THOMAS HAWKSLEY LECTURE.*

THE GAS ENGINEER OF THE LAST CENTURY.

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Dr. W. Cawthorne Unwin, F.R.S., *President*, in the Chair.

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Introductory.—Before commencing this Lecture I desire to say that I consider it a privilege to be allowed to deal with a branch of the history of the "Giant Age" of the nation's Engineering progress during the past century. If this term appear extravagant, I would ask consideration first, for the problems that the Engineers of the day had to solve and, second, for the entire absence of skilled and experienced contractors to furnish the means of meeting their solution, coupled with deficient or bad transport in the dawn of the railway and canal systems.

To-day, with the wide and fuller extent of experience, these difficulties have largely disappeared, while the facilities afforded for meeting them have greatly increased by the advance in machinery for construction of plant and in the skill of the necessary workers in all the metals and building materials on the largest scale, due to modern inventions. To-day, plant, implements, and machinery of the most microscopic delicacy and efficiency are found everywhere, while even the largest of the enormous constructions necessary are well within the scope of the average practical builder and contractor.

* *First* Thomas Hawksley *Lecture*, by E. B. Ellington, Proceedings, I. Mech. E., 1913, page 1215. *Second Lecture*, by W. B. Bryan, 1914, page 811. *Third Lecture*, by Dugald Clerk, D.Sc., F.R.S., 1915, page 591.

Thomas Hawksley.—The subject personality of this Lecture presents at once a powerful and picturesque figure among the early pioneers of the Engineering profession prosecuting the industrial progress of the country in transport, mechanical production, cultivation and, not least, provisions for the sanitation, convenience, and comfort of the population in all directions.

I propose to follow the maxim: "ne sutor ultro crepidem," and to illustrate, as far as may be, from personal records and experience, the history of the progress in the special industry of gas lighting and to trace and compare the careers and duties of a Gas Engineer of Mr. Hawksley's day with those of the present. He was, like all the early Engineers, a *general* practitioner. Not only did he improve the health and brighten the homes of the masses in our great towns by his imposing and monumental works of water supply, followed up by the consequential development of sanitation by sewage works—only possible where adequate water was already provided—but he further practised extensively in the installation of gas supply which, originally confined to Lighting, soon expanded in the direction of Heating, Power, Ventilation and the numerous uses to which it has grown to-day, so that he is linked insolubly with the history of coal-gas.

It will be informing and interesting to consider the Engineer's work, its responsibility and its difficulty in this branch, in the early part of the nineteenth century, when little was known of the necessary requirements in plant and the methods of applying them, and practically nothing of its special operations for purifying.

No Contractors.—Contractors did not exist for the specialities as they do to-day, and the Engineer necessarily had to furnish drawings, specifications, and workshop instructions in the fullest detail. Moreover, for the section work on furnaces, retorts, purifying plant and storage, as well as for the installing and carrying on the operations essential to the construction of the sections, methods had to be devised, and the contractor and his workmen had to be instructed in them in a degree beyond the understanding of Engineers and Contractors of the present day, who have had all the benefit of their predecessors' experience for the three generations which have passed. It will be seen that the Engineer had much more to devise and to superintend than at the present time, when so many standard examples exist and when competent contractors are found in any number all round.

Personal Instruction of Artizans.—I would guard against being understood to suggest that essential elements in design and execution are even now to be in any degree passed over by the Engineer. I am referring solely to the fact than when the Engineer had completed his drawings, specifications, and his estimates, he had to ensure, by circumspect and close supervision, and indeed, practical instruction, how the work was to be done in detail by the artizans.

History of the Gas Industry.

I proceed now to a review of the history of the gas industry down to the present time, illustrated in a measure from personal experience. It is hoped this may be of some interest to the Institution of Mechanical Engineers, of which I am proud to have been a Member for nearly forty years.

As coal-gas was born with the last century as a practical illuminant, though experimenters had found it in the Chemist's laboratory in the preceding century (by Clayton, Dean of Kildare, and Bishop Watson of Llandaff), it is worth while to see what need there was for it, who were the Engineers who practised in it, what difficulties were presented to them, how they surmounted them and what progress followed their work; and later to see what is the position and what should be the aim of the Engineer to-day.

As to the need for a cheap illuminant we have no record of the prices of illuminating materials at that day, but, judging by the comparative costs given by Dr. Ure, as late as 1841, namely, tallow candles (dips) 8*d.* per lb., wax candles 2*s.* 6*d.* per lb., and sperm oil 9*s.* per gallon, we may be sure that in 1805 gas had even more costly sources of light to compete with.

The invention of *practical* gas-making, due to Murdoch in England and claimed by Philip Lebon for France, took shape in the lighting of Murdoch's own house in Cornwall in 1792 and of the Soho Works of Boulton and Watt in 1802, the further lighting of London streets in 1804 by Winsor, followed by Parliamentary schemes of 1809–10–12–14 for the National Light and Heat Company, afterwards the Chartered Gas Company, now the Gaslight and Coke Company of London. The plans submitted to Parliament by Winsor were very crude, and Plate 5 shows the square gas-holder, condenser in tank, hand-power purifier, and first part of London lighted.

The lighting of Paris streets, by Lebon, followed in 1815. Winsor's schemes prospered in the hands of Clegg, Malam, and other prominent engineers, and by 1827 the whole of the public oil lanterns in London were replaced by gaslamps.

Peckston's Account of the Chartered Gas Company.—By the year 1823 the growth of plant to meet the advancing demand can be judged by Peckston's illustrations* of typical retorts, condensers of vertical pattern, group of four purifiers with valve, larger gas-holders and the telescope addition, Fig. 3, and his account of the Chartered Gas Company, which records three gasworks (Westminster, Brick Lane, and Curtain Road) collectively producing two-thirds of a million, say 660,000 cubic feet of gas daily, and supplying 30,000 burners—probably Cockspur Jets. These works used 911 retorts and 33 gas-holders, of which 15 were at Westminster, 12 at Brick Lane, and 6 at Curtain Road, and which must therefore have averaged only 22,000 cubic feet each.

This Company alone more than equalled the sum of the three others then operating in the heart of London, namely:—

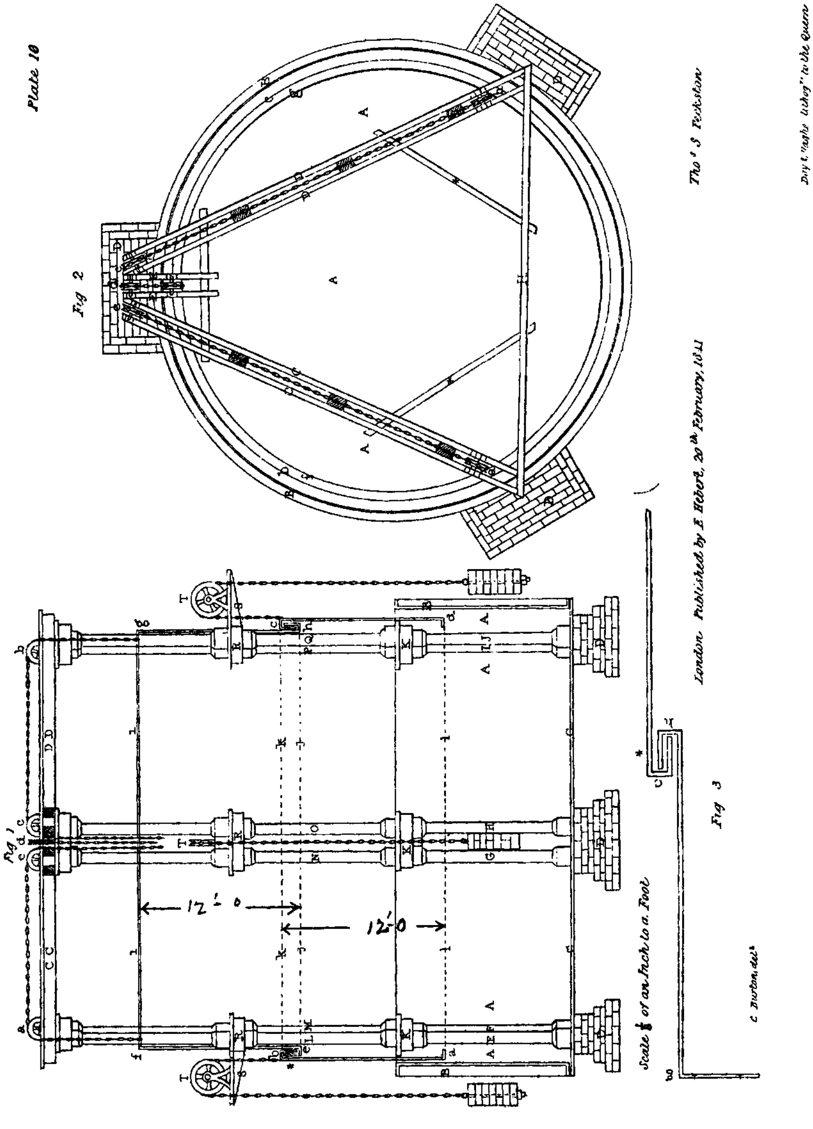
(1) The City of London Company, founded in 1813, at Blackfriars, which at one time had works at Aldgate fitted with Clegg's collapsible bellows holders.

(2) The "South London," afterwards the Phœnix, Gas Company with works at Bankside and at Vauxhall Bridge; both perpetuated in existing works.

The whole of these were only equal to one-fifth of the consumption already secured by the then Chartered Gas Company, as just stated.

* "Practical Treatise on the Manufacture of Gas," 1841.

FIG. 3.—*Gas-holder. Capacity* 17,500 *cubic feet,* 32 *feet diameter.*
(Photo from the original engraving, "Practical Treatise on the Manufacture of Gas." Peckston. 1841.)



The price of gas was in the neighbourhood of 15*s.* per 1,000 cubic feet, calculated by the number of single jet lights (cockspurs) consuming 1 foot per hour.

There were no meters, though at the works the filling of the holders was indicated and recorded.

In outer London, the Imperial Gas Company, founded in 1813, had works at Hackney Road, which are continued by works now in existence, denominated the Haggerston Station. The 6 holders at that station were only of 10,000 cubic feet content each, which contraction of scale was due to the popular alarm, which limited the contents of any single holder to about this quantity. Gas was then looked upon as a dangerous explosive in itself, apart from the admixture of air now known to be necessary for its explosion. It was indeed proposed by learned Societies that holders should be limited, and further, that they should always be enclosed inside buildings.

Ratcliff Gas Company.—In the same year of 1813 the Ratcliff Gas Company was founded, incorporated in 1823, and later merged in the Commercial Gas Company.

East London Gas Company.—There were also small works at this date, owned by the East London Gas Company, for supplying Mile End, of which there are traces at the Johnson Street Gasworks of the old Ratcliff Company.

British Gas Company.—There were, further, works at School House Lane, Shadwell, belonging to the British Gas Company, which had works in other parts of the Kingdom. These works became absorbed by the Commercial Gas Company about the year 1852. There were also gasworks at Millwall belonging to the Poplar and East London Gas Company. These works were also absorbed in the early "Fifties" by the Commercial Gas Company.

At this date there was a great predilection for gas made from oil, and in addition to the small works at Aldgate, which later became the property of the City of London Gas Company, there were some works for the supply of Stratford in existence on the River Lea at Bow Bridge. These were absorbed by the Commercial Gas Company.

Small Increase of Gas Consumption.—But with all the above works, the total annual London consumption of gas had only grown by the year 1837 to some 1,600 millions cubic feet, showing the moderate advance of about 60 per cent. in 14 years. By 1848 the consumption of gas in London had doubled this, amounting to 3,200 millions, and requiring at 9,500 cubic feet per ton, some 355,000 tons of coal. The average price of gas at this time was 6*s.* per thousand cubic feet for private consumption and 3*s.* 10*d.* for public lighting.

To deal with this business in London, there existed no less than 13 gas companies, the dates of incorporation of which are given in the accompanying Table 1; but it must be borne in mind that in nearly all cases they were founded several years earlier than the dates of incorporation. They carried on their operations with a good deal of rivalry and contest, being allowed to open the roads by the indulgence of the various Local Authorities, who, in fact, did not appear to have been aware of the rights, if any, which they had to prevent the unauthorized operations.

TABLE 1.

Dates of Incorporation of 13 *London Gas Companies.*

Chartered	1810	South Metropolitan	1833
City of London	1819	London	1833
Imperial	1821	Commercial	1836
Ratcliff	1823	Great Central	1849
Phœnix	1824	The Western (Commercial Gas)	1848
Independent	1824	Surrey Consumers	1851
Equitable	1830		

Meanwhile, by the year 1847, so much activity in prosecuting gasworks had been shown all over the country, that Parliament found it necessary to pass a General Act, to be incorporated in the future with all the private local Acts, which, while conferring privileges as to the opening of roads and bridges, etc.—all subject to satisfactory reinstatement—regulated the proceedings and administration of the undertakers both financially and commercially on definite general lines.

The growth from this time in London is shown on Table 2, being an advance, between 1837 and 1915, from 1,600 millions to 42,624 millions cubic feet in the 78 years, with the average price of gas

TABLE 2.

London Gas only.

(From *Peckston* and earlier to 1869, and from *Field* 1869 onward.)

—	1837	1849	1869	1879	1889	1899	1909	1915
Coals used (tons)	—	—	1,171,588	1,870,000	2,678,000	3,195,500	2,992,000	2,866,775
Gas sold (millions)	1,600	3,200	9,885	17,635	20,649	34,057	38,300	42,624
Price (average) .	6/-	6/-	4/-	3/6	2/5	2/2	2/2	2/8·4
No. of Consumers per Mile of Main . . .	—	—	—	—	105	178	278	306
Gas sold per Mile of Main (1,000's)	—	—	—	—	8,906	10,469	10,327	10,050

reducing gradually from 6*s.* to 2*s.* 8*d.* The number of consumers per mile of main grew from 105 in 1889 to 306 in 1915, and the sale per mile of main from 8,906,000 cubic feet to 10,050,000 cubic feet in the same period.

These figures show in recent years how the general population has increased its use of gas, as distinguished from that formerly used. It is largely due to the introduction of the working-man's Slot-Meter.

Turning now to the progress throughout the country at large. Beyond the list published by the *Journal of Gas Lighting* in the early years of its issue (1849–50) in which there were no fewer than 750 established gas companies in the Kingdom, there are no records available of the general position throughout England and Wales, Scotland or Ireland, before 1880, when the Board of Trade collected Returns and published them by order of Parliament; the leading features of which are shown on Table 3 (page 640).

From Table 3 it will be seen that in one generation (35 years):—

The Capital has increased 224 per cent.,
Coal used has increased 170 per cent.,
Gas consumed has increased 300 per cent.,
Number of Consumers has increased 500 per cent.,

and as between 1890–1914 the extent of mains was only increased by 80 per cent., namely, from 21,970 to 39,100 miles, it is clear from this disproportion there was an increasing use over the same areas. The sale per mile of main rose in 24 years from 4·3 millions cubic feet to 5·4 millions, and the average per consumer fell from 41,000 to 23,000, showing the largely extended adoption by the poorer classes.

Looking to the competition from electricity in the lighting branch, the increase shown in number of public lamps, from 286,300 to 741,703 (of which 20,918 fell in the last four years of the Return), does not seem as if, for economically lighting the largest areas, gas was going out of use.

According to Dr. Ure, published in 1841, the ton of coal was computed to produce:

9,500 cubic feet of Gas,
13½ cwt. of Coke,
12 gallons of Tar (showing low heat of retorts), and
10 gallons of Ammonia Water (which would have been of a strength of about 12 oz. to the gallon)

TABLE 3.

Particulars from Board of Trade Returns as to Growth of the Gas Industry throughout the Kingdom.

Year.	No. of Authorized Under-takings.	Capital paid-up and borrowed.	Tons of Coal Carbonized.	Gas Sold (1,000's cubic feet).	Length of Mains. (Miles).	Number of Consumers.	Number of Public Lamps lighted.	Sale of Gas per mile of main (1,000's cubic feet).
		£						
1880	not given	43,400,000	6,081,000	52,000,000	not given	1,530,000	286,300	—
1890	594	61,344,357	10,242,427	94,645,613	21,969½	2,297,278	460,384	4,308
1900	693	102,924,220	13,906,288	140,418,454	27,591	3,713,289	605,156	5,090
1910	809	134,683,695	15,397,783	182,833,928	36,122	6,417,849	720,785	5,062
*1914	834	139,727,277	16,684,087	210,907,376	39,100	7,298,007	741,703	5,402

* Latest available Returns.

About this date (1839) a curious Estimate was put out by J. Hedley, from Sheffield and Dublin, for Profit on Gas Supply. A ton of coal, costing 17*s*., produced for sale:—

	£	*s.*	*d.*
8,500 cubic feet of Gas @ 9/-	3	16	6
12 sacks of Coke at 1/-	0	12	0
19 gallons of Tar @ $2\frac{1}{2}d.$	0	3	$11\frac{1}{2}$
	£4	12	$5\frac{1}{2}$

Services to consumers' houses were originally of lead, as for water supply. These were superseded by old gun-barrels screwed together, until in 1825 Whitehouse brought out a patent of Russell's, dated 1817, for cheaply made tube of greater length and uniform section of metal, welded by a patent process and screwed together by suitable sockets. For many years the term "barrel" was applied still to the new pipes, just as the expression "trunk mains" was taken, from water practice, to apply to cast-iron.

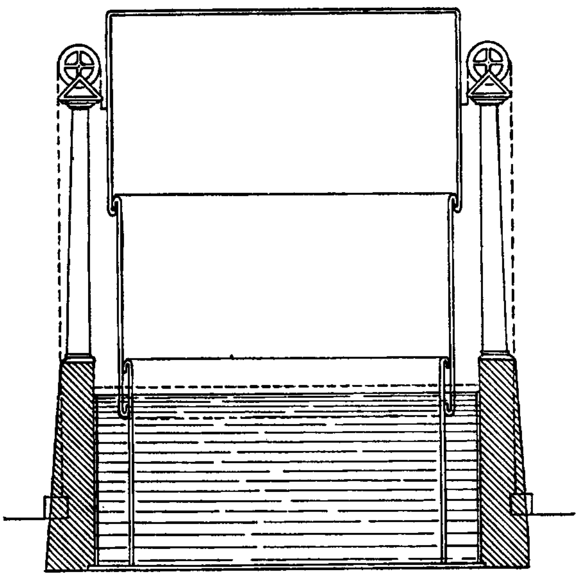
Only in 1830 did dry lime purifiers come into gradual use to supersede wet lime vessels, the nuisance from "Blue Billy" being even greater than the dry lime caused; but the older system was still to be seen in 1854 at the London Gas Company's Works, Vauxhall.

The bulk of the gas-holders were still only about 30,000 cubic feet capacity, though the Chartered Company's Engineer, Mr. John Evans, is said by Dr. Ure to have been contemplating one in a single lift 95 feet diameter by 40 feet high, containing 250,000 cubic feet, which, when compared with Sir George Livesey's great work of 12 millions, and the Birmingham holder of 6 millions, by the veteran Charles Hunt, only impresses one by the magnitude of the development over the intervening half century.

In 1822 the proposition for telescoping gas-holders, Fig. 4 (page 642), to save deepening the tanks was made by one, Tait, of Mile End, using similar water-luted grip to that used to-day, but the hydraulic cups were *internal* (where their condition as to leakage and as to the free working of rollers could not possibly be seen or rectified). Fortunately the engineers of the day rejected the suggestion. The use of similar grips or cups, placed externally, was later introduced by one, Hutchinson, having been applied at the City Gasworks in 1844, and this arrangement continues in use to-day.

During the craze for oil-gas, Godwin brought out a patent in 1819 for bottling it up in metal globular vases at high pressure, 20 to 30 atmospheres, and it was in carrying out this process that

FIG. 4.—*Telescopic Gas-holder* (*Tait*), 1822.



benzol was observed to be precipitated by Sir Humphrey Davy, who was consulted on the phenomenon. You know that to-day the duty has been placed upon gas undertakings to take benzol out of gas, as far as they can do so, and supply it to the War Department for war purposes. The whole amount of illuminating matter of that sort is only three per cent. in our gas, and whilst the removal of benzol does seriously alter the illuminating effect in a naked burner, it has very little effect, certainly not more than four or five per cent. upon the heating power, which is the one that is realized in the Welsbach incandescent mantle. The proposition therefore to remove it is not a very serious one to the consumer, although it is of very great importance to the War Department. The patent was worked later by the London Portable Gaslight Company, but was soon superseded by the cheaper coal-gas owing to improved economy of distribution by cast-iron mains.

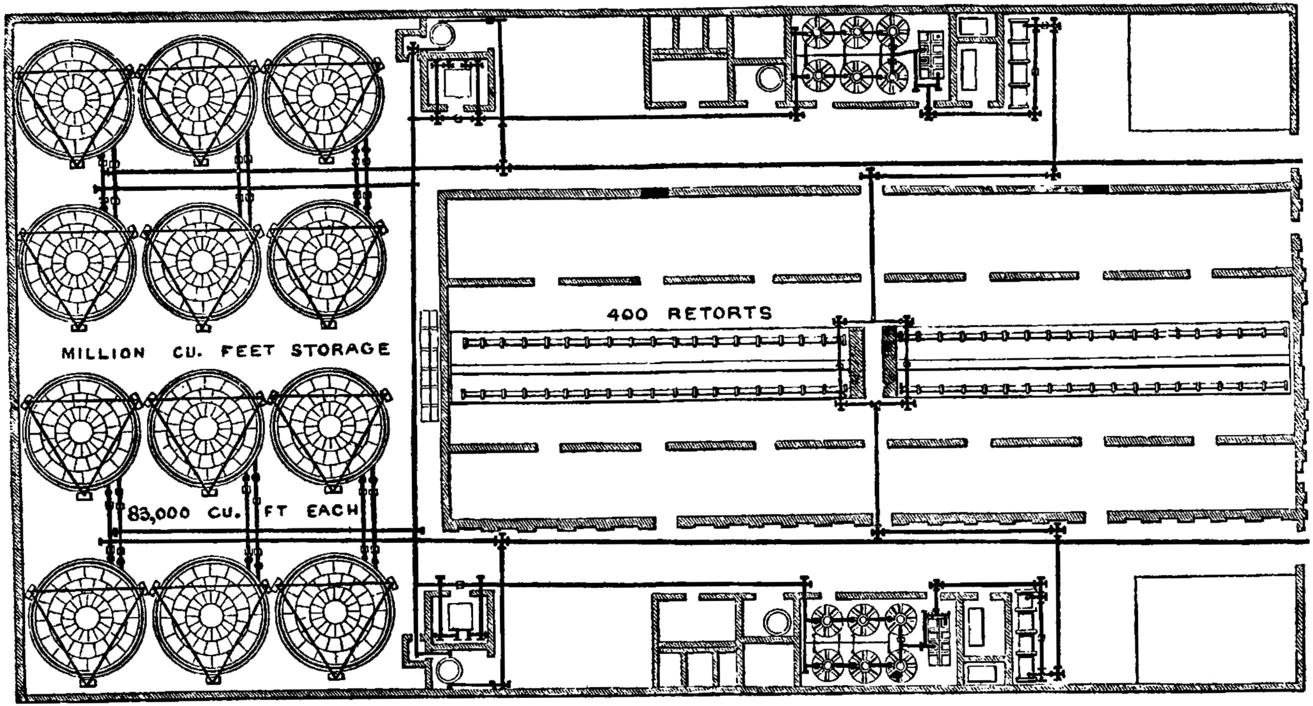
In Hebert's Engineering Encyclopædia, published 1841, there are shown designs for 3-throw compression pumps and for 2-wheeled carts to carry the gas in folding compartments constructed on the Bellows principle, of canvas, from which the bottles kept at the houses were to be filled. The companies formed for this sort of portable gas supply, however, rapidly came to grief.

As above stated, oil-gas was started at Aldgate for the supply of Whitechapel, but soon came to an end. An oil-gas works for Stratford also failed, and was taken over by the Commercial Gas Company in 1852. The predilection for compressed oil-gas arose in consequence of the cost and difficulties in the distribution of coal-gas, which are specially lamented in the preface to the Memoirs of Samuel Clegg's early working, elsewhere mentioned. The pipes were scarce and dear at £14 per ton, and the jointing was very imperfect.

Plant Development.—In the development of plant there were gradually introduced materials and forms less crude and more economical and convenient, gradually leading to those we are accustomed to see employed to-day on the enormously increased scale necessary. A striking illustration of the structural advance in scale and methods is furnished by the design of a gasworks for 1 million cubic feet per day, by Jos. Hedley, of Dublin and London, published in 1845 by Dr. Ure, Fig. 5 (page 644). It is remarkable for the multitude of units of purification and storage and their crowded position, with inadequate working spaces for coke and materials, there being 12 gas-holders of only 83,000 cubic feet capacity each, and 12 purifiers, for 1 million feet of gas per diem, whereas to-day 3 purifiers suffice for 4 million cubic feet per diem.

Fig. 5.—*Design of a Gasworks for* 1 *million cubic feet per day.*

(Photo from the original engraving in "Ure's Recent Improvements in Arts and Manufacturers." Jos. Hedley. 1845.)



In the earlier days cast-iron retorts of circular, oval and kidney section were generally used in carbonizing. About 1820, clay retorts were introduced and used by Fraser in Scotland and by Grafton in England, but were not generally used in England till after 1840.

Retorts of fire-clay, though obviously more refractory and enduring than the expensive heavy cast-iron retorts previously used, cost, by Clegg's treatise, upwards of £20 per ton; nevertheless, owing to the porosity and liability to crack and gape when cooled down in the necessary periods of idleness, were very little in favour, and did not come into exclusive use until after the year 1850, when the perfection of the exhausting plant enabled them to be worked under very low back-pressures, saving the waste by leakage and the choking by deposited carbon, that made their use in careless hands more precarious and expensive than it need have been. So late as the year 1864, iron retorts were used by Croll and George Anderson, in settings where the primary hot gases of the furnace were directed to clay retorts set above the iron retorts, and these were drawn when reduced in temperature round the iron retorts below. This system claimed especially to save fuel, and was successfully worked for many years both at the Surrey Consumers and the Great Central Works.

For the conservation of heat, retort benches came to be placed with the furnaces back to back, leading ultimately to the retorts being made continuous, of double length, with duplicate mouthpieces and ascension pipes. This facilitates cleaning off the carbon deposited owing to their porosity. The loss by leakage and the excessive deposit of carbon were cured ultimately by Grafton's invention of the exhauster, by which internal pressure was relieved from the retort and the gases removed as fast as made. Fraser in Scotland, John Eunson and Robert Jones in the Midlands and in London in the "Forties" and "Fifties," did much to establish the durability and the superior efficiency in carbonizing of the clay retorts, in early days, while both A. Croll and G. Anderson were great and persistent advocates of the value, in more recent times, from 1845 onwards.

The furnaces for heating retorts have undergone important changes since the Siemens' reverbatory furnace for smelting was invented. This was proposed in 1863 for a gasworks scheme in Birmingham. Mr. C. Hunt, in Birmingham, gave great attention to the new system, as did Hyslop in Scotland, and we are indebted to the labours of both these gentlemen for the early steps leading to the present success which gives great control of temperature as well as saving of fuel.

MACHINERY.

Modes of Charging Retorts.—Gradually, to save cost and the strenuous and excessive labour of charging retorts on a large scale, there has been introduced machinery, which in the early stages took first the form of a machine with a number of scoops such as had previously been handled by workmen, projected into the retort, imitating the precise action of the workmen. These machines were soon abandoned, as the wear and tear and power costs were excessive.

The next machine was one introduced by Mr. Robert Morton at the London Gasworks, for employing steam-jet propulsion of coal in successive parcels into the retort in the manner imitating the shovel charging of earlier days. This again gave way to the hydraulic machine, the best of which is still to be seen working in many gasworks. The Arrol-Foulis, due to the combined ingenuity of the late William Foulis of the Glasgow Undertaking, and Sir William Arrol, was introduced. For low wear and tear and steady action these machines are not easy to beat to-day.

An extremely successful and economical plant is the West system of charging, the power being given by compressed air. It is working to-day with the greatest efficiency at several gasworks in London. The inventor of this system, Mr. West, was formerly the engineer of the Maidstone Gas Company, and his plant, always combined with a very efficient retort setting on the regenerative principle, is successful wherever applied. An economical machine is the French DeBrouwer, which projects the coal into the retort without introducing any mechanical parts of the machine into the retort itself. It is widely used on the Continent and extensively in this country. A later machine is the Fiddes-Aldridge, which takes the coal, by articulated sections of the machine, into the retort, and at the same time pushes out the exhausted coke. This machinery is gaining ground. With all these systems the coke is expelled by mechanical pushers, avoiding the tedious and exhausting labour of drawing by hand-rakes.

Machinery.—These operations of retort charging and discharging, coal elevating and trimming, are to-day performed by machinery for labour-saving motives. This, sometimes driven by hydraulic pressure, sometimes by compressed air, is latterly most frequently performed by the distribution of the power of gas engines through electrical current. It is fair to say that in these ways, while the cost for labour has been reduced by 30 to 35 per cent., there is an addition of at least 25 per cent. to the wear and tear charges. A very important advantage of machinery is the even progress of the operations and its being less liable to the variations always arising from the human element, and another, that the type of labour essential to be used with machinery is of a more intelligent and responsible class.

On the question of labour generally, the introduction of the Livesey Profit-Sharing has very much improved the service, as the men rapidly realize the greater independence and stability of their position, especially when they have become investors in the Undertaking which employs them.

At the present day efforts are being made to produce a better coke by carbonizing the coal in ovens on lines approaching that of the coke-producing plants working at the various collieries. These are not new ideas, as the old London Gas Company had, in my own memory in 1854, ovens for making gas and coke on a principle such as is now suggested and indeed in use at Birmingham. They were introduced by M. Michele, a French engineer, but they were ruinously inefficient, chiefly through bad construction, and the company were working without profit until, on the death of Michele (who was killed whilst making experiments with benzol), the Company consulted the late Robert Jones of the Commercial

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Gas Company, who replaced the ovens by clay retorts on his system (which is illustrated in Samuel Clegg's Manual). The Company were in a few years paying a dividend of 10 per cent. in consequence of the change to retorts.

There have been successively introduced, to displace the horizontal retort, the inclined system (the invention of M. Coze, of Rheims), which has been widely used, and at the present time, a great development of a system which employs the force of gravitation even more effectively, that is, the vertical retort brought out originally by Mr. Harold Woodall of the Bournemouth Gas Company. This invention, perfected and worked out by the collaboration of his partner, Mr. Duckham, has been widely and successfully applied. There are a great many modifications of the system being introduced, and they are favourably reputed; but so effective has the carbonization been found of a good regenerative system of furnace and thoroughly efficient machinery for charging, as to preserve still the original horizontal system, though with modified furnaces and fittings.

Condensers, generally of extended lengths of ordinary cast-iron pipes returning by bends or coils so as to be drained into tar-collecting wells or cisterns, were successively introduced by Malam in 1817, George Low in 1839, John Kirkham near the same time, Marten of Perth, and later, Alexander Wright of Kensal Green. But the saturation of the condensed liquor with ammonia, sulphur, carbonic acid, and sulpho-cyanide being desired, the tubes of a condenser are now arranged horizontally rather than vertically. On the older plan the rapid separation of the ammoniacal water removes it whilst too hot to be capable of exercising its full affinity for the impurities. It is now further sought to cool the gas more gradually, and always in contact with both the liquor and tar. Therefore, the contact is now extended by making them flow together as long as possible, always avoiding sudden changes of temperature, which with the vertical pipe condenser cannot be prevented. Usually, to-day, the condenser pipes are either staged or suspended so as to incline slightly from the horizontal, keeping the liquids flowing along with the gas.

PURIFICATION.

For the first 50 years of the last century the purification for ammonia was not much practised, but gradually the value of the product brought its extraction into almost universal use. The apparatus employed was originally vertical scrubbers of cast-iron, in which a counter-current stream of water met the flow of gas.

A different form of plant, being a rotating screen working in water through a large horizontal cylinder, originated in the invention of Mr. Paddon of the Brighton Works, and is still to be seen there. His plan, with extensive modifications, has been widely used since. It remains to be said, however, that the earlier form of plant has great simplicity and freedom of working parts to recommend it, and has completely met the most searching tests of efficiency.

Purifying was carried on by lime in water vessels down to 1858, when they were to be seen at the old London Gas Company's works near Vauxhall Bridge. (These works were interesting, as they were constructed on the grounds and park of the original Vaux Hall from which the Gunpowder Plot was directed by Guido de Vaux.) But purifying by hydrated lime in a dry condition had been introduced gradually for many years before this time. Patents were taken out at various dates for purifying by oxide of iron instead of lime, and so avoiding nuisance. This process is now almost universally applied, with the advantage of recovering the sulphur for acid-making.

For the removal of ammonia, Croll brought out a patent for its elimination by chloride of manganese, but this was not only expensive and required commodious plant, but it was less effective than the system of washing and scrubbing by water now universally practised.

Great economy and efficiency is gained by the provision of sufficient surplus cubic capacity for purifiers, so as to provide not only for the incremental growth from year to year, but to avoid back-pressure and to secure a lower speed and longer contact with the gas. The ordinary rules of half a square foot of area per 1,000 cubic feet per diem in each vessel on the series of the purifiers, and a slightly larger one, 0·6 square foot for lime in purifiers, can be exceeded with great saving of labour and increased efficiency of material. Nowadays, revivification of the material is almost universally secured *in situ*, avoiding much unnecessary labour in discharging and refilling the material into the purifier. Owing to the value of sulphur for the manufacture of sulphuric acid nowadays, it is possible, with a sufficient margin of area, to purify at practically no cost, but some small profit. With a view to economy, some Engineers, including myself, have constructed purifiers in concrete, sunk into the soil. Subject to special construction to avoid the leakage arising from a porous material, there is no real difficulty or objection to their employment.

GAS-HOLDERS.

Gas-holder Tanks.—Tanks of brickwork or masonry were proposed by one, Tunks, for gas-holders, and in this he no doubt was following the much earlier system of waterworks reservoirs. But cast-iron tanks of flanged plates were extensively used where foundations were bad, and these were only displaced by steel and wrought-iron plated work, which continue to be used for the smaller dimensions. For tanks on the scale now common for gas-holders, of from 2 to 10 millions, the water pressures demand such heavy sections as make the execution of them in metal very difficult and uncertain in efficiency, so that the larger works are carried out chiefly in Portland cement concrete, executed simply and rapidly in parallel vertical section in timbered trench work. They are made much shallower in proportion to diameter, to avoid cost of construction and, further, in some places, serious engineering difficulties, arising from penetrating water-logged strata of peat and running sand, through a better foundation. This was found by Sir George Livesey at the East Greenwich Works, and by Mr. Trewby at the Beckton Works, when they were digging to the depth that was necessary to carry the great holders that they installed.

Gas-holders.—The gas-holders themselves are often of from 3 to 6 telescopic lifts, and almost invariably without roof-framing beyond the timber support on which they rest when landed empty. The adoption of multiple lifts in their construction gives scope for great economy, especially on large scales. The whole work of tank and gas-holder complete has been effected on a scale of 3 millions at the cost of little over £5 per 1,000 cubic feet, whereas such gas-holders as were contemplated in the illustration of Hedley, Fig. 5 (page 644), are known to have cost from £40 to £50 per 1,000 cubic feet.

Distribution.—The distribution of gas is carried on to-day through cast-iron pipes corresponding very closely with those illustrated in Winsor's applications to Parliament for his schemes. They were reported in Clegg's period to be costing £14 per ton, being of cold-blast iron. Probably they cost higher prices than these in Winsor's early day, so they must have been rarely used. The Water Companies at that date, for corresponding purposes, used largely the trunks of trees, hollowed out and jointed by metal rings. This water practice must have been for economy, because as early as 1668 the water fountains at Versailles were supplied by small cast-iron pipes, showing the earlier use of metal.

The pressure employed for distributing are now much in excess of those in vogue until quite lately. Though Parliament only insists upon a pressure of 6/10ths in the daytime and 10/10ths at night, of head of water, the needs of supplies compel the use of pressures of 40/10ths and 50/10ths head, and often more. This is not found to increase the leakage, as was formerly feared, showing that the modern system of main-laying must be very perfect.

Systems of distribution are now extended far into rural districts, much beyond the earlier practice, and though some of the more concentrated supply areas distribute so much as 11 and 12 millions cubic feet per mile per annum, there are areas connected with rural Companies in which not more than 1½ to 2 million cubic feet per mile per annum are distributed. The pressures used and the capacities of the pipes laid in modern times are much affected by the very large increase in the use of gas by the lower classes of the population for domestic purposes on the slot system, which by prevailing through the hours of daylight and extending further through the summer period of daylight, goes far to level the peak of the load upon the various systems. Indeed, one of the distinctive marks of the recent progress of gas-lighting is this adoption by the working-man of gas in place of coal.

In the service pipes a heavier type of wrought-iron tubing has been gradually brought into use, such as is generally used for steam purposes. Where this is coated with pitch when originally laid, and is put at a suitable depth to protect it, especially under the waterproof road surfaces that are now in favour, it confers a very much longer life on this, which was formerly the most perishable part of the fixed plant of a gas undertaking.

To complete this branch of my subject, reference must be made to the perfection in the accuracy and in the improved substantial construction of the meters employed, the life of which again is considerably extended; possibly in some degree owing to the improved purity with which the gas is supplied, as against ancient days. Dry meters have practically displaced the wet system, except abroad and in India.

In 1850 the whole of the mains for the Great Central Gas Company were laid throughout the City of London, by stipulation with the Corporation, during the hours of night, the pavements being restored for use in the daytime. This has often suggested the avoidance of the inconvenience of paving repairs which are to-day carried out by the same Corporation in the hours of daylight. In London, in 1864, subways to contain gas-pipes were first of all used in Southwark Street, constructed by the then Metropolitan Board of Works. Pipes were laid in these by myself as a test case, the Engineers concerned for the Act of Parliament having been Messrs. Bramwell and Sir Joseph Bazalgette.

Carburetted Water-Gas.

From the "Eighties," carburetted water-gas plants came into use somewhat extensively, at first for enrichment purposes, eventually as auxiliary supplementary means of production for various emergencies and contingencies. In America the form of water-gas plant, on the principle identified with that tried by George Lowe in the "Thirties," had been modified and applied to the exclusive lighting of communities, as it utilized the large production of the residual oil from the great wells, after the petrol spirit and the lamp oil had been distilled. As this oil was of low commercial value as a by-product, a very high illuminating power could be cheaply got by the generous use of it with water-gas, because for each gallon that was cracked in the superheaters a value in lighting of from 7 to 8 candles could be given to each 1,000 cubic feet of gas produced.

In England, the illuminating standards were quite above the potentiality of ordinary coals, cannel coal—then becoming scarce and very dear, besides furnishing little residual by-products—had to be used to large proportions: often 10 to 12 per cent. The introduction of the new plant to English gas undertakings, chiefly at the hands of the firm of Humphreys and Glasgow, was therefore welcomed, the more so as the then price in this country of the necessary gas-oil from America was in the region of 2*d.* per gallon. As the plant occupies a much smaller area and costs much less to install per unit of output, gives its output very promptly when used intermittently, and produces any quantity of gas required within the limitations of maximum scale to replace the dearer cannel-gas, it naturally sprung into favour. The flexibility and facility so enjoyed enabled the manufacturer to supplement suddenly, and in great volume, the supply from the ordinary process, and so met emergencies without calling upon storage accommodation. Moreover, it had the merit of turning to useful account surplus unsaleable coke, and in this way was convenient and profitable as enhancing the value of coke generally.

Further, for getting over the peak of mid-winter demand without calling for extra labour or extra supplies of raw material, as well as for clearing away the redundant output of coke due to the season, the plant was, and ever will be, of great value in the practical carrying on of gas supply. Unfortunately, unless heavily enriched with oil, the heat efficiency is much below that of coal-gas, while the price of the oil has so risen in later years (quite apart from the present War effect) that, looking to the modern standards of calorific value and illuminating power, there has been little temptation to its use. The more general appreciation of the value of coke for trade and steam use is against the process, as is also the more constant demand for gas through the daylight hours, which largely dispenses with the need for storage, and so robs the water-gas system of one of its greatest advantages in saving capital outlay and space for works.

For producing raw water-gas the system known as the Kramer and Artz has been found very useful, but for meeting the necessary standard of calorific value it needs the addition of hydrocarbon vapour.

INVENTORS.

Let us now see who were the Engineers, Inventors, and Mechanicians who met the needs of the successive stages of the great development shown by the figures quoted on Table 3 (page 640). Three figures stand out prominently:—

Winsor.—Winsor does not seem to have been so much the Engineer as the promoter. He put up Accum as the technician in the evidence before Parliament for his Bills for lighting London, at first as the National Light and Heat Company, afterwards the Chartered Gas Company. Until 1813, when Clegg came into the service of the Chartered Company, no practical or financial success was obtained.

Samuel Clegg.—From the earliest date of practical construction of gasworks the name of Samuel Clegg recurs frequently in all authorities and is represented by such substantial patents and improvements in the plant necessary to work out the practical operation of the primitive and crude schemes promoted by Winsor, that he deserves considerable notice at our hands. He appeared to have had a thorough Engineer's training and practice. Up to 1813 he was working at Boulton and Watt's (no doubt in contact with Murdoch), while he seems to have assisted in putting up gasworks on a small scale in the years 1806, 1807, and 1809, under Murdoch. He was, moreover, recognized by the Society of Arts for his description and plan of plant for the supply of Akermann's premises in London in 1812, for which he received the Society's Silver Medal. In 1813 he was appointed Engineer to the Chartered Company at their Peters Street Works. At these works he was assisted by Malam, whose name occurs later on in connexion with many useful works. While at Peters Street, Clegg was injured by an explosion in the purifiers.

In the year 1817 Clegg left the Chartered Company's service and afterwards was building works at Birmingham, Bristol, Worcester, Bury St. Edmunds, and in many other minor towns. In the year 1850 he was writing vigorously to the "Journal of Gas Lighting," vindicating his claim to the invention of the wet meter, which was being contested by his old associate, Malam. In that year he also supported Croll's application for Parliamentary powers for the Great Central Gas Company, and speaking of having established 40 gasworks of various scales. The latest record to be found of him is in the form of memoirs of his early works, published by his son, Samuel Clegg, Junior (who pre-deceased him), in three editions, 1841, 1853, and 1859 respectively, which forms a very valuable manual on gasworks construction and management.

The invention of the wet meter and of the hydraulic seal in retort mains, valves, purifier covers and gas-holders, are all credited to Clegg, and justly so. Though there were advantages in Malam's meter invention, it is clearly an improved adaptation of Clegg's earlier appliance. It seems very obvious, however, that the hydraulic seals in all these appliances were borrowed from the Chemical Laboratory, where the collection of gases experimentally was always made, as now, in bell-jars over a water cistern through which the pipe from the still passed, being turned upwards within the perimeter of the inverted dome; this was so converted into an inspirating gas-holder by being filled with water and inverted while covered with water. Lavoisier, in 1795, designed an experimental metal gas-holder working in a metal tank of water, which is practically the identical apparatus used in testing meters to-day, and contains the exact principle, in miniature, of the largest gas-holder works of the present day.

In regard to Clegg's general use of hydraulic seals, while modern pressures render the use of mechanical joints more convenient for meters, valves and covers of purifiers, etc., and for movable sliding chandeliers, it was found both by Sir George Livesey and by the Lecturer, that no mechanically-faced valve of large bore was so secure in preventing small leakages from contaminating the gas when purified, as a water-sealed diaphragm valve. On the other hand, the dry meter has almost invariably displaced water-sealed meters in Great Britain. In any case, Clegg's inventions and methods of meeting physical difficulties command our admiration, as they were very remarkable and their utility prevails to the present day. In 1817 he patented a collapsible gas-holder of flexible canvas, applied on the principle of the ordinary fire bellows. These holders are recorded as being actually in use at an oil-gas works in Aldgate for lighting Whitechapel, previously referred to. These bellows worked with the lower edges of the side boards in a water-tank. The difficulty of collapsing any flexible canvas or leather with gas in that way is perhaps not so difficult between the hinged sides as it is when you bring the bottom edges of the boards, the wider edges of the boards, together. There is nothing would adapt itself to the motion of the side boards and the valvular motion like immersing them in water, and these gas-holders stood over a tank of water in which these side boards were placed. Nevertheless it was a very ingenious idea of Clegg's, as the gas-holder question was a very difficult one in those early days, because it was far and away the most expensive part of the plant that engineers had to contend with. He further invented a rotary gas-holder working in a tank of water, and also a system of pot retorts slowly rotating over a furnace gradually bringing the coal to the hottest flame. The Gas Industry is clearly indebted to Clegg for most of the practical inventions which conduced to the early extension of the use of gas, and many of which are in general use up to to-day. A very interesting and important figure—in fact, he stands out pre-eminent in practical work of value for the first twenty-five years of the development of gas.

Malam, Clegg's old foreman and associate in both the Soho Works of Boulton and Watt and at the Westminster Gasworks of the then called Chartered Gas Company. He seems to have done a good deal of work in the provinces and in the north, where his name is still to be seen on old pieces of plant. Probably much of this at first was done under Clegg's superintendence, as Malam appears to have, like a number of other engineers, become contractor by force of circumstances. He patented in 1820 an improved wet meter, introducing the Archimedean screw into the shape of the four revolving chambers, which were divided similarly to Clegg's original patent for two revolving chambers. In 1822 he patented a lime purifier, and, later, various subsidiary improvements. He seems to have been quite a practical man and a sound engineer.

Mabon, a Scotch Engineer, appears to have done a good deal of work in Scotland and the north at the same period as Malam.

Sadler, in connexion with the Liverpool Gas, preceded the very notable Wm. King, uncle of the late Alfred King, and a grand-uncle of the present Wm. King, all three of whom carried the history of Liverpool Gas from its foundation to the end of the century.

Peckston, the author of the "Practical Treatise on the Manufacture of Gas," which reached a third edition in 1841, describes himself as responsible for some 12 different works, of which the chief was at Bury St. Edmunds; but he appears to have been largely assisted by Malam.

Grafton, a pupil of Malam's, practised in the "Forties" in the provinces, and was responsible in a large degree for the introduction of clay retorts, and of an exhauster to relieve pressure on them—which reduced leakage.

John Evans, believed to have been the father of F. J. Evans, and his brother George Evans, Engineers respectively of the Chartered and Brentford Gas Companies, followed Clegg as Engineer to the Chartered Company, having charge of the Westminster Works.

George Lowe, who followed John Evans about 1849, was an important figure among gas engineers, and was largely consulted by them. He had a long connexion with the Chartered Company, and trained the sons of his predecessor, who had positions under him, at Brick Lane and elsewhere. He had a system for water-gas.

John Kirkham, father of the late Thos. N. Kirkham, played a conspicuous part in the conduct of the Imperial Gas Company, and specially of the Fulham Works.

D. Methven was for some time Engineer to the Commercial Gas Company, and later to the Imperial Works at Haggerston. He supported Croll's scheme for the Great Central Gas Company.

John Eunson, at Wolverhampton up to 1846, played a very useful and considerable part in the introduction of clay retorts. He had all the plant and furnaces for making them at the gasworks at Wolverhampton, where he was followed by Robert Jones. After leaving the Gas Company, Eunson practised in Wolverhampton as a Consulting Engineer, and at the same time manufactured and contracted for retorts. He went to Northampton Gas Company later, where he was followed by his son.

E. Goddard, of the Ipswich Gas Company, had a long and valued career with that Company and as a Consultant. He was one of the pioneers, with Alfred King of Liverpool, in demonstrating the service of gas for domestic uses.

The brothers *Charles* and *George Robinson*, Engineers respectively of the original Gas Companies of Leicester and Coventry, were connected professionally very widely. They were acting for the Belfast and other important Companies. They were early pioneers in tar distilling at both Leicester and Coventry, and demonstrated its value; but the general run of undertakings, on even larger scale, neglected to follow them, and the trade in general went to outside contractors.

Bartholomew is a name associated with the earliest history of gasworks in Glasgow, but one fails to find particulars of his work or of those who immediately followed him.

Glasgow gas will ever be associated with the name of *William Foulis*, who reconstructed the original works for the Corporation, and added at least two very important new works on new sites, which are conspicuous for their good placing, efficiency in operation, and low cost. The low selling price of gas in Glasgow is largely due to the skill and care of this talented Engineer, who was prematurely cut off. He was a student under Rankine and Lord Kelvin.

There are records of the name of *Reid* in connexion with the early history of the Edinburgh Gas Undertaking. This undertaking was bought by the Corporation, as was also the Leith Gas Undertaking, and the supply is now carried on by a large works at Granton, designed by W. R. Herring.

F. J. Evans followed G. Lowe in 1837, and remained all his life with the Chartered Company, afterwards the Gaslight and Coke Company. He advised and laid out the extension of older works, and ultimately their removal from London to Beckton, where he designed and executed those enormous works up to the date of his retiring and becoming a Director of the Company. It was an immense piece of work, and he was well advised to call in the aid of an independent Civil Engineer, Vitruvius Wyatt, who acted with him, and continued to act for the Company after Mr. Evans retired. These works are so large and important that they cannot be described here beyond stating that to-day they are equal to an output of 60 million cubic feet per diem, or 12,000 millions per annum.* Many serious engineering difficulties had to be met in foundation work, owing to the construction being on what had formerly, no doubt, been the bed of a prehistoric river delta.

George Evans, a brother of F. J. Evans, was largely identified with the foundation and progress of the Brentford Gas Company, which from comparatively small beginnings has grown into a Company third in importance in connexion with the Metropolis.

Robert Jones, at Chester in 1840, afterwards at Bath, in 1846 at Wolverhampton, and later at the London Commercial Company, was standing Consulting Engineer for many years of the London Gas Company, whose works at Nine Elms he originally laid out and constructed. Later, he was Consulting Engineer to the Surrey

* *See* Proceedings, I. Mech. E., 1886, page 422, and Plan of Works in Detailed Programme, 1886.

Consumers' Gas Company, having works at Rotherhithe, a lease of which was surrendered to A. A. Croll, Esq., about 1855. He built the new Poplar Works of the Commercial Gas Company, 1876, which for economical expenditure of capital was always held by the late Sir George Livesey to be a prominent example. He reconstructed the Stepney Gasworks of the same Company. He was also consulted widely in the south of England, acting for many years for Chester, Leamington, Canterbury, Ramsgate and, in early days, the Wandsworth and Epsom Companies. Perhaps one of the most important of his consultative works was his negotiation for the Corporation of Birmingham for the acquisition, without arbitration, of the old Birmingham Gas Company's Undertaking, and the still larger one of the Birmingham and Staffordshire Company.

In his day Robert Jones led the way in large gas-holder construction at Stepney, where his holder for 2 millions cubic feet, afterwards increased to 3 millions, was at the period of its construction, in 1863, the largest known. He was a pioneer of high-temperature carbonization, such as to-day is represented by his successors and descendants in the very successful results obtained in the Companies that he specially directed. He paid great attention to the manufacture of clay retorts, which he carried on for the Wolverhampton Company. He established at Wolverhampton, about 1850, a private tar distillery and sulphate of ammonia works, in default of persuading his Company to take that step. He was, further, a pioneer in accepting the Sliding Scale Legislation for the Commercial Gas Company, which has operated with extraordinary success, that Company charging, at the present time, the lowest price for gas of the Central London Companies. He was a great admirer of Mr. Thomas Hawksley, and often conferred with him.

Alexander Wright.—Associated with London gas, as largely responsible for the Western Gas Company's Works at Kensal Green, is the name of one, Palmer, but the chief part of the works as existing in modern times, was the work of Alexander Wright, who was a man of considerable attainments. He was identified with improvements in gas-meters and also in photometric and testing apparatus. He was for some time, also, responsible for the administration of the Great Central Gas Company, whose works are at Bow Common.

A. A. Croll.—Alexander Angus Croll, assisted throughout by Mr. George Anderson, was responsible for the construction of the Great Central Works at Bow Common, having previously had charge of the Surrey Consumers' Gasworks at Bermondsey, which last he worked upon a lease. These works are rather special; they show very great economy of material and design in the details of the larger constructions, and worked, into quite modern times, a combination of iron retorts with clay, utilizing on the more susceptible metal the waste heat from the higher temperature at which the clay retorts were operated in adjoining settings. This system accomplished in its day a very large economy of fuel. This gas undertaking was the pioneer of the supply of cheap gas in and around London, where it was founded to compete with the Chartered and the old City Companies. It was absorbed, together with the City Company, by the Gaslight and Coke Company, in pursuance of the new legislation of 1868, which will be dealt with later on.

Carrying on the development, and belonging to a later period than the foregoing, came:—

T. Newbigging, of Bacup, in 1864, some time in charge of important works at Pernambuco, and later Consulting Engineer in Manchester, the writer of several very useful Manuals and books of Tables for Gas Engineers. Specially he was Editor of "King's Treatise on Gas Lighting," an important work running into three quarto volumes, published from 1878 onwards. Mr. Newbigging had a very happy knack of writing on subjects outside gas altogether, of general or local interest, and showed considerable culture and poetic taste. His wide experience and attainments made him a very important figure in the history of gas and won for him an extensive consulting practice.

J. B. Paddon, for many years connected, as Engineer and ultimately as Chairman of the Directors, with the history of the

Brighton and Hove Gas, played an important part in its extension and was responsible for some extremely difficult work of an unusual and very interesting kind to the Civil Engineer. Particularly was this shown in the completeness of his designs and plans of all sorts of plant. He acquired a very special skill in recovering land from the sea, by the study of groyning, by which he gained a very large area for the site of the important gasworks at Portslade, near Hove, before the accomplishment of which he had some exciting experience in battling with the storm influences affecting the beach on which his works are constructed. His great success in this matter makes it unfortunate that records were not left, for the guidance of Engineers charged with maintenance, and security from coast erosion generally. He developed many other important undertakings: Southampton, Winchester, Lewes, Southgate, Lea Bridge, Hornsey, and was a Director of the Gaslight Company.

G. W. Stevenson.—No record of the persons engaged in the development of gas could be complete without reference to Mr. G. W. Stevenson, formerly of Halifax, who secured the erection of the gasworks at West Bromwich by competitive plans. This gentleman was mainly engaged in the last years of his life in arbitration and Parliamentary work.

Jabez Church, in the Eastern Counties, had a considerable practice in gasworks of a secondary scale.

Thomas Kirkham, of the Fulham Gasworks of the Imperial Company, carried out very large extensions of those works and also was responsible for the construction of the new Bromley Works of the same company, which is of large scale. He was responsible for no less than six gas-holders.

Robert Morton, the inventor of many useful devices in connexion with gasworks construction and administration, was for many years in charge of the London Gasworks, until its amalgamation with the Gaslight and Coke Company.

T. G. Barlow, formerly editor of the *Gaslight Journal*, was for some time engaged as Consulting Engineer to the Dublin Gas Company. Before that he carried out a number of works on the Continent, working with Messrs. Manby and Wilson, who with him played a considerable part in the establishment of works at the important towns of Havre, Rouen, and Amiens, now the property of the European Gas Company.

Sir Corbet Woodall, first at Woolwich, later at the Phœnix Gasworks at Vauxhall, became Chief Engineer to that Company, following William Innes. He retired on the amalgamation of the Company with the South Metropolitan, and for many years carried on an extensive practice in arbitration and Parliamentary work, at the same time being associated with the direction of many important gas undertakings, of which the chief was the Gaslight and Coke Company of London, until he died early in 1916. He constructed specially a holder for 3 million cubic feet at Kennington, in which he dispensed with truss framing, having given his allegiance to that form of economic construction in early days.

Thomas Hawksley.—But for extent and magnitude of practice in gasworks construction, carried out from 1830 to 1893, Mr. Thomas Hawksley could not be equalled by any engineer of any date within the nineteenth century or since, and this is obvious from the list (given below) of the works he built for towns he originally supplied with gas—apart from the extensive consulting practice on works construction and Parliamentary and arbitration proceedings —and if it be remembered that his practice was chiefly in waterworks of extensive scale, in course of which he brought water into no less than 150 towns in England and abroad, it will be clearly seen that his work was simply prodigious in extent and variety. To illustrate this, I appeal to the list of gasworks designed either in whole or in part by Thomas Hawksley, and carried out under his direction :—

Great Britain: Nottingham, Sunderland, Derby, Cambridge, Oxford, Burton-on-Trent, Folkestone, Radcliffe, Chesterfield, Mansfield, Barnsley, Gosport, Bishop Auckland, Newark-on-Trent, King's Lynn, Normanton, Victoria Docks, Lowestoft.

Foreign Countries and Colonies: Melbourne (Australia), Bombay, Hobart (Tasmania), Launceston (Tasmania), Danish Gas (Copenhagen).

Seeing that Thomas Hawksley had, in the early days, little assistance from contractors with experienced or skilled labour, foundries, rolling mills or machine-tools, and therefore had largely to teach his various contractors in all the specialities, such as retort setting, gas-holder and tank construction, as well as in purification plant and largely in steam plant, his labours must have been such as would have overpowered anyone with a weaker physique and less vital energy.

An examination of his earlier works, which were of Roman endurance, shows that the number of explosions which alarmed the public very much (such as those at Westminster in purifiers, in 1814, which injured Clegg, of the gas-holder at Manchester in 1819, the purifiers at Old Kent Road in 1835, the benzol explosion at the London Gasworks in 1857, which killed Michele) made it appear necessary to impart a strength of material that to-day is not found necessary. It, however, had the merit of an endurance which made the old plant valuable and serviceable when replaced to work in fresh situations.

Specimens of Mr. Hawksley's work, in designs and drawings for the Derby Gasworks, 1871–2, were shown. For fulness and completeness of detail and finish they would not be excelled, if equalled, in any Engineer's office at the present day. They are good standards in all respects.

Mr. Hawksley shone when advising Parliamentary Committees. He carried conviction by his thorough practical acquaintance with his subject and the prompt and fluent expression he could give, in legal terms, to frame any suggestion suddenly arising for alteration of clauses. This was cheerfully acknowledged by his many friends at the Bar. He was very sympathetic with the difficulties of young engineers and freely helped them with technical advice, and on occasions when necessary he had no difficulty in helping them in a more substantial fashion.

In the Institution of Civil Engineers, of which Mr. Hawksley was a President, and for many years a leading Member of the Council, his memory is deservedly preserved as an Engineer of the first eminence and distinction, and of unimpeachable personal honour. He was a Member of the Council of the Institution of

Mechanical Engineers from 1862, and was President for two years, 1876–77. He was the first President of the British Association of Gas Managers, presiding at the first General Meeting in 1864, when there were gathered round him most of those who have been referred to as occupying important positions in the progress of gas supply. His extraordinarily useful and successful career, extending over so long a period, makes him an exemplary figure for the followers of his Profession. He must certainly be considered an important pioneer in the history of Gas Engineers during the last century.

Sir George Livesey.—There is no other such striking personality in the history of Gas Engineering until we come to the late Sir George Livesey, very like Mr. Hawksley in the personal qualities of courage, originality, and resource in difficulties, strong in will and fixed in purpose, and, like him, kindly, helpful, and considerate to the point of gentleness where sympathy came in. Though not engaged so widely and variously, Livesey executed some of the largest and most original departures in gasworks constructions. These were illustrated by a lantern slide showing the Plan of the East Greenwich Works of the South Metropolitan Gas Company, which are equal to the large daily output of roughly 30 million cubic feet. There you have not only jetties, viaducts, wharf walling, deep tanks and the loftiest gas-holders yet ventured upon in this country, extensive carbonizing retort buildings and special purifying plant, but also a tar distillery, sulphuric acid works, and plant for following up all the ramifications and labyrinths of the enormous family of secondary by-products arising therefrom. Thus he executed works of serious Engineering difficulty, in connection with deep foundations, sand pumping and grabbing through water-bearing strata, mining, construction of deep tanks in unstable soils often water-logged and under heavy pressure from neighbourhood of main river channels.

Besides the execution of some of the largest and boldest constructions in gas plant and works containing novel principles, such as gas-holder tanks in concrete, holders without internal framing, and of late years omitting the upper sections of the external framing, omitting houses of protection for such portions of the plant as purifiers and station meters, the introduction of generator furnace work for retorts fed centrally from external producers on lines very much the same as those of Mr. Foulis, of Glasgow; finally constructing gas-holders of enormous capacity (one of 12 millions per diem with six telescopic lifts), while generally advising freely and gratuitously a large number of his professional compeers in important works, Sir George played an unexampled part in swaying and directing the policy and financial aspect of gas supply over the eventful period between 1865 and his death in 1908. Only in less degree than the late J. O. Phillips, General Manager of the Gaslight Company, was he active in amalgamations, which he brought in all cases to a complete financial success, while he rapidly reduced the cost of gas to the consumer. He fought to a victory one of the most determined and protracted strikes, and thereafter established a new and most successful settlement of labour conditions by means of his profit-sharing system, later called the co-partnership. (His workmen-Directors scheme was only followed by the Crystal Palace Company.)

He may be credited with the present form of the sliding scale clauses, for adjusting the dividend inversely with the price of gas, which are now almost universal, though it is right to say that a scale, working only upward on dividend, had existed in one or two cases before. In advising this method, he did not hesitate to criticize very severely the machinery enacted in 1868 for revising the terms of price of gas by a court of referees. Perhaps his services to the industry were most important in removing the vexatious and useless restrictions on the manufacture of the gas, and still more in securing that the means of testing employed fair and suitable methods and standards.

His position as Chairman of the second most important Gas Undertaking in the world, with control of ample resources for supporting the burdens of successive Parliamentary battles with the Authorities who were vested with the control of the testing, enabled him to prosecute his aims and measures always to a successful end, based as they invariably were on the policy of protecting the real interests of the consumers. By courageous and successful appeals to Parliament, he liberated the industry from the trammels and the crippling ties of being legislatively submitted to tests of a vexatious and a necessarily microscopic character. These comprehended heavy penalties for infinitesimal proportions of ammonia not removed from the gas, though the value of such ammonia, when recovered, was at least £50 a ton, giving every possible impulse to its being abstracted. A form of impurity present in very small proportions, namely, bisulphide of carbon, was visited with very heavy penalties for a few grains per hundred cubic feet. With the modern class of burners, which reduce the consumption per unit of light thirty-fold, the injury, always very doubtful, was proved, to the satisfaction of a Commission, to be negligible.

Again, he relieved the industry from the use in testing for illuminating power of a burner which exaggerated small deficiencies, as it was incapable of testing with accuracy, and without serious damage to the gas, for small defects. The correction of this injustice has enabled a calorific standard to be fixed which is satisfactory alike to both the consumer and the supplier, and is, moreover, a very much simpler method of determination of the value, being much less liable to personal variation, defective sight, etc. The inventor of the burner, the adoption of which brought about this condition, was Dr. Charles C. Carpenter, *Member*, Chairman of the South Metropolitan Gas Company.

The source of Livesey's extraordinary influence was his obvious sincerity and earnest purpose. His great breadth of grasp and thorough knowledge of the subjects he studied and made his own, made him the most convincing witness, and no cross-examination could shake him, as his views were very firmly and deliberately formed, and from all sides of the question. Those who differed from some of his views could never regard him without entire respect. After overcoming a dangerous strike, which lasted for many weeks, by his masterful and able methods of providing for the workers, he devoted his mind to a very careful study of the labour problem. This led him to the establishment of equitable and co-operative systems, the successful development of which at, successively, the South Metropolitan, the South Suburban, the Commercial, and many other companies, made him much regarded in public opinion as an authority on social questions.

Through many years he exercised so benignant an influence over the district in which his chief work of the South Metropolitan Gas Company lay, that his funeral furnished the extraordinary and impressive sight of some two to three miles of streets lined two-deep with men, women and children, quite outside a large number of employees who were present at the cemetery.

Having dealt with the personal elements at work I would now deal finally with the general position of the industry to-day and the problems still before the Gas Engineer.

A development of special consequence in the later years arises from the Slot Meter consumption, which is found to be very valuable as levelling the load between summer and winter. This enables capital already spent to be more fully utilized in works and mains and services, while the nature of the demand so far dispenses with the need for storage that large capital outlays contemplated in the past have proved for the present to be unnecessary. In this way the slot consumer may claim to have been specially profitable, and therefore to be entitled to consideration in the price. A very similar claim has arisen and been met by discounts on daylight and summer consumption in factories which are rapidly realizing the value of gas-power in engines, and even still more the efficiency of gas in heating, smelting, and countless trade operations. A measure is afforded of the advantage arising from this development between 1900 and 1915, in the progress of three of the lowest-priced gas companies in and about London. From 1900, on a joint mileage of 1,403, there was an increase up to 1915 of 540 miles = 38 per cent., while consumers per mile increased from 262,020 to 566,859 = 113 per cent.

A further proof is given by the experience of the Wandsworth, Wimbledon, and Epsom District Gas Company, 40,000 slot-meters consume in the summer six months 10,207 cubic feet each, against the consumption in the winter six months of 11,026 cubic feet each, or within 8 per cent. of the same quantity in summer as in winter. As in the case of many other undertakings, the highest peak of the demand is between midday and 1 p.m. on a summer Sunday. It is clear this increasing domestic use must displace coal, and to that extent counteract the rise in coal prices. It is interesting to learn that His Majesty's Mint and Messrs. Rothschild's Refineries consume respectively as much gas as towns of 10,000 inhabitants, as both find the power of gas, applied in suitable furnaces, to be greater than that of any fuel of equal cost. In this relation, one London Gas Company which has been making munitions, and to that end melting down and amalgamating certain important metals for fuses, has been asked to extend their work in smelting on the ground that the metals so reduced are found to give higher tests of value than those prepared generally elsewhere. This preference must be specially gratifying, as it points to the extension of service in a new and unsuspected direction.

Generally, it must be recognized that as the incandescent light of Welsbach only needs an adequate heating-power, the old aim at illuminating-power, *per se* (in the early years the only object of gas manufacture), has now finally given way to the far more generally useful heating-power. If this be so, our former anxious efforts, at great sacrifice of cost, are no longer needed, and what we have to do is to find a really cheap, serviceable fuel, to be distributed by our systems of arterial and service mains, such as will meet all wants. Our distributing systems would not deal with a very low grade heating-gas, even if such a gas would be generally useful, which is more than doubtful; but we must recognize the demand will necessarily be for the cheapest fuel of like efficiency.

It is impossible to maintain the old traditions and prejudices, and it is therefore a very welcome opening that is being given by the Government in the shape of Mr. Pretyman's Act of Parliament, enabling specially such undertakings as are recovering hydrocarbons for War Services to exchange their present illuminating-power standards for a heating standard. The special experience of the Wandsworth, the South Suburban, and the Gaslight Companies, who accepted this change some years ago, has been that it gives no practical inconvenience or loss to the consumer, while it affords considerable latitude towards economy of production to the gas-maker. As nearly all the gas companies are under Sliding Scale Legislation it follows that from three-fourths to nine-tenths of any saving arising will react in reducing the selling-price of the gas, and that again will operate to the expansion of the supply.

War Demands.—This leads to the consideration of what aid is being given directly to War Service in entirely new directions. While undergoing a restricted supply of coals and shipping which largely increases our costs, and a denuding of our manual labour to the point of exhaustion, the larger gasworks, already making shells and fuses, have been further called upon to recover certain hydro-carbons and to furnish ammonia in concentrated form, as well as certain acids, and this demand has been met to such an extent, that some large works where special efforts are being made are almost devoted to War Service. This is all being done without profit of any kind, and even the services of head of staffs are further given ungrudgingly, as indeed should be expected in a national emergency. One must believe that the experience gained in doing these things in war time will react and enure to future benefit when peace is restored.

Under war conditions, as the Ministry of Munitions stated to the Westminster City Council, no profit can arise to the Gas Undertakings, who indeed have been put to considerable out-of-pocket expenditure in order to secure the operations in addition to the permanent cost of working. After the war is over, there is reasonable hope that the various plants installed for National Service may continue to be employed in productions useful in the Arts and Manufactures of the country at large. This would assist in reducing the price of gas to the consumer, as it adds value to most of the residuals.

It is obvious that all economies realizable in this way are, in the interests of gas consumers, best got at the source of the supply. They arise from bulky and somewhat unsavoury raw products, so that the cost of transport and re-transport of products should be saved and the control kept in the hands of the producers. Even the sulphur, which is the chief impurity in crude gas, is now easily recovered from the spent purifying material and turned into sulphuric acid, which again fixes the volatile ammonia in the condensed, convenient, and valuable form of the sulphate, for which there is a world-wide demand as fertilizer.

In pursuance of these valuable productions, and the consequent profit to the user of gas, the companies have, with Government aid, extended and developed their plants for war purposes, but there can be no doubt whatever that all these products will have a permanent value in the future, and that the importance of them all will be widely recognized. Our astute enemy, Germany, has for years past been acquiring and accumulating our products, which gave great advantage for the first months of fighting.

Problems.—The Engineers of to-day: What task is before them? What problem is to be solved? Is it not to find a gaseous fuel, superior to the producer-gas, and therefore worth distributing, and yet cheaper than that which is now supplied, because the valuable residuals should all be recovered to the last ounce? Are we not working towards it by the successive steps of discarding cannel and high-power gas in favour of a universal standard of an adequate calorific efficiency, but calling for no fanciful cost or waste in its preparation? The specific gravity of such a gas enables it to be distributed at a low cost, whether of capital in canalization or for the propulsion. Dr. Mond shows us that for gas of low calorific values the recovery of ammonia is so increased as to greatly diminish the net cost for material; and we may have much to learn here. But the larger volume necessary to carry the same thermal efficiency puts so weak a gas out of the range of suitability for town distribution through the systems of main pipes as existing.

These systems represent a large expenditure, and are so packed below costly pavements as to prohibit their replacement or enlargement except by hazarding a great capital outlay. If they are to be used and made most serviceable, even under greater compressions and propulsion costs, clearly we must not lower much further the present standard of calorific. Has not the replacement of tests for illuminating power by calorific test already rid us of the fanciful and expensive expedients that formerly were demanded by the damaging effects of unsuitable testing burners of destructive action? Can we not establish the real fuel value of our coke—improve the output of ammonia—seek out and bring to account all the value of the numerous family of hydrocarbons that is resident in the tar, such as fill so many practical uses in arts, colours, scents, antiseptics, drugs, solvents, motor-power fluids, road-making materials, fertilizers, acids, and the countless other products, and so realize a cost of production under improved labour-saving appliances so as to enable us to supply power and heat for all purposes, trade and domestic, at charges which would make it worth no one's while to employ any other sort of fuel, specially looking to the facility of obtaining it unlimited at will afforded by the constant supply from the street mains.

For rural communities, scattered over areas remote from railway depots for coal, the supply of heat by gas carried at a nominal cost in the arterial mains is a great boon, because the cartage of coal on such small scales and over such distances as they require is practically prohibitive. Gas can quite profitably be distributed on so low a demand as 1½ million cubic feet per mile without incurring a cost for capital and working charges of more than 2*d.* to 3*d.* per 1,000 cubic feet.

It is a source of satisfaction to remember that the use of town gas in the earliest and crudest forms of internal-combustion engines (which the industry has always helped and encouraged by adoption and employment long before they reached their present efficiency and economy) has developed to a general service which seems much appreciated by power-users at large. The employment of ordinary town gas for this purpose grows continuously, and is especially in favour on the Continent, where gas companies are under the greatest pressure to hire and sell the engines to power-users of all scales.

It is clear that the perfecting of the gas-engine, in which Dr. Dugald Clerk has played a very prominent part, has led to and made possible the auto-motor cars and traction engines as well as for the purpose of aviation. Mr. Hanbury Thomas lately stated that the Sheffield Gas Company had in the last five years raised the number of gas-engines supplied by 15,116 h.p., and that the total quantity of gas so supplied in 1915 was 789 million cubic feet annually. This figure may be better understood as demanding the use of about 72,000 tons of coal. The development of the growing use of gas, in replacing smelting and other furnaces demanding the highest heats, by the Sheffield Company, is equally shown by the fact that the Company have sent out 642 furnaces, using 372 million cubic feet of gas.

Professor Bone is responsible for the statement that 60 millions sterling yearly could be saved, by the replacement of gaseous fuel for the raw coal, by the values saved of the by-products on the former system. Obviously the national interest demands that the direct use of raw coal for heating purposes, where a solid fuel is not indispensable, should be controlled and checked so that all the valuable elements should be recovered. For such uses as a solid fuel would appear desirable, the residual coke can be proved to be serviceable, with the advantage that it is smokeless, sootless, and more enduring, weight for weight, than coal, while it yields less impurity to contaminate any substance or metal heated by it.

The Board of Trade Return of Total Annual Coal Production is put at 189 million tons in 1913. Of this, 16 million tons is used by gasworks, which also might use 2 million more by avoiding the use of imported oil: say, a total of 18 million tons—in the whole of which the by-products are recoverable. The coke ovens account for 20 million more, according to Professor Bone, of which only some two-thirds have the by-products recovered; making, therefore, a total of 32 million tons, or little over one-sixth of the whole, which is economically used, and after allowing for export it is clear that there is an enormous national loss going on.

One must support the further view of Professor Bone, that the practical chemist has an extensive and important future in guarding against this loss and in helping to its avoidance. From having personally enjoyed the assistance in gas management from so early a date as 1875 of distinguished chemists, I can endorse the

Professor's urgent advocacy for the fuller and wider employment of chemical science. But I must insist that it shall be supplementary, and not to replace the engineer's science, always demanded, and of which I have quoted notable and successful examples.

The claims of the War have conferred a new sphere of usefulness upon us, which, as it serves the national safety, adds nothing short of a special dignity to our work. Let us see that we spare no personal effort in this hour of trial to give the best that is in us, and above all, let it rouse our sense of responsibility to do honour and give credit to our profession by persevering study and faithful loyalty to the worthy examples afforded by our predecessors, "The Gas Engineers of the Last Century."

The Lecture is illustrated by Plate 5 and 3 Figs. in the letterpress.

The attendance was 52 Members and 53 Visitors.

The LECTURE was repeated by Mr. JONES in Cardiff, at the South Wales Institute of Engineers, Park Place, on Thursday, 9th November. Mr. DAVID E. ROBERTS (*Member*) presided, and 30 were present. Mr. JONES, in replying to a Vote of Thanks, reminded the Meeting that, in addition to works referred to in the Lecture, Thomas Hawksley had carried out some extensive waterworks in South Wales, and had installed over 150 waterworks of the highest importance in the United Kingdom.

Fig. 1. *A District of London, 1809-14.*

a. Brick Lane gasometer.
b. Norton Folgate ,,
c. Westminster ,,
A.B.C. Inter-communication junctions between a.b.c.
—— Principal gas mains.
------ Branch ,, ,,

1. River Thames.
2. Strand.
3. Whitehall.
4. Charing Cross.
5. Haymarket.
6. Coventry St.
7. Piccadilly.
8. St. James's St.
9. Pall Mall.

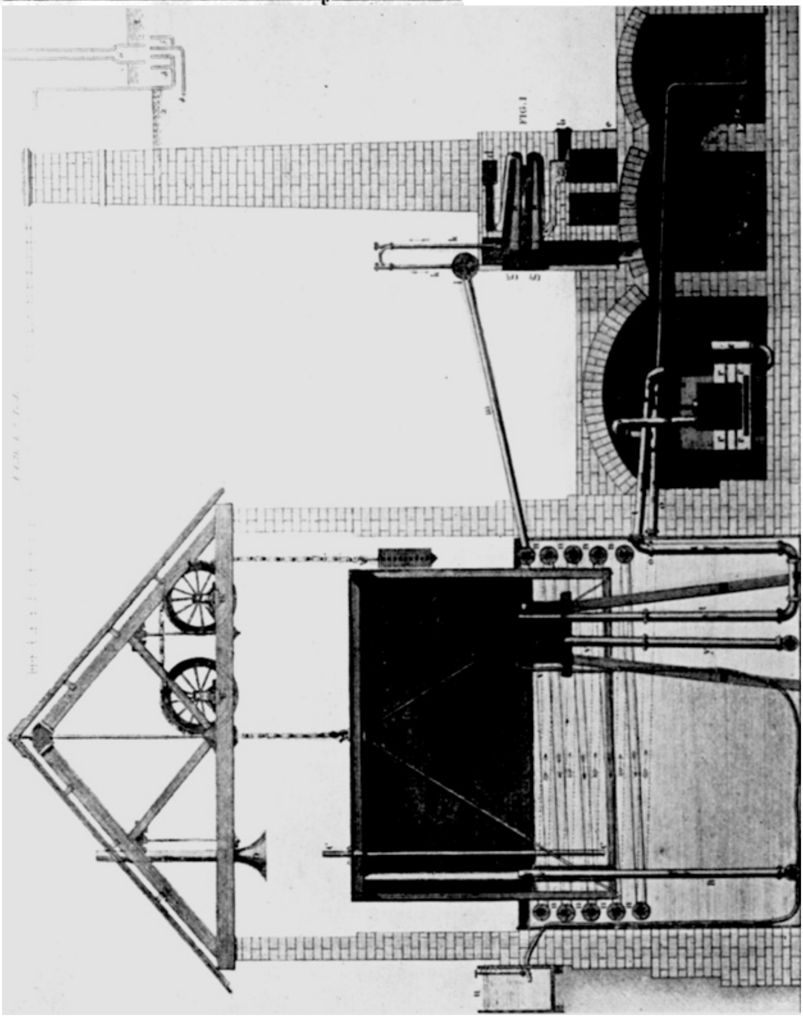

Fig. 2. *Gasometer designed by Winsor, 1809-14.*

(Photos from the original engravings, Traité pratique, 1816.)