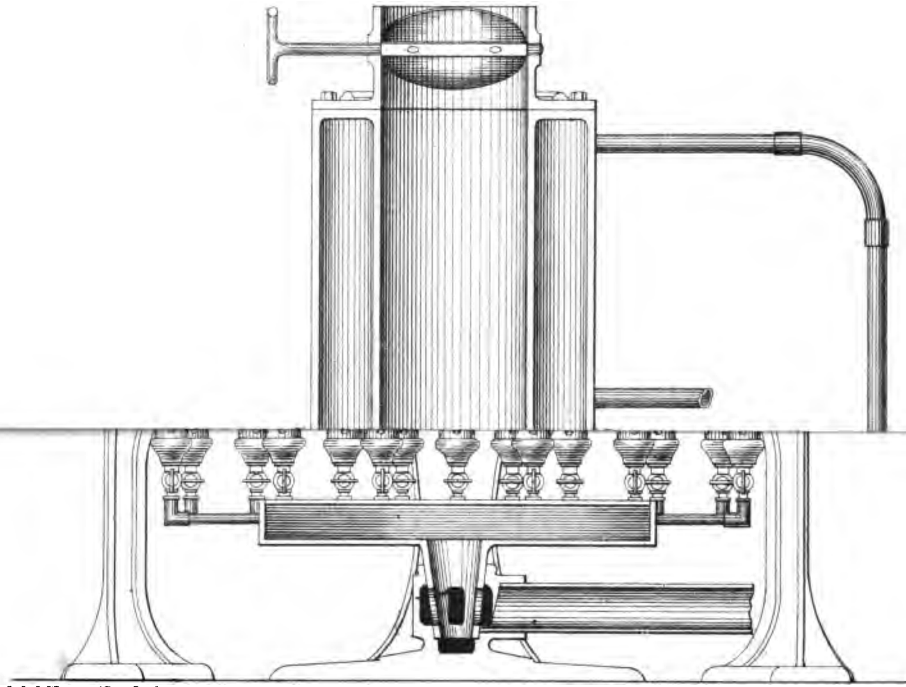
Mr. SOMERVILLE: Yes; the lids of the retorts were slacked; the exhauster was stopped about three hours before the last retort ought to be off, so that there was not the least danger.

The PRESIDENT said he thought it was a very good suggestion to adjourn the consideration of the question, and to refer it to the committee already appointed to glean such information as could be obtained before the next meeting.

The motion was put, and carried unanimously.

Mr. MORTON said he was pleased to find that the paper he had read was so well received. With regard to Mr. Methven's suggestion about having relays

JACKSON'S PATENT
GAS BOILER.



Litho by Whiteman & Bass, London.

SECTION.

of men to supply the place of those who took the holiday, that was not lessening Sunday labour at all. For some time past at the London works he had shut off one-third of the retorts on Sunday, thus giving the men who worked that section the opportunity for rest. They were simply told that they would not be required till Monday morning, and they made no difficulty about the work being stopped. At those works the custom was to give a holiday once a fortnight during the summer, and once a month during the winter. The men entitled to their holidays were included in this batch, so that not the whole of them lost their pay. To prevent damage to the retorts, the plan adopted was to leave the coke in, with the lids screwed up, and to open a hole in the hydraulic main, a valve being shut off between that and the exhauster.

Mr. E. GODDARD (Ipswich) read the following paper:—

ON THE APPLICATION OF GAS TO GENERATING STEAM.

The subject of my remarks, the application of gas to generating steam, is one which, if judiciously carried out, may become of great importance to gas companies, in securing an increased consumption of gas in the daytime, and also of great value and convenience to the public. There are many localities and trades where steam power is greatly needed, and where, if it could be applied, it would add greatly to the productive power of the country, and to the reduction of manual labour.

The great obstacles to the use of steam are the danger attendant upon the fuel employed, the want of space, and the cost of boiler-setting and the erection of shafts, together with the objection raised by landlords in consequence of the difficulty of effecting insurances except at high rates of premium.

The want of space in many of the metropolitan buildings as to where a steam-boiler could be fixed is a sufficient consideration to prohibit the use of steam power, where but for this circumstance it could be most advantageously applied. Attempts have been made from time to time to obviate these difficulties by the application of gas. The adoption of gas-engines has to some extent removed the objection, but not altogether so, but an ingenious invention patented by Mr. Arthur Jackson, and carried out by Mr. Thomas Middleton, the enterprising engineer of Loman Street, Southwark, has recently come under my observation, which to my mind has most effectually removed the difficulties to which I have referred.

The invention consists of a vertical tubular boiler so constructed as to possess great power of generating steam, but of very small dimensions; the tubes are not more than 1-inch bore, and are placed very close to each other, so that an enormous heating surface is obtained; beneath the tubes, on a revolving plate, are a number of atmospheric burners, each supplied with a cock, so that the heating power is completely under control, and can be increased or diminished at pleasure as more or less power may be required.

I have on the table before me an arrangement of burners intended for a 4-horse power boiler, and the diagrams upon the walls will fully illustrate the construction of the boiler, but I may further remark that the space required for a

½-horse	power	boiler is only	17	inches.
1	"	"	23	"
2	"	"	36	"
3	"	"	42	"
4	"	"	48	"

No flue or chimney being required, the boiler may be placed outside any building, either in the area or on a platform projecting from the top storey of the highest building.

The time occupied in getting up the steam to 40 lbs. or 50 lbs. to the square inch for a 4-horse power engine is from 20 minutes to 25 minutes. A very small modicum of gas is required to maintain the pressure of steam when the engine is at rest, and hence the value of the invention is greatly enhanced where intermitting power is required—such, for instance, as is the case in working hoists in warehouses, hotels, buildings in course of erection, &c., &c., and particularly as the full power may be almost instantaneously restored when needed; and when the work of the engine is continuous, the pressure of steam may be maintained at its maximum with the greatest uniformity, without a particle of steam being wasted.

I have had an opportunity of inspecting several of these patent boilers now at work, and I find upon inquiry the average consumption of gas per horse power per hour to be about 100 cubic feet.

I have been furnished with the results of an experiment very carefully made upon Jackson's patent boiler, now at work at Wool Quay, supplying steam to a 2-horse power engine. The quantity of water used was 27 gallons, which was raised from a temperature of 67° to 212° Fahr. in 13 minutes, the consumption of gas being 60 cubic feet. The lightness and portability of a boiler of this description, if placed upon a carriage, would be of great utility in a gas establishment for steaming out apparatus in any part of the works, or any portion of the street-mains which may be blocked by the deposit of naphthalene, and which could be worked without the slightest danger or inconvenience to the public.

I think I have said sufficient to awaken the interest of the association on this subject. The great merits of this invention are—first, economy of space; secondly, economy of labour and fuel; and thirdly, the perfect freedom from risk of conflagration—merits which I am sure will be appreciated by every gas engineer present, and recommended wherever an opportunity presents itself of increasing mechanical power by the application of gas.

Mr. Sharp (Southampton) said for many years he had made a boiler similar to the one described, and a very large one was exhibited in the Exhibition of 1851. He had always used it in cooking, and it was really surprising how the steam was kept up with so small a quantity of gas. Certainly he had not used an atmospheric burner, but after the steam once got up the flame might be turned down to a blue speck, and still steam would be generated. This showed the advantage of the tubular form of boiler, which exposed so large a surface to the action of the heat. It would be a great advantage to many parties if boilers of the sort described came more generally into use.

Mr. Plumb and Mr. Hutchinson having been appointed scrutineers of the votes for the election of the committee for the ensuing year, the proceedings of this sitting terminated.

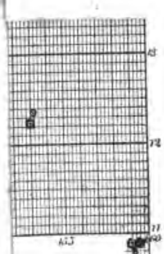
The members reassembled at seven o'clock in the evening—G. Anderson, Esq., in the chair—when the following lecture was delivered:—

PHOTOMETRY AS APPLIED TO THE ESTIMATION OF THE VALUE OF COAL GASES.

By Messrs. T. N. Kirkham, C.E., and W. Sugg, A.I.C.E.

Deeply sensible as we are of the honour you have done us in asking us to deliver the customary evening lecture, yet, finding it no easy task to fulfil, we are induced to ask your kind consideration for us in our efforts to place before you all that is known up to the present time of a science peculiarly interesting to managers—viz., that of photometry, as applied to the purposes of gas lighting. In his first lecture, at Manchester, in 1864, Dr. Letheby gave a short description of his photometer, as fixed at Jewry Street, City; and Mr. Barlow, on May 24, 1866, read a paper to you upon the registering jet photometer.

This is all the information you have had officially placed before you upon this most important subject, and it is the intention of my colleague and myself in this lecture to give you a condensed epitome of all that has been done in this branch of philosophic science since the commencement of gas lighting up to the present time, so that you may be in a position to realize the entire question, and be in a position to judge for yourselves what is best to be done in order to obtain that desideratum—an uniform standard of measurement of the illuminating power of coal gases. The want of this standard is felt more and more as the science of gas lighting advances. In the early days of gas lighting, it was sufficient for the gas manager to know how much gas could be produced from a ton of coals, and the cost of production. Gradually, however, it has dawned upon the minds of municipal authorities and consumers generally that something more than mere quantity is required in the supply of gas. Quality and purity have become, if not household, at least "parliamentary words," and it is now usual, whenever companies are before Parliament for increase of capital, or further powers of any kind, for the municipal authorities to put on the screw in their best possible manner to obtain an extra candle or two in the illuminating power proposed by the company, as well as a reduction in price, and thus obtain a



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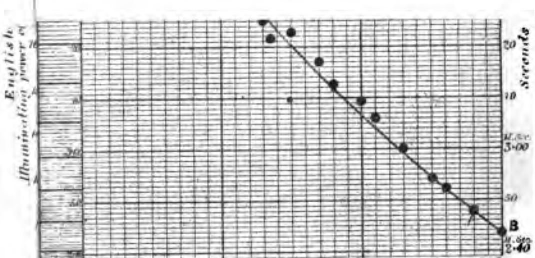
hich each experiment was



Pressure at point of Ignition of Jet Photometers, range of 3/10 of an Inch.

DURATION TEST.

Photo

double advantage. And even if there is no opposition such as this, yet the gas manager, in making his report of the working of the establishment under his charge, must state not only the quantity of gas he can produce, but also the illuminating power of that gas, in order that his work may contrast favourably with that of *confrères* in other establishments. In addition to all this, we have in the City of London and the Dublin Gas Acts a new phase in gas legislation, which may be taken as a precedent in prospective cases, and imperatively commands our attention to the subject of how the illuminating value of gas is to be determined; for it is proposed to exact heavy penalties in every case in which the company fails to supply gas not up to the standard fixed in their Act.

Already questions have arisen upon this subject, and it is for us to examine it well, and be prepared to state what is a just and reasonable mode of examining the quality of the gas, so that both buyer and seller may be mutually satisfied.

At the outset, the science of photometry, as applied to gas, divides itself between two systems. The one by which it is sought to measure the illuminating power of a gas by means of some property peculiar to itself; the other, by which the amount of light produced from the gas under examination is compared with some other artificial light.

The first-mentioned section includes within its limits such photometers as the—

Lowe's jet photometer.
The various duration tests, Dr. Fyfe's, or others.
Erdmann's "Gas-Prover."
Chambeyron's photometer (see "Clegg," 1859 edition, p. 363).

And the second section those of—

Wheatstone, Bunsen, Letheby, Ritchie, Arago;
Church and Mann;
Rumford, Foucault, and Evans.

As this lecture is not intended to be a history of photometry, but rather an explanation of what it is, and how it applies to the manufacture and distribution of gas, we shall not deal with the subject in the chronological order of the invention of the various photometers, but as it ranges itself under the two heads mentioned above.

First, then, the simplest—viz., that system which proposes to measure the illuminating value of the gas, not by comparison with other artificial lights, but by certain physical phenomena peculiar to each quality of gas.

One of the most admired of these was certainly the bromine test, because it seemed that a chemical experiment which could always be performed in the same manner, and with instruments made upon one model, must necessarily give true results, being quite independent of faults of vision or irregularities in the working of apparatus. The principle upon which the system is founded is common to other systems, and is this—"The gas which will give the highest illuminating power is that which contains the most carbon." To find the quantity of carbon in the gas is then the object of the bromine test.

Bromine is a metalloid, and at ordinary temperatures is of a deep brownish red colour. It is liquid, and boils at 113° Fahr. Its specific gravity is 2·97. Its vapour resembles that of nitric acid, but has a peculiarly disagreeable pungent smell. It is poisonous, and acts so strongly on the lining membrane of the nose, that smelling a bottle of bromine is often followed by painful irritation of the nostrils, attended with a copious flow of tears lasting for hours or even for days.

Such is the description of bromine. The method of performing the experiment is as follows:—

A Cooper's tube is filled with gas, and a small quantity of bromine is introduced, and the whole shaken up together. Any excess of bromine is neutralized by the introduction, after condensation has taken place, of a little caustic potash.

The amount of condensation is greater or less according as the gas contains more or less carbon. The value of the degrees of condensation having been once definitely settled, it would appear to be only necessary to perform this apparently simple experiment to determine without doubt the value of the gas under examination.

Its advocates, however, have reluctantly been compelled to abandon it, because, although it absorbs hydrocarbon vapours, so it does other things as well, and its indications are therefore now considered to be valueless. It may be mentioned that the vapour of bromine is not an agreeable thing for operators at all careful about their throats or lungs. If it had been a successful system, the science of photometry might have had its martyrs as well as others.

Lowe's Jet Photometer

might, perhaps, have taken its place first, if the subject were considered in the chronological order of the invention of the instruments of photometry, because it seems that several persons claim to have made use of such an instrument many years ago, at the very commencement of gas lighting, *if not even before it*. They appear to be much annoyed that the name of George Lowe should be given to this instrument any more than the name of any of those who are said to have used it very long before he did. If there is any wrong done to any one in the naming of this instrument, it is for your humble servant to cry *peccavi*. Although the principle upon which it was constructed may have been discovered by other persons, it was nevertheless he who made it of any practical value; and it is indebted to my colleague and myself for those improvements upon Lowe's instrument which have placed it in the position it now occupies in the estimation of gas managers. I trust you will not impute to us any idea of unduly praising ourselves, but it is advisable to clear up as we go on, so as to prevent misapprehensions in future.

The principle upon which it works is exactly the same as that of the bromine test—viz., that the richest gas contains the most carbon; to this is added the words, "and requires the greatest quantity of oxygen for its combustion."

It will be seen that this principle is applied to another instrument which operates in a different manner to arrive at a solution of the question—viz., Erdmann's gas-prover, which will be explained in its proper order.

Lowe's theory is substantially this: A jet of gas issuing from an orifice of fixed dimensions under a constant pressure, and requiring a certain amount of oxygen for its proper combustion, must necessarily, if the gas contains a greater quantity of carbon per cubic foot, produce a longer flame than that which contains a lesser quantity, because it must go higher to come in contact with that oxygen. Thus the richer the gas the higher the flame.

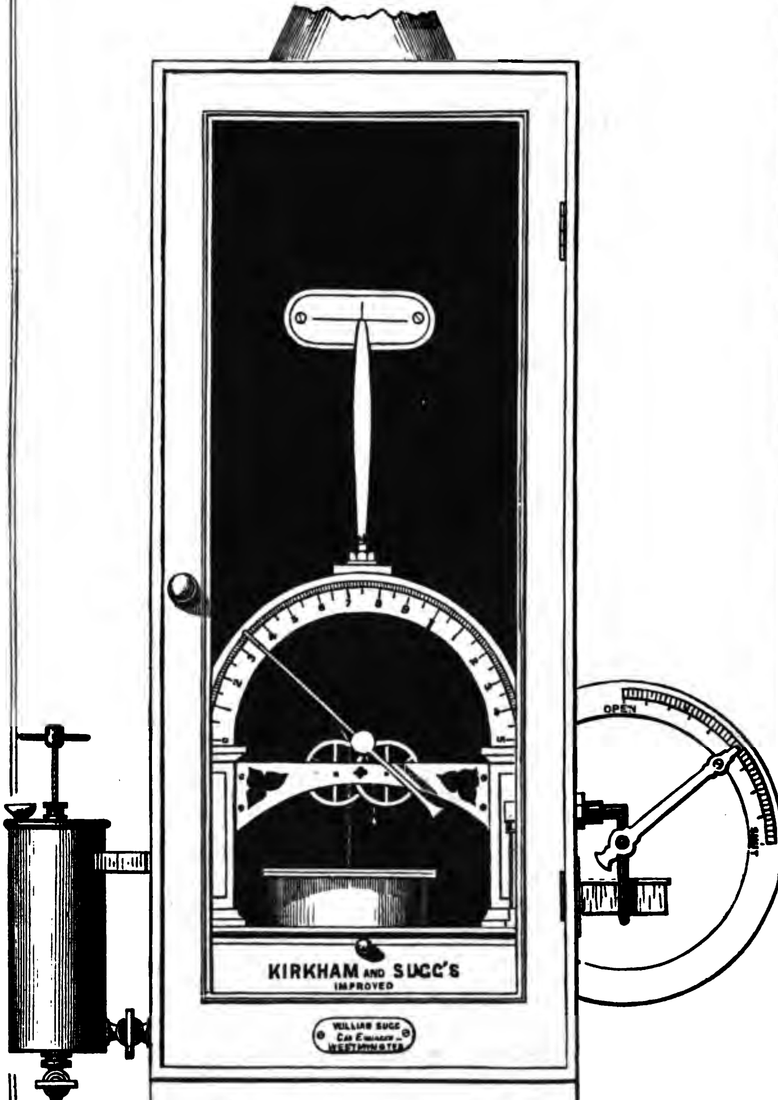
Now, in order that every quality of gas may be estimated under the same circumstances, Mr. Kirkham and myself have found it more convenient to substitute for his theory this, which amounts to the same thing in the end—viz.: Maintaining a 7-inch flame from an orifice of certain fixed dimensions, the illuminating power of gas is in direct proportion inversely as the pressure.

To explain this popularly, we refer you to the diagram of the jet photometer arranged for the use of these instruments. By inspection it will be seen that it is ruled off in lateral and longitudinal lines; the former corresponds to the illuminating power of the gas in candles, the latter to the pressure required to give a 7-inch flame. This is the height of flame which we have adopted as standard for gases of from 9·6 to 22 parliamentary sperm candles, six to the pound, burning at the rate of 120 grains per hour. Thus, then, it will be seen that at ·63 pressure, 14-candle gas with our standard jet gives a flame of 7 inches in height; that 12-candle gas requires ·685 pressure to give the same height of flame; that 16-candle gas gives the standard flame at ·575 pressure; that 20-candle gas gives the standard flame at ·465 pressure, and so on for all other qualities of gas within the range previously stated.

So that to ascertain at once by simple inspection the exact illuminating power of any gas to be examined by the aid of this instrument, it is only necessary to adjust the height of the flame to 7 inches, note the pressure required, consult the diagram, and read off the answer in sperm candles without further calculation. Now, you will naturally say, "Yes; this is all very well, but what proof can you give to substantiate your theory?" Before answering this question, it is necessary to premise that this theory, like many others, was not thought out first and afterwards proved by experiments, but that, on the contrary, the theory was constructed upon the tabulated results of experiments conducted for another purpose. We might even say, if you will pardon the simile, that our object was to convert the indications of the Lowe's jet into sperm candles and carcel lamps; but, like the Zulu Kaffirs did in the case of a celebrated calculating hierarch of the Church of England sent over for their benefit, Lowe's jet converted us. Thus its correctness claims our assent to the fullest extent to which truth can be demonstrated by induction.

My colleague and myself had undertaken a rather long series of experiments for the purpose of determining the relative value of the English and French

LOWE'S JET PHOTOMETER.



standards of illuminating power, the particulars of which will be communicated to you in their proper order, and very early in our first series we were led to remark the regularity with which a Lowe's jet photometer, which was supplied with the same gas as that upon which we were experimenting, answered to every increased per centage of richer gas added to the ordinary gas we had prepared. We therefore decided, after having carried out the first series, to commence a second series, in which we used two Lowe's jet photometers, made precisely alike, and connected to and supplied with the same gas as that burned in our other photometers, which were the "cross" photometer and the Foucault photometer, both here exhibited.

In order to save confusion, we must ask you to assume for the present that which we shall doubtless amply prove to you in another part of this lecture—viz., that the system adopted by us in our experiments upon the standards of light, was the best possible to arrive at the truth.

Four operators at the cross photometer made simultaneously an estimation of the illuminating power of the gas as compared with sperm candles, in the ordinary manner adopted by gas examiners. For better security they repeated this twice, making in all twelve experiments. Upon a diagram prepared precisely in the same manner as this one, but without the red diagonal line, was marked the average result of these twelve experiments, care being taken that the mark should be put on that lateral line corresponding to the illuminating power in candles (as found) at its intersection with that longitudinal one, corresponding to the pressure required to give a 7-inch flame, with the same gas burning in one of the Lowe's jet photometers. Thus the mark for 14-candle gas was put upon that longitudinal line marked ·63, and opposite the figure 14. The black quatrefoil is the mark. The second Lowe's jet was kept at a constant pressure, the height of the flame rising as the quality of the gas increased. This diagram shows the position of the several instruments.

Simultaneously with these experiments a fifth operator made three experiments with the Foucault photometer, which is fitted in the same manner as those employed by the municipality of Paris for the verification of the gas supplied to that city. His operations were conducted nearly in accordance with the instructions issued by the municipality as a guide to their gas examiners.

The average of these three experiments was marked on the diagram in that position, as regards illuminating power, corresponding to the value of the gas according to the French system, in the terms of the English standard candle. The red star is that mark.

A sixth operator took charge of the Lowe's jets, and observed the pressure required to give a 7-inch flame with each of the different gases examined. He also noted the time required for the consumption of ·1 of a cubic foot of such gas.

These results, we consider, clearly demonstrate the truth of our theory, for by no known law of physics can any other line be found, from an examination of these experiments, than that laid down by us.

It will be observed that there are a sufficient number of experiments of both kinds which fall on the line to justify us, without mentioning those on either side of it, which are also very conclusive.*

Erdmann's Gas-Prover.

We must now rapidly glance at the Erdmann's gas-prover, and, to justify the shortness of the time which we shall devote to it, I shall take the description and opinion of its value given by Mr. Schilling, the talented director of the München Gas Company, in his "Traité d'Eclairage," a work which corresponds to our own "Clegg on Gas Lighting."

It consists of a Bunsen burner arranged in such a manner that the supply of air is admitted through a long narrow slit. A scale attached shows how far it is open, and, from the size of this aperture, it is sought to establish the rate of the passage of air demanded for the perfect oxidation of the gas burning at the top of the burner; and from this, according to the theory before mentioned, that the richer the gas the greater the quantity of air required for its perfect combustion, to determine the illuminating power of the gas.

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* An enlarged coloured diagram of these experiments is published for the use of operators testing with Lowe's jet photometers.

Mr. Schilling considers that the instrument requires meters or other apparatus to measure exactly the quantity of air and gas burned together in order that its indications may be of any value whatever, and, from a number of carefully conducted experiments published by him—which, if time had allowed, should have been pleased to place before you—he demonstrates that it is not at present a reliable instrument.

Mr. Friedleben, of Frankfort-on-Maine, has in his gasograph remedied in theory some of these defects, although his instrument has not within itself those elements of precision which are demanded by self-photometers such as these. The instrument is here at work, and it consists of a revolving vertical dial, which turns on its axis once in twelve hours. A very small meter in the interior gives motion to a piece of apparatus, by which at every revolution a hole is punctured in the paper. The number of points per hour bear relation to the illuminating value of the gas.

A very pretty little instrument, a modification of Erdmann's gas-prover, was exhibited at the Exhibition of 1862, by Mr. S. Elster, of Berlin, which certainly amended all the faults in the original invention.

In consisted of a small gasholder, with a very beautifully made and large scale attached to it.

The contents of the gasholder were about half a tenth of a cubic foot. Into this gasholder was admitted a quantity of gas, and the rest of the holder was filled with air. At the base of the holder, and connected thereto by means of a short tube, was fixed a burner with a number of holes, somewhat in form resembling the rose of a very small watering-pot. The gas and air was allowed to burn in this burner at a certain height, when, if it was perfectly oxidized, and burned with a perfectly blue flame, the quantity of air which had been admitted to the holder was taken to represent, by comparison with a specially prepared table, the illuminating power of the gas; if, on the contrary, the gas burned with a white tip, or was too much oxidized, the gasholder was emptied, and the trial repeated till the result of complete oxidation was obtained.

This may be termed a tentative process, and I took the liberty, in conversation with Mr. Elster, to observe to him that however good it might be, it was an instrument requiring great care on the part of the operator—a mistake might result in an experiment upon the explosive force of certain mixtures of gas and air of a very unsatisfactory nature to the operator—but he could not see it. Probably German operators never make a mistake, or are too absorbed in their scientific experiments to let the thoroughness of their investigations be interfered with by their personal inconvenience. Nevertheless, if this system of burning the gas with air be of any use to us, this method seems to be the right way of employing it.

The duration test is said by some to have originated with Dr. Fyfe, but this is not substantiated that we are aware of. The very idea, however, bears the stamp of a shrewd North Briton. It is still founded on the theory that the richest gas contains the most carbon, but we have no mention of a chemical analysis to find how much carbon there is in it, but this shrewd practical question—How long will it burn? And so we have this theory altered thus: Issuing from a constant orifice at a constant pressure, the *richest* gas will burn the longest time. This is, in fact, the true application of all photometrical tests, for to the consumer the advantage of an increase of illuminating power means, or should mean, a reduction of the quantity of gas required to light his house with the same amount of light he enjoyed before the alteration.

Careful examination of the theory shows, however, a radical defect in it, which exercises a very important effect upon the test, as well as upon the commercial result.

It is not practically true that richer gas issuing from a constant aperture, at a constant pressure, will burn longer than a poorer gas. Theoretically it will, but the difference between the richer and the poorer gases is so small that it is difficult to tell one from the other. Thus, a jet of 12-candle gas, burning on a jet photometer at a pressure of 6/10ths of an inch, consumed 2 cubic feet of gas in one hour. A jet of cannel gas, equal to 23 candles illuminating power, burning on the same instrument under exactly the same circumstances, consumed 1·9 cubic foot. At first sight this sounds anomalous, and you will naturally ask, "Then what is the difference between the two? And what advantage is it, then, to burn cannel gas?" Doubtless, to many of you, these questions are as familiar as possible. Consumers are constantly asking them. The difference in the two jets is in the length of the flame. With the 12-candle gas we get, perhaps, a 7-inch, and with the 23-candle gas we get a 9 or 10-inch flame. One more element must then be taken into consideration, and that is the height of the flame, and the theory must be altered as follows:—Burning from an aperture of fixed dimensions, a richer gas will supply a flame of a constant height for a longer period than will a poorer gas. It necessarily follows that a lesser pressure is required for the richer gas than for the poorer. Thus with poor gas we have a 7-inch flame at ·685, while with 22-candle gas we have a 7-inch flame with ·40 pressure.

These flames consume respectively 1-10th of a foot of gas—the 12-candle gas in 2 minutes 46 seconds, or a little over 2 cubic feet per hour; the 22-candle gas in 4 minutes 12 seconds, or 1·45 cubic foot per hour. The difference between the two is 55-100ths of a foot of gas per hour, or at the rate of 5·5-100ths of a cubic foot of gas per candle, if the decrease per candle is in direct proportion, which you will perceive it is not; but this is near enough for the purposes of explanation. It has therefore appeared to my colleague and myself that the duration test may be employed in conjunction with the jet photometer in three ways, either of which may be made self-registering, and may be attached to any jet photometer fitted upon our new system. Thus an apparatus similar to the one here exhibited, which is simply this: A flat paper dial is made to revolve by means of an 8-day clock, with a heavy 40-inch pendulum. An electro-magnet with an armature is fixed at one side of it, and the circuit of a current of electricity is completed through it every time the meter here completes one revolution, which is equal to 1-10th of a cubic foot. The armature is thereby attracted to the face of the magnet, and in jumping to it punches a hole in the paper by means of the point fixed to one end of it. Thus we should have 14·5 points in one hour with 22-candle gas, and 20·5 points with 12-candle gas, or ·6 of a point per candle.

Another instrument (which is here shown) for the same purpose works in this manner: An 8-day clock, with a 40-inch pendulum, is made to wind off a strip of paper from one wheel to another at the rate of about 2 inches per minute. A meter is made which, by a simple touch arrangement, completes the circuit of a current of electricity through an electro-magnet every time the 100th of a foot of gas passes through it, causing it to punch a hole in the paper as it passes along. Another electro-magnet punches a hole in the middle of the paper every minute, while a third does the same thing every hour. Thus, as before, for 22-candle gas we should find 10 points in 4 minutes 12 seconds, or 145 points in an hour, and with 12-candle gas we should find 10 points in 2 minutes 46 seconds, or 204 points in an hour. One is a slow instrument, and the other a quick one. The difference between the two is this, that while the slow instrument gives good practical results in an hour, and is sufficient for most manufacturing purposes, the quick one, which is more carefully constructed, will show the illuminating power of the gas in five minutes at most.

The third method of using the duration test is by attaching the meter registering tenths of a foot of gas to the latter-mentioned clock apparatus, and the result obtained on the paper will be the number of minutes and parts of a minute that a flame of 7 inches will be maintained with a tenth of a foot of gas. From such data the illuminating power of that gas may be ascertained by a reference to the diagram. For example, it is found that a 7-inch flame has been maintained in the jet photometer for 3 minutes 20 seconds by the consumption of 1-10th of a foot of gas, Question: What is the illuminating power of such gas? Answer: Referring to the diagram, we find, opposite the lateral line, 3 minutes 20 seconds, a little over 16-point 9-candle gas. Such a quality gas will do this, and no other.

Now to show how the jet photometer and duration test are combined in practice.

We will suppose that we have a gas under examination which gives a 7-inch flame at 5-point 6-10ths pressure. Referring to the diagram headed "Retrograde Scale," we find that the longitudinal line corresponding to 5-point 6-10ths cuts the red diagonal line on the sixth lateral line between 16 and 17 candles; the value of the gas is therefore 16·6 candles.

The corresponding duration test is found by referring to that part of the jet photometer diagram headed "Duration Test." Finding the longitudinal line corresponding to 5-point 6-10ths pressure, we follow it up till it cuts the red line. This we find it does at that lateral line corresponding to 3 minutes 17 seconds, which is the time a tenth of a foot of such gas ought to last. If the slow-registering apparatus is used, we should find 17 points on the paper in one hour; or, if the quick instrument is used, 172 points in one hour; or, on the hird system, 1 point every 3 minutes 17 seconds.

But none of these self-instruments, however good they may be in themselves, are of any practical value to us, unless their indications can be compared with the standard adopted by the British Parliament, as a point of comparison from which to deduce the value of gas supplied to the public, and which is inserted in all Acts of Parliament relating to gas. That standard is a sperm candle of six to the pound, burning at the rate of 120 grains per hour. Naturally nothing can be more easy of comprehension to the British public than this, that a burner consuming 5 cubic feet of gas per hour shall give a light equal to a certain number of sperm candles.

According to the first and only official system of gas examination for illuminating power, which is that described in the instructions issued by the gas referees appointed under the City of London Gas Act of 1868, the time at which the tests for illuminating power are to be made fall within those hours during which the gas is likely to be most extensively consumed—from five to eight o'clock p.m. in winter, and from eight to ten in summer.

The average of a number of tests are to be taken.

The apparatus is to be constructed upon an improved model, and fixed in an approved manner, similarly to that set up in the office of the gas referees, and which is to be taken as a guide, and the entire apparatus when in use is subject to occasional visits of inspection by these officers.

It consists of a photometer, either on the Evans or Letheby system, arranged for two candles.

A meter with combination index, by which both the time and the consumption of the gas are simultaneously indicated on the same dial.

A delicate balance governor.

A King's pressure-gauge, showing the 100th of an inch, and fitted with an arrangement by which the pressure on the inlet and outlet of meter, outlet of governor, and at the point of ignition can be readily ascertained.

A standard burner, known as the "London" burner, No. 1 size, and fitted to take either a 6, 7, or 8-inch chimney. A delicate candle-balance capable of weighing to the tenth of a grain.

A cubic foot measure, for the purpose of verifying the accuracy of the meter from time to time.

As the *modus operandi* as described by the gas referees is very short, it will be best to take it from their printed instructions.

Mode and Times of Testing for Illuminating Power.

Until the end of September next, the testings for illuminating power shall be three in number, and shall commence at the following hours:—

For Common Gas.		*For Cannel Gas.*	
1st Testing	at 8 P.M.	1st Testing	at 8.30 P.M.
2nd ,, ...	,, 9 ,,	2nd ,, ...	,, 9.30 ,,
3rd ,, ...	,, 10 ,,	3rd ,, ...	,, 10.30 ,,

The photometers to be used in the testing-stations shall, until further order, be the improved forms of the Bunsen photometer, which have been certified by the referees. The burner to be used for testing the common gas of the Gaslight and Coke Company, the City of London Gas Company, and the Great Central Gas Company (which is required to have an illuminating power of 16 candles) shall be Sugg's "London" Argand No. 1, with a 6-inch by 2-inch chimney; and for the gas of the Imperial Gas Company and the South Metropolitan Gas Company (which is required to have an illuminating power of 14 candles) Sugg's "London" Argand No. 1, with a 6-inch by 1¾-inch chimney. If at any time the gas-flame tails over the top of the glass, a 7-inch by 2-inch chimney shall be used for the 16-candle gas, and a 6-inch by 2-inch chimney for the 14-candle gas. The chimneys must be cleaned daily, at the commencement of the testings. The burner to be used in testing cannel gas shall be Sugg's steatite bat's-wing No. 7. The candles shall be sperm, and two candles shall be used together. The gas in the photometer is to be lighted at least ten minutes before the testings begin, and shall be kept continuously burning from the beginning to the end of the tests.

Each testing shall include ten observations of the photometer, made at intervals of one minute. The gas is to be consumed at the rate of 5 cubic feet per hour. The standard rate of consumption for the candles shall be 120 grains each per hour. Before and after making each set of ten observations of the photometer, the gas examiner shall weigh the candles; and if the rate of combustion shall have been more or less per candle than 120 grains per hour, he shall make (and record in a book to be kept for the purpose) the calculations requisite to neutralize the effects of this difference.

These calculations are made by simple proportion as usual. The gas examiners are, at least once a week, to test the meter-clocks, by the standard clock in each testing-station, and corrections are also to be made for temperature and barometric pressure according to tables provided by the gas referees. The average of each set of ten observations is to be taken as representing the illuminating power for that testing. And the average of the three testings is to be taken as representing the illuminating power of the gas for the day.

Besides this the gas referees have taken a vast amount of trouble, and have made a very great number of experiments with a view of obtaining sperm candles of uniform quality capable of consuming the standard quantity of 120 grains with average regularity, and they supply to each gas examiner the candles which he shall use in his tests.

These instructions leave nothing to be desired either in the reliability of the apparatus or the correctness of the mode of procedure, and, indeed, afford an example of the most perfect system of testing which can be adopted in connexion with the present parliamentary standard.

But in order that the system of testing for illuminating power shall be conclusive as a scientific test, it is still desirable that they should carry their investigations further. The important question still remains unresolved—What is a sperm candle?

What is a sperm candle? And what is the just amount of light which ought to be obtained from the combustion of 120 grains of sperm per hour consumed by one of these candles? *Quis custodiet ipsos custodes?* By what standard shall we measure the standard?

It is here proper to mention that the parliamentary rate of consumption of sperm candles of six to the pound appears to be abnormal, for in the report of Messrs. Graham, Cooper, Brande, and Leeson, given in the Great Central arbitration case, page 223, we find the average consumption ranges from 130 to 135 candles. There parliamentary rate, therefore, must have been arbitrarily assumed.

Now we shall proceed to show you how we set about answering this question, by referring you to a set of diagrams, showing the results of a number of experiments made by my colleague and myself for this purpose. In the first place, we must tell you that to do this properly it was necessary to devise a special instrument. That instrument is before you, and it is called the "cross" photometer. It is, as you will see, a combination of the two most approved comparison photometers in general use—viz., that devised by Mr. F. J. Evans, the engineer-in-chief to the Chartered Gaslight Company; and that devised by Dr Letheby, the chief gas examiner for London. Two of the arms of the cross are Evans photometers; the other two are Letheby photometers. It is so contrived that all the four instruments can be used simultaneously and independently to determine the illuminating power of the gas consumed by one burner fixed in the centre of the instruments, and equidistant from the candles, or other standards of comparison, placed at the end of each photometer. Each photometer is provided with plumb-lines, so that the flames of the candles, or other standards used, can be accurately placed at their proper distances. The diagram exhibits the cross photometer as it was arranged for making comparisons between the English and French systems, and it will be seen that for the purposes of this series of experiments two of the arms were supplied with French lamps, burning colza oil, and the other two with standard sperm candles. The instrument as it is now before you is arranged for candles at each photometer. The four photometers give each precisely the same results if tested by means of jets of gas of equal illuminating power fixed in the places usually occupied by the standard candles.

It will be seen also that a clock-meter, King's pressure-gauge, and a delicate balance governor is attached to the instrument, for adjusting and maintaining the quantity of gas to be consumed by the testing-burner.

Each photometer is also provided with a minute-clock and a balance, for ascertaining the consumption of each pair of candles during the course of the experiments.

Four operators can, therefore, at the same time test the same gas.

For the experiments we are about to point out to you, the *modus operandi* was as follows:—

Each photometer is distinguished from the others by a separate mark, and all experiments performed at that particular instrument are shown on the diagram by that mark.

These marks are a △, a +, a ○, and a □.

At the conclusion of every experiment each operator marked the result on a prepared diagram, ruled in the same manner as these.

The explanation of the ruling of the diagrams is as follows:—

The base line and the longitudinal lines ascending from it represent the weight of material consumed—one line to every grain, ranging from 118 grains up to 160 in diagram No. 1.

The lateral lines show the illuminating power, and correspond to the divisions on the photometer-bar, ranging in diagram 1 from 12 to 17 candles.

The strong black on all the diagrams encloses all those experiments in which the candles consumed within the limits of what are considered good experiments—viz., from 118 to 130 grains per hour.

Diagram 1, Plate 19.—Commencing with experiments Nos. 56 and 58, in No. 56, with a consumption of 119 grains, the illuminating power of the standard gas is represented as 15·3 candles; whilst in No. 58, with a consumption of 121·2 grains, it is 14·5 candles. The difference between these two experiments, made with candles which happen to be nearly within the parliamentary standard, is ·8 of a candle. In experiment No. 51, burning the normal standard quantity of 135 grains, the same gas is represented as being 15·48 candles; and in No. 61, consuming 134·4 grains, or ·6 of a grain less, it is shown to be 16·28 candles, the difference being in this case also ·8 of a candle. In experiment No. 60, with a consumption of 134·7 grains, or only ·3 of a grain more, the gas was shown to be equal to 18·18 candles, a difference of 2·70 candles. Thus candles, practically burning the same amount of sperm per hour, show a difference in the illuminating power of the gas of 2·70 candles. In experiment No. 51, with a consumption of 129 grains of sperm, the gas is shown, by the reading of the photometer, to have an illuminating power of 12·6 candles. In experiment No. 52, with a consumption of 145·2 grains, the gas appears, from the reading of the photometer, also to be equal to 12·6 candles. Experiment No. 52, with a consumption of 157·2 grains, shows the gas to be equal to 12·54 candles, by the reading of the photometer. The last three experiments were examples of candles consuming different quantities of sperm, yet giving the same amount of light, the correction of which to the parliamentary standard of 120 grains creates error. Experiments Nos. 57 and 54, each with the same consumption of 130·2 grains, show the difference in the illuminating power of the gas to be 2·42 candles; the former representing it as 13·02, and the latter as 15·44 candles, by the readings of the photometer. These are examples of candles burning the same quantity of sperm, yet giving a different amount of light. The greatest difference in the illuminating power of the "standard gas" shown throughout the 44 experiments made upon this day was 4·60 candles; being between experiment No. 51, with a consumption of 129 grains, giving an illuminating power of 13·58 candles, and experiment No. 60, consuming 134·7 grains, representing the gas to be 18·18 candles.

An examination of the various diagrams demonstrates that the differences in the candles may be classed under five heads, viz.:—1. Differences in the illuminating power of parliamentary standard candles, burning at the rate of 120 grains per hour. 2. Differences in the illuminating power of normal standard candles, burning at the rate of 135 grains per hour. 3. Candles with different rates of consumption giving the same amount of light. 4. Candles with the same rates of consumption giving a different amount of light. 5. Greatest differences of illuminating power in the whole number of experiments when corrected to the parliamentary standard.

From the following tabulated results of three other sets of experiments belonging to this series, it appears that in one (diagram No. 4), where the consumption of sperm varies from 109·2 grains to 134·4 grains, the greatest difference in the illuminating power of the gas, corrected to the parliamentary standard, is 4·59 candles. In the next (diagram No. 5), where the consumption ranges from 120·9 grains to 130 8 grains, this difference is 3·06 candles; while in the third (diagram No. 6), with a consumption of from 120 grains to 142·5 grains, the difference is 4·21 candles.

DIAGRAM No. 4.

	Numbers of Experiment.	Consumption of Sperm by the Candles in Grains per Hour.	Difference in Illuminating Power, corrected to the Parliamentary Standard, in Number of Candles.
Difference in illuminating power of parliamentary standard candles of 120 grains per hour	..	..	—
Difference in illuminating power of normal standard candles of 135 grains per hour	81 & 80	134·1 & 134·4	2·28
Candles giving same amount of light, but consuming different quantities of material	83 & 85	109·2 & 140·1	3·53
Candles consuming same quantity of material, but giving different amounts of light	81 & 80	134·1 & 134·4	2·28
Greatest difference in illuminating power of gas, corrected to the parliamentary standard, shown in the whole number of experiments	83 & 80	109·2 & 134·4	4·59

DIAGRAM No. 5.

Difference in illuminating power of parliamentary standard candles of 120 grains per hour	..	..	—
Difference in illuminating power of normal standard candles of 135 grains per hour	..	..	—
Candles giving same amount of light, but consuming different quantities of material	1 & 5	120·9 & 144	2·57
Candles consuming same quantity of material, but giving different amounts of light	2 & 4	136·2 & 136·2	·63
Greatest difference in illuminating power of gas, corrected to the parliamentary standard, shown in the whole number of experiments	1 & 5	120·9 & 130·8	3·06

DIAGRAM No. 6.

Difference in illuminating power of parliamentary standard candles of 120 grains per hour	6 & 6	120· & 120·3	·43
Difference in illuminating power of normal standard candles of 135 grains per hour	..	..	—
Candles giving same amount of light, but consuming different quantities of material	6 & 9	120· & 146·1	2·83
Candles consuming same quantity of material, but giving different amounts of light	8 & 7	142·5 & 142·5	2·30
Greatest difference in illuminating power of gas, corrected to the parliamentary standard, shown in the whole number of experiments	6 & 7	120· & 142·5	4·21

As the Institute of Civil Engineers have considered these investigations of sufficient importance to induce them to make a special publication of them for the use of their members, which is probably in the hands of most of you, it will be unnecessary for us to detain you further in respect of them. We beg only to remark that the unsuitableness of a sperm candle for the purposes of a standard is so conclusively shown that it remains with the gas referees to justify its continued adoption.

The difficulty is the selection of such a standard. As the French system of photometry has been very well spoken of at different times by those who are qualified to form an opinion on this subject, it will be now the proper time to explain to you shortly what it is.

First, then, the standard of comparison is colza oil, refined in a peculiar manner, and carefully verified by proper persons appointed by the municipality of Paris for the purpose. The process cannot be given here for want of time, but I may mention that the same oil is used for all the Government lighthouses in France, and is also tested chemically and otherwise by the officers belonging to this department. Up to the present time they have without doubt managed to keep the oil practically to the original standard, as arranged by Dumas and Regnault about 12 years ago.

It is consumed in a carcel or moderator lamp. This is the kind of lamp fitted with proper glasses, both lamp and glasses made to a specified pattern.

The kind of photometer used is that called Foucault's photometer, which is a modification of the original Count Rumford's photometer, a diagram of which is here.

It will be seen, by reference to the coloured diagram of the French photometer, that the two lights to be compared—the gas and the lamp—are placed side by side.

The rays from each light fall upon a disc of glass prepared with ground rice so as to be rendered opalescent.

Now, as to whether the lamp burning colza oil is more reliable than the standard candle, we unhesitatingly answer in the affirmative. In the first place it is readily adjusted, and the required consumption of oil can be obtained, even by inexperienced operators, in a very short time. A moderately experienced operator will get it within a few grains every time. Once adjusted it will burn without any very sensible alteration for two or three hours together.

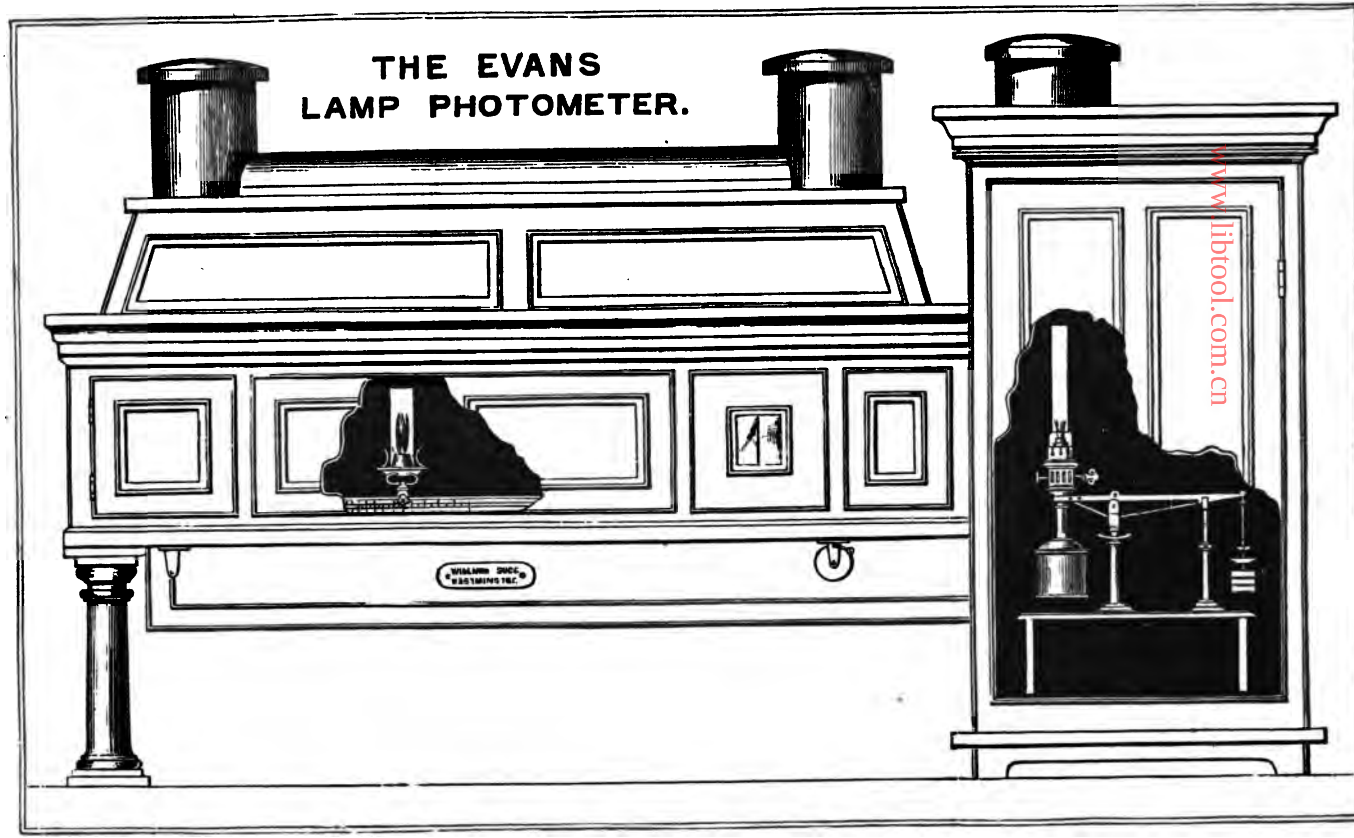
To show you how reliable it is as a standard, we shall refer you to the diagrams marked "Theory of Jet Photometer and Duration Test."

On the first—on the diagram, "Retrogade Scale"—you will see a number of red stars. Each of these red stars represents three experiments performed at the French photometer in a very ordinary manner. Understand clearly that no extra care was taken to make the lamp burn well—not so much as would be taken by an ordinary operator—yet you will see that the regularity of the red stars is much greater than that of the black quatrefoil, which represents the average of twelve experiments with sperm candles, each quatrefoil.

The widest lamp experiment is 1½ candle out; the widest candle experiment is 1·8 candle out. The difference is not great between the two in appearance, but when you consider that the quatrefoil represents twelve experiments, while the red star represents only three, it will necessarily follow that had the same number of experiments been performed with the lamp as with the candles, they would all have been much closer to the truth. More than this, in these experiments several variations were made in the management of the lamp—for instance, in some experiments it was allowed to burn for ten minutes before commencing the first experiment; in others it was lighted, and the experiment commenced in about two minutes. Again, in some experiments the lamp continued to burn untrimmed from the first to the last; in others it was trimmed every time. So that you will see no favour was shown to the lamp at all. The candles, on the other hand, were doing their best in the hands of trained operators.

Shortly, then, if the lamp is properly trimmed and allowed to burn, as defined by the French authorities, half an hour before being used for experiments, we think that, as a standard, it will be far before the candles in reliability and ease of manipulation. You will have no trouble with the standard burning more or less than it ought. The exact quantity required may be readily fixed, and a very slight alteration only will take place after it has been burning for an hour or two.

Probably it will be objected that it is impossible to make use of a French model


THE EVANS
LAMP PHOTOMETER.

carcel or moderator lamp for English testing, because the method of gas examination as arranged by Dumas and Regnault is so totally different to ours, that the public would not understand at all what is meant by a 22-litre gas or a 20-litre gas. Permit us to set your minds perfectly at rest on this score; we do not propose to ask the public to do anything of the sort.

The new Evans's lamp photometer, which is here, settles that difficulty at once. The operator reads off the scale in true standard sperm candles, the same as with any other instrument provided with candles as a comparison. No calculation is necessary on the part of the operator to convert the terms of the lamp into those of the true sperm candle. A short description of the instrument will prove this to you.

Like the ordinary Evans's photometer this requires no dark room, both the standard light and that for the gas to be examined are enclosed so as not to be affected by extraneous light, although they are not at all closed to the admission of an abundent supply of air without draughts.

The disc, which is fixed, is not, in the one before you, in the middle of the photometer scale, but nearer to the lamp. The scale on the left side of the disc goes from 1 at the disc to 30 on the left of the disc. The value of a lamp of the Paris model burning the same kind of oil as that used by the municipality of Paris, at the rate of 648 grains per hour, is, we have found, 9·6 candles; that is average well-made sperm candles such as are used for gas-testing purposes all over the country. Therefore the lamp is placed at that distance from the disc which is equal to the distance marked on the scale for 9·6 candles, whatever that may be. No calculation, therefore, is required.

The gas, which is made to move by means of a simple action worked by a pinion of 10 into a wheel of 100 in a smooth steady manner, is brought by the operator into that position in which it illuminates the left side of the disc to the same extent as does the lamp that on the right. The figure on the scale at which the pointer stops represents candles—thus, suppose the pointer is found at 14, then the gas is equal to 14 sperm candles, supposing the lamp to have burned at the rate of 648 grains per hour.

Diagram No. 10 shows by inspection the correction required to be made for any variation in the consumption of oil by the lamp. The balance upon which the lamp hangs is one designed by Mr. Keates, one of the gas examiners for the Metropolitan Board of Works, a gentleman who has had great experience in the testing of gas and oil. You will observe it is much lighter than that devised by my illustrious *confrère* Adrien Deleuil of Paris, a name well known in the scientific world of that capital.

It will turn readily to half a grain when loaded; Deleuil's turns to three-quarters under the same circumstances. A simple spot of mercury at the tail of the beam on the supporting crutch is made to complete the circuit of a current of electricity when the quantity of oil required is consumed, and either to stop the clock, or by the ringing of a bell to call the operator's attention to that fact. This method of ascertaining when the lamp had burned its proper quantity was adopted in the construction of the "cross" photometer, and used in all our experiments, and was found to be very effective.

Mr. Mann, of the City of London Gas-Works, has kindly lent us a clock which he has arranged so that it can be stopped and started by electricity, or by the hand, at the option of the operator.

The regulation and measurement of the gas is effected in the ordinary way by means of a clock-meter, governor, and micrometer adjustment.

The *modus operandi* of the experiment is similar to that described in the gas referees instructions—viz., ten minutes observations—the only difference being that 108 grains of oil are consumed instead of 40 grains of sperm candle.

What, then, is the outcome of all these experiments, and how do they apply to the general every-day business of the supply of gas? This is what we shall now proceed to show. First, then, the great desideratum for the gas manager is an uniform quality of gas. Irregularities in the purity of gas are only discovered after a careful chemical examination; and, till they are told of it, the majority of consumers are, unless in very bad cases, totally unaware of the presence of impurities in the gas they are burning. Such is not the case with regard to illuminating power. Any falling off in that respect manifests itself at once to every consumer. The eye is a very good photometer, and persons who have been accustomed to read or work by the same light every night readily detect a difference. Nor does it necessarily follow that in all such cases the gas is, as consumers say, bad or defective in illuminating power. Not at all; the difference may be in this, that the gas complained of may be quite up to the standard, or even beyond it, but from some cause or other it is not quite so good as that which may have been supplied on previous nights, which was, perhaps, considerably above the standard. Therefore we maintain that it is quite as injurious to the consumer to supply him with gas of a higher quality than the standard or normal gas which he is prepared to consume, and for which his burners may be arranged, as it is to take the contrary course. The desideratum is uniformity of quality, which is to be obtained, without any large amount of trouble, by all.

Our own experience, and that of many other engineers who have had ample opportunities of practically testing their qualities, leads us to this conclusion, that a good Lowe's jet photometer on the gas after it is purified, and before going into the holders, will, if its indications are attended to, ensure something very like uniformity in the quality of the gas made. Some have said that it can be done, on large establishments, to as near a point as half a candle. Be this as it may, we see ourselves no reason to doubt this assertion.

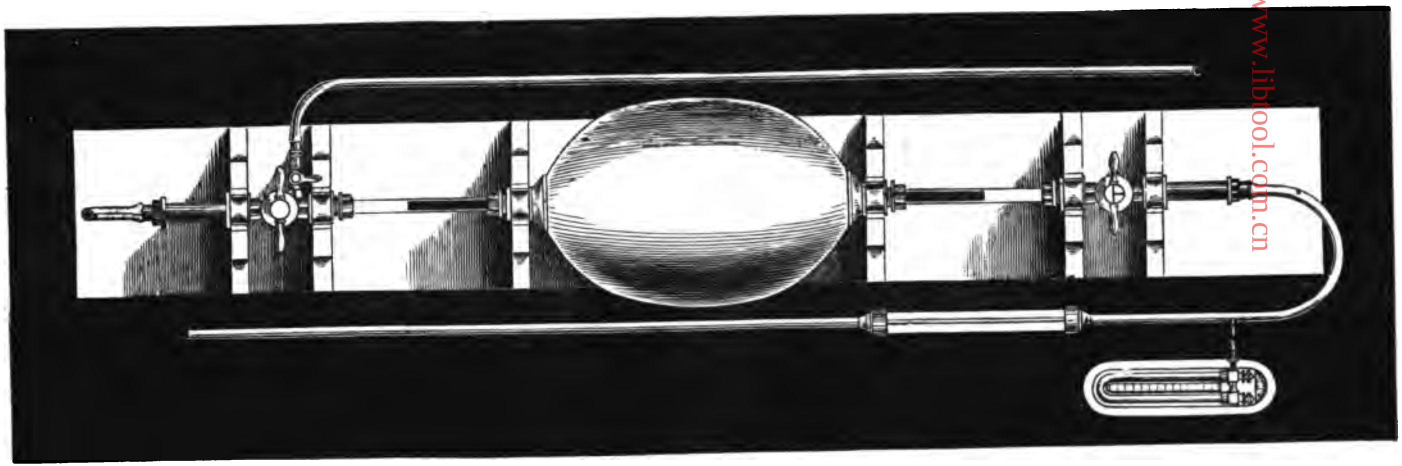
There should also be another on the gas which issues to the public. Any variation in the illuminating value of the gas is thus easily detected without any scientific experiment, or anything more than a glance at the flame of the jet. Under ordinary circumstances, so long as the manager himself is on the works to make experiments or judge of the gas which is being made by the look of the flame which he always keeps burning for the purpose, all will go on rightly; but if he be called away or is gone to bed—for even gas managers must eventually go to bed, at least the married ones—an unlooked-for variation in the quality of the coal or other causes may be the means of producing inferior gas, which is only discovered by the manager long after it has gone into the gasholders.

But on the system proposed by us let us suppose, for instance, it is required to supply gas equal to 14 candles at the testing-station. It is usual in such cases to make the gas so that at the works it is about 2 candles above the standard. The diagram for the jet photometer shows that 16-candle gas will maintain a flame of 7 inches on one of the instruments adjusted to this system, at a pressure of ·575—*i.e.*, 57½-100ths of an inch; therefore the manager simply puts such weights upon the second of the two governors attached to the photometer as will maintain that pressure. His instructions to his subordinates are then to keep the flame at 7 inches, using cannel if requisite. Their careful attention to the jet obviates all collision with the authorities or the consumers, and the gas manager is saved the crowd of blessings, or their opposites, invoked upon his head whenever the quality of the gas is from any cause changed from its normal value.

As a check upon the general working of the jet photometer, the registering duration test here exhibited will be found most valuable, and easy of practical application.

When this instrument is made use of, the flame of the jet must be under all circumstances kept to 7 inches; if above, the pressure must be lowered, and if below that height, raised. Therefore it is evident the manager must set his governor to give such a pressure as will be required by the lowest quality gas he may happen to make. Thus worked, at the end of twelve hours the card-dial will have registered upon it the illuminating power of the gas from hour to hour—one card for the day and one for the night. But all self-photometers must be occasionally examined by the aid of a comparison photometer. Various causes produce derangements in them, which, though they may be slight, or otherwise, are not discoverable except by now and again comparing them with some accepted standard of comparison. Of course, an occasional comparative experiment for the purpose of verifying instruments is a very different thing to the continual estimation of the illuminating power by such proper instruments, and more time and care may be devoted to such a purpose than could possibly be spared out of the ordinary course of the duties of a gas manager.

As well for this purpose as for the verification of the gas by the public examiners, the standard we propose for adoption is a moderator lamp and balance, similar to the one here exhibited, burning colza oil similar in quality to that made use of by the municipality of Paris, at the rate of 648 grains per hour, fitted to a photometer arranged in such a manner that the illuminating power can be read off the scale of the instrument in average standard sperm candles. This average is given on the chart of the jet photometer, and is 9·6 candles for the



Cubic Foot Measure.

value of the light given by the lamp, at 648 grains per hour. Corrections for variations from the true standard of consumption of oil to be made by the use of the curve marked on diagram 10.

The quantity of gas supplied to the burner to be registered by a meter similar to the one exhibited. The meter to be provided with a minute-clock in combination with its index, working by means of a weight. This clock to serve as well for the lamp as the gas. No other clock to be used in the experiment. The regulation of the gas to be effected in the manner as at present adopted.

The lamp once trimmed and lighted, to burn half an hour before the commencement of the experiment.

The verification of the measurement of the meter to be performed by means of the cubic foot measure, in the manner pointed out in the instructions of the gas referees appointed under the City of London Gas Act.

The verification of the oil to be carried out in sufficient bulk by the aid of the "cross" photometer, fitted with two sets of lamps and two sets of candles.

The gas pillar in the centre of the photometer to be supplied with a constant quantity of ordinary gas—as example, of not more than 14 candles illuminating power consumed; a standard Argand burner, capable of perfectly consuming the gas, and maintaining a steady flame.

The candles to be these made by two or more first-class makers, and such as they declare to be genuine sperm candles.

A sufficient number of experiments to be made to justify the acceptation of the grand average as correct.

This expression of opinion is in sum similar to that expressed by Mr. Kirkham in his paper read at the Institute of Civil Engineers.

There is upon the table a moderator lamp fitted to burn sperm oil, constructed according to designs furnished by Mr. Keates, already mentioned, whose experience in the matter of oil testing is, perhaps, second to none. This gentleman, it is fair to say, advocates the adoption of sperm oil, and his lamp is said to burn very regularly. My colleague and myself wish it to be thoroughly understood that we do not condemn the adoption of sperm oil as a standard, nor do we set our opinion as to the reliability of colza oil over that of Mr. Keates. We only say that at the time we performed our experiments there was no lamp in existence that we were aware of that would burn sperm oil so well as the French lamp did colza oil, and that we examined the oil obtained from Paris, and found that our experiments agreed very nearly, within one or two decimal points, of the value of the lamp, as ascertained by the comparison with sperm candles made by Dumas and Regnault about ten or twelve years ago.

In conversation with M. Leblanc, the officer appointed to carry out the whole system of testing on the part of the municipality of Paris, about two months ago, I was led to believe that our average was even truer than that they had obtained.

At the same time, if it is proved that Mr. Keates's lamp and sperm oil is more reliable than that we propose, it is easy to substitute the one for the other, the only alteration required being the distance of the lamp from the disc in the photometer, and the scale altered to suit it, in case the illuminating power of his lamp is more or less than 9·6 candles.

Thus by these two systems we believe general satisfaction will be given, and the determination of the illuminating power will be less troublesome and more exact.

There is one point which now arises frequently in photometrical examinations, and which causes much trouble, although we believe it is easy of settlement—that is, the question of the proper consumption of the specified quantity of gas. As an illustration of this difficulty, we cite the following case:—The gas companies who supply the City of London are bound to supply 16-candle gas to their customers. Now to do this they must, to keep themselves safe, make the quality up to 18 candles as a rule. The gas referees fixed the burner by which the gas was to be tested, and which was with a 6 by 1¾-inch chimney—the same as this one—suitable for the combustion of 5 cubic feet of 14-candle gas; but as the standard candle is not reliable, the companies found that if they supplied only 16-candle gas they were likely to be returned as below the standard, and were indeed so returned from one or two stations. The gas was, therefore, raised from 16 to 18 candles. The result was no better; in fact, the better the gas supplied, the worse the return of the examiners. The cause of this unsatisfactory state of affairs was very simply this—the flame tailed over the top of the chimney when the gas was burning 5 feet per hour.

It is an axiom that the gas must be consumed. The reason why it is so is this: Although, for the purposes of testing, Parliament wisely fixes the rate at which the gas to be tested is to be consumed, so that all gases may be examined under the same circumstances; yet the consumer, for whose protection the system of testing is established, is not bound to consume any definite quantity of gas. He wants a certain amount of light, and the price being fixed, the better the gas he is supplied with by the company, the cheaper he gets his required amount of light; therefore, it is bare justice that in testing the gas none of it should be allowed to tail over the glass of the testing-burner, and so diminish the photometrical result.

The remedy is simply this: If the 6-inch chimney will not promote the perfect combustion of the richer gas, put on a 7-inch; and if that will not do it, put on an 8-inch. Increasing the length of the chimney with the standard testing-burner augments the quantity of air supplied to the flame. In all cases that chimney which is sufficient for the proper combustion of the gas only must be used.

As this lecture has already exceeded the limits which we had prescribed for ourselves, many important subjects which we should have liked to have brought under your notice are necessarily omitted. We have, however, given you the salient points connected with our subject, which must be discursive, owing to the want of a definite basis of operations from which to start, and the most perfect of all experiments being but approximations to the truth. It may happen that at some future time, let us hope not far distant, the practice of photometry may be reduced to a mathematical certainty, but till that halcyon day arrives, we must be content to go as carefully as we can, and get as near the truth as possible.

We cannot conclude without expressing our obligations to Mr. Keates for the loan of lamps and balance; to Mr. J. O. N. Rutter, of Brighton, who kindly lent for exhibition a Dr. Fox's shadow photometer and a Ritchie sighting-box, which, being before you, we have thought it unnecessary to explain in detail; and to Messrs. Fred. and Arthur M'Minn, of Fulham, as well as to several members of my own staff, for their kind assistance; and if our remarks should have for result increased appreciation of the value of photometry as at present applied, or in the production of some marked improvements in its practice, both we ourselves and those who identify themselves with us will feel amply compensated for any trouble we have taken.

WEDNESDAY, JUNE 8.

The PRESIDENT took the chair at eleven o'clock this morning, and the first paper read was by Mr. F. W. HARTLEY, entitled—

REMARKS ON PHOTOMETRY.

In common with most persons who have had much to do with photometry, the writer laments the defects of the present system, and would gladly welcome any modification of it, or any other system of estimating the illuminating value of artificial lights, which would ensure a degree of accuracy alike satisfactory to the mere business man who wants to find whether the article which he is selling or buying, as the case may be, is of the proper quality, and to the scientific investigator whose object is to accumulate facts from which to deduce general laws.

While, however, ready to accept anything which is new, providing only that it be of the character just indicated, and while warmly sympathizing with those whose efforts are directed to the invention of new photometers and new standards of light, the writer inclines strongly to the belief that for a long time there has been a growing disposition to undervalue and decry the present system of photometry, and to exaggerate its defects. Indeed, it has become almost a fashion to regard the results of the present system as of the least possible, or even as of no value, because they, like the results of most experimental investigations, are but approximations to the actual truth.

It is true of photometrical as of other experimental results, that the degree of approximation to truth depends very much upon the intelligence, the judgment, and the skill exercised by the investigator. Now, although it may seem almost heresy to say so, there is possibly less of those qualities exercised generally in photometry than in any other experimental investigation; because, in the first place, it is too much the fashion to regard the operations of photometry as being merely mechanical—demanding only a certain amount of visual experience and skill, and in the next place as being unworthy of the serious attention of the man of science, owing to the untrustworthiness of their indications.

That the matter is pretty much in the condition which the writer has assumed, would appear evident from a fact which has on several occasions come under his notice, which is that some so-called "good operators" will rest quite satisfied that a fair and proper experiment has been made when the light from a 5 feet per hour gas-flame has been compared ten times in as many minutes with the light of one or of a pair of sperm candles, and the rate of the candles consumption ascertained and correction made for variation, if any. Sometimes such operators may repeat the ten minutes experiment, but the chances are much against any change being made with the candles.

In this respect even the gas referees, who, by virtue of their official position, must be accepted as the highest authorities on photometry, have not thought it at all needful to lay down instructions; for, although they order two candles to be used at one time, they do not specify that a different pair shall be used in each comparative experiment, but merely say that "the candle shall be sperm, and two candles shall be used together."

"The standard rate of consumption for the candles shall be 120 grains each per hour. Before and after making each set of ten observations of the photometer, the gas examiner shall weigh the candle, and if the rate of combustion shall have been more or less per candle than 120 grains per hour, he shall make (and record in the above-mentioned book*) the calculations necessary to neutralize the effects of this difference." And again: "The average of each set of ten observations is to be taken as representing the illuminating power of that testing; and the average of the three testings is to be taken as representing the illuminating power of the gas for that day."

In the experimental determination of the products of coal by distillation in small quantity, it is, as is well known to the members of this association, usual to reduce a considerable mass to small fragments, and from such mass to take three distinct samples for as many distillations—the mean of the results so obtained being accepted as indicating as nearly as may be the characteristics of the coal. The writer is well assured that no gas-maker would attach the least degree of value to an experiment made upon one special lump of coal.

The candle, is like coal, a compound body, both chemically and physically, and in the process of burning is converted into gases and vapours just as the volatile portions of the coal are on distillation, only that in the case of the candle there is no sensible interval between the distillation and the combustion of the material. Now it is well known that in the case of coal, although the chemical composition of two samples may be identical, yet that what appear to be but small differences in the conditions of distillation modify to a considerable extent both the character and the amount of the products. So it may be with candles, the sperm may be apparently identical in composition, and the wicks be alike as to quality of cotton, number and size of its strands, &c., and yet, owing to causes of an obscure nature, the rate of burning or the light yielded by any two may not be, and indeed is almost certain not to be exactly equal. Hence in photometry it is necessary, as it is frequently in the chemical analysis of various bodies, to accept the mean of the results obtained by operating on different samples, and it is utterly unwise to depend on any experiment made with one candle only. Moreover, just as the trustworthy analyst would be careful to obtain fair samples of coal, so should the photometrist be careful to select his sperm candles.

At first the idea of selecting the candles may seem to involve the conclusion that the operator might make the gas to appear good or bad at will; but in fact the selection would have just the contrary effect, and would narrow the boundaries within which errors might be made. The elaborate experiments of Mr. Kirkham on "the standards of comparison employed for testing the illuminating power of coal gas,"† also appear, on first examination, to prove

* A book named in the referees instructions.

† Proceedings of the Institution of Civil Engineers, April 13, 1869.

that the defectiveness or variation in the value of the candle's light is so gross as to render the candle standard utterly worthless, and consequently any great care expended upon it a mere waste of time and trouble. But a re-examination of Mr. Kirkham's experiments induces a somewhat different view of the matter

That gentleman found an extreme difference of 4·59 candles in the illuminating power of the same gas, as compared with different candles, and fter correction for the rate of consumption of the latter; but the candles were indiscriminately obtained from various makers, without regard probably to their fitness for photometry, and the consumptions ranged far below and far above the parliamentary rate—viz., 109·2 and 134·4 grains per hour. The after experiments show that with other sperm candles and with a reasonable variation in the rate of consumption, that is, between 118·1 and 129·1, the variation amounted to 1·27 candles only. It is true that in the first series of experiments, with consumptions of 120·1 and 129 grains, the difference in the value of the gas was shown as 1·7 candles; but then the candles were, as before said, indiscriminately purchased, and moreover the differences in the first series are more extreme than in the later experiments.

With candles consuming the same quantity of material, but giving different amounts of light, the greatest difference was 2·28 candles, the consumption being 134·1 and 134·4 grains, and 2·3 candles with consumptions of 142·5 grains; in both cases far above the standard rate. When the consumption is nearer to the latter rate, as shown in Mr. Kirkham's diagram 7A, experiment 16, consumption 129·6 grains, the difference was only 0·43 candle; and as shown in diagram 10B, experiments 44 and 47, consumption 126 grains, it was 1·13 candle.

With candles giving the same amount of light with different consumptions, he found the greatest difference in the value of the gas to be 3·53 candles, but the consumptions ranged from 109·2 to 140·1 grains. On comparing the results obtained with candles burning nearer to the standard rate, as in diagram 10B, experiments 50 and 48, consumptions 126 and 131 grains, the difference was only 0·56 candle; and even as in diagram 7A, experiments 16 and 15, with consumptions of 129·6 and 134·4 grains, the difference was 0·39 candle only.

Thus it appears from Mr. Kirkham's experiments that within reasonable limits of consumption—that is, from 118 to 125 or even to 129 grains per hour—the errors in the estimation of the illuminating value of gas, when tested once only, are not likely to exceed 1¼, or, at the very utmost, 1½ candle—a possible error which the writer is by no means disposed to pass over lightly or to treat with indifference; on the contrary, it confirms him in the conviction which he has long held, that when exactness is required, and especially when tests are made against a gas company, the results of which may subject the company both to pecuniary penalties and to discredit, no photometric estimation of the value of the gas should be accepted which was based upon less than three or even four consecutive experiments with different candles, each experiment lasting for at least ten minutes, so that an operator might easily make the whole test in one hour; or if, as in many country towns, this would involve too much labour, if done in one evening, the examiner might make one trial on each of four evenings in a week, and then the average of the whole would represent the illuminating value for the week.

If, in such a series, one of the experiments should work out very discordantly with the rest, that experiment should be rejected, and a fresh experiment be made, or, if that be not possible, a mean taken from those experiments which were nearer in agreement. Such a practice would go far towards securing agreement between the results of different operators.

There ought also to be a limitation to the extent of deviation in consumption from the standard rate. The referees at first imposed a limit, but it was much too narrow, as it permitted a deviation of 5 grains per candle per hour only. A practical limit would be between 117 and 128 grains. Part of the trouble with sperm candles doubtless arises from the parliamentary but absurd stipulation that they shall be of the size of six to the pound. The candles are in consequence of considerable length—8¾ inches—and from necessity the difference in the diameter at the two ends is much greater than would be needful were the candles made twelve or any other convenient number to the pound. The diminished length would also permit of a more perfect centering of the wicks. These changes would tend to diminish irregularities in burning.

In respect to the selection of candles for experiment, there are certain appearances about a good sperm candle when burning (and all must be burned preliminarily, to get them into a proper condition for use) which go far to show whether the candle is or is not a fair specimen. These appearances can be much better practically illustrated than described, but the writer may mention some of them. The candle should burn with a shallow cup, and the sperm within an eighth of an inch of the top of the candle should, after it has been burning some time, be firm, and bear a good squeeze between the finger and thumb without yielding to the pressure. The wick should appear somewhat small and compactly woven, and not bend to an exceeding degree out of the upright. Lastly, on looking down into the sperm cup, there should appear to be a number of radial dashes (something like the dotted lines in a drawing, but much more irregular), extending from the wick to the circumference. If a candle contains paraffin or stearine, some or all of these peculiarities are wanting. The cup will be deeper, its edge will soften and give way on a very slight pressure, the wick will be generally larger, and there will be no appearance of radial lines in the sperm cup. The peculiarities mentioned apply in part, however, only to candles which have been made some little time. Candles which are quite new generally burn somewhat irregularly, and the radial dashes in the cup are mostly absent, doubtless owing to a temporary disturbance of molicular arrangement, consequent on the heating of the sperm when the candles are made.

The conditions under which a candle is burned exercise a material influence on the amount of light which it yields, as well as upon the rate of consumption and uniformity of the light. The atmosphere surrounding it should be tranquil, otherwise the candle is almost certain to form an irregular cup, to gutter, and to smoke. If in a tranquil atmosphere the candle burns thus irregularly, it is an evidence of its unfitness for photometrical use. The candle may be fairly protected by screens from draughts, but not, the writer thinks, absolutely enclosed in a box, inasmuch as, when so enclosed, the surrounding air may (unless, indeed, the box be enormously capacious) be somewhat heated, the supply be not so free, and the candle be burned, in consequence, under abnormal conditions. Moreover, when so enclosed, its condition is not so readily observed by the operator.

Another important matter is the accurate determination of the rate of consumption of the candles. The writer is fully aware that most photometrists take the utmost care in this matter, and find the rate even to the 100th of a grain; but there are some who are content to use scales not capable of weighing closer than half a grain. Now if, for the sake of argument, it is admitted as a fact that, within certain narrow limits, the light yielded by a candle is in direct proportion to the quantity of material consumed, then such a defect in weighing, with one candle and ten minutes as the time of burning, would induce an error of 2¼ per cent., which, in 14-candle gas, would amount to more than a third of a candle's value.

The method of weighing the candle before lighting, using at the photometer, extinguishing. and reweighing, should be utterly discarded; not on the ground that the weighing may be inaccurate, but because the candle cannot, in an i nstant, be completely put into a proper state of burning, and consequently the readings of the photometer during the first two or even three minutes will be much above the real comparative value of the gas.

The real lighting value of a candle may be considered as the average of its light during the whole time it burns, and as the average of its light during the first ten minutes after ignition would be undoubtedly considerably lower than the average for the whole time during which it is capable of burning, it is manifestly unfair to employ the candle under the conditions mentioned.

Even the ordinary system of weighing the candle while burning at its best, then removing it from the balance to the photometer, and thence again in due time to the balance, is objectionable—first, on account of the needless trouble thrown upon the operator, and, more importantly, on account of the liability to disturb the regularity of combustion by the necessary motion, and also to destroy an experiment by the dropping or spilling of sperm.

The only method of weighing which is at once rational, facile, and accurate, is that in which the candles are weighed *in situ;* that is, while in position for photometric comparisons. This method was first practised by Mr. Keats, who constructed and affixed to the photometer-bar itself a specially formed balance.

A point which is made the most of by the objectors to the present system of photometry is the variation in the sensibility of the eyes of the operators; in fact, the referees say that "a slight variation in the sensibility of the eye of the gas examiner may easily make a difference of half a candle in his recorded testings."

Granting for the moment that this may be the case, it only shows the necessity for repeated series of observations, in order to obtain an average which may be regarded as truthful; for it is hardly to be conceived that the variation in sensibility would continuously give an error in one direction, and consequently if three or four sets of ten observations be made, it is almost impossible to doubt that accuracy would be very nearly, if not absolutely, attained. The writer is, however, somewhat sceptical as to the variation in visual sensibility lasting with an operator for more than a very limited time, as he is also as to the existence of any material difference in visual sensibility between different operators, if they be experienced.

It is true that differences do arise, but the wherefore is by no means satisfactorily settled. Judging from his own experience, the writer is convinced that were a skilled photometrist (with the graduations of the photometer-bar hidden from his sight, but visible to another observer, who should note the values) comparing lights of unvarying intensity during a considerable time, it would be found that the average intensity, as deduced from any one set of ten consecutive readings, and the average as deduced from any other set of ten consecutive readings, would be very close the one to the other, if not actually identical.

Further, that if each of two photometrists were at the same time comparing against a single flame common to both, the light from one of two gas-flames, which were maintained exactly equal to each other, and of uniform intensity, it would be found that, although the averages of a few readings might differ, the averages of a greater number would approximate very closely. In proof of which he may cite the results of some trials upon gas of varying quality (uniform quality not being obtainable), and with different candles, but each candle common to both photometers, which trials were made by himself and by a no means practised photometrist. These trials were made in a perfectly fair and proper manner, and each observer took his own readings, without the least reference to what his opponent was doing or finding.

The following are the averages of sets of ten readings, the operators being designated A and B:—

No. 1 ..	A 18·14	B 18·3	Difference 0·16
„ 2 ..	„ 18·75	„ 19·2	„ 0·45
„ 3 ..	„ 18·8	„ 18·75	„ 0·05
„ 4 ..	„ 16·1	„ 16·1	„ 0·0
	4)71·79(=17·95	4)72·35(=18·09	
	Mean difference		0·14

No. 1 ..	A 14·875	B 14·875	Difference 0.0
„ 2 ..	„ 15·175	„ 14·95	„ 0·225
„ 3 ..	„ 16·05	„ 16·085	„ 0·035
„ 4 ..	„ 13·9	„ 13·67	„ 0·23
	4)60·000(=15·0	4)59·58(=14·895	
	Mean difference		0·105

This is by no means a special experience of the writers; he has on many occasions, and with different persons, arrived at similar results, although not quite so satisfactorily, inasmuch as a single photometer has been employed, and consequently it was not possible for both operators to take readings at the same time.

The simultaneous determination of illuminating value by several persons is both interesting and valuable, and it would be well were every individual, previously to being appointed to the office of gas examiner, compelled to go through a course of practice with a skilled operator, and upon duplicate instruments. By such a procedure the visual fitness or otherwise of the individual would be determined, and his mind impressed with a due sense of the nature of his duties.

Mr. Kirkham's "cross" photometer, which he employed in making the experiments already referred to, permitted four persons to make observations at the same time; but, admirably as that instrument was adapted for the purpose of the experiments, the discovery of the degree of variation in the light given by sperm candles and by carcel lamps, it is quite unfitted for the determination of the amount of error, if any, due to differences in visual sensibility between operators, and simply for the reason that with it the flame to be tested, and not the testing flame, is common to all the operators; in other words, the gas-flame is in the centre of the cross, and each operator must use a different candle or lamp.

For the purpose of finding the extent of the possible or probable errors between operators, the candle or other standard of light must occupy the central position. Such an apparatus the writer was requested some time since, by Mr. Somerville, of the Alliance and Dublin Gas Company, to construct, that gentleman wishing, among other things, to have the power of testing simultaneously the gas as soon as made, the gas in stock, and gas made experimentally. It was to consist of three photometers converging to a common centre, and to embrace any novelty or improvement which the writer could devise capable of facilitating the investigations and of securing accuracy. This apparatus has lately been completed, and will be submitted to the inspection of any members of the association who are sufficiently interested to pay a visit to 55, Millbank Street, the apparatus being of such a character as to render its exhibition in a public hall scarcely possible. The points of novelty consist in the general arrangement of the parts, in the construction of some of them, and in the employment of electricity for timekeeping; each photometer being as usual provided with meter, governor, micrometer, King's gauge, &c., and each meter having combined with its index an electric time indicator, a fourth time indicator being provided for timing the rate of the consumption of the candle, which is suspended *in situ* from the end of a balance-beam in the manner devised by the writer some years since. The time indicators are controlled by an accurate clock, beating dead seconds, and the weighing of the candle is automatic, for as soon as any predetermined number of grains of sperm have been consumed, the time indicator stops, and the operators are informed by an alarum that the time is up. The operators have complete command over these time indicators, each one of which may be set going and stopped at will, without in the least degree interfering with the others. As the meters of this apparatus agree exactly with each other in registration, and as the time indications must also of necessity be synchronous, and one standard of light is common to all the operators, it follows that the elements of error are reduced to two only, which are differences in the visual sensibility of the operators, and differences in the light-developing power of the several burners.

The latter element may, of course, be readily eliminated by a few experiments, and the per centage of difference, if any, allowed for in after experiments, so that any apparent differences in the results must be attributed to errors in the operators themselves. Such an apparatus is not only valuable as an agent for instruction, but inasmuch as each operator is working, as it were, competitively with others, unflagging carefulness is ensured, and hence the experiments must be of a specially reliable nature—that is, if several trials with different candles have on each occasion been made.

It would be well if some such system of duplicate or triplicate testing could be carried out on all occasions. No doubt, however, there are difficulties and objections in the way.

There are some other objections urged against the present system of photometry. One is, the time which is occupied in making a proper experiment; another, the trouble there is in doing it; and a third, the intermittent nature of the test, and that it only relates to a small portion of the whole time during which gas is being consumed.

These objections cannot be denied or even disputed; but, apart from them, the writer thinks the system as now carried out generally worthy of some considerable admiration, and entitled to a high degree of, if not to complete, confidence. It is undoubtedly not perfect, but it has the special merit of appealing in understandable language to the minds of those who are, in respect to their being the greatest in number, the most interested in gas-testing—namely, the general public of gas consumers, who, although they may know little or nothing about the details of the experiment, are quite able and willing to believe in that valuation of a gaslight which is made by contrasting it with the light of a candle.

At the same time the writer must admit that it is most desirable that a better, simpler, more philosophical, and more continuous method of testing gas should be sought for, and when found adopted. Of all proposed methods, that in which the jet photometer is used, to show length of flame in connexion with specific gravity and durability, is most entitled to confidence. It was one of the earliest and best means used for comparing the relative values of gases. When last year, at the Institute of Civil Engineers, the writer heard Mr. Kirkham's paper read, and imperfectly heard or understood one part, he objected to the jet photometer as a standard test; but his objections applied more to what he conceived to be the proposed method of using it than to the instrument itself, and he then distinctly said that when used as a durability test it is of the greatest value to the scientific experimentalist. Being now fully aware that Mr. Kirkham proposes to use the jet in the truly philosophical manner, the writer's objections are for the greater part overcome, but he is certainly still obliged to hold to the opinion that the jet photometer is "not an instrument to satisfy the public," and dissatisfaction would especially be felt in country places. Under existing circumstances, litigious consumers may be often satisfied by an imposing process of comparison of a gas and of a candle light. The whole matter looks so commonplace and reasonable that it leaves scarce room for disputation; but if a jet photometer were put forward in proof of quality, would there not be, as the writer has before asserted, doubt and mystification? The writer is quite sensible that what he has said forms by no means a weighty argument against the jet when properly used. If it be fitted for a standard test, it will become so in spite of objections; but before it can be accepted for such purpose, the following, and possibly some other questions, would have to be decided.

The agreement or extent of difference in the indicated illuminating power of gas, as determined by the Bunsen and by the jet, under different atmospheric densities, under various temperatures, and with carbonic oxide in varying proportions in the gas.

In ordinary photometry it is well known that the same light cannot be obtained from a 5 cubic feet per hour gas-flame in an atmosphere of 29 inches density as in an atmosphere of 30 inches, because, in the first place, a lesser weight of gas is consumed in a given time (5 volumes at 29 inches containing in weight an equivalent to only 4·833 volumes at 30 inches); and secondly, because in a dense atmosphere flames tend to give more light, Dr. Frankland having proved that even those gases which, under the usual atmospheric pressure, give *no* light, can, in very condensed atmospheres, be made to and do give a considerable amount. Now, in ordinary photometry, the quantity of gas is limited to 5 cubic feet consumption per hour, whatever be the atmospheric density, and, reasoning from analogy, it appears probable, although it remains yet to be proved as a fact, that if the magnitudes of the flames for 5 cubic feet could be accurately measured, it would be found that their dimensions varied only to a trifling extent; for as the atmospheric pressure becomes reduced, so must the flame expand to some extent in bulk—that is in length and breadth—just as in what are called vacuum-tubes (which are really tubes containing a very attenuated atmosphere) electric sparks, which in the open air are minute and intensely brilliant, become expanded, and appear almost like discs or circles of phosphorescent light.

The jet photometer is affected in two ways by a change in atmospheric density. If the density diminish, the gas is attenuated, and the weight of combustible and light-giving matter in a given volume reduced, and as a consequence a larger volume tends to escape from the jet orifice under the same acting pressure. Secondly, there is the natural increase in the bulk of the flame, owing to its burning in a more rarefied medium.

In respect to the first effect, let it be assumed that a gas whose specific gravity is 400 be discharged into the atmosphere, when its density is 30 inches, at the rate of 2 cubic feet per hour, then with no other alteration than a reduction of atmospheric density to 29 inches the rate of issue would be increased to 2·034 cubic feet per hour, the rate of discharge being in the inverse ratio to the square roots of the gravities, which would be 400 and 386·8, and the roots 20 and 19·67. Thus the rate of discharge would be increased to the extent of 1·7 per cent. in volume, although the *weight* of combustible matter in the increased volume would be less than that in the 2 feet at 30 inches.

Thus it *might* be possible for the gas to be indicated, under one atmospheric density, as of one and the same illuminating value, by both the jet and the Bunsen photometer, and yet for the indicated values to be different under any other atmospheric density. The illustration refers particularly to reduction in density of atmosphere, but, of course, the reasoning applies with equal force to increase of density.

The durability test, pure and simple, may not be entirely free from possibility of error, for although the determination of value is dependent on time and volume, or, what is the same thing, on the rate of consumption, yet if flames produced by consumpts of equal weights of a combustible become enlarged and reduced as the atmospheric density diminishes or increases, it may be that equal volumes of gas will at different atmospheric densities produce flames of equal lengths, and thus lead at times to the under or over estimation of the illuminating value of the gas.

On further consideration, it would also appear that there must at times arise some disagreement between the indications given by the jet photometer itself; that is, between its indications when used in accordance with the asserted law, that, "maintaining a 7-inch flame from an orifice of fixed dimensions, the illuminating power of the gas is in direct proportion inversely as the pressure," and its indications when used to determine "durability." For, as it has been already shown, an increased volume tends to escape from the orifice, under the same acting pressure, when the atmospheric density is reduced, and no notice is taken of such increase, while with the durability test the quantity is fixed, and the time for its consumption determined. Now if, as seems probable, the increased rate of consumption by volume, in the one case, simply maintained the flame at the 7-inch length, it is manifest that a given volume—say the tenth of a cubic foot—could not maintain a 7-inch flame under the same acting pressure at 29 inches for so long a time as that quantity of the same gas would do at 30 inches atmospheric density. Hence while the one test showed the gas to be up to the standard value, the other test would exhibit the gas as below that value. No such possible discordance must exist in a new photometric standard.

In ordinary photometry the candle-flame is also affected, without doubt, by changes in atmospheric pressure, and it may be in nearly the same ratio, both in respect to weight of material consumed in a given time (although on this point the writer is very doubtful), and the amount of light yielded. If so, an argument might be established thereon in favour of the system of comparison of artificial lights. For if these be equally affected by atmospheric changes, the normal relations between any two or more would at all events be at all times easily determinable.

Atmospheric temperature also exercises an important influence in respect to the jet, although not to the same extent as density. Temperature can moreover be to a considerable extent controlled in testing-rooms.

Carbonic oxide increases the gravity, whilst it certainly is much more likely to diminish than to enhance the illuminating power. Its gravity is ·9678 (olefiant being but ·9713), and although it is true that on ignition it gives out a considerable amount of heat, it gives by its own combustion little or no light, and is instantly converted into carbonic acid. So that its influence on the density and illuminating power of coal gas must be important, the per centage which London gas contains appearing from Dr. Frankland's statements to range from 7 to 9 per cent., and in some other towns even to above 10 per cent. Carbonic acid and ammonia have not been named because the gas ought to be free from these impurities, or at all events contain but a trifling quantity of either.

These observations are not made in a spirit of antagonism to the jet photometer, but only with a view to sweep away causes of error.

The degrees, so to speak, of the jet photometer scale are so narrow—a variation of ·025 of an inch water pressure being sufficient to determine a difference equal to the light of an entire candle—that it is important, if it is to be used for the purposes of public testing, that every element of error be eliminated.

A better system than that commonly practised is wanted, but before a change is made it is advisable that photometry generally should be subjected to a most exhaustive inquiry, so as to avoid any danger of falling into one evil while escaping from another.

Whatever be the future system of testing the illuminating power of coal gas, it must, in order to serve the interests of the consumers generally, be quite as facile in application as the present system, and be of a simple character, so as to render the test available, not only in the large towns and cities, but even in the smallest village of the United Kingdom in which gas is used.

Mr. Alfred Upward read the following paper:—

ON THE ECONOMICAL PURIFICATION OF COAL GAS.

Having been requested to write a paper for this meeting, I think that one of the most important subjects to which I can call your attention is that of "The Economical Purification of Coal Gas." It is well known that for many years past gas companies in large towns have been compelled to abandon the use of wet lime purification owing to the great difficulty of getting rid of the "blue billy," as it was called, and in order to overcome this difficulty dry lime purification was commenced, but in a very few years the inhabitants surrounding gas establishments made such serious complaints as caused gas companies to look out for some other material which would remove the nuisance complained of; and it was shortly after this date that the oxide of iron purification became general. This last plan gives no cause of complaint, but it is, nevertheless, a more expensive plan than the old wet lime purification, and at the same time, if only the oxide be used, it does not purify the gas from carbonic acid. Now, if this last-named impurity be present in the gas it destroys to some extent the illuminating power, so I think it is evident that if some plan could be adopted to overcome, or considerably lessen the expense of either dry lime or oxide of iron purification, and at the same time render the gas free both from sulphuretted hydrogen and carbonic acid, a great point would be gained. My object in calling attention to this matter is that, having been invited to inspect a plan lately invented by Mr. F. C. Hills, of Deptford, I felt that a description of that plan might be useful to some of the members of this association, and I am thus induced to lay before the meeting a few facts relating to this important subject. It has been long known that caustic ammonia will purify coal gas, but no plan has hitherto been found by which liquid ammonia could be obtained of sufficient purity and cheapness to purify gas until Mr. Hills made the way clear. The plan he adopts is to make the ammoniacal liquor produced at gas-works of sufficient purity to become a cheap and effective purifying agent for depriving gas of its sulphuretted hydrogen and carbonic acid. The gas liquor being made on the works is always ready for use, and when purified by the process hereafter described, is run through the common scrubber, and the gas allowed (in the usual way) to pass up through the scrubber. It then comes in contact with purified ammoniacal liquor, which deprives it of its impurities, and thus the desired result is obtained, and all expense of excessive labour is put to an end.

The mode Mr. Hills employs to purify the gas liquor is as follows:—He uses a series of stills or vessels placed one above another, which vessels are partly filled with the gas liquor to be purified. The gas liquor runs through these vessels by means of connecting pipes from the top to the bottom. In the bottom vessel the gas liquor is caused to boil. By this boiling the carbonic acid and sulphuretted hydrogen, in combination with the gas liquor, are driven off to a great extent, and also a little ammonia; these products are caused to pass into the liquor in the next vessel above, by which the ammonia vapour is mostly absorbed, but not the carbonic acid or sulphuretted hydrogen, and, by passing these products in like manner through the whole series of vessels, the ammoniacal vapour driven off from the boiling gas liquor is absorbed by the gas liquor in the higher vessels, and the carbonic acid and sulphuretted hydrogen are left free to pass away wherever desired. The hot purified gas liquor, as it runs out, heats the cold gas liquor which is to be purified by passing in oppos'te directions through a series of pipes, so that very little heat is required for purifying the gas liquor. If wished, the whole of the gas may be purified entirely by this gas liquor, but as the quantity required would be considerable, it is perhaps best to purify the gas about two-thirds by this process, and then to finish the purification with oxide of iron. When the purification of gas is effected by means of liquid in scrubbers, it becomes of great importance to secure a good spreader of the liquid over the surface of the media contained in the scrubber. Mr. Hills has contrived a new spreader, by means of which the liquid to be used can be caused to spread quite evenly, and in the exact proportion required, over every part of the surface of the media contained in tho

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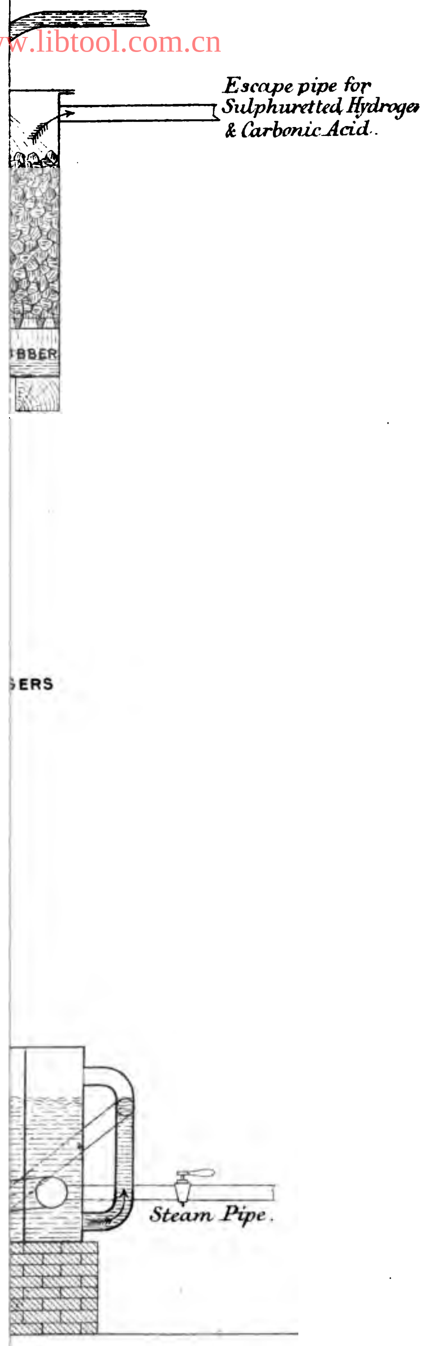
Escape pipe for
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scrubber, so that no one part shall have a greater proportion of purifying liquid than another. By this means a minimum quantity of liquor can be made to do its maximum quantity of work.

It thus appears that the present plan promises all the advantages of the old wet purification, whilst at the same time the products of the improved method are valuable, and will pay for their removal, and, in addition, be a source of profit to the gas company. It is simple in operation, and the gas manufacturer has at his own command the purifying agent required.

I may add that this plan is now being experimented upon by Mr. George Livesey, who was the inventor of a plan somewhat similar to that now described.

As to the surface required, it is expected that the present scrubber surface at the South Metropolitan Gas-Works will be sufficient to purify the gas made at those works, so that in adopting Mr. Hills's new plan no additional expense will be incurred at that station in purifying surface.

Mr. George T. Livesey read the following paper:—

ON SCRUBBERS.

It is of very little use going to "Clegg on Gas" for information on any modern invention introduced within the last 20 or 25 years. Newbigging gives the pith of Clegg's article on "Scrubbers" in one laconic sentence, which, after all, refers more to the mechanical filtering or separation of the tar than to the extraction of ammonia and other impurities.

Newbigging tell us, quoting from Clegg, that, "for every 1000 feet of gas produced in 24 hours, one cubic foot of wet scrubbing material is required," which is certainly rather vague. Let me here observe that I say nothing in disparagement of our late auditor's work; on the contrary, I am bound to speak very highly of the book he has published, as containing a mass of valuable and reliable information that will be of use to every manager.

An endeavour has been made to trace the first introduction of scrubbers, but without success. It seems probable that a Darwinian system of development, if not of natural selection, has been in operation. All the older gas men remember the tar filters, or breeze boxes, as they were sometimes called, that were in use 20 or 30 years ago—vessels constructed like ordinary purifiers, but filled with coke or coarse breeze, through which the gas passed after leaving the condenser or washer, in order to arrest the lighter tar that would otherwise be carried forward into the purifiers, an object that was successfully attained by these means. The spent tan from the tan yards was sometimes used instead of the coke, with a very good result.

This might be called a scrubbing process; but the origin of the term is obscure, so is the first use of water to absorb the ammonia, though it is more than probable that the ammonia manufacturers were the first to suggest its use. The transition from breeze boxes or tar filters to scrubbers was accomplished merely by increasing the depth, and allowing water to trickle through; but only a small quantity of water being required, the difficulty was to distribute it equally. To meet this, Mr. F. C. Hills, of Deptford, adapted the well-known "Barker's mill" (one of which is now in the room) to the purpose, but even this ingenious contrivance was not sufficient of itself; it distributed the water equally, but the quantity required to keep it going made the resulting liquor too weak to be profitable. Hills then introduced a tumbler, as it was called—a sort of double trough, or an oblong pan or dish, with a division across its centre, and so balanced over an open box that the small stream of water alternately filled first one division and then the other, the division into which the water runs remaining in position until it is filled, when it is, so to speak, overbalanced, and tumbles over, emptying its contents into the box, and thus affording a sufficient quantity of water to cause the Barker's mill to turn for a minute or two, which stops when the supply is exhausted. In the meantime the other division is filling, and in its turn tumbles over, and gives another supply of water to the mill; a very small quantity of water was thus supplied at regular intervals, and distributed equally to the scrubber.

The Barker's mill is not much used now—though I decidedly consider it the best of all the distributors that have been invented—the chief difficulty arising from the small holes getting stopped, which was an almost daily occurrence; hence its disuse. The tumbler, also, is not often seen, though it did its work well, its only drawback being the periodical knock which it gave every time it fell, and the vibration thus produced rendered it difficult to prevent a constant leakage of water from the joints. It is more than 20 years since Hills introduced the Barker's mill and tumbler. Ammonia at that time was beginning to rise in value, and scrubbers for its extraction were being brought into use, thus superseding the original "washer," which had hitherto been used to remove the ammonia. It was effective for the purpose, but the drawback to its use, when clay retorts were introduced, was the pressure it gave. The scrubber, therefore, in modern gas-works, does the work for which two separate contrivances were employed formerly.

The principle of the washer was the forcing of the gas through water, while the scrubber aims at bringing the gas into contact with water or a wetted surface without pressure. The liquor thus produced was at first not worth much; but, to give an instance of its increase in value, about 1855, Laming (who had given a great deal of attention to this subject, and to whom the gas world is much indebted) offered the South Metropolitan Company £250 a year for their scrubber liquor. This was considered a liberal offer, and for 10 years he had the said liquor for this sum. At the expiration of the first five years its value had much increased, but considering that in the first place the company was indebted to Laming for getting anything for this liquor, his contract was renewed for a second term of five years, by which time the scrubber liquor had about doubled in value, after allowing for increase of make.

For a long time coke only was used for filling scrubbers. Hills recommended that it should have the breeze and dust separated, and that the large pieces should form the lowest layer, of, say, a few feet in thickness, then a similar layer of smaller pieces, and so on, until the last layer was composed of pieces of about the size of walnuts. This plan involved a good deal of trouble, but it was certainly better than the indiscriminate throwing in of the coke, in that it was more effective, and did not get so soon choked with tar.

The other plan (so far as I can learn) that has been longest in use was the adoption of the Goldsworthy Gurney jet—a jet of water under great pressure impinging on a small disc or button, which scatters the water as fine spray throughout the vessel, such vessel being empty, or at most having perhaps one or two tiers of perforated trays, the water thus descending in the form of rain through the gas. I am told this effectively removes the ammonia, but at some places where it is in use, on asking what the liquor fetches, the reply has been that the liquor is not saleable; which means, most probably, that by this means of scrubbing the quantity of water required to remove the ammonia is so great that the resulting liquor is too weak for sale. The water descends too rapidly, and is not, therefore, in contact with the gas for a sufficiently long time. The object in putting anything in a scrubber is simply to retard and divide the water in its passage downwards.

I now proceed to describe some of the plans at present in successful use for charging or fitting up the modern scrubber, and the various methods adopted for distributing the water or liquor.

The following may be stated as the principles to be kept in view:—

1. That the gas should travel as slowly and freely as possible, and therefore with the minimum of pressure or resistance.

2. That in its passage it should be brought into contact with the largest possible wetted surface.

3. That, in order to comply with No. 1, the scrubbing material should occupy as little as possible of the space in the scrubber.

4. That the scrubbing material should not be liable to get choked with tar and naphthaline, and, consequently, not require changing.

5. That, in order to obtain strong liquor, the water should be distributed equally all over, and in very small quantity, this being also necessary to avoid impoverishing the gas.

The most common method of filling scrubbers at the present time is with coke, as above described. The chief objection I have to make against it is not as to its effectiveness for removing ammonia, but that it gets choked with tar, &c., and must therefore be emptied and refilled. At one large London works the scrubbers are changed twice a year. In my case they will go for about two years. There is one now in use, 15 feet 6 inches diameter, and with only 40,000 feet an hour passing through it, giving between 4 inches and 5 inches pressure. The gas is thoroughly condensed, but as 500 gallons of liquor per hour have been passing through this vessel, a considerable quantity of tar has been deposited in the coke. At the City of London works, where Mr. Mann has worked his scrubbers very successfully for many years, they require changing very seldom indeed, but he passes nothing through them but water. I have one other objection to coke, and that is, that it occupies so much of the area or cubic contents of the vessel charged with it. If a vessel of 1200 cubic feet contents is filled with coke, the interstitial space is 610 feet, or, say, one-half of the whole, the relative proportions will vary to some extent with the size of the pieces, but my experiment was with the coke in its ordinary state. This rule, of course, only applies when the coke in a scrubber is quite free from tar, &c., and when in that state the gas passes slowly and freely; but when the coke becomes choked to such an extent as to show its effect on the pressure-gauge, the interstitial space must be reduced very much, when the gas must pass very quickly, while the water or liquor probably flows down two or three small channels, instead of gently working its way through the whole mass, as it does when the coke is clean. It therefore comes to this: If the gas is thoroughly condensed, and nothing but water is used, as at the City Gas-Works, coke answers the purpose admirably, and lasts for an indefinite time; but if tar to any extent comes in contact with it, either from imperfect condensation or where the gas is washed with liquor, which deposits its tar in the coke, the result will be that in a longer or shorter time the coke must be changed, which is a great nuisance.

At some places brickbats are used; the remarks about coke apply equally here, the bricks probably lie closer, and therefore in this respect are inferior to coke.

Broken pottery has been tried, but did not succeed; it fills up too much of the space, and forms a succession of cups or dishes which catch and retain the tar and liquor.

Drain-pipes of different forms and sizes have also been used with success. That form and arrangement which is found most useful is now in work at the Phœnix Gas-Works at Vauxhall. Three layers of 2-inch unglazed drain-pipes are placed on each of the two trays; these pipes stand on end, and consequently offer no resistance to the passage of the gas, which is divided into a great number of small streams, while the water or liquor is spread over a large surface, and I should think there could be no risk of this arrangement becoming choked. Boulders or pebbles are also used, and I believe answer very well, though they are difficult to get in many places, are very heavy, and take up much space.

There is just one other plan, which, after much consideration of the subject, I have adopted. I believe I was the first to try it. The circumstances that led to the idea were the difficulties and nuisance attending the use of coke. Something being wanted that should present the largest possible surface with the freest passage for the gas, and after experimenting with various things, and more especially different forms of drain tiles or pipes and pottery, the arrangement of thin boards which I now exhibit was tried. A scrubber was fitted up in 1866 with them, which has been in use ever since, and to all appearances will go on continuously without risk or possibility of becoming choked. This arrangement presents a larger surface than any of the others; the material in a cubic foot occupies less space, and there can be no question about the freeness with which the gas passes, which is moreover divided into a vast number of such thin streams that with the rolling sort of motion that fluids assume, caused by friction in passing over surfaces (somewhat rough as these are), every particle of the gas must be brought into contact with the wet surface of the boards over and over again.

To fit up a scrubber on this plan, the wood required is as follows:—The boards are cut from deals or planks, 9 or 11 inches wide, 3 inches thick, and with nine deep cuts dividing them into ten thin boards about a quarter of an inch thick. The small upright blocks which are nailed between the boards to keep them a proper distance apart are 1 inch by half an inch, while to keep each tier separate from those above and below it, and to serve also for sleepers or joists, I use pieces 1½ or 2 inches square.

With this plan care must be taken to prevent the gas going up all in one place, and to attain this I fix a sort of inverted trough, made of 1¼-inch boards, which covers the inlet and extends across the bottom of the scrubber; the gas escapes from this trough through a number of small apertures in its sides, and is thus distributed with sufficient uniformity.

The fitting of the boards is now proceeded with. The first tier is laid on the bottom tier of sieves which used to carry the coke, and tier above tier is fitted, until the vessel is nearly half filled; a space is then left of about 2 feet 6 inches, when another succession of tiers is laid which fill the remaining half, and on the top is placed coarse cocoa-nut matting to spread the water. I am now fitting up a scrubber 15 feet 6 inches diameter and 28 feet high; in it will be placed 22 tiers of these boards, 258 in a tier, which will expose a surface of over 128,000 square feet, or within a trifle of three acres, and at the same time in each tier of 188 cubic feet the boards occupy not more than 60 to 65 feet, thus leaving 120 feet for the passage of the gas; the boards, in fact, in the part filled by them, take up one-third of the space, leaving two-thirds for the gas.

But what is the result? My system of working is to pass the gas through three scrubbers. I happen to have four, and so use three, but find two are sufficient with this plan of fitting up. The first two are supplied with a large quantity of liquor, and the last with a small quantity of water. The greater part of the ammonia is absorbed by the liquor, which consists of that from the condenser, as well as that from the water scrubber (by this means it is increased in strength to 10 or 11 ozs.); the remaining ammonia is quite removed by the use of from 5 to 6 gallons of water in the last scrubber to the ton of coal, or hardly more than half a gallon to 1000 feet of gas; the liquor so produced being from 7 to 9 ozs. strength after passing through the wood scrubber, while the same vessel filled with coke required 3 or 4 gallons more water to the ton, and produced liquor of only 3 to 5 ozs. strength. The arrangement of thin boards is therefore about twice as good as the coke.

I have endeavoured to ascertain the average amount of surface exposed to the action of the gas when coke is used, but from its irregularities cannot arrive at it correctly, having been obliged to estimate in order to make a comparison with the surface exposed by other materials, such as drain-pipes and boards. The result, as nearly as I can make out, is as follows, the only uncertainty being in respect to the coke:—

Taking one cubic foot of the space occupied, I find

Coke gives about	$8\frac{1}{2}$	square feet of surface.
3-inch drain-pipes . . .	17	,, ,,
2-inch ,, . . .	21	,, ,,
Boards, as above described .	31	,, ,,
Coke occupies . .	$\frac{1}{2}$	the space.
3-inch drain-pipes .	$\frac{1}{3}$	,,
2-inch ,, .	$\frac{4}{9}$	,,
Boards	$\frac{1}{3}$	,,

Distributing Apparatus: First comes the Barker's mill, which was used for a number of years with varying success, but was liable to several objections, among them the holes, being small, were often stopped up, and the machine would not revolve in consequence; then, for lightness, it was made of brass tube, which, under the action of ammonia, speedily corroded; but, supposing these defects overcome, the instrument possesses great advantages, one being that if it can be kept going it distributes the water or liquor very equally, and being self-acting all gearing or machinery is avoided. In the mill now in the room the danger of the holes stopping is avoided by making them larger, about 5-16th of an inch diameter; they are so arranged that each hole in its circle has to supply liquor to 20 square feet of surface. Corrosion is prevented by using tin pipe, which lasts three or four years, with liquor passing through it, longer with water. The mill works on a steel centre at the bottom, and at the top has a steel spindle working in a small hole in the top plate, while to see that it is at work a notch is cut in the top of this spindle, which takes hold of a corresponding projection on the end of another spindle, at the top of which is a T, which, projecting above the scrubber, and revolving with the spreader, shows whether the latter is working properly. Instead of a gland, a water-joint is used, through which the spindle works without friction. The mill will work for from three to six months without any attention. At Exeter a Barker's mill of wrought-iron pipe, with four arms, is found to answer the purpose admirably.

When water is used, the quantity being too small to turn the mill, an intermittent stream is needed, and instead of the tumbling box a square or round vessel holding seven or eight gallons is fitted with a valve at the bottom, the spindle of the valve reaching to the top. A float slides on this spindle, which rises with the water, and when at the proper height lifts a weighted bell-crank, which, in its turn, lifts the valve. As the box empties itself the float sinks, and by its weight causes the loaded bell-crank to return to its original position, thus closing the valve and shutting off the supply of water until the box is again filled.

The Gurney jet has already been mentioned. Fixed perforated arms of iron pipe require no description. They were commonly used, and are still in some places.

Another plan is with a series of troughs, arranged a short distance apart, and branching out on both sides of a large centre trough, such troughs being kept nearly full of liquor, and having a great number of notches cut in their edges, while in these notches are laid pieces of loose cotton or woollen material, the theory being that the liquor is sucked up by capillary attraction, and flows over in small quantities, falling in drops in the scrubber. This is a very pretty theory, but I very much doubt whether it will continue to work well. I should think the capillary action would soon be stopped with the tar.

The ordinary revolving arms turned by machinery require very little notice, there being no necessity to take up time in going into detail. The difficulty has been with the small holes getting corroded, and to avoid this Mr. Mann devised a system, afterwards modified by Mr. Trewby—a model of which is in the room—by which this inconvenience was entirely obviated. He used two spreaders revolving on their own centres, and the spreaders themselves also revolving in a circle half the diameter of the scrubber, the liquor or water issuing only from the ends. The result was that by this double motion the water was distributed in a series of eccentric circles over the whole area of the birch wood. Theoretically, as much was discharged in the small area of the centre as in the larger area of the circumference; but practically it appears this inequality was of no perceptible importance. However, but Mr. Mann has by a very simple arrangement of a pair of eccentric wheels provided for a perfectly equal distribution if necessary, which can hardly be, seeing the success with which he works. His system, of which he has kindly given me particulars for this association, is to divide his gas between his five scrubbers, about 12 feet diameter by 28 feet high, into each of which he passes a small quantity of water. It is supplied in the proportion of ten gallons to the ton of coal, and no liquor is pumped into his scrubbers, the result being that the whole of the ammonia is removed. On leaving the top tier of coke 8 feet deep, the water has attained the strength of only half an ounce, which, of course, shows that the greater part of the ammonia has been extracted by the lower tiers, the second or middle one showing 2½ ozs. strength, while from the third or bottom one the strength has increased to 14 or 15 ozs., which liquor mixing with that condensed brings up the whole to 10 ozs., of which he gets about 20 gallons to the ton of coal.

Mr. Mann now recommends six tiers, of 8 feet each, instead of three, believing that the highly concentrated liquor which would be produced would probably absorb a portion of the sulphur compounds which give so much trouble, and the increased height would require less water to absorb the ammonia.

I have also on the table a model, kindly lent by Mr. F. C. Hills, which, if perfect regularity of distribution of the water is required, effects it with mathematical precision. The water runs into a circular revolving trough, divided into as many compartments as is thought necessary, and from these divisions, which vary in size, the water flows into a number of concentric troughs, which, revolving, supply equal quantities all over the surface of the coke or the rotating brushwood. It is a most ingenious contrivance, and would doubtless do the work admirably.

The uses of scrubbers are, first, to remove ammonia, which they will do perfectly; the ammonia, in its turn, absorbs a very large quantity of sulphuretted hydrogen, not less than half the total quantity. They have also been looked upon as the best and most hopeful means of reducing the sulphur compounds, and, at the instance of the gas referees, who are engaged in investigating the sulphur question with a view to determine a maximum for this impurity, a number of experiments have recently been made, according to their instructions, in seven of the large gas-works of the metropolis, with a view to ascertain the effect of scrubbing on the sulphur compounds other than sulphuretted hydrogen. The results of these experiments were most unexpected and extraordinary. Washing the gas with liquor has of late been looked to as the most hopeful means of reducing the quantity of these troublesome compounds of sulphur. But the above-mentioned experiments instituted by the referees appear to contradict this expectation; for out of the seven sets of experiments only two showed any good from scrubbing at all, the remaining five showing a greater quantity of sulphur compounds in the gas on leaving the scrubbers than on entering them. In consequence of the startling character of these results, the referees have instituted a further set of experiments of the same kind, as well as in regard to the effect of the purifiers, whether lime or oxide of iron. In these experiments, and generally in the important investigations which devolve on them, the referees have the willing assistance of the engineers of the various companies with whom they have to do. The experiments now instituted by the referees will take a very considerable time to execute, but they are calculated to render much service to the science of gas manufacture, and I hope to be able next year to lay before the society some further and more definite information on the subject.

The gas should always flow to meet the water or liquor, so that its last contact may be with the weakest liquor, or pure water. I mention this, because in some places an oblong scrubber is used with a division in the centre, the gas passing up one side, meeting the water, and down the other, thus travelling with it. This half of the scrubber, when worked in this manner, is worse than useless.

As to the power of water to absorb ammonia, Dr. Odling, in this room, two years ago, showed, by a beautiful experiment, that pure ammonia gas was instantly absorbed, but when mixed with only 25 per cent. of another gas or air, a very long time elapsed before the absorption took place.

My excuse for reading so long a paper is the desire to give as much information as possible.

Mr. GODDARD thanked Mr. Livesey for the very practical paper just read. He stated that he once tried brushwood in his scrubbers, but found that the blocking up by tar rendered the pressure so great that it had to be removed; and now for some years he had been using boulder stones, which proved better than any other material. He employed coke for a considerable period, but the same objection to it which Mr. Livesey pointed out was realized by him. The boulders he used were of various sizes according to their position in the scrubber, and they presented less obstruction to the passage of the gas than anything else.

Mr. DOUGLAS (Newcastle) said he obtained 30 gallons of 10-oz. liquor per ton of coals. He employed new bricks, and filled the scrubbers up with them, pumping a large quantity of liquor through and using no water. Formerly he ran the refuse liquor from the ammonia-works into the river, but, that being a nuisance, he now pumped it in bulk into the scrubbers a second time instead of using clean water. It was worked over and over again, and the results he obtained were highly satisfactory.

Mr. CRAVEN said he had a large scrubber, with four divisions, at each of his works. The three first divisions were empty, and were supplied, through a Gurney's jet, with the ammoniacal liquor, which was pumped up again and again for use in the scrubber. He was thus able to increase the strength from 8 to 16 ozs. The last of the divisions was filled with winss, or brushwood, which was found to answer very well, and presented so little obstruction, that, after twelve months use, the pressure was not increased more than half an inch.

Mr. WARNER said he endorsed all that Mr. Livesey had written, but he claimed to divide honours with him in the construction of the kind of scrubber described in the paper. It was about the same time that Mr. Livesey spoke of that he (Mr. Warner) constructed a large scrubber on a similar principle, but his boards were arranged differently. He found from experience that if, instead of placing them vertically, they were placed obliquely one to another, the water or ammoniacal liquor did a much larger amount of work than otherwise. He produced a model of his arrangement, which he stated he had sent to London twelve months ago. There was no complex arrangement on the top of his scrubber for effecting the distribution, but, by a simple arrangement of troughs, the water flowed down from board to board throughout the whole series. In looking through the tiers of trays it would be seen that there was quite a shower as of rain, and, if placed at their proper angle, the water trickled down both sides, so that both surfaces of the boards were entirely wetted. By this plan no spreader was required, but it was found that complete distribution of the water or liquor was effected. He had had such a scrubber in use since 1866, and it had worked satisfactorily ever since. The year before last he erected another, which was 16 feet square and about 18 feet high, with an overflow-trough on the top, and he found that a very small quantity of water did a large quantity of work. Both vessels were divided into four compartments.

Mr. UPWARD, referring to the question of an increased quantity of sulphur being found upon the outlet of the scrubber, said he thought it might be attributed to the coke employed, and therefore, in a scrubber formed as Mr. Livesey had shown, in all probability this difficulty would be removed. Some little time ago he made experiments with a scrubber, using only water and coke, and he found the same result as Mr. Livesey had described—an additional quantity of sulphur compounds upon the outlet.

Mr. HARRIS (Great Central Gas-Works) said there was no doubt as to the efficiency of the scrubber described, for removing ammonia. At his works, some twelve years ago, a patent was put into operation by Mr. Laming for the purpose of purifying gas by the use of ammonia. His system was to purify the ammonia as Mr. Hills proposed, by means of oxide of iron, and then to take the pure caustic ammonia and wash the gas with it. That process was carried on for some time, but it never thoroughly succeeded, though it would be successful possibly for half an hour at a time. The difficulty appeared to be to bring the caustic ammonia sufficiently in contact with the gas. Since then various improvements had been made in the water-distributing apparatus, and doubtless the system of Mr. Hills stood a better chance of success now on that account. There was not the slightest question that ammonia would act as a perfect purifier for gas if in the first instance it was itself purified and then brought in contact with the impure gas. The scrubbers, having failed for the purpose intended, had since been used as ordinary scrubbers. He did not succeed in taking out the whole of the ammonia from his gas; but recent experiments showed that the quantity was reduced to 1 or 2 grains per 100 cubic feet. He had four scrubbers in operation, and the crude gas entering the first passed in succession through the whole of them. The last was supplied with 10 gallons of water to the ton of coals, and this water found its way through the entire series. Formerly coke was employed as the scrubbing material, but it was found that the superstratum of coke so broke the lower portions that the gas would not pass through. He now placed half bricks at the bottom of the scrubbers, and gradually reduced the size of the bats till at the top they were about the size of eggs. Scrubbers thus worked were very efficient, and did not require any cleaning out more than once in two years—not until it was found that there was a very large amount of pressure. With respect to the removal of the sulphur compounds from gas, Mr. Livesey spoke of several experiments made in London, in which it was found that there was more sulphur at the outlet than at the inlet of the scrubbers. His (Mr. Harris's) case was a most notable instance of the kind, for upon the average of a month's working the sulphur increased to the extent of 4 grains. He thought possibly this might arise from the ammoniacal liquor giving off some sulphur compounds to the gas. He then adopted the system of simply washing with water, previously having used partly water and partly liquor, but this did not make any appreciable difference in the amount of sulphur at the extreme end. The experiments were now under consideration, and he doubted not that, with the attention which the engineers of London were paying to the subject, during the next twelve months some very important facts would be elicited as to the presence of sulphur compounds in gas.

Mr. UPWARD said that Laming's process of purifying liquor was a different thing to that which he had spoken of. The purified liquor as described in his paper was entirely free from carbonic acid as well as sulphuretted hydrogen. This could not be effected by the use of oxide of iron simply, and the importance of getting rid of the carbonic acid would be seen at once when it was remembered that 1 per cent. of that impurity in gas would lower its illuminating power by 2 candles.

Mr. LIVESEY, in reply, said Mr. Warner's idea of constructing a scrubber had occurred to him, but he gave it up for this reason, that he thought the gas would strike on the under surfaces of the boards, whereas the greater portion of the water would run down on the upper surfaces. This, however, appeared to be only a theoretical objection, as Mr. Warner said his plan answered very well. Mr. Warner spoke of producing a copious shower in the purifier; the difficulty seemed to be to distribute a small quantity. With a copious shower there was something more valuable washed out of the gas than ammonia. As to the remarks about Mr. Laming's process, he felt that a great deal of credit was due to that gentleman, who was the first to put forward the idea that liquor purified from its sulphuretted hydrogen would purify the gas. He (Mr. Livesey) made an unsuccessful attempt in the same direction, but Mr. Hills had been fortunate in bringing the process into practical working. The only point at which a failure might take place was that it might take too much heat to boil off the carbonic acid and sulphuretted hydrogen; but Mr. Hills seemed to have taken the best possible means to save the heat in the apparatus erected at the South Metropolitan Gas-Works. It was also necessary to provide against the loss of ammonia by this process.

Mr. METHVEN read the following paper:—

ON THE MANUFACTURE OF TAR PAVEMENT.

In most provincial towns there are two important bodies of men, the Paving Commissioners and the gas directors. The one is pledged to keep the rates low, and the other to keep the price of gas as low as will enable them to provide the statutory dividend. As one means of ensuring a cheap supply of gas is to create a greater demand and obtain a better price for the residual products, I have great pleasure in introducing a subject the adoption of which would be advantageous to both of these bodies. It is not a new one, but has hitherto been a neglected source of revenue to gas companies, and will also be a great benefit to the public. That subject is tar pavement. In some counties, such as Yorkshire, where stone is as abundant as brain is said to be, tar pavement will receive but little attention; but in the eastern and some other counties, where the same conditions do not exist, but where York flag costs 7s. per yard laid, tar pavement is a desideratum. In such districts there is a scramble for pavement, and on account of the high price, unless a Paving Commissioner reside in the street, it remains unpaved. The foot-passenger has thus, to his great discomfort, to walk on gravel, or, as in Colchester, on stones laid in such a manner as would have done discredit to any of the Roman paviors who once resided in that neighbourhood.

Tar pavement may be made of the ordinary cinder-dirt produced in gas-works, of shingle, or of a mixture of both. The material is burnt in heaps like ballast, and when hot is mixed with hot tar. In practice, I make a small fire of coke on the ground, and cover it with cinder-dirt or shingle. When this layer is hot another is added, and so on in succession until a heap large enough has been provided. The tar is now boiled in an iron copper, and taken when hot and mixed with the hot material from the heap already described, in quantities of two bushels at a time, in about the proportion of one gallon to every bushel of cinder-dirt, and slightly less than a gallon for the gravel. It is turned over and over with the shovel until every part of the material has got a covering of tar. Then I pass the whole through a sieve with a ⅝-inch mesh, and part of it through another with ¼-inch mesh, and put the whole in heaps until required, as it may be kept for months before being laid down.

Before the pavement is laid, an edging should be provided about 2 inches thick, and projecting 2 inches above the surface of the ground to be covered, which should be tolerably even. It is advisable to have the ground next the kerb well trodden on or rammed before the pavement is laid, otherwise there will be an unseemly hollow next the kerb. In laying, the rough stuff is put down first and rolled tolerably firm, then the second quality is put on, then the third, and when the whole has been raked level a little of the finest material is sifted on through a sieve with ⅛-inch meshes, and a little fine white shingle or Derbyshire spar is sprinkled on the top. The whole must now be well rolled. The best roller is a water ballast roller, which at first is used without ballast, and well wetted to prevent adhesion of the material, and when the pavement is slightly consolidated the full weight should be applied.

For heavy cart traffic the material should be made of shingle only, heated and mixed as above, and well rolled. Both descriptions of pavement are laid best and most easily in warm weather, and should be rolled when the sun has warmed it well. Those parts in angles should be well rammed, and trimmed off with a light shovel.

Though apparently a simple manufacture, there is a little difficulty in ascertaining the proportion of tar to gravel or cinder-dirt. A little experience only will be necessary, in this as well as in all other manufactures, to enable any one to carry it out successfully.

I cannot recommend this pavement too much, as it is cheap, wears well, and can be easily repaired. The colour, which never can be made to equal York flag, and the smell for some time after it is laid, are the only objections to its use. It can be laid with a good profit in any district at 1s. 4d. per square yard, and besides being a boon to the public, who must otherwise walk on gravel, is a great advantage to gas companies. To them it provides a remunerative outlet for their tar, which often otherwise must be sold at a low price to distant distillers.

Since writing the above I have seen a paragraph in the *Times*, which states that it is proposed to pave the streets of London with stone laid in asphalte instead of lime grout. This is just a more systematic application of the above-described plan; for the tar, by being boiled and thrown on hot stones, becomes an elastic asphalte.

Mr. Livesey said he was glad the subject had been brought forward, because it was one upon which they all wanted information. At his own place they had been trying for years to get a good tar pavement, and had never succeeded. The paper just read described so clearly what was the right way to do it, that he and many others would now be able to make their attempt with some hope of accomplishing it.

Mr. Irons (Gosport) said in the public works at Portsmouth some miles of tar pavement had been laid. It was found to be very cheap, and to answer remarkably well. The material used in London was the Seyssel asphalte, which was rather better than tar.

Mr. Anderson thought those members of the association who visited Nottingham two or three years ago could not fail to remember that a large proportion of the pavements of the town were of this description. He was so pleased with what he saw there that he determined to try the experiment at Dover, where there was a considerable amount of paving to do in connexion with the gas-works. He wrote to Nottingham, and, through the kindness of Mr. Loam, obtained the services of a man who had a thorough experience in this kind of work. The matter was put into his hands entirely, and he made both foot-paving and cart-road over the whole of the works, which was so satisfactory that he was persuaded it would never be given up. He then went further. A good many people resorted to Dover for the benefit of their health. The town had been paved with small pebbles, and he frequently called the attention of the authorities to what had been done at the gas-works, and asked permission to lay down some of this paving in a public thoroughfare, where a new church had been erected. Having obtained leave, the same man was employed, and so satisfactory was the result that next year the same person was engaged to do nearly the whole of the paving of the side paths that had not hitherto been paved, and, so far as he could judge, it was perfectly satisfactory. It was a capital paving, and a paving that justified each one of them in their several localities to take some trouble in introducing. It was very difficult to get public bodies to move, but by incessant application they could overcome their inertia. For cart-road paving this system was equally applicable. In making an experiment of this kind they should insist upon having a concrete foundation at the beginning. The history of all good road-making depended upon a good foundation. They might make a road as good as they liked at the surface, but if the substratum was apt to yield, the chances were hollows would be formed, water would get in, and when the frost came it would expand the water and destroy the road. The best system in the world might be condemned through want of proper appliances in the execution of it. The Seyssel asphalte was a very extraordinary substance. The streets of Paris had been for a great number of years largely paved with that substance, and in January last he saw them doing it on what appeared to be a perfectly novel plan. Formerly they used to put it on in a liquid form, but now they had discovered that the same matter ground into fine powder, and heated to such a heat as could be well borne in the hand, put down in the shape of that dry powder in the warm state and rolled, became in a couple of hours so hard that carriages could pass over it. All these pavements were, in his opinion, far superior to stone, even if they got stone cheaper. They were agreeable to walk upon. In very warm weather they would yield a little, but if properly executed they did not melt sufficiently to form marks that the next foot-mark did not obliterate. No harm was done to the pavement when a good solid foundation was given. One agreeable feature in the pavement was that it dried almost immediately after a shower of rain. The water ran off, and as soon as ever the atmosphere became of a dry character the pavement was quite dry. This was a matter each should take up in his own locality, because it was not only a great convenience to the town, but was a mode of disposing of a waste product which was not always profitable.

Mr. CHURCH said Mr. Methven recommended tar paving as being more economical than stone. No evidence was before them in support of the statement, and he doubted its accuracy. He had something to do with public bodies in these matters, and always found York pavement was the cheapest and most durable pavement that could be used. There was an immense amount of friction on pavement generally, and even with York pavement it was astonishing how soon it wore. Then the appearance of the tar pavement was very objectionable. A town covered with tar pavement presented a most sombre and unpleasant appearance. He did not think people who lived in towns paved in that manner could be at all of a sanguine temperament. Another objection was the difficulty of repairing it. What with the frequent necessity for putting in gas services, and the execution of sanitary works, laying water-pipes and telegraph wires, the pavements of towns were constantly being ripped up; and if composed of tar they would be more difficult to repair and relay than stone. As persons connected with gas-works frequently disturbed the roads, the economy of the question was of some importance to them. He had seen bricks tried of various kinds, but in the end always found that such pavement wore out in one-third of the time of stone. Seyssel asphalte was remarkable stuff, but it was quite as dear as stone. This was the only kind of asphalte to be depended upon, for inferior descriptions were liable to expansion and contraction, which, of course, was most prejudicial to its endurance, and duration must be considered as well as first cost.

The PRESIDENT asked whether Mr. Church could give any particulars of the duration of the different pavements, stones and tar.

Mr. CHURCH said ordinary stone pavement lasted about ten years—*i. e.*, it required taking up and dressing, and could then be relaid. Bricks would last about half that time. He believed asphalte was fully equal to stone. A very good specimen of asphalte was that laid down on the French system near the Bank of England, and certainly so far as it had gone it was a success. There was a difficulty lately with the telegraph company. They had to carry their lines of telegraph there, and they were trying, as far as they could, to get out of the road, because of the difficulty in repairing it. There was an amount of skilled labour required in this matter, which was not always to be had.

Mr. DUNNING said for some years he had the surveyorship of the town of Middlesborough, where tar pavement had been employed, and he could give some information as to the results. The cost of flagging with Yorkshire stone had been from 4s. 8d. to 5s. a superficial yard. The cost of Staffordshire bricks was 3s. 6d. The cost of the tar pavement, which had been made very much in the same way as described by Mr. Anderson, was 1s. Those were prices that had been in vogue for the last 15 years. He laid down tar pavement in one locality ten years ago, and to all appearance it was as good now as the first year it was laid down, with this slight exception—it was an elevated footpath supported by a low retaining wall of brick, and that had given a little, so that a channel had formed just inside the kerbstone. The whole of the rest of the asphalte was as good as it was the first day it was laid down. They had not experienced any difficulty about the pipes. It certainly required very great care on the part of the men in repairing it, but if they were careful the repair was quite equal to that of flags or bricks, because, in nine cases out of ten, in taking up and laying down flags they were chipped, and they seldom got the same good joint with flag and brick that they did with asphalte. With regard to telegraph wires there could be no difficulty, because those wires might be laid under the kerbstone, which could be supported by brickwork on both sides. The 1s. a yard left a very good profit, so it was evidently to their advantage to encourage the making of the tar pavement

Mr. MEAD (Reigate) said in the south of England, where York flags cost 9s. per square yard, tar paving presented many advantages. He had himself introduced it with great success. It was economically constructed. It was inexpensive in maintenance, and where formerly there was a miserable, muddy path, he had now a sound paving which was dry in ten minutes after rain.

Mr. JONES said the tar pavement at Dover cost 10d. per yard, which price included the carriage of material from the beach to the works, and from thence to the place where it was laid down. If the materials could be procured on the spot the cost would not exceed 6d. or 8d. per yard. The piece Mr. Anderson referred to was laid three years ago, and was quite as good as it was when first put down. A practical stonemason in the town said he was perfectly satisfied that tar pavement would last very much longer than flagging. It was always desirable slightly to distil the tar so at to take off the oil, otherwise it would not have the cohesive property which was necessary.

Mr. Broadhead said tar pavement had been laid down in Grimsby at 13½d. per yard, while flagging cost 4s. 6d. They were now laying down a considerable quantity of tar pavement. It was prepared in the following way:—The contractor got the gravel from the coast, sifted it, and took out the rough gravel; that was put into crude tar. He then went to the gas-works and the factories of the town and got all their ashes; these were put through a fine sieve, then put into ovens, and afterwards mixed with the crude tar. He picked the foot-paths (kerbed with 4-inch kerbs) up about 2 inches deep, laid on the rough gravel that has been already in tar, rolled it, and then put on the fine ashes that had been saturated with tar. This was rolled down, and was then sprinkled with Derbyshire spar. He himself laid down a tar pavement round the gas-works eight or ten years ago, which, though somewhat rough now, had been very satisfactory. There was no difficulty in relaying such paving after it had been broken up for gas or water services, and in a day or two afterwards there was no visible marks of the paving having been removed.

Mr. Livesay (Ventnor) said, as town surveyor, he was very well acquainted with the Pyrimont asphalte which had been referred to. He thought tar was a valuable material for pavement, but its success would depend very much upon the manner in which it was mixed and laid. The nearer its condition was assimilated to that of asphalte, the greater satisfaction would result from its use. The Seyssel asphalte was composed of limestone from the Jura Mountains, which was thoroughly impregnated with mineral tar. It was brought to this country, ground down and melted, and grit mixed with it. If grit or sand were introduced into the tar pavement along with shingle, it would render it much more binding in character. The asphalte paving in Trafalgar Square had proved very successful, and the wear was almost imperceptible. If managers and engineers of gas-works were to study that material a little more, and the mode of obtaining and using it, the experience so gained would be of great advantage in introducing tar pavement, which he should like to see adopted universally.

Mr. Anderson said they were favoured with the presence of M. Ellissen, of the Paris Gas-Works, who wished him to say a few words in more detailed explanation of what had been stated respecting Paris asphalte; but before doing so he desired to make a remark in reference to what had fallen from Mr. Church. Mr. Church fancied that people who could admire dark pavement must be of a sombre disposition. He joined issue on that proposition, for it appeared to him that the man who could not enjoy the sombre aspect of the pavement must be too sombre, and that the man who could had more elasticity in his nature than the man who could not. But it was not necessary that the paving should have this sombre character. He had seen it beautifully granitified, if he might so say, on the top, by fine particles of Derbyshire spar, and whether sombre or not, when it had the spar upon it it was a sparkling pavement, far superior to anything to be got in the way of stone. Passing from that, M. Ellissen wished it to be stated that the asphalte in the streets of Paris was not the pure asphalte which was put down on the foot-pavements, but the whole of the limestone with the asphalte combined was ground up into a fine powder and distributed in the way mentioned, and, instead of being rolled, was stamped with warm stampers. It was heated to 107° Cent. He was also informed that the material naturally had about 15 per cent. of tar in it.

Mr. Methven, in reply, said cart-roads could be made by using large stones only, about the size of walnuts, without any intermixture of cinder-dust at all. Sometimes they might fail in mixing it, but it was a matter of experience as to the right method of proceeding. He had a road laid for two or three years with this tar pavement, over which he had carted between 4000 and 5000 tons a year, and it stood very well. Wherever there were gas-works they could make a very good foot-pavement merely with the breeze, simply heating it and mixing it with tar. That did not always answer when there was a hot exposure, but some shingle mixed with it would make it hard. Mr. Church had referred to the want of evidence as to its durability, but after what the speakers had said he must be satisfied on that point. As to the question of repairing, this was very easily done. They only wanted the stuff, and then any labourer could do it. If it was left a little higher than the old pavement, so that allowance was made for the settlement of the material, in a short time they would not be able to discover the joint. There was no difficulty in mending it, because the stuff could be kept on the work for months without receiving any injury. When laid, if sprinkled with spar or light gravel, its appearance was much improved.

THE INTERNATIONAL EXHIBITION, 1871.

Mr. P. Le Neve Foster (Secretary to the Society of Arts): Gentlemen, having the permission of your chairman to interrupt your proceedings at the present stage, I will as briefly as possible state the object I am desirous to bring before you. Her Majesty's Commissioners for the International Exhibition which is to take place in 1871 were anxious that I should bring before this meeting, composed as it is of gentlemen from all parts of the kingdom, and connected with a large and important branch of manufacture, the nature of that exhibition, in the hope that they may have your aid, assistance, and co-operation in making it as successful as possible. I dare say you have heard that there is to be a series of exhibitions of an international character, the first of which will take place next year. These exhibitions will embrace various manufactures arranged in sections. That of next year will consist of six divisions, one of which embraces the fine arts, the others certain classes of manufacture—viz., pottery, woollen and worsted fabrics, educational works, and appliances. But under the division of manufacture, which includes machinery and raw materials, there is a division for scientific inventions and new discoveries of all kinds, and it was hoped that, by making this announcement, some gentlemen connected with the British Association of Gas Managers might be induced to bring forward, at that exhibition, some of the various interesting inventions which we know are continually being made in gas manufacture.

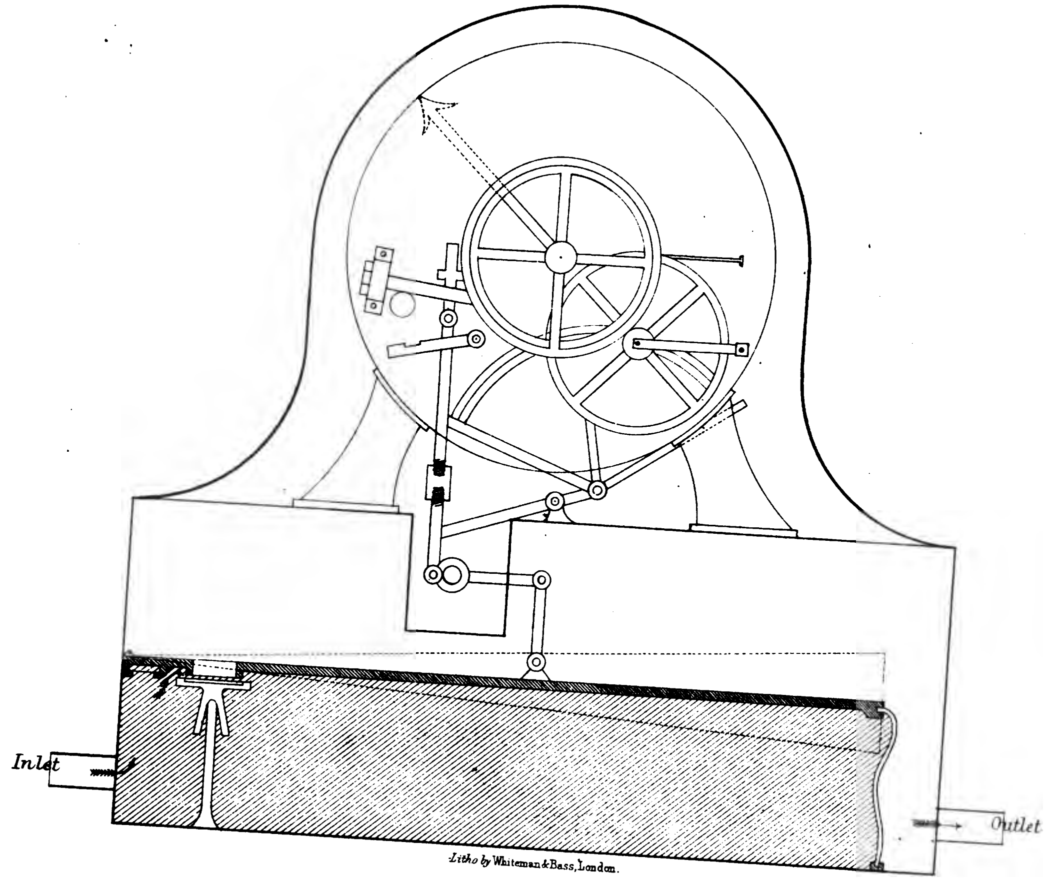
Mr. Warner (South Shields) presented the following paper, which, owing to the limited time at the disposal of the association, was only partly read.

ON GAS-METERS.

The talented writer of the "History of the Gas-Meter," published upwards of twenty years since in the Journal of Gas Lighting, has divided the instruments into three classes—wet, dry, and inferential.

The latter class may be fairly represented by the article patented in 1824 by a very notable character in his day—Sir William Congreve. He proposed "to measure and register the flow of gas (I quote his specification) through a pipe or cock, *when the pressure is uniform*, by registering the length of time the pipe or cock is open. For this purpose there is applied to each cock or pipe a small clock movement, which will be started by the opening of the cock, and stopped again by closing it. The dial attached will indicate any number of hours the clock may have gone." From Richards's edition of "Hughes on Gas Lighting" it will be seen that this instrument was much used at one time in France. Though the arrangement is to be applied "*when the pressure is uniform*," nothing is devised to ensure the same. But four years previous (1820), Malam was a patentee of a meter which met this want. It was essentially a dry governor, consisting of an oblong plate with leather sides, and a conical valve, for regulating the pressure; and at the same time the speed of the clock was adjusted by it being made to go faster or slower according to the depression or elevation of the plate, and so of the quantity of gas passing. The regulation and adjustment, however, were not according to the consumption only, but to the initial pressure, and hence the subsequent labours and patents of Clegg upon this principle. A modification of the principle was patented, too, by Clegg in 1848, though it had been previously patented by Edge in 1842. It is "the measurement of a *fractional* part of the volume of gas only, and is effected by regulating the ingress-*valves*, so that a small valve leading to a meter will always in size bear a relative proportion to that of the valve for the general passage of the gas." In 1857 another idea was patented. A vessel is to be partially filled with a liquid with which the gas is to be saturated, and from the upper part of the vessel are to be suspended a number of strings or threads of fibrous material which by capillary action are to draw up a quantity of the liquid, and so present an extensive evaporating surface to the action of the gas in its passage through the vessel, the gas thus carries off a

MALAM'S INFERENTIAL METER.



Litho by Whiteman & Bass, London.

certain quantity of the liquid; so that by weighing or measuring what remains the amount of gas passed through may be ascertained.

As in the meter proper, however, we are indebted to the ingenious and indefatigable Clegg, so in the order of merit his inferential meter of 1830 stands pre-eminently first. Though we can but say it is a very beautiful philosophical toy, yet doubtless much time, and money, and ingenuity, were spent upon it. The principal is that known as the *pulse glasses*. There is one upon the table. It consists of two small glass globes, connected together by a small rod working upon centres, and contains alcohol. In action, two currents of gas are directed against these globes, one is heated by a small flame and directed against the lower glass, from which, by vaporization, the alcohol passes to the upper glass, in which it is again condensed by the current of cool gas being directed against it; the balance is thus disturbed—the heavy glass now takes the place of the first, and so causes a pulsation; the alcohol is again vaporized, and then condensed, and so the action is continued. You will here note that there is no positive measurement effected by any of these contrivances. This last arrangement of Clegg's may be more properly termed a differential thermometric gauge than a meter. Indeed, none of them should be so classified; there is no actual measurement—no measurement of volume.

In 1820 a small pamphlet was published by Mr. Clegg giving an account of his inventions. He says: "In 1813 I undertook the direction of the different works belonging to the Chartered Gaslight Company in London and Westminster, and during the *four* following years lighted a great part of both these cities. In the course of *that period* I invented and adopted the rotative retorts, the semi-fluid lime machine, the *rotative and reciprocating gas-meters*, the governor or regulator, and an apparatus for the decomposition of oil, tar, &c., and in 1817 I invented the collapsing gasholder." Mr. Clegg, jun., writes, in "A Brief Historical Sketch of the Introduction of Lighting by Coal Gas," "The gas-works at Peter Street, Westminster, were commenced under the direction of Mr. Clegg, in 1813. The ground upon which they were erected was a swamp, nearly on a level with the Thames, and formerly overflowed by the river. It was impossible to sink for a tank, and an iron one would then have been very expensive. This gave occasion for the construction of a *revolving gasholder*, which worked with greater regularity and less friction than any other." Now, it is somewhat surprising that this holder is not mentioned in the pamphlet that has been quoted, especially as it apparently overcame, in a very bold, ingenious, and admirable manner, a considerable difficulty.

It was, too, but the year before the publication of this pamphlet (1819) that Accum, in his "Coal Gas," gave an elaborate and minute description of the machine, and illustrated it by two engravings, one of which is on the title-page. It is this machine, I believe, that suggested the gas-meter; between them there is a strong analogy; but between the meter and the archimedian screw for raising water, as supposed by the author of the "History of the Gas-Meter," the analogy, as is justly observed by the editor of "Clegg," "seems so faint as scarcely to be capable of suggesting such an application." In one case we have a cylinder with its axis at an angle to the horizon, and several pipes coiled around it for raising water; in the other, an annular vessel with its axis horizontal and hollow for the passage of gas into the vessel from a stuffing-box, the inlet and outlet being from the two ends of the shaft. The same description answers for the meter, only it has two chambers instead of one, and the necessary arrangement for opening and closing the communications between them; moreover the revolving gasholder was used as a meter, a pointer and dial being attached. "In fact, this machine" (the improved gas-meter), Accum says, "performs the office of three *revolving gasholders*." A Mr. Matthews, in "An Historical Sketch of the Origin and Progress of Gas Lighting," also, and indeed more clearly and decidedly expresses the same opinion. "Mr. Clegg," he says, "had previously devised and constructed a gasholder in the form of that portion of a circle which makes 250°, and which moved vertically upon a horizontal axis, and acted upon the principle of the hydraulic bellows. As the circle was accurately graduated to indicate the quantity of gas entering in or passing from the machine, *probably it was this circumstance that suggested to Mr. Clegg the original idea of his gas-meter.*" Further, Peckstone says, the four chambers of the meter "are a *range of gasholders* acting with a rotary motion instead of a vertical one."

Now, as to the other side—the archimedian theory. It is probable it arose from this same writer, Peckstone. He says, "Mr. Malam suggested to me the idea of making a gas-meter on the principle of Archimedes screw; indeed, he made a small one on that plan in the beginning of the year 1816, having the L-shaped pipe of supply and receiving-chamber."

This "L-shaped pipe and receiving-chamber" are the spout and hollow cover of the drum, and distinctly mark the second stage of the invention of the gas-meter. This *improvement*, as some have called it, bears about the same relation to the meter as the inventions of James Watt do to the condensing engine—each becomes essentially a part of the whole, and without them the machines, for the work required of them, are practically useless. Men so gifted as Clegg and Malam, and running so closely in an arduous race along an undefined course, could not fail to make warm and zealous partizans, who claimed for each what belonged to both. Peckstone was one of them. As late as 1841 he writes: "As to our holding up Mr. Malam as the *inventor* of the gas-meter in preference to Mr. Clegg, we do so under the most perfect conviction that we are correct." However, he adds, "We have no hesitation in admitting that Mr. Clegg was the first person who patented a machine with a rotary motion intended to measure gas; but at the same time we as strenuously assert that no useful instrument for that purpose was made known till April, 1817, when Mr. Malam exhibited one in action at the Westminster Gas-Works."

In contradistinction to this we can find in vol. xxxvii. (1820) of the "Transactions of the Society of Arts and Sciences," the following report:—"Mr. Malam's gas-meter *is* constructed upon the same general principles, but with such improvements as induced the society to confer a high honorary reward (the Isis gold medal); but whether the machine, in their opinion so improved, is completely open to public use *before the expiry* of Mr. Clegg's patent, the society does not presume to determine." I should think not. It was, however, settled, and in the Court of King's Bench, too (*Crosley v. Beverley*, 1829). "The patent sustained as the new apparatus contained the *essence* of the patented meter—THAT OF A DIVIDED WHEEL REVOLVING BELOW WATER."

In the examination of *any* meter it will be found to consist of three separate, distinct, and essential parts—MEASURE, VALVE, and INDEX. In the first wet, as in the ordinary dry meter, this is obvious to almost the uninitiated; there are the little gasholder or diaphragm, and the valves for opening and closing the passages between these measures and the unmeasured and measured gas; in other words, for turning the gas on into the measures for measurement, turning it off when full, and then turning the gas on again that has been measured to the burners. This is also obvious in Clegg's first rotary meter, in which the inlet-*pipes* are alternately filled and emptied of water. It is not so obvious in the present wet meter, however, though the effect is the same by the quarters or hoods entering into and rising from the water as the wheel rotates. And so of the index there are a few modifications that may be noticed, but the work is alike essentially the same in all—to keep a record of the number of measures of gas passed through the instrument, though it has been used, as it were, for the adjustment of the registration of the meter; but this is simply adapting the index to the meter instead of the meter to the index, as is usual.

In both of Clegg's rotary meters, as in the reciprocating one, the measures are *perfect* in principle; both by the rising of the gasholder and the rotation of the wheel a positive, determinate, and invariable quantity is measured at each complete action of the machine. As the *cubical capacity* of the space passed through is always the same, the displacement must be invariable, and hence the measure invariable too. This is obvious in the case of the gasholder—the only variation that can take place is in the water-line, which cannot affect the measurement; the space passed through by the top of the holder being always the same, the displacement must be the same. So, the wheel being *annular* and the water-line below the axis, the capacity of the annulus cannot be affected, all the sides being of metal and rigid—hence we have a perfect measure. The complicated valvular arrangement was so defective notwithstanding, that the measure had to be modified. The spout and cover were introduced, and so the water-line had to be raised above the axis; but the principle was not altered, the spout being placed in the concentric space; it, however, could now be reduced in size, which was done, a 4-light meter, as per Peckstone, being reduced from 30 inches diameter and 8 inches deep to 12 inches diameter and 6 inches deep. "But, notwithstanding its superiority," the same writer says, "over the patent (Clegg's) gas-meter, the inventor (Malam) felt desirous of making a meter which would occupy even *less* room than it did." This idea was carried out; the inside cylinder was removed, and the principle of the measure was thus altered from an invariable annular to a variable wheel, with but *five* out of the six sides being rigid, the other being formed by the ever-varying surface of the water. The L-shaped pipe or spout was placed in its present position, external to the wheel, and the hollow cover placed over it. Thus it has been continued up to the present time, notwithstanding many attempts at improvement. The most original was that of Clegg himself. In 1858 he returned to the annular principle, but the internal cylinder was made proportionately larger, and converted into a float (but this was patented in 1848), and the measures or chambers were placed eccentrically around. The idea of flotation of gas-measures does not belong to Clegg, though his object was to lessen the friction of the wheel as well as Malam's, to maintain the correctness of measure. The friction, however, by an examination of the shaft of his drum on the table, does not appear to be lessened; and I may add that if the bearings of an ordinary wet meter be examined, it will be seen that the wear is not from the weight of the wheel, but from the pressure of the gas, the upper parts of the bearings being the portions worn. Malam patented the float in connexion with a very ingenious modification of the wheel; he turned the cylinder on end, placed one end of the shaft in a step, and attached the other end to a crank, by which he obtained a circular undulating movement, as it were, similar to a dry meter re-patented by Remington and Berry in 1852, or like a colour-top or teetotum when nearly spent. These same patentees also claimed the placing of a wheel at an angle with the horizon, and rotating obliquely, a rotatory valve being attached. Smith, in 1845, also modified the wheel; he placed a small box or chamber in the centre of the wheel, and attached the partitions to it, for the purpose of preventing gas passing when tilted. The Messrs. Braddock make a meter somewhat similar, one of which is on the table, but not with the same object, theirs being to lessen the variation in measurement. Mr. Smith also carried the partitions down to the axis in the ordinary form of wheel. Richards's wheel, patented 1858, is a simple modification by which the ordinary wheel is made to approach the annular form, and so lessen as much as possible the variation of capacity by the alteration of water-line. The sides are placed very close together at the shaft, and in a section parallel with the shaft the chambers are triangular in shape. It is rather strange that Richards should have allowed the error of Hughes, making the inlets outlets, to have continued in his book. The same clever inventor also, in the name of Mr. Newton, patented, in 1859, other modifications of the wheel; the annular drum was adapted with diagonal passages and lips to the internal cylinder for the passage of water.

Again, in 1860, a Mr. Sim applied for a patent for a drum with solid central disc and plates diverging angularly, also one with an internal cylinder. Mr. Kromschroeder patented a combination of Clegg's eccentric meter with *five* chambers; and again in 1862 he patented an annular drum and float, with inlet passages through the cylinder, and outlets through the rim. The real archimedian-screw meter cropped out in 1865. Mr. Brooman patented an internal drum carrying a central perforated tube and spiral vanes. Again, in the same year, Mr. Webster patented a drum with fans, the blades of which are helical or in screw form around the centre drum, nearly identical with the previous one. The original reciprocating meter of Clegg has been patented again and again, the ordinary gasholder being such an exceedingly suggestive machine, and *apparently* so simple, which indeed it is in itself as a measure, any tin pot answering the purpose, but it is the complication of parts—guides, connecting-rods, valves, &c.—that places it far below, incomparably below the ordinary wet meter.

At the commencement of a business so original as gas-making, there could not be otherwise than much attention given to so important a part of the apparatus as that for storing the gas. So we find many patents recorded for schemes of improvement, and as might be supposed those of Clegg and Malam. That of the former is the only one to which I have to refer; it bears date 1818, and the title is "An Improved Gasometer or Gasholder." It is not at all improbable that the idea for this was taken from what it is said in the specification to resemble—"a portfolio or letter-case" with its edges in a shallow tray of water. It had two sides, and two ends meeting together at top in ridge, like the roof of a house, and united together by hinges, the joints being covered by some flexible material which retained the gas, and allowed the sides to fold together. This was the first flexible expanding and contracting gas-chamber devised for coal gas purposes. Malam soon followed (1820) with a patent "For measuring the *flow* of gas," one of the contrivances being a flexible expanding chamber to be used as a governor or regulator, the water being dispensed with as used in Clegg's governor and flexible holder. A number of these chambers or "bellows" as they were named, are arranged around a hollow valvular shaft, with which they revolve, and through which they are filled in succession. It is worthy of observation that as in the wet meter he obviated the use of the objectionable stuffing-box and hollow shaft, yet introduced it in a less practical form in this so-called dry meter. It is due to Malam that we should note that although the writer of the "History of the Gas-Meter" gives him the credit of having thus invented the first dry meter, he himself did not deem this a meter proper. It was a substitute for a clock, or, as he calls it, "the maintaining power," for clockwork to record the quantity of regulated gas passed by *inferential meter*. It was, however, a very suggestive arrangement, and served as a model for several inventors and patentees. A very zealous supporter of Malam, Peckstone, with Le Capelain patented, in 1841, a dry rotary meter; also Mr. Farwig in 1843, and a Mr. Duckham as late as 1860. The cylindro-piston form of chamber was patented, in 1823, by a Mr. Caslon, as improvements in gasometers—a "plunger" in a frame with air-tight material sides. A round "*diaphragm*" was patented, too, by Samuel Crosley in 1825, identical, it may be said, with the many thousands that are now to be seen on the top of the lamp-pillars in every large town.

The first *dry meter* patented was by Miles Berry, in 1833, the invention of an intelligent American workman, named Bogardus, and, though said to have been a rude piece of mechanism, yet in its measure or expandable chamber it was not approached in those subsequently produced by the persons who were said to have improved it. The diaphragm consisted of a large inflexible plate, moving upon a hinge, with flexible sides just sufficient to allow of the formation of the chamber, every portion of which was entirely under control, and differed materially from the long or semi-bladder form which was manufactured by the North Road Meter Company, at a loss of something like £24,000. In 1832 another meter of Bogardus's was patented by a Mr. Sullivan, and it is on this principle—two diaphragms—all, or nearly all, are now made. A round diaphragm was used, similar to Crosley's regulator diaphragm, considerably inferior as a measure to the first one, working upon a hinge; a *large* disc of leather being used, and but a *small* inflexible plate *in the centre*. The arrangement of Defries and Taylor is the next worthy of notice, and differs materially from the former. It was patented in 1842, and somewhat resembled Clegg's flexible holder in its measures, the flexible partitions being formed of several inflexible surfaces combined together by a flexible material, by which means the flexibility of each partition results from the bending of the partitions at the lines of junction. Croll and Richards very worthily followed these patentees. Though there is nothing strikingly original in their meter, yet the marked simplicity of their arrangement, and the correctness of the measure of their diaphragm—"a *large* disc of metal surrounded by *as narrow* a margin of flexible material as possible"—could not but be followed, as it has been, by general adoption, rather than what appeared to be the better measure of their immediate predecessors. Croll and Richards, it will thus be seen, have laid down a principle for the construction of this diaphragm—"a *large* disc of metal with as narrow a band of leather as possible"—but there is also another principle involved in their arrangement which scarcely allows this to be carried out in practice, that the disc shall not pass through its plane of connexion or attachment to the meter, so as to prevent, as far as possible, the bending of the leather when in action. This, however, has not been deemed essential by several makers, nor in practice does it seem of any importance. In Defries's diaphragm this action is more likely to be felt than in any other, and yet meters are taken down of this make, as of Croll's, that have been in use 20 years, and are perfectly sound. Unfortunately very few meters attain that age, but still there is sufficient proof that the bending of the leather, it being so very slight, is not injurious to it. Unquestionably there are cases in which it appears otherwise; diaphragms of Defries make have *appeared* to go at the bending, but upon examination it will be found that it has been caused by defective workmanship, as, in the case of the round diaphragm, a sharp edge of the tin has cut the leather, or it has received a blow. As experience will support this view, we may then reduce the quantity of leather employed by passing the disc through the plane of connexion, and thus reduce the quantity to a minimum. Meters are now being made upon this principle by Smith, Milne, and Messrs. Cowan, and they were also manufactured by Mr. Thomas Edge, in 1853, under a patent of my own.

We now come to the valvular arrangements, or the various modes that have been devised for passing the gas into and from these measures. In a letter to Malam from Clegg, in 1817, which was a caution against infringing the patent, he observes the shutting off the gas may be effected in various ways—that is to say, "by valves, or sealing the pipes with water." I quote Peckstone, who then adds, "If the reader examines the figures representing Mr. Malam's gas-meter, he will find there is not a valve in either, and also that there is not any pipe to be sealed with water." It is certainly due to Clegg that we should take him as our authority rather than Peckstone, and so we shall find that there are not only valves, but valves of a very beautiful description, in Malam's meter, and that they are partly in principle identical with Clegg's. Further, this passage quoted by Peckstone from Clegg is the strongest evidence we can have that Clegg was thoroughly alive to the imperfections of his meter. He at once put his finger upon them, and probably would have remedied them had not Malam's knowledge of the subject and ever active ingenuity been scarcely less than that of his chief. But it was not equal to that which Peckstone has given him credit for—getting gas into and from a vessel without an aperture. Such being necessary, and being opened and closed by the aid of water, became a valve the same in principle as Clegg's, though not the same in construction.

Looking at the drawing of Clegg's meter with, of course, the knowledge we possess now of the subject, and of which we cannot divest ourselves, improvements in the action of the meter, similar to what Malam made, appear to suggest themselves. Thus by cutting the syphons in two, and lengthening the leg attached to the measure or chamber, the little buckets for carrying the water for sealing these syphons might be dispensed with. This, though not in form, is indeed in principle one of Malam's improvements, so altering the *inlet* that the ends of the pipes as they rose from and entered the water opened and closed as the wheel revolved, just the same as the *outlet* orifices were opened and closed by the drum revolving in Clegg's meter. In fact, Malam changed these outlet orifices of Clegg's meters into inlets, and placed the outlet passages at the rim of the wheel. By altering these syphons thus it will be seen that they displace the *spring*-valves for the *water*-inlets, the syphon legs forming inlet water-ways themselves into the chamber, and then we may almost trace the progressive steps of improvement in the formation of the wheel.

These water-ways, extending the whole depth of the wheel, were a decided improvement upon the small clack-valve used by Clegg, and a simplification of his curved ways, yet in one respect the action of the meter was similar: all the water to fill the chamber had to pass through these passages, and the whole of the water, the entire contents of the chamber, had to pass through each chamber in succession; the speed, too, at which it entered and left differed in Malam's meter, the inlet being at the centre, and the outlet at the rim of the wheel, the opening and closing of the gas inlet and outlet passages being, likewise, so affected, the variation of the water line would also affect the flow of gas through the meter. "Three-tenths of an inch of pressure," it appears, were absorbed by a "wheel 9 inches in diameter, and the difference of friction at various parts of the rotation of the wheel amounted to three-twentieths of an inch." The purchaser of Clegg's patent—Samuel Crosley—did not rest upon the patentee's ingenuity and experience, but exercising his own, which was considerable, and applying his practical knowledge of the working of metals, remedied these defects, and made the meter what it is this day—a good practical durable machine. He it was who gave the wheel the archimedian principle, placing the partitions spirally around the shaft, and doing the same with the inlet and outlet hoods, which he placed at the two ends of the cylinder, thus allowing the wheel to work freely through the water, instead of forcing it through the wheel; the friction being thus reduced, and the flow of gas uniform. Wright also worked in this direction, and by cutting away a portion of the hoods the friction was still further reduced, and the wheel could thus be made of less depth, and so approach a more correct measure. The valves being placed at the two ends of the drum, and on opposite sides of the shaft, and extending from the same to the periphery, allow a variation of water-line without the flow or action being impeded; the two channels holding the measure of gas between them, and adapting themselves to the ever-varying water-line in a manner that is worthy of all admiration, but which is almost entirely overlooked, though scarcely second to Malam's improvements in beauty and simplicity; so simple, indeed, that Malam is almost justified in appealing to the observer to bear witness to the truth of his assertion that there are no valves. Yes, no valves! but by the formation of the chambers—no nicely adjusted mechanism, no carefully wrought surfaces, not a pin to move beyond the shaft—as rough and as simple as a grindstone, yet as delicate as the finest balance. Notwithstanding, we find patent after patent obtained for so-called improvements to supersede it by clicks and clacks, and gimcracks of every possible conceivable arrangement. Hydraulic, clack, slide, and rotatory valves have all been employed, with their usual and necessary accompaniments, in the formation of meters with the different kind of wet measuring-chambers to which I have alluded.

The first dry-meter valve, if we are to consider Malam's a meter, is a cylindrical one, but doubtless was made slightly conical; Berry's is a four-way cock; Paterson used the common clack; Sullivan's was a rotary; Defries and Taylor's slide, changed by Mr. Defries to the rotary; Wright's, as manufactured by Edge, a rotary, but afterwards changed to a slide; Croll has always used the ordinary D slide; Lizar's is a rotatary, or eccentric, of nearly a square shape; the North Road Company used one moving in an arc of a circle, which has also since been used by several persons; and Le Capelain has arranged one with a lever, or a flute key. Mr. Croll's is the only patent, I believe, for a composition of the ordinary metals used, and he employs a harder one for the cover than for the seat of the valve—the former being 6 parts of antimony to 16 parts of tin, and the cover 8 parts of antimony to 16 parts of tin. Mr. Defries tried glass covers, but abandoned them for leather, which has now been used for many years. The North Road Company used ivory at one time, which has been since patented, with glass, stone, pebbles, and glazed ware; and another inventor proposes to silver them; and, in opposition to this, another has claimed the exclusive use of felt. However, most—indeed, all—are manufactured of an amalgam such as Mr. Croll patented, differing more or less in the proportion; some also using lead, which is certainly objectionable. The faces are finished by grinding on stone and glass. Some makers use emery or other grinding powder, but I prefer the simple stone and glass alone.

We will now pass on to the construction of these machines—the various combinations of these elements that have been devised for the measurement of gas. Clegg's were constructed with two and three chambers, but the two-chamber was the one used at first. The water-line being below the axis, the meter in action resolved itself into a four-chamber meter, the surface of the water forming, as it were, the other two partitions. There is one disadvantage that is obvious to all in the two and three chamber meter; the number of partitions immersed is not the same in all parts of a revolution, and hence irregularity of flow. The number of chambers since Malam's has always been *four*, I believe; and Clegg followed the same example in his new eccentric meter. A Mr. Kromschroeder, who, I believe, had the management of the manufacture of this meter, patented an arrangement of five of these eccentric chambers.

In the reciprocating wet meter two kinds have been arranged—*single* and *double*. By *single* I mean the use of the *interior or exterior only* of the reciprocating vessel; the same, when the interior is used, as an ordinary gasholder, and externally by placing a cover over the same, using the exterior, and leaving the interior open to the atmosphere or *outlet* pressure; and *double* with this construction, but using alternately both sides of the vessel. Examples of the two in the dry meter will be found first in Malam's radiating dry meter, the gas being admitted into the interior only, and the double principle will be found in Berry's first patent, in which the *diaphragm* is made to assume its proper functions, and divide the chamber into two measures, and so is double-action, the same as an ordinary steam-engine. The combination and arrangement of these chambers, complete within themselves of measure and valve, are very various. The most complete, perfect, and simple form unquestionably is that of the wet meter arranged around a horizontal shaft. This form is followed in Malam's dry meter. He also patented a wet meter, with four chambers arranged around a vertical shaft, and having a rotating undulatory action. One of the arrangements of Defries and Taylor, 1842, was *seven* diaphragms ("in preference!") separately acting upon and working the rotary valve affixed to an upright shaft.

In the year previous Peckstone and Le Capelain patented a dry rotatory meter and valve after the model of Malam's dry meter, only with a definite action, and consequently much more complex. The defects of the dry meter revolving on a horizontal shaft are obvious—an increase of friction by the *whole* apparatus having to be set in motion instead of but a very slight portion, and irregularity of action by balance of the wheel being destroyed by condensation. A Mr. Farwig, in 1843, claimed a number of arrangements of rotary meters with vertical spindles or shafts; and though they may not suffer from condensation, yet the whole has to be set in motion instead of a part, and a rotary valve must be used, or a hollow shaft and stuffing-box, and complications in detail upon which I need not dwell.

It need scarcely be said that the first dry meter proper—the double-action single-diaphragm of Berry—is the most simple in principle that can be made, and many attempts have been made to perfect it. A considerable amount of time, money, and ingenuity has been expended upon it, but it still remains the will-o'-the-wisp of patentees. Upwards of a dozen patents have been taken out for modifications of this principle. The defect is irregularity of action, the motion of the valve or valves being dependent upon an extraneous power, either spring or weight, to that derivable from the diaphragm; or rather, the power is supplementary to that of the diaphragm, and hence the action of this is affected by the irregular resistance of the weight or spring. The power of these, too, being constant, and the work—actuating the valve or valves variable, irregularity arises from want of precision in change. This is a defect that no amount of ingenuity can overcome. It is a defect in principle. The next most simple meter is that of the late Mr. Alexander Wright. I here come to his first recorded invention in the form of patent (1844), but it is assumed that it is well known he was connected with others, and that he devoted much and useful attention to the gas-meter. I feel that we are much indebted to him for practical as well as theoretical knowledge upon this subject, and take this opportunity of recording my admiration of his talents. His meter is that which was manufactured by Mr. Edge, and consists of three chambers formed by two diaphragms. Defries and Taylor—dare I say so?—were superstitiously attached to odd numbers, and so amongst other arrangements patented three chambers, but formed them by three diaphragms—single-action, of course. Wright's, however, was much improved in form and construction, and overcame the defect of the two-chamber meter without being scarcely more complex, as in the latest improved two-chamber meter a second diaphragm was attached as a kind of regulator, and the valve—a rotatory one—was entirely under the control of the diaphragms. The two diaphragms were placed parallel, forming two external chambers proper, and one common to both, in which the rotary valve was placed, and was actuated by a central vertical shaft, which received direct action from the diaphragm through two cranks.

To those striving after simplicity, here is a noteworthy model, and, to those needing it, an example not to depart from first principles, and one of these, in the construction of meters, is surely that a *constant* flow of gas shall pass through the instrument. This is absolutely necessary—not even second to measurement; and, upon an examination of this principle, it will be seen that it fails in this essential. There is in a portion of its action, as in the four-chamber meter, two chambers delivering, and hence one filling; to which we will not object, nor to the opposite of it—two filling and one delivering; but we may fairly object to the arrangement by which two diaphragms are in action and but the duty of one being done, or, in other words, in which each diaphragm has not only to do its own work but to carry its neighbour too, which is the case with this meter. The slide-valve was subsequently adopted, three single ones being used, the form, and action of which were decidedly bad; but with this alteration, I believe, Mr. Wright had nothing to do—indeed, objected to it. This meter needed but a sheet of tin between its diaphragms, and with one valve less would have been a better instrument. Mr. Smith patented such an arrangement in 1846—two years after Wright's patent—two cranks at right angles being placed in the interior of the meter, and the shaft passing through stuffing-boxes to the valve-chamber.

Before leaving Wright's meter, we must notice that the single-action diaphragm has this defect: that, whatever the power be required to move it—and it differs in different meters, and in the condition of those meters—that power becomes doubled, or rather the absorption of power of the single-action diaphragm is twice that of the double action. Had Sullivan's principle been followed closely by subsequent patentees and manufacturers, and the ingenuity expended upon modified principles been spent upon that meter, a better meter would have been produced at an earlier date, and much prejudice against the dry meter avoided.

In this was the success of Croll and Richards. They took Sullivan's meter, enlarged the disc of diaphragm, reduced the quantity of leather, and brought it under control, substituted the slide-valve for the rotary, and otherwise so altered and improved the instrument that it has become, as Crosley's wheel has become, the model which all have followed. The meter of Defries and Taylor having six chambers, formed by the three solid diaphragms arranged triangularly in a very compact and neat manner, was unquestionably the first good practical meter in the market, and was well worthy of the popularity it created for itself. Defries has not been the only manufacturer of six-chambered meters. The ingenious Taylor, co-patentee of Defries, amongst many, many schemes that have come from his fertile brain, produced a six-chambered meter, patented in 1844. The diaphragms, being single action, were coupled together in pairs, each pair having a separate crank, &c.—a complicated and troublesome arrangement. It was manufactured by Mr. Sugg, who afterwards very wisely modified the arrangement to the three-diaphragmed six-chambered meter. Several other makers have also manufactured upon this principle, including even the Messrs. Parkinson, of Cottage Lane, but who have since abandoned it for the four-chambered meter, as indeed the successor to Mr. Nathan Defries has done. We may, then, take it as an admitted fact that for all practical purposes—and our experience of one is equal to that of the other—the four-chambered meter has an advantage over the six. As less than four is defective, so more than four is an unnecessary complication and expense.

Not having had occasion to mention the names of Messrs. Glover and some other principal manufacturers, it is but right that I should here take the opportunity of saying that I have as high an opinion of their meters as any manufactured, but I have purposely confined myself to principles. Durability, dependent upon manufacture, is a question of experience, as is the cause of failure in action, and so fairly come within the scope of discussion. But the causes of variation in the registration and action of meters, and the examination of the arrangements that have been devised to maintain their accuracy and efficiency, will, with the permission of your committee, form the subject of another paper that I hope to have the honour of presenting to this association.

DESCRIPTION OF DIAGRAMS.

The same letters refer to the same parts in all. A are the gas-ways, B are the inlets, and C the outlets, to the chambers or measures, D.

Fig 1. Clegg's Revolving Gasholder.
2. Clegg's Rotative Gas-Meter.
3. Malam's Undulating Meter.
4. Malam's Wheel, with L-pipe or spout.
5. Malam's Improved, without central chamber.
6. Crosley's Wheel, one chamber shown.
7. Crosley's Wheel, formation of, at periphery of wheel.
8. Clegg's Hydraulic Gas-Meter.
9. Richards's Wheel.

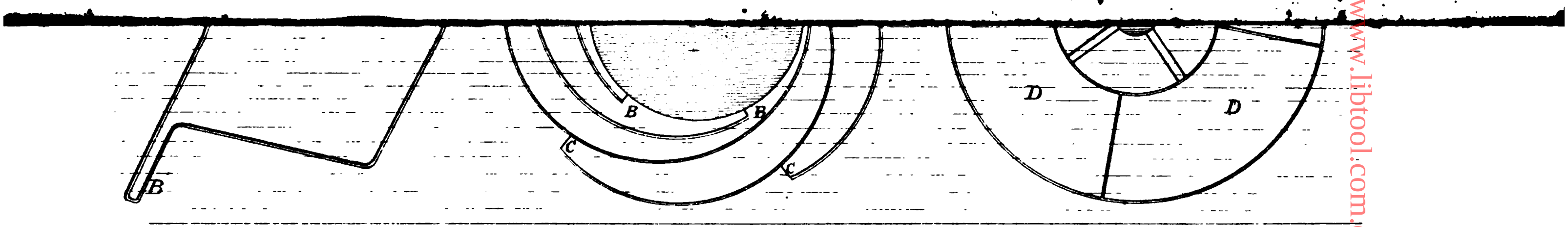
The HONORARY SECRETARY read the following paper by Mr. Davies, who was introduced by Mr. E. White, of Birmingham:—

ON AN IMPROVED ROTARY EXHAUSTER.

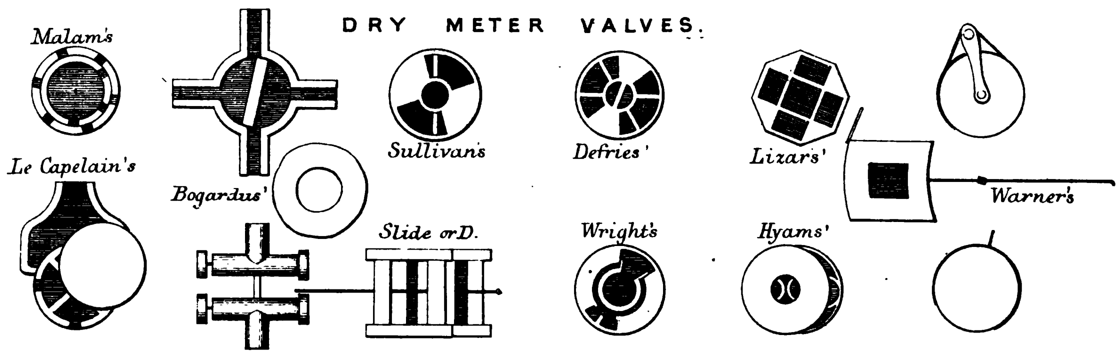
The writer has been practically connected with the manufacturing of gas exhausters for the last 27 years, having perfected the first machine that was brought into general public use, and seeing the great increase in the manufacture of gas, called the writer's attention to the construction of an exhauster that would offer facilities for being carried out upon a large scale, and would work free and smooth with a small amount of friction, and also work at high or low velocity against a considerably higher pressure than is made use of in any of the ordinary gas-works. And in carrying out the invention two ordinary cylinders are employed, and arranged end to end, their axis being in the same horizontal line; and between the cylinder a partition-plate is secured by means of flanges on the abutting cylinders. Each cylinder is closed by a lid, and a rotating piston works in each cylinder, the pistons being carried by a horizontal shaft passing through both cylinders.

The pistons are not fixed at the same angle, but the part of the greatest radius of the piston in one cylinder is situated opposite the part of the least radius of

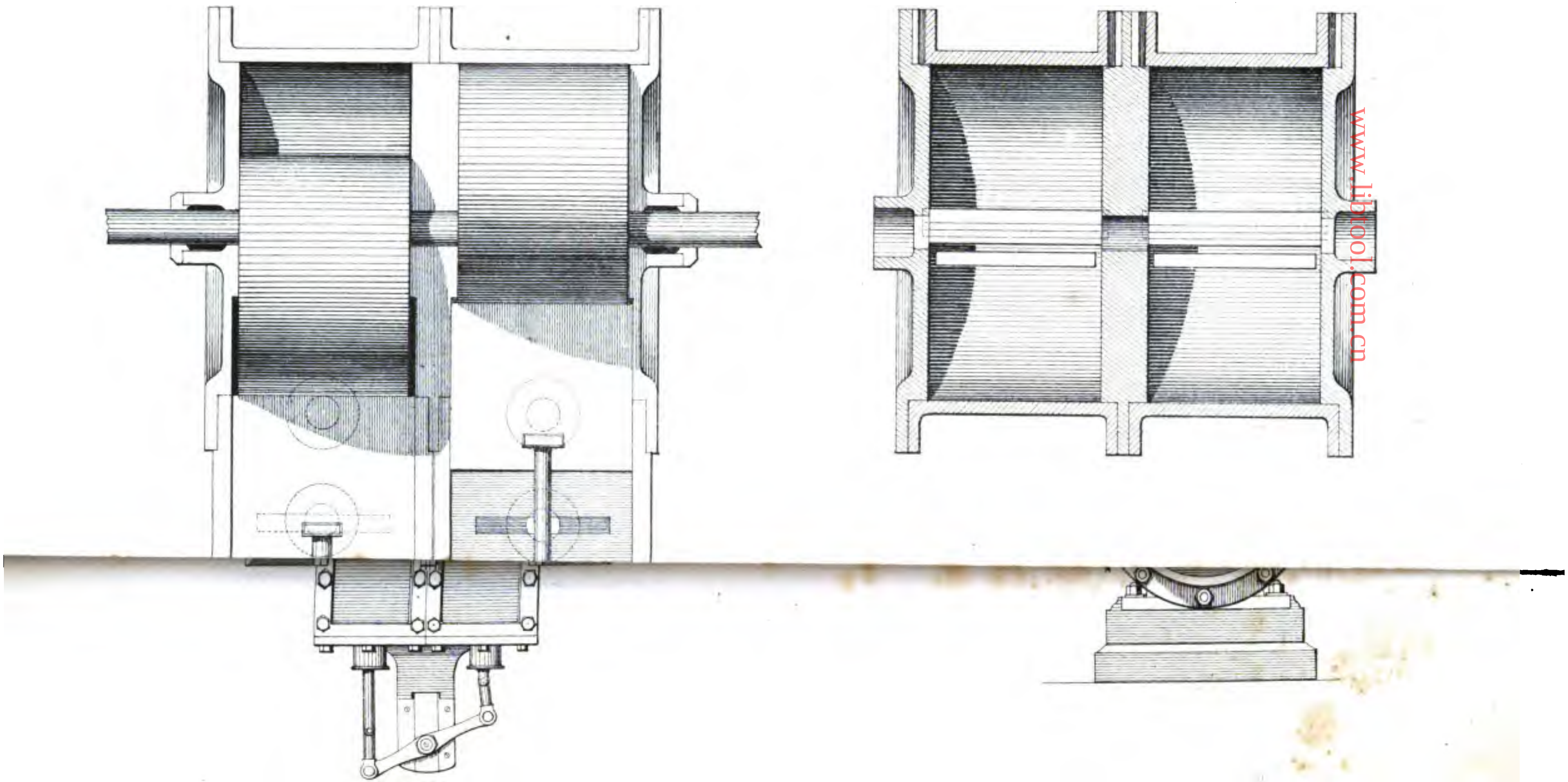
Diagrams illustrating Mr. W. J. Warner's paper upon Gas Meters.



DRY METER VALVES.



Litho by Whiteman & Bass, London.



Litho by Whiteman & Bass, London.

the piston in the adjacent cylinder. On the front of each cylinder a horizontal nozzle is fixed, in which the outlet-ports or passages are made; sliding in the nozzles are plates, constituting stops or valves, the inner ends of the said plates bearing against the cylindrical surface of the rotating piston. Each sliding-stop works in channels made in the nozzle partition-plate and cylinder-lids. The channels are cut truly in the parts in the same plane as the face of the nozzle, and thereby form a perfect bearing for the stops to work upon, and prevent the escape of gas at these parts. These sliding stops when they are at the end of their inner stroke divide the space between the piston and cylinder into two parts or chambers. In each cylinder and underside of the stop the inlet-port for the gas is made, the said inlet-port being always open; the outlet-port or passage being made in the nozzle hereinbefore described, which opens into the cylinder on the other side of the said stop.

By the arrangement described of the pistons on their shafts, the sliding-stops and valves are alternately moved backwards and forwards in their nozzles, and the outlet-ports in the said nozzles thereby alternately open and close. The two sliding-stops are connected together by means of links and lever working on a pivot, so that as the stop in one piston is moved outwards to close its outlet-port, the stop in the other cylinder is pressed inwardly against its piston to open its outlet-port. By the revolution of the piston in the cylinder, the gas which has been delivered on one side the stop is driven by the piston through the outlet-port on the other side of the said stop into the open nozzle. As soon as the piston has driven the gas in front of it from the cylinder, and is about to pass the sliding-stop, the outlet-port in the nozzle is closed by the said stop, and the gas which has entered the cylinder on the other side of the piston and stop is prevented from escaping through the outlet. On the continued rotation of the piston another volume of gas is forced out of the cylinder, and so on. The inlet and outlet ports, being narrow channels the whole length of the cylinders, admit of a short cessation of the impelling-action of the piston, and the gas that has been forced into the outlet-main is prevented from returning by means of the sliding valves and stop covering the outlet-port. The revolving piston is made to work in close proximity to the inner surface of the cylinder, and it is very desirable that there should be a ready means of always keeping the revolving shaft in the centre of the cylinder, and by examining the model it will be seen that standard brackets are fixed outside the cylinder-lids for supporting the shafts, and are provided with a taper wedge cutter, screwed at each end, and passing through the bracket under the bottom of the bearing. Under the shaft a gauge is fixed, working on a pivot, which is so made that it will just pass under the shaft; and if at any time the shaft should wear down in the bearings, it is only necessary to slacken the nut at the large end of the wedge and tighten the nut at the small end, and may be repeated at any time without disturbing the internal parts of the machine.

The peculiar action of the motion in front of the nozzles always keeps the inner ends of the sliding stops in close contact with the revolving pistons irrespective of wear or packing—an effect that has not previously been obtained. It will be seen by the model and drawings that all the parts in the machine are in perfect balance one with the other, and consequently the power required to drive it will be uniform, and the writer believes that no exhauster has yet been made that will give off the same amount of duty with an equal quantity of power to drive it. Under different pressures, he has found all through his experience that exhausters working without any internal packing are liable to a great amount of slip, even when contending against a small pressure; and those that require internal packing, and are not in balance, take so much extra power to drive them. The present invention will be found to remedy both of these evils.

ELECTION OF OFFICERS.

The SCRUTINEERS reported the result of their labours, which showed that the following gentlemen had been elected as officers, &c., for the ensuing year:—

President, Mr. Thomas Livesey.

Vice-Presidents, Mr. Edward White, Mr. T. N. Kirkham, Mr. G. Anderson.

Treasurer, Mr. Henry Newall.

Committee, Mr. I. A. Crookenden, Mr. George Garnett, Mr. Jabez Church.

Auditors, Mr. Leather and Mr. Hersey.

Hon. Sec., Mr. W. H. Bennett.

Mr. ANDERSON said he was much obliged for the honour intended to be conferred upon him, but would prefer to retire from the vice-presidentship in favour of the gentleman next highest on the ballot.

Mr. GODDARD said he thought the present was the right time to take into consideration the afflictive dispensation which had deprived the association of the presence of Mr. Esson at these meetings, and, believing that it would be acceptable to the members, he would move the following resolution—"That the chairman be requested to convey to Mr. Esson our expression of sympathy and of condolence with him and his family under their present affliction."

Mr. WHITE (Birmingham) seconded the motion, which was put, and carried unanimously.

The PRESIDENT said the meeting would now proceed to the election of extra-ordinary members. The committee had considered the subject, and one of their number would make a few remarks upon it.

Mr. ANDERSON said, since the meeting of yesterday, when this matter was adjourned, the committee had considered it very carefully. The rule No. 4 of the association applied to the admission of extra-ordinary members who were declared to be persons taking an interest in matters connected with gas-works. That phrase had always been understood to mean gentlemen who were intellectually interested, and not merely interested in a commercial point of view. To some extent the rule had been broken through, owing rather to the peculiar position of some gentlemen, who happened to be connected both with gas-works and with manufacturing and business operations which brought them in contact with gas managers. The committee felt that while the rule No. 4 stood in its present form it would be unfair to exclude others somewhat similarly situated who might now apply for admission. At the same time they were quite aware of the strong feeling which had been often expressed, that the association ought not to allow extra-ordinary members to come in for the mere purpose of advancing their monetary interests. They were desirous to respond to that feeling, and, in order to reconcile their past conduct with their present desire, they suggested an alteration of a portion of the rule. Personally they could have no feeling against the introduction of any number of gas apparatus manufacturers, but there was an objection to their taking part in the proceedings, which, as the rule now stood, they could do. It was therefore proposed to add to the rule these words, "but they shall not be allowed to vote or take part in the proceedings unless requested to do so by the chair." The committee, in making this proposi ion, felt that many gentlemen might come in as extra-ordinary members who possessed a large amount of information, and would be able to interest the association and benefit it by the result of their experience, and they believed that these gentlemen would not take umbrage at the limitation thus put upon them.

Mr. C. WOODALL seconded the motion.

Mr. BROADHEAD asked whether the rule could be altered without notice.

The PRESIDENT said it could.

Mr. WARNER objected that the proposed alteration was a reflection upon those gentlemen who now sought admission. They ought to be elected on the same terms as those already admitted, and the rule altered afterwards. He moved as an amendment—"That these gentlemen be admitted on the present rules of the association."

Mr. DOUGLAS seconded the amendment.

Mr. ANDERSON said the committee had considered that view of the question, and they had come to the conclusion that if the rule was ever to be altered it was better to do it at once.

The PRESIDENT said he did not think the gentlemen who were candidates for extra-ordinary membership at the present moment would consider the alteration cast any reflection upon them. It was a very important matter, and, as he understood from the conversation on the previous day, it was apprehended that under the existing rule the extra-ordinary members might in time come to swamp the ordinary members of the association.

Mr. ANDERSON thought it would be more disrespectful to admit the candidates now proposed, and to alter the rule afterwards.

Mr. CATHELS, on the other hand, thought the alteration would be a reflection upon them, and he could not at all understand what objection there was to the introduction of extra-ordinary members. Many of them were better acquainted with their special subjects of study than the ordinary members of the association, and their admission would add to the common stock of experience. He was at a loss to know what questions were likely to arise in which the votes of extra-ordinary members would peril the interests of the association.

Mr. Jones said at the present time there were nine extra-ordinary members, who were elected on the understanding that they would have the right to take part in the proceedings at the meetings. The association had received £5 from each of them, and it would be an act of injustice to deprive them, by an alteration of the rules, of one of the privileges, on the faith of obtaining which they became members. He suggested to the committee that it would be better to withdraw the resolution.

Mr. John Aird, as an extra-ordinary member, said his own feeling was that to deprive this class of members of the right to take part in the proceedings would be to take away the pleasure they had in being connected with the association. It was entirely in the hands of the members to refuse to elect persons whom they considered not worthy to be admitted, or who were without sufficient discretion to act as gentlemen when elected.

After some further conversation, in which Mr. Irons, Mr. Goddard, Mr. Methven, Mr. Craven, and others took part, the amendment was withdrawn, and the following substituted on the motion of Mr. Warner, seconded by Mr. Douglas—"That the applicants who have now been nominated for extra-ordinary membership be elected according to the present rule of the association."

Mr. Simpson said he had been a member from the commencement, and he could vouch for the great intelligence and energy which the extra-ordinary members had displayed. Until last year he was on the committee, and knew that no inconvenience had ever been sustained by them. He thought, therefore, it would be doing a great wrong if, without any excuse, they now limited the privileges of that class of members.

Mr. H. P. Stephenson objected to the amendment only because it proposed to elect the extra-ordinary members on the present occasion hodge-podge. He thought it would be better to alter the terms of it, and simply say—"That the original rule be adhered to," and then proceed to the election accordingly.

The amendment was put and carried.

The following gentlemen were then elected extra-ordinary members of the association:—

Williams, F.	Mark Lane, London.
Pollard, J. W.	Mincing Lane, London.
Robertson, G.	Leadenhall Street, London.
Fraser, W.	Inverkeithing.
Donaldson, A.	Edinburgh.
Horsley, C.	Wharf Road, London.
Payne, G.	Millwall, London.
Thorneloe	London Wall, London.
Waller, G.	Holland Street, London.

Mr. Methven proposed an alteration in rule 7, to the effect that the presidents, past presidents, and treasurers shall be *ex officio* members of the committee.

Mr. Arnott seconded the motion.

Mr. Irons objected, because he thought the increase of *ex officio* members would lead to the transfer of the business of the association from the hands of the representative members of the committee.

Mr. H. P. Stephenson approved of the proposed alteration, because it was desirable to have gentlemen connected with the management who had some practical knowledge of the working of the association.

Mr. Garnett said in municipal government it was found a very wholesome rule to continue the ex-mayor as a magistrate for the twelve months succeeding his tenure of office, as it gave the corporation the benefit of the experience he had obtained. But because a man had once attained the highest honour which it was in the power of his follow-members to confer, to make him a member of the administration for ever was not likely to work well. It would remove the difficulty, and perhaps meet the view of the proposer of the motion, to say, "the president, &c., for the past year."

Mr. Methven accepted the alteration.

Mr. A. Williams objected to any alteration of the rules without due notice.

The President ruled that notice must be given.

Mr. SIMPSON proposed an amendment in rule 37.

The PRESIDENT said the committee would consider the subject, and bring it forward at the next meeting.

On the motion of Mr. LIVESEY, seconded by Mr. GODDARD, thanks were voted to the scrutineers for their services, and Mr. PLUMB acknowledged the compliment.

Mr. DOUGLAS moved, and Mr. HUNTER seconded, a resolution, which was adopted, giving the committee on the benevolent fund and Sunday labour questions power to increase their number to nine, of whom three are to form a quorum.

On the motion of Mr. C. WOODALL, seconded by Mr. E. WHITE, it was resolved—"That the most cordial thanks of this meeting be presented to the gentlemen who have so kindly furnished papers and drawings for this session."

A conversation then arose with reference to the place for holding the next meeting.

Mr. JONES, of Dover, proposed Dublin, and expressed a hope that the members of the North British Association would attend the meeting. He also suggested that the committee should send an invitation to our American cousins to favour the association with a visit.

Mr. WOOD, of Bury, seconded the motion.

Mr. BROADHEAD brought forward his usual motion in favour of Leeds, in which he was seconded by Mr. HOLMES.

Mr. GODDARD, looking to the marked success which had always attended the sittings in the metropolis, moved—"That the next meeting be held in London."

Mr. SLIP, of Redhill, seconded the motion, and on a show of hands there appeared—

For Dublin	47
,, Leeds	6
,, London	37

It was, therefore, decided to hold the next sittings in Dublin.

Mr. M'NIE moved—"That the cordial thanks of the meeting be given to the committee for the manner in which they have conducted the business of the association during the past year."

Mr. WARNER seconded the motion, and at the same time acknowledged the vote of thanks which had just been presented to the contributors of papers.

The motion was very cordially adopted, and Mr. LIVESEY acknowledged the vote.

On the motion of Mr. SIMPSON, seconded by Mr. CRAVEN, thanks were given to the treasurer for his past services.

Mr. W. C. PARKINSON, on behalf of the visitors, tendered thanks to the association for the opportunity afforded them of being present during the session.

Mr. CATHELS moved, and Mr. WARNER seconded, a vote of thanks to the council of the Society of Arts for granting the use of the rooms for this meeting, and also to Mr. P. Le Neve Foster, their secretary, for the courtesy shown by him in connexionwith the arrangements.

Mr. DUNNING moved, and Mr. GODDARD seconded, a vote of thanks to Mr. Ohren for his admirable inaugural address, and for the ability with which he had presided over the business of the sittings.

The motion having been unanimously adopted,

Mr. OHREN said: Gentlemen, I thank you very much for this cordial recognition of my desire and endeavour to serve the association. I assure you it has been a great pleasure to me not only to prepare the address which I had the honour to read, but also to preside over the interesting and important proceedings at these meetings. If in doing so I have given you satisfaction I am abundantly rewarded for any labour it has occasioned me.

Mr. WOODALL moved, and Mr. WHITE seconded, a vote of thanks to Mr. W. H. Bennett, the honorary secretary of the association, for the very careful and laborious attention which he had bestowed upon the duties of his office during the past year.

The motion was unanimously adopted.

Mr. BENNETT: Gentlemen, I am really very much obliged to you for the kind expression of your approval of the manner in which I have endeavoured to discharge my duties. I am pleased to find that the association is progressing so rapidly, both in numbers and in usefulness, and it is an additional pleasure that I am permitted to contribute, as far as I am able, to promote its efficiency.

The proceedings then terminated.

THURSDAY, JUNE 9.

This morning the members and friends, to the number of about 180, proceeded by special steamer to visit the new gas-works of the Chartered Company, in course of erection at Beckton. On their arrival they were met by Mr. F. J. Evans, the company's engineer-in-chief, from whose designs and under whose superintendence the works are being built, who most courteously conducted them through every department, and exhibited the series of elaborate drawings prepared by him in connexion with this great undertaking. The inspection afforded the highest satisfaction, and Mr. Evans afterwards entertained the party to a substantial luncheon, to which full justice was done. The health of Mr. Evans and "Prosperity to the Chartered Gas Company" were subsequently drunk with enthusiasm. On the voyage down the river the boat halted at Messrs. Brown and Co.'s wharf, Deptford, where an opportunity was afforded the members to witness the performance of Burleigh's patent steam and pneumatic rock-drilling machine, and on the return voyage a visit was paid to the iron-works of Messrs. S. Cutler and Sons, and the sulphate of ammonia works belonging to Messrs. Simpson, Payne, and Co., at Millwall.

APPENDIX.

The following papers presented at the meeting of the Association were, for want of time, taken as read, and were ordered to be entered on the "Transactions":—

ON THE PRACTICAL RESULTS OF DIFFERENT METHODS OF PURIFYING GAS, AS SHOWN IN THE REPORTS OF THE DAILY TESTINGS OF GAS SUPPLIED TO THE METROPOLIS DURING THE LAST ELEVEN MONTHS.

By H. LETHEBY, M.B., M A., &c.,

Professor of Chemistry in the College of the London Hospital, and Chief Gas Examiner for the Metropolis.

Among the many advantages of a constant and systematic examination of the illuminating power and chemical quality of the gas supplied to the public, is the opportunity which it affords of contrasting the results of different methods of gas manufacture. This is remarkably shown in the reports of the daily testings of the gas supplied to the several testing-places appointed under the provisions of the City of London and Chartered Gas Acts of 1868; and I have classified the facts in the accompanying table, under the headings of illuminating power and chemical purity, the latter having reference to the proportions of sulphur and ammonia in the gas of each of the companies.

The average illuminating power of the Chartered gas during the last eleven months has been 16·29 standard sperm candles at Leadenhall Street, 16·26 at Gray's Inn Lane, and 16·32 at Arundel Street, Haymarket, making a general average of 16·29 candles for all the stations of the Chartered Company. The power of the gas of the City Company at Cannon Street station has been 16·75 candles, and of the Great Central Company, at Friendly Place, it has been 17·13 candles.

As regards cannel gas, the average illuminating power of the gas of the Chartered Company has been 23 standard sperm candles, and of the City of London Company it has been 25·98 candles.

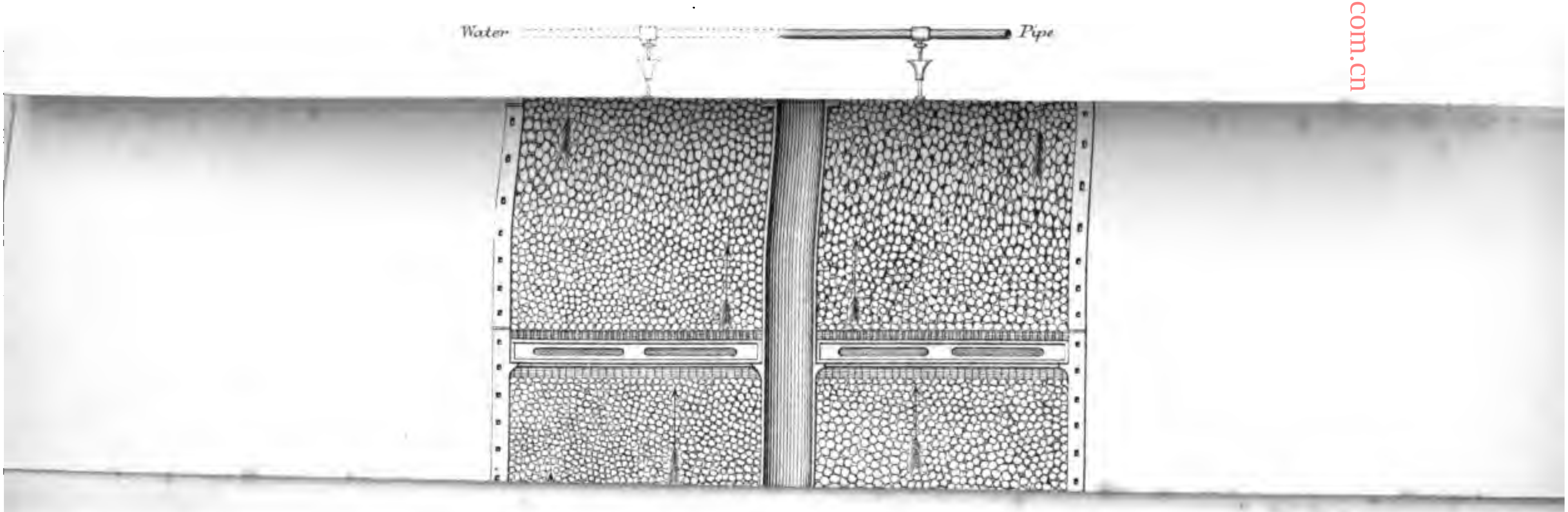
The average proportions of sulphur in the common gas have been as follows:—21·59 grains per 100 cubic feet of the Chartered gas at Leadenhall Street, 25·15 grains at Gray's Inn Lane, and 28·47 grains at Arundel Street; the mean amount in the Chartered gas at all these places being 25·07 grains per 100 cubic feet. In the City of London gas it has averaged 19·75 grains, and in the Great Central gas it has been 12·51 grains. The sulphur of the cannel gas has averaged 24·59 grains in that of the Chartered Company, and 10·19 grains in that of the City Company.

The average quantity of ammonia in the common gas of the Chartered Company has been 2·82 grains per 100 feet at Gray's Inn Lane, 3·1 grains at Leadenhall Street, and 4·08 grains at Arundel Street; the mean amount at all these places having been 3·34 grains. The common gas supplied by the City Company has been always quite free from ammonia, while that of the Great Central Company has averaged only 0·73 of a grain of ammonia per 100 cubic feet.

The cannel gas of the City Company has also been at all times free from ammonia, the proportion in the Chartered Company having been 2·53 grains per 100 feet.

It is right to observe that the several testing-stations at which the gas of the several companies is examined are all as near as may be to 1000 yards from the works; and it will be remarked that the quarterly averages of the impurities are nearly the same in each particular case, showing unquestionably that

MANN'S SCRUBBER.



the results are entirely due to different methods of purification; and this is the practical point to which I am anxious to direct your attention.

I am not well acquainted with the details of the system of purification adopted by the Chartered Company at their several stations, but it is manifest that the condensing power is defective, and that the means of removing sulphur is not as perfect as it might be.

At the works of the City Company, where the whole of the ammonia is entirely removed from the gas, and where the proportion of sulphur is less than 20 grains per 100 cubic feet, the gas is purified by means of five large scrubbers, the invention of their talented engineer, Mr. Mann. Each scrubber presents a large surface of moistened coke for the absorption of ammoniacal compounds. Water is delivered at the top of the scrubbers from a series of revolving jets, which discharge the water at the rate of 1 gallon for every 1000 feet of gas, on to a horizontal revolving tray covered with birchwood, and thereby distributed evenly over the coke; and as the gas rises against the downward flow of water, it is deprived of all its ammonia, and of much sulphuretted hydrogen, so that the liquor leaves the scrubber of a strength of 14 ounces of strong sulphuric acid. In this way the amount of ammoniacal liquor has been increased from about 9 gallons per ton of coals to 22 gallons, the average strength of it as it leaves the works being equal to 10 ounces of commercial acid per gallon of liquor. Mr. Mann has given a full description of the apparatus in the JOURNAL OF GAS LIGHTING for the 31st of March, 1868.* After leaving the scrubber, the gas is purified by means of lime and oxide of iron.

At the Great Central Gas-Works, which are under the management of Mr. Harris, the ammonia is removed from the gas by a series of three large scrubbers, the first two being charged with a stream of ammoniacal liquor, and the third with water. The gas is then passed through a series of dry lime purifiers, which present a very large surface for absorption, and the lime is purposely left in the purifiers after it has become foul, and until a good deal of the sulphuretted hydrogen first absorbed is displaced by carbonic acid. In this manner the natural affinity of sulphide of calcium for bisulphide of carbon is permitted to act, and much sulphur, in this objectionable form, is retained. Leaving the lime purifiers, the gas, which is still charged with more or less of sulphuretted hydrogen, is passed through oxide of iron.

These operations, especially at the Great Central works, are most instructive, for they show that with proper management a large yield of ammoniacal liquor of good commercial strength may be ensured. At the City works it amounts, as I have said, to 22 gallons, of 10 ounces strength, per ton of coals, and at the Great Central works it is 20 gallons, of from 10 to 11 ounces strength, per ton. When I had the honour of lecturing to this society at its meeting at Birmingham, in 1865, I dwelt particularly on the importance of removing all trace of ammonia from gas before it is delivered to the public, and I instanced the works of the Birmingham and Staffordshire Gas Company, at Saltley, where, by the excellent management of the engineer, Mr. Young, the amount of liquor obtained per ton of Staveley coal is 44 gallons of from 7 to 8 ounces strength. This is effected by copious washing of the gas with water and weak liquor, without injury to the illuminating power, and the commercial result is a profit of more than £2000 per annum above the ordinary return for liquor.

The chemical effect of these operations is very intelligible, for sulphide of ammonium and sulphide of calcium are both endowed with the power of combining with bisulphide of carbon, and therefore of absorbing and fixing this objectionable impurity. It is manifestly, then, of the greatest importance that coal gas should be kept in contact with these substances as long as possible during the process of purification. In the case of ammoniacal liquor, it should be effected by a great length of pipe from the hydraulic main to the condenser, and the condensation of tar and liquor should be perfect. The gas should then be scrubbed with liquor, so as to bring the liquor to not less than 14 or 15 ounces strength, and Mr. Mann's double scrubber is excellently well suited for this purpose. In the case of sulphide of calcium, it should be permitted to act for some time after the lime has become foul, for it is in this condition that it is most effective, and a lime purifier should not be changed until the sulphuretted hydrogen of the foul lime is largely displaced by the carbonic acid of the raw gas. If it be necessary to use oxide of iron, on account of the difficulty of disposing of foul lime, it should be used after the lime.

Looking at the results of the testings in London, it would seem that gas purified in an ordinary way contains about 25 grains of sulphur, and from 3 to 4 grains of ammonia per 100 cubic feet of gas, but that if pains are taken to remove all the ammonia by a process which keeps the sulphide of ammonium in contact with the gas for some time, the proportion of sulphur declines to less than 20 grains per 100 cubic feet, in the case of common gas, and to about 10 grains in cannel gas; and that if, as at the Great Central works, sulphide of calcium, or foul lime, is also used as an agent of purification, the proportion of sulphur is reduced to 12·5 grains per 100 feet, as was the proportion in gas in the old days of lime purification.

It will be noted that these processes of purification are effected without loss of illuminating power, for the only hydrocarbon which is likely to be removed from the gas with the ammonia is naphthaline, and this is certainly better out of the gas than in it; wherever, in fact, ammonia is thoroughly removed from coal gas, there is no complaint of the mischief arising from the deposit of naphthaline. At the Birmingham and Staffordshire works, for example, this impurity is entirely unknown, and so also is the corrosive action of ammonia on the copper fittings of meters and service-pipes.

It has occurred to me that these facts would have a practical as well as a commercial interest for you.

Average Illuminating Power and Chemical Purity of the Gas supplied to the Metropolis by the Chartered, the City of London, and the Great Central Companies during the last Eleven Months.

Illuminating Power in Standard Sperm Candles.

		Quarter ending Sep., 1869.	Quarter ending Dec., 1869.	Quarter ending Mar., 1870.	April and May, 1870.	Entire Year.
Chartered common gas.	Leadenhall Street .	14·96	14·78	17·84	17·60	16·29
	Gray's Inn Lane .	15·63	15·69	16·70	17·04	16·26
	Arundel Street. .	15·47	14·98	17·60	17·22	16·32
Average of Chartered common gas		15·35	15·15	17·38	17·19	16·29
Ditto City of London ditto . . .		16·03	16·26	16·95	17·77	16·75
Ditto Great Central ditto . . .		15·69	17·55	17·46	17·82	17·13
City of London cannel gas . . .		24·58	25·07	26·09	28·19	25·98
Chartered ditto		21·66	21·71	24·12	24·51	23·00

Grains of Sulphur per 100 Cubic Feet.

		Quarter ending Sep., 1869.	Quarter ending Dec., 1869.	Quarter ending Mar., 1870.	April and May, 1870.	Entire Year.
Chartered common gas.	Leadenhall Street .	17·35	23·73	22·47	22·83	21·59
	Gray's Inn Lane .	25·97	24·46	24·43	25·75	25·15
	Arundel Street. .	25·44	29·94	29·31	29·21	28·47
Average of Chartered common gas		22·92	26·04	25·40	25·93	25·07
Ditto City of London ditto . . .		19·75	19·71	19·99	19·56	19·75
Ditto Great Central ditto . . .		12·71	12·47	14·19	10·66	12·51
City of London cannel gas . . .		8·63	10·29	9·54	12·31	10·19
Chartered ditto		24·10	23·47	25·88	24·93	24·59

* Mr. Mann has since proposed that the scrubber should be 48 feet in height instead of 24, and that the water should be delivered at the rate of half a gallon per 1000 cubic feet of gas instead of 1 gallon. By this arrangement, which he calls a double scrubber, the liquor will acquire a maximum strength, and will thus be in the best condition to remove, by absorption and chemical combination, the bisulphide of carbon from the gas. This, in my opinion, is a very effective arrangement, and will prove of great service in the purification of gas, for it is strictly in accordance with the principles of both theory and practice.

Grains of Ammonia per 100 Cubic Feet.

	Quarter ending Sep., 1869.	Quarter ending Dec., 1869.	Quarter ending Mar., 1870.	April and May, 1870.	Entire Year.
Chartered common gas. Leadenhall Street	3·42	3·84	1·48	3·66	3·10
Chartered common gas. Gray's Inn Lane	None.	6·73	0·86	3 68	2·82
Chartered common gas. Arundel Street	6·94	3·36	3·28	2·80	4·09
Average of Chartered common gas	3·45	4·64	1·87	3 38	3·34
Ditto City of London ditto	None.	None.	None.	None.	None.
Ditto Great Central ditto	1·31	1·01	0 21	0·38	0·73
City of London cannel gas	None.	None.	None.	None.	None.
Chartered ditto	3·30	2·68	2·10	2·04	2 53

Note.—Prior to the 1st of January, 1870, the illuminating power of the common gas, as prescribed in the City of London Gas Act, 1868, was 14 standard sperm candles. but since then it has been 16 candles.

REMARKS ON THE BURNERS USED IN TESTING THE ILLUMINATING POWER OF COAL GAS.

By Chas. Heisch, F.C.S.,

Lecturer on Chemistry at the Middlesex Hospital, and Gas Examiner to the Corporation of the City of London.

A slight error has been made in the title which has been published of this paper, which makes it more pretentious than I intended; it should have been as above. I must apologize for the somewhat crude state of these remarks, but when I tell you that, owing to having been obliged to move my laboratory, all my gas apparatus has been for some months in the hands of one of those necessary evils, an instrument maker, and that instead of receiving it as promised, two months ago, I only got it last week. I feel sure you will sympathise with my condition, and pardon my shortcomings.

The question, What should be the definition of a test-burner? has always been a vexed one; and, as far as I know, all the so-called definitions yet given have been so vague that burners of very different kinds might be and have been included under them. Putting aside altogether the commercial view of the subject, as in discussions of this kind I think we are bound to do, there are two points on which I think we shall be all agreed—1st, that the burner should be so defined as to be unmistakable; 2nd, that all experiments made with it should, if possible, be strictly comparable, no matter what be the quality of the gas. The question of whether or not a test-burner is fit for the consumer's use is, I think, of very small importance abstractedly. If it fulfil the purpose of a test-burner well, its relations to the various burners used by consumers will soon be made out. Now, if we turn for a few moments to the burners which have at different times been used as test-burners, we shall see how very far they are from fulfilling either of the conditions specified above. Here is a burner (Platow's Patent Argand) which was some years ago proposed, and by some used, as a test-burner. It is an Argand with 15 holes, and burns 5 cubic feet of gas well with a 7-inch chimney, so it corresponds with the old definition of a test-burner, but it was objected to on the ground that it had a cone; nevertheless it is a very good burner. In the days of which I am now speaking gas was not in London what it is now, or was not supposed to be, and this burner gave a light of something over 12 candles. Then came Dr. Letheby's test-burner, also an Argand with 15 holes, and this same gas became of 14-candle power; and last year, the old definition having been abandoned, we had Mr. Sugg's London Argand, and the gas became 16-candle gas. In fact, when the illuminating power of a gas was stated it conveyed no real meaning at all. But going a step further we come to a still more extraordinary state of things. At the beginning of the present year certain companies were bound to increase the illuminating power of their gas, but when they did so this same London Argand would not properly burn 5 feet an hour, and the gas was reported sometimes no better, and sometimes worse than it had been. A chimney of larger diameter was then used, and finally one of increased length also; but even thus the gas was imperfectly burnt, and its real illuminating power was much under-stated. All this time cannel gas had been tested with a bat's-wing burner, and it occurred to me to try the ordinary gas with the same burner; and in the table appended you have the results, which are very instructive, as showing the varying relation in the light given by these two burners with gas of different qualities. When the gas is of low quality, the Argand is very much higher; where it is of high quality, the bat's-wing gives the best results. In fact, with the London Argand, with a chimney of 2 inches diameter and 7 inches long, we may have two 16-candle gases, one really about 2 candles better than the other. The are easily distinguished, as the flame of one is much whiter than that of the candles, whilst the flame of the other is quite yellow as compared with them. In none of these experiments the gas tailed over the chimney. We have, then, the following different kinds of gas, all called 16 candles when tested by the London Argand in its different states of development:—

1. The 14-candle gas of the Letheby burner, which becomes 16-candle when burnt in the London with a chimney 1¾ inch wide and 6 inches long, and burns well.

2. A gas too rich for this, but which burns well in the same burner, with a chimney 2 inches diameter and 6 inches long, but is still only 16-candle gas.

3. A still richer gas, which, with the same burner, requires a chimney 2 inches diameter and 7 inches long, but is again only 16-candle gas.

We will say nothing at present of the yellow burning gas, which is almost too rich for this arrangement, but which is another specimen of 16-candle gas.

Now, if we test the three kinds of gas just spoken of by a good bat's-wing burner, even though it be constructed with no special precautions, we find that they have about the following relations—13, 16, and 18 candles, which surely expresses much more nearly the real relative values of the gas.

If we now go a step backward and try the relation which exists between the present test-burner, with its long chimney, burning the gas at present supplied, and the older test-burners, we find that the Letheby and Platow's have, to a certain extent, changed places, the lights being respectively—London Argand, 17; Platow, 16·7; Letheby, 15·1, as a mean of many experiments.

Under these circumstances, it seems to me that a gas manager has no choice left but to make his gas to the test-burner, rather than take account of its real quality.

Having thus brought prominently before you the very unsatisfactory state of the question at present, I would make a few remarks on what I believe to be the direction in which to seek for a remedy.

Were it possible to establish any simple relation between the quantity of gas burnt and the light given the problem would be much simplified. If we strictly defined all the dimensions, &c., of a burner, and then burned through it just that amount of gas that would pass at a given pressure, we should be able to calculate to a uniform quantity. But at present no such simple relation has been made out.

All of you doubtless read a paper, which was much extolled before its publication, by Professor Silliman, in which he announced that the light given by gas varied as the square of the consumption. Putting on one side some very gross errors in principle, which one would hope were the printer's rather than the professor's, the results quoted by no means bore out the theory; but as the experiments contained one fundamental source of error—viz, using the same burner for all consumptions, which is manifestly not burning the gas under comparable conditions, I thought it worth while to make a series of experiments in which this error should be eliminated. These were made with Sugg's lava bat's-wing burners, as their conditions are more easy to ascertain than those of Argand's. One burner having been fixed on as the standard, it was made to burn 5 feet per hour. All the others were then made to burn the amount of gas that passed them at the same pressure, and the result was that the light calculated from the square of the consumption was not nearer the truth than that from the direct ratio; in fact, when about 4·5 feet were burnt, the one was just about as much too high as the other was too low. Either might be represented by a curve, but it would not be one which could readily be applied in practice. The suggestions I would venture to make are these:—

1. No burner should be admitted as a test-burner in which the conditions of pressure, &c., under which the gas is burned are not known.

2. (My next suggestion will, I know, be received by many as rank heresy; but we are here to discuss things freely in the search for truth.) That, considering the almost imperceptible differences in the various parts of an Argand burner, or its chimney, which make a material difference in the results of the testing, Argand burners should no longer be used as test-burners. I am quite aware that by giving up these burners we should give up the advantage of steadiness, and perhaps some others; but, if we obtain even an approach to uniformity, I, for one, would willingly do so.

3. That a series of bat's-wing burners should be made, the external and internal diameters of which should be precisely identical; the material of which they are constructed and its thickness be identical; the depth of the slot in all identical; the width of the slot so varied that one may be readily selected which will deliver 5 cubic feet of the gas to be tested under a given pressure, or so near it as that the difference shall be of no practical importance. I may mention that I have found by experiment that a difference of ·03 pressure in bat's-wing burners, otherwise alike, makes no appreciable difference in the light they produce. I had hoped to lay before the meeting some experimental proofs that with burners thus constructed strictly comparable results might be obtained with gases of almost any composition; but owing to the circumstances before spoken of, I have been interrupted in the middle of the experiments, and must hope to detail the results at a future time. Meanwhile, if I have succeded in calling the attention of those most interested fairly to the subject, or have offered one suggestion of practical use, my purpose will have been answered.

The following table shows the relation of the illuminating power of various qualities of gas, as determined by Sugg's London Argand with chimney 2 inches diameter and 7 inches long, and Sugg's No. 7 Lava bat's-wing, each burning 5 feet per hour:—

Bat's-wing in Candles.	London Argand in Candles.	Bat's-wing in Candles.	London Argand in Candles.
12·1	15·6	18.0	16·4
16·3	16 9	18·0	16·6
16·6	16·2	18·1	16·8
16·7	16·4	18·1	17·1
16·7	16·7	18·2	17·0
16·8	16·4	18·2	17·0
17·1	16 3	18·3	16·7
17·2	16·6	18·3	16 7
17·2	16 6	18·4	16·7
17 3	17 3	18·6	16·5
17·4	16·7	18·6	16·3
17·5	17·4	18·9	17·1
17·6	16·0	19·0	17·4
17·8	16·8	19 2	18 2
17·8	16·3	19·3	17 8
17·8	17·2	19·3	17·4
17 8	17·2	19·6	18·0
17·9	16·9		

ON ARTIFICIAL ALIZARINE.

By W. T. Fewtrell, F.C.S.

The short paper I have the honour to submit to the association is merely intended as a sort of appendix to the exhaustive lecture "On the Utilization of the Waste Products of the Manufacture of Gas," delivered by Dr. Letheby to the association at Nottingham, in 1867, and it describes the only important addition made to the industry of gas products since the date of that lecture.

Natural alizarine, as no doubt all here well know, is a colouring matter derived from the madder root. Chemists have differed a good deal as to the exact composition of alizarine; but the researches made with the artificial product leave no doubt that its constitution is accurately expressed by the formula

$$C_{14} H_8 O_4,$$

which is very nearly the same as that given some years ago by Dr. Schunck, of Manchester.

Now, on referring to the elaborate table of constituents of coal tar given in Dr. Letheby's lecture, the reader will see among the neutral bodies the name of anthracene, which, according to the chemical notation now in use, has the formula

$$C_{14} H_{10},$$

and, therefore, anthracene differs from alizarine only by wanting four atoms of oxygen, and containing an excess of two atoms of hydrogen.

In the distillation of coal tar, anthracene passes over with the heavy oils. The amount of it present in the tar is not well known. The quantity is generally assumed to be very small; but Mr. Perkin states that, from experiments he has made, he has been led to believe that the tar contains considerable quantities of anthracene.

In a table given by Dr. Roscoe, the products obtained from 100 tons of tar are set down as follows. The quantities are given as the average results of a series of experiments carefully made by a large tar distiller. One hundred tons of tar yield on distillation—

	Naphtha.	Light Oils and Carbolic Acid.	Heavy Oils, Naphthaline, Anthracene.	Pitch.	Water and Loss.
1	3·0	1·5	35·0	50	10·5
2	3·0	0·8	25·0	60	12·2

Tar distillers have, as yet, had but little experience in the separation of anthracene, and, as I have said, the amount contained in the tar is not well known. We may be certain, however, that it is a variable quantity, the amount of it produced depending upon a variety of circumstances, among others, the nature of the coals used, and the heat at which they are distilled.

In one experiment mentioned by Dr. Roscoe, the amount obtained from one ton of tar was only 0·63 of a ton of anthracene, which must not, however, be supposed to be all there was in the tar. Much, no doubt, was left in the pitch.

The circumstance that led Graebe and Liebermann, the first producers of artificial alizarine, to look to anthracene as a source of that body, was the fact they discovered, that the destructive distillation of natural alizarine yielded anthracene. The suggestion was obvious that alizarine might possibly be produced from a body so nearly allied to it in composition. Curiously enough the first step towards this transformation had been made several years ago (in 1861) by Dr. Anderson, of Glasgow, who, by treating anthracene with nitric acid, produced an oxygenated compound of that body, to which he gave the name oxyanthracene, but which now, in accordance with more modern chemical ideas on the classification of bodies, is called anthraquinone.

The composition of this body is expressed by the formula

$$C_{14} H_8 O_2,$$

which shows that we have gone so far towards alizarine as the abstraction of the two atoms of hydrogen, and the addition of two of the four necessary atoms of oxygen. To complete the transformation another process is required, which results in chemical changes of some complexity. I shall pass over the method pursued by Graebe and Liebermann, the original discoverers, and only mention briefly that pursued by Mr. W. H. Perkin, F.R.S., to whom belongs the merit of having devised a process so easy and cheap as to have already made artificial alizarine an industrial product, and not a chemical curiosity. The process adopted by Mr. Perkin is, first of all, to treat the anthraquinone with strong sulphuric acid, by which means a sulpho-acid—disulpho-anthraquinonic acid—is produced. When this substance is heated with potash it is split up, and forms sulphite of potash, and a compound of alizarine and potash; and on decomposing this latter compound with an acid a bright yellow precipitate is obtained, which is the desired alizarine nearly in a state of purity. The broad result of the chemical changes occurring in these latter stages of the process is the addition of two atoms of oxygen to the anthraquinone; but, strictly speaking, this addition is effected by the substitution of two atoms of hydroxyl (H O) in the potash for two atoms of the hydrogen in the anthraquinone.

The foregoing, I need hardly say, is only a description of the chemical changes by which the transformation of the anthracene into alizarine are brought about. The manufacturing details of the process are naturally kept secret. In describing the changes, I have purposely avoided the somewhat abstruse chemical considerations involved in the scientific elucidation of the processes, and have preferred a broad statement of the facts, such as I have supposed would be most intelligible to, and possessed most interest for, my hearers.

A comparison of the physical and chemical properties of the natural and artificially produced alizarine leaves no doubt that the two substances are absolutely identical. They crystallize in the same form, they behave in exactly the same way with reagents, and they have the same action on light.

Every discovery of this kind naturally enhances the value of gas products, and therefore possesses a special interest to gas managers. The time may come when it will be of as much importance to conduct the manufacture of gas with a view to the quality of tar as to the quality of the gas produced. In the present case there is a peculiar interest in the fact of one of the tar products hitherto considered of little value, and condemned with ignoble associates to the humble duty of lubricrating machinery, being now made the starting-point for the production of one of the most beautiful dyes that gladden our sight.

The discovery I have described is probably destined to produce as great changes in the madder trade as the aniline dyes have made in the cochineal and other trades. Up to the present time we have imported and used madder in this country at the rate of about a million sterling a year. But as the artificial replaces the natural dye, it is only reasonable to believe that some part of this million will remain at home for the benefit of gas producers.

British Association of Gas Managers.

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,, H. Cockey	Frome	1	1	0
,, W. H. Chambers	Lowestoft	1	1	0
,, T. Wilkinson	Drighlington	1	1	0
,, J. R. Frith	Runcorn	0	10	6
,, J. T. Hall	Liverpool	1	1	0
,, J. Paterson	Warrington	1	1	0
,, J. Young	Stoke-on-Trent	1	1	0
,, W. J. Warner	South Shields	0	10	6
,, W. Stout	Boston	0	10	6
,, T. H. Bouttell	Sleaford	0	10	6
Carried forward		£20	8	6

		Brought forward	£20	8	6
Mr.	M. Broadhead	Great Grimsby	1	1	0
,,	E. Goddard	Ipswich	1	1	0
,,	T. Andrews	Swansea	1	1	0
,,	A. F. Phillips	St. Albans	1	1	0
,,	Jos. Wood	Bury	1	1	0
,,	H. G. Crowe	Wellington	0	10	6
,,	D. Clarke	Sunderland	0	10	6
,,	T. Varley	Colne	1	1	0
,,	W. Ford	Stockton-on-Tees	0	10	6
,,	W. Miles	Clitheroe	0	10	6
,,	T. Miles	Rochdale	0	10	6
,,	W. Romans	London	1	1	0
,,	J. R. Smith	Padiham	0	10	6
,,	J. Rowe	Wrexham	0	10	6
,,	C. Copland, jun.	Hull	0	10	6
,,	H. Veevers	Bolton	1	1	0
,,	W. T. Walker	Donnington	1	1	0
,,	J. Johnson	London	1	1	0
,,	T. W. R. White	Sherborne	0	10	6
,,	W. C. Rafarel	Barnstaple	1	1	0
,,	T. Green	Heckmondwike	0	10	6
,,	J. Burgess	Huddersfield	0	10	6
,,	J. Barras	Rotherham	0	10	6
,,	W. Fleming	Lancaster	0	10	6
,,	W. Smith, jun.	Hyde	0	10	6
,,	J. H. Cox	Sunderland	1	1	0
,,	J. Hepworth	Brighouse	0	10	6
,,	J. Lacock	Keighley	0	10	6
,,	J. Niven	Clayton	0	10	6
,,	W. Wright	Shipley	0	10	6
,,	W. R. Cooper	Banbury	0	10	6
,,	A. Potter	Newcastle	1	1	0
,,	G. A. Allan	Newcastle	1	1	0
,,	W. J. Larkum	Ripon	1	1	0
,,	J. Macnie	Londonderry	1	1	0
,,	T. Melling	Rainhill	1	1	0
,,	J. Marsland	Enniskillen	1	1	0
,,	S. Hunter	Louth	0	10	6
,,	T. Newbigging	Bacup	0	10	6
,,	H. Woodall	Longport	0	10	6
,,	E. H. Harris	Wallasey	0	10	6
,,	D. Helps	Bath	0	10	6
,,	Geo. Anderson	London	1	1	0
,,	J. Tindall	Wakefield	0	10	6
,,	D. Burton	Ossett	0	10	6
,,	W. Prescott	Prescot	1	1	0
,,	P. H. Wilkinson	Harrogate	0	10	6
,,	R. H. Jones	Dover	1	1	0
,,	J. Braddock	Droylsden	0	10	6
,,	J. Fingland	Todmorden	0	10	6
,,	C. A. Craven	Dewsbury	0	10	6
,,	W. C. Holmes	Huddersfield	1	1	0
,,	O. Brothers, jun.	Blackburn	1	1	0
,,	W. Wright	Lewes	0	10	6
,,	J. Russel	Uxbridge	0	10	6
,,	J. Hunter	Woolwich	1	1	0
		Carried forward	£62	8	6

			£	s.	d.
		Brought forward	£62	8	6
Mr.	R. Douglas	Newcastle	1	1	0
,,	J. Douglas	Portsea	1	1	0
,,	G. M. Ford	Falmouth	0	10	6
,,	H. Green	Preston	0	10	6
,,	A. Penny	London	1	1	0
,,	L. Hislop	Woolwich	0	10	6
,,	J. Hale	Ballymena	0	10	6
,,	S. Cutler, jun.	London	0	10	6
,,	J. McMillan	Newry	0	10	6
,,	R. Gardiner	Newcastle	0	10	6
,,	E. Jones	Knutsford	0	10	6
,,	C. R. Mead	Reigate	1	1	0
,,	W. U. Tinney	Winchester	1	1	0
,,	M. Martin	Drogheda	0	10	6
,,	B. G. Venner	Eton	0	10	6
,,	C. R. Robinson	Coventry	1	1	0
,,	W. L. Robinson	Coventry	1	1	0
,,	J. Reid	Newcastle-on-Tyne	0	10	6
,,	R. Little	Billington	0	10	6
,,	J. Harris	Ross	1	1	0
,,	W. P. Thresby	Lincoln	1	1	0
,,	W. T. Carpenter	Sheerness	0	10	6
,,	Jos. Phelps	Marlborough	0	10	6
,,	W. A. Plumbe	Sutton-in-Ashfield	0	10	6
,,	G. J. Parkinson	Birmingham	1	1	0
,,	J. B. Spence	Manchester	0	10	6
,,	W. Moor	Fence Houses	0	10	6
,,	Jas. Lowe	Bridport	0	10	6
,,	J. H. Robinson	Leamington	1	1	0
,,	R. J. Fennesey	London	0	10	6
,,	E. White	Birmingham	1	1	0
,,	J. Lyne	Wexford	0	10	6
,,	Jas. Eadington	Blyth	0	10	6
,,	W. Fiddes	Bristol	1	1	0
,,	W. Wood	Cambridge	0	10	6
,,	C. Hawksley	London	1	1	0
,,	C. Tadman	Norwich	0	10	6
,,	E. Smith	Droitwich	0	10	6
,,	R. Darney	Faversham	0	10	6
,,	Jos. Reed	Newport, I. W.	0	10	6
,,	J. Hodgson	Ulverston	0	10	6
,,	A. H. Wood	Hastings	1	1	0
,,	W. Syms	Rochester	1	1	0
,,	T. H. Methven	Bury St. Edmunds	1	1	0
,,	A. Williams	London	1	1	0
,,	Geo. Garnett	Ryde	1	1	0
,,	J. Aird, jun.	London	0	10	6
,,	J. Storer	Stafford	0	10	6
,,	M. H. Loam	Nottingham	0	10	6
,,	Geo. Smedley	Buxton	0	10	6
,,	J. Read	Tunbridge Wells	0	10	6
,,	D. Clark	Brymbo	0	10	6
,,	W. Shimeld	Dundalk	0	10	6
,,	T. N. Kirkham	Fulham	1	1	0
,,	A. E. Baron	King's Lynn	0	10	6
,,	J. A. Cowen	Blaydon-on-Tyne	0	10	6
		Carried forward	£102	6	6

Brought forward		£102	6	6
Mr. G. B. Irons	Gosport	0	10	6
,, J. Waugh	Southport	0	10	6
,, E. S. Cathels	Lower Sydenham	1	1	0
,, M. Ohren	Lower Sydenham	1	1	0
,, J. Ohren	Rio de Janeiro	0	10	6
,, J. Sharp	Southampton	0	10	6
,, E Chattwood	Ramsbottom	0	10	6
,, Chas. Read	Congleton	0	10	6
,, J. Booth, jun.	Stalybridge	0	10	6
,, W. H. Willis	Great Yarmouth	0	10	6
,, H. Newall	Manchester	1	1	0
,, R. Brown	Arbroath	0	10	6
,, T. May	Ramsgate	0	10	6
,, T. Stone	Weymouth	0	10	6
,, T. Livesey	London	1	1	0
,, G. T. Livesey	London	1	1	0
,, J. Kelsall	Ashton-under-Lyne	1	1	0
,, J. Somerville	Dublin	1	1	0
,, R. Morton	London	0	10	6
,, H. Brothers	London	0	10	6
,, J. M. Darwin	Longton	0	10	6
,, J. Danning	Middlesborough	1	1	0
,, T. Bull	Tamworth	0	10	6
,, T. Bell	Selby	0	10	6
,, G. D. Malam	Halifax	1	1	0
,, P. J. Wates	Loughborough	0	10	6
,, Jas. Wadeson	Windsor	0	10	6
,, Jabez Church	Chelmsford	0	10	6
,, W. Parlby	Chepstow	0	10	6
,, H. T. Everist	Red Hill	0	10	6
,, Robt. Bell	Rochdale	0	10	6
,, I. A. Crookenden	London	0	10	6
,, E. H. Thorman	West Ham	0	10	6
,, J. G Livesay	Ventnor	0	10	6
,, A. F. Livesay	Portsmouth	0	10	6
,, P. Simpson	Rugby	1	1	0
,, J Stevenson	Dublin	1	1	0
,, L H. Green	Dartford	0	10	6
,, J. Donaldson	Dover	1	1	0
,, Geo. Rait	London	1	1	0
,, W. Davis	Hereford	1	1	0
,, W. Stiven	Inverness	0	10	6
,, W. Osmond	Dorchester	0	10	6
,, A. Field	Widnes	0	10	6
,, E. L. Ridgway	Abingdon	0	10	6
,, T. R. Mellor	London	0	10	6
,, H. Veevers	Bolton	1	1	0
,, C. Dixon	Chichester	1	1	0
,, S. P. Leather	Burnley	1	1	0
,, J. Mudie	Burton-on-Trent	0	10	6
,, Geo. Harding	Broad Green	0	10	6
,, T. Forrest	Walker	0	10	6
,, H. Lyon	Manchester	0	10	6
,, E. Church	Huntingdon	0	10	6
,, W. Blackledge	Chorley	1	1	0
,, T. Pearson	Portland	0	10	6
Carried forward		£141	3	6

	Brought forward		£141	3	6
Mr. R. Church	Chichester		0	10	6
„ D. Brandwood	Radcliffe		0	10	6
„ H. M'Pherson	Newcastle		0	10	6
„ H. Bartholomew	Glasgow		1	1	0
„ J. Cockcroft	Littleborough		0	10	6
„ A. M. Murphy	Cirencester		0	10	6
„ A. C. Fraser	Colchester		0	10	6
„ R. Dempster	Elland		0	10	6
„ J. Hutchinson	Barnsley		0	10	6
„ W. W. Hutchinson	Barnsley		0	10	6
„ J. B. Coulson	London		0	10	6
„ W. B. Emmerson	Portadown		0	10	6
„ W. H. Slip	Red Hill		1	1	0
„ C. Woodall	London		1	1	0
„ J. Davis	Kidsgrove		0	10	6
„ J. Eldridge	Richmond		1	1	0
„ J. Leslie	Moscow		2	2	0
„ G. W. Stevenson	London		1	1	0
„ E. Baker	Reading		0	10	6
„ W. Brown	Manchester		0	10	6
„ T. Hardick	Salisbury		1	1	0
„ T. Trewhitt	West Hartlepool		1	1	0
„ W. Longworth	Dukinfield		0	10	6
„ J. B. Ball	Yeovil		0	10	6
„ A. Upward	London		1	1	0
„ J. M. Jameson	Fleetwood		0	10	6
„ J. West	Maidstone		1	1	0
„ J. Annan	Wolverhampton		0	10	6
„ J. Arnott	Leeds		1	1	0
„ T. Newbigging	Pernambuco		1	1	0
„ T. Douglas	Barnet		1	1	0
„ R. P. Spice	London		1	0	0
„ H. Bowen	Cardiff		0	10	6
„ F. J. Stevens	London		1	1	0
„ H. B. Billows	Queenstown		1	0	0
„ J. T. B. Porter	Lincoln		0	10	6
„ H. P. Stephenson	Lincoln		1	1	0
„ J. Martin	Ormskirk		0	10	6
„ A. Giles	London		1	1	0
„ S. B. Darwin	Shrewsbury		0	10	6
			£172	11	6

SALE OF REPORTS.

Mr. C. Hawksley	London	£0	8	0
„ J. H. Cox	Sunderland	0	8	0
„ J. Jowett	Leeds	0	11	0
„ J. Lowe	Bridport	0	2	0
„ B. Stuttard	Kirkham	0	11	0
„ W. Fiddes	Bristol	0	3	0
„ J. Jowett	Leeds	0	3	9
„ G. Anderson	London	0	5	0
„ D. M. Nelson	Glasgow	0	7	6
„ W. Wright	Lewes	0	7	0
Carried forward		£3	6	3

	Brought forward		£3	6	3
Mr. J. Paterson		Warrington	2	5	0
„ J. Macnie		Londonderry	0	16	8
„ J. Sidebottom		Glossop	0	9	3
„ S. Hunter		Louth	0	19	5
„ T. Littlehales		Wormwood Scrubbs	0	7	6
„ S. Johnson		London	0	11	0
„ J. Niven		Clayton	1	0	6
„ J. West		Maidstone	0	10	6
„ J. Arnott		Leeds	0	7	6
„ T. Littlehales		Wormwood Scrubbs	0	4	2
„ J. Deakes		Worcester	0	4	0
„ D. Terrace		London	0	11	9
„ S. Studholm		Whitehaven	0	3	9
			£11	17	3

ENTRANCE FEES.

Mr. S. Cutler, Jun.	Millwall	£5	0	0
„ J. B. Spence	Manchester	5	0	0
„ Geo. Rait	London	5	0	0
		£15	0	0

BRITISH ASSOCIATION OF GAS MANAGERS.

BALANCE-SHEET, APRIL 30, 1870.

Dr.

		£	s.	d.
April 30, 1869.				
To Balance brought forward		62	19	5
April 30, 1870.				
To Life Subscriptions	£21 0 0			
,, Annual Subscriptions	172 11 6			
		193	11	6
,, Donation from T. Hawksley, Esq.		5	5	0
,, Sale of Reports		11	17	3
,, Entrance Fees from Extraordinary Members		15	0	0
,, Interest allowed by Treasurer on Balance up to Dec. 31, 1869		1	8	9
		£290	1	11

Cr.

	£	s.	d.
April 30, 1870.			
By Printing, Stationery, and Postages	27	6	0
,, Expenses of Meeting in Liverpool, June, 1869	14	14	0
,, Professor Anderson's Fee	12	12	0
,, Printing, Lithographing, Binding Reports, and Advertising	70	8	0
,, Carriage of Parcels and Sundry Expenses	4	18	5
,, Amount allowed to Honorary Secretary as per Minute, June 1, 1869	25	0	0
,, Balance in Treasurer's hands	135	3	6
	£290	1	11

Examined and found correct,

(Signed) SAMUEL P. LEATHER, *Auditor.*

May 13th, 1870.