A TREATISE ON

GAS WORKS

AND THE PRACTICE OF MANUFACTURING AND DISTRIBUTING COAL GAS

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FOURTH EDITION, WITH ILLUSTRATIONS

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Capio Lumen

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PREFACE.

THE engagements of Mr. Hughes having prevented his making the necessary revisions for a new Edition of this book, I have been entrusted with the task, and in accepting it have endeavoured to make a really practical manual of the present condition of gas manufacture.

The great change which has taken place in this branch of industry during the past few years, has demanded considerable alteration in the work; much new matter has been added, and several woodcuts illustrative of the various apparatus have been introduced; so that I trust the present Edition may be found equal to the requirements of those interested in the production and distribution of gas.

WILLIAM RICHARDS.

CONTENTS.

CHAPTER I.

EARLY HISTORY OF GAS-LIGHTING.

APPLICATION OF COAL GAS TO USEFUL PURPOSES.

CHAPTER II.

ON THE CHEMISTRY OF GAS LIGHTING.

CHAPTER III.

COAL USED IN GAS MAKING.

CHAPTER IV.

ON THE CARBONISATION OF COAL.

CHAPTER V.

SITES MOST APPROPRIATE FOR GAS-WORKS.

CHAPTER VI.

ON THE RETORT-HOUSE AND BUILDINGS.

CHAPTER VII.

ON THE RETORTS USED IN GAS-MAKING.

CHAPTER VIII.

ON RETORT SETTINGS.

CHAPTER IX.

METHOD OF COMBINING CLAY AND IRON RETORTS.

CHAPTER X.

THE HYDRAULIC MAIN.

CHAPTER XI.

ON THE PURIFICATION OF GAS.

CHAPTER XII.

VARIOUS MODES OF PURIFYING GAS.

CHAPTER XIII.

THE GASHOLDER.

CHAPTER XIV.

ON THE EXHAUSTER.

CHAPTER XV.

ON GAS-METERS.

CHAPTER XVI.

ON LAYING MAINS AND SERVICES.

CHAPTER XVII.

ON APPARATUS FOR INDICATING AND RECORDING PRESSURE.

CHAPTER XVIII.

THE GOVERNOR AND REGULATOR.

CHAPTER XIX.

EXPERIMENTS ON COAL GAS.

CHAPTER XX.

ON THE MODE OF BURNING GAS.

CHAPTER XXI.

RESIDUAL PRODUCTS FROM COAL.

CHAPTER XXII.

EXPLOSIONS OF GAS.

CHAPTER XXIII.

ON WATER GAS, OR THE HYDROCARBON PROCESS OF GAS-MAKING.

CHAPTER XXIV.

ON THE RATING OF GAS-WORKS IN PAROCHIAL ASSESSMENTS.

ON THE

MANUFACTURE AND DISTRIBUTION OF COAL GAS.

CHAPTER I.

EARLY HISTORY OF GAS-LIGHTING.

The discovery and earliest observation of elastic aëriform fluids, capable of being inflamed and of imparting light and heat, must undoubtedly have been of great antiquity; inasmuch as many ancient writings contain notices of inflammable vapours springing from fissures and cavities in the earth. It is evident, therefore, that gas being a natural production, no such human individual as its discoverer or inventor ever existed. Modern chemistry demonstrates that inflammable gases, whether arising naturally from springs, or produced artificially by destructive distillation or otherwise, are composed of very simple elements, and present a remarkable analogy to the common carburetted hydrogen, which is the gas chiefly burnt in our street lamps and houses at the present day.

Inflammable gas may be truly said to be as old as the creation of organic matter, for wherever animal or vegetable substances have existed, by the immutable laws of nature they have been subject to decomposition; and wherever decomposition has taken place, a variety of gases have been produced, some of them inflammable, and others not so. Whether the decomposition be that caused by the slow combustion of decay, or the more rapid process caused by the application of sensible heat, the effect is the same—the gases are equally produced in the two cases.

Gas may with truth be called a more natural production than steam, although the latter has existed from the first creation of water, and in its palpable state, as proceeding from boiling water, must have been observed in all ages, although without any views of its present application having been conceived.

The discoveries of man with respect to gas and steam ought rather to be called applications ; they are conquests over the elements, and the subjugation of great powers in nature to his use and convenience. So it is with nearly all great inventions, in which we find one power of nature after another chained, confined, bound down, stored, and then let loose when required, and made to work machines, to propel ships across the ocean, to supply the place of human labour itself in a thousand variety of ways,—nay, to pass far beyond the bounds of human labour, and effect that, by a single effort, which the manual strength of a world could scarcely accomplish.

If such astonishing applications of steam and gas had been made in the days of ancient Greece, what magnificent, all-expressive, world-astounding names would have been found to convey their meaning: instead of such contemptible little monosyllables as *gas* and *steam*, one might have heard of the soul of coal and the spirit of water, with some superlative adjective to stamp the vast importance of each. In such an age these wonderful conquests would have thrown all meaner efforts into the shade ; for them, perhaps, would poetry have strung its harp, and the grandest epic productions of genius might have commemorated the victory of man over the inanimate matter of nature, instead of dedicating her loftiest songs to the art of war.

The avidity with which the early nations seized on all natural phenomena, and all exhibitions of great natural powers, is evident from the veneration paid to the burning flames which issued forth from fissures and cavities in the earth where probably lakes of petroleum existed, or in the neighbourhood of coal or bituminous schists. Some of the earliest nations have considered fire as a type of divinity; and we can scarcely wonder at the feelings of veneration and superstition occasioned by mysterious outbursts of flame, whose origin appeared utterly incomprehensible. Hence Superstition erected her altars over such flames, and claimed the interference of the Gods to sustain the perpetual miracle. But all that had been observed with reference to inflammable vapours in ancient times was very far indeed from approaching to anything like a useful purpose. Far from leading to any attempt to collect and use these vapours, their very nature and composition were unknown, and the most mistaken ideas prevailed as to their real elements. It was not till modern chemistry had exploded volumes of ancient dogmas,—had traced the so-called elements to far simpler forms,—and had divulged the laws according to which elements are combined in order to constitute all forms of matter,—it was not till then that it began to be seen that the inflammable vapour of coal, wood, oils, and other fatty substances, was analogous with the marsh gas which arises in bubbles from the decomposition of vegetables under water; that it was of a similar nature to the fatal dancing "Will-o'-the-Wisp," which on the wild moor or bog has lighted many a traveller to destruction; finally, that it resembled the gas which arises from the decomposition of water, however produced; and, in fact, that water, the greatest antagonist and extinguisher of flame, was itself composed of the most inflammable substance in nature, namely, hydrogen gas; while oxygen, the other element of water, is the greatest known supporter of combustion.

Many opinions have been hazarded to account for the almost perpetual fires which were kept burning on the ancient altars. Strabo and Plutarch mention these fires, which they describe as constantly burning, to which they add, that they are lighted by invisible means. This seems to involve a contradiction; for if they were always burning they could not require lighting.

The altar in the Temple of Ægina may be taken as an example of most of the ancient Greek fire-altars as exhibited in the temples. Here a round hole, about 13 inches in diameter, is observed in a block of stone. This round orifice opens into a square hole, which passes down through solid stone to a depth of several feet. The lower end of the square hole communicates with a cavity in which Mr. Dodwell supposes a fire to have been constantly kept burning, so that the flame did not appear above the surface of the circular opening. He says nothing more would be necessary than to pour oil into the opening, when the flames would immediately burst forth, and appear to have a miraculous origin.

The writings of Herodotus, Ctesias, and Vitruvius, mention the bituminous wells of Zakunthus, the modern island of Zante. Ælian notices springs near Apollonia; and Plutarch, in his Life of Alexander, mentions the fountain of naphtha with fire issuing from the earth in the territory of Ecbatana in Media (the modern Hamadan).*

The Babylonian bitumen, used for cementing masonry, was obtained from the district which now forms the pashalic of Bagdad. Bituminous strata also exist in Switzerland, Germany, France, in the papal territory, in Great Britain, Ireland, Cuba, and other parts of the world.

The springs described by Herodotus are not now worked; but their place is defined by the remains of a circular wall about 70 feet in diameter, within which the space is nearly filled up with earth. The opening from which the bitumen was extracted in his day is described as communicating with the sea, which, in calm weather, is tinged with the iridescent colours of the bitumen as it rises up to the surface of the water.

The bitumen is now drawn from small wells about 5 feet diameter and 3 or 4 feet deep. This mineral was much used by the ancients, as not only suitable for mortar, but also for cementing reeds together, and forming floors and ceilings.

The superstitions of eastern countries have always identified fire with the loftiest attributes of Divinity, and even with Divinity itself—while traces of fire-worship are said to exist

* Dodwell's "Classical and Topographical Tour through Greece." London, 1819.

even at the present day. In Plutarch's Life of Aristides there is a passage marking the superstitious reverence which the fire of their celebrated altars enjoyed, where the conquering Greeks under Pausanias are directed by the oracle of Delphi to build an altar to Jupiter the Deliverer, but not to offer any sacrifice on it till they had extinguished all the fires in the country, because it had been polluted by the barbarians (the Persians), and supplied themselves with pure fire from the altar at Delphi. In consequence of this the Grecian generals went all over the country and caused all the fires to be put out.*

The Chinese are said to use to this day, for economical purposes, the gas which escapes spontaneously from beds of bituminous coal. Within 30 miles of Pekin is a coal-field having beds of salt associated with the coal, and streams of gas rising naturally from the coal are conveyed to the salt-works by means of bamboo tubes, and there used for the boiling and evaporation of the salt. Other pipes convey the gas intended for lighting the streets and houses.†

There are many other instances at the present day where inflammable gases issue from the surface of the earth: this is the case at several places in the Apennines, particularly near Pietra Mala, on the road from Bologna to Florence. A similar case occurs in a mountain of Lycia, near the shore of the Gulf of Adalia in Asia Minor. Most of these phenomena no doubt arise from coal or other bituminous sub-

* Extract from Plutarch, relative to the fountain of naphtha in Ecbatana, or Hamadan. Alexander "traversed all the province of Babylon, which immediately made its submission; and in the district of Ecbatana he was particularly struck with a gulf of fire, which streamed continually, as from an inexhaustible force. He admired also a flood of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles the bitumen, but it is much more inflammable. Before any fire touches it, it catches light from a flame at some distance, and often kindles all the intermediate air. The barbarians, to show the king its force and the subtilty of its nature, scattered some drops of it in the street which led to his lodgings; and standing at one end, they applied their torches to some of the first drops; for it was night. The flame communicated itself swifter than thought, and the street was instantaneously all on fire."—"Life of Alexander," book v. p. 152, Langhorne's translation. 1832.

† R. C. Taylor, on the Coal-fields of China, in the Journal of the Franklin Institute. A similar instance occurs in the village of Fredonia, N.Y., where the inflammable gas issues from a small stream, called Canada Way, over which a gasometer is erected for collecting it.—Brewster's Journal, 1830.

stances, which by earthquake or like means have been buried at such a depth as to be distilled by the heat from the interior of our globe, so that the gas is expelled, and escapes through the fissures of the earth.

APPLICATION OF COAL GAS TO USEFUL PURPOSES.

We find among the "Philosophical Transactions" of 1667, a paper by Mr. Shirley, describing a spring arising in the coal district of Wigan in Lancashire, and which was supposed at the time to be a burning spring, because the vapour on the surface of it could be inflamed. Mr. Shirley pointed out that it was not the water which burnt, but the gas by which it was accompanied; and he traced its origin to the beds of coal which abound in that part of the country where the spring broke out.

Although these observations of Mr. Shirley referred the origin of the burning spring to the right cause, and clearly pointed to the possibility of procuring the same kind of gas by the combustion of coal, the subject appears to have received no particular attention at the time, and it was not till many years had elapsed that we find another observer prompted by this very same spring to institute experiments of a practical nature on the distillation of coal.

Probably the first authentic record of an experiment on the distillation of coal, appears in Dr. Hales' work on "Vegetable Statics," published in 1726, where he states that from the distillation of 158 grains of Newcastle coal he obtained 180 cubic inches of air (or gas), which weighed 51 grains, being nearly one-third of the whole. This result, which is rather more than 8,500 cubic feet per ton, agrees very nearly with the production of gas actually realised from Newcastle coal at the present day.

A few years afterwards, namely, in 1733, we find in the "Transactions of the Royal Society" a communication from Sir James Lowther, on the inflammable air issuing from the shaft of a coal mine near Whitehaven. The workmen were surprised on sinking to the depth of 42 fathoms to find a rush of air taking place, which caught fire from the flame of a candle and burnt with great intensity, making a blaze about 3 feet diameter and 6 feet high. Several experiments were made on this flame by the steward and others, who successively caused it to be extinguished by beating it down and smothering it with the colliers' hats and again lighting it. At length the heat communicated by the flame was found to be very inconvenient, as it warmed the pit to a high degree, and it was necessary to have recourse to water in order to extinguish it. After this the gas was not again allowed to be lighted till the sinking had proceeded down to a depth of several feet below the bed of coal through which the gas first made its appearance. The part of the pit at which the gas escaped was then securely walled off, and a tube about 2 inches square extended up the shaft to a height of 12 feet above the surface of the ground. Through this tube the gas was allowed to escape into the open air, which it continued to do in undiminished quantity for several years. Many observations and experiments were made on the gas which was thus discharged from the extremity of the tube. It was collected in bladders, tied up and preserved for many days. When a small pipe was fixed in the mouth of the bladder, and the gas gently pressed out against the flame of a candle by squeezing it, the gas was observed to take fire, and to burn so long as the bladder was gently squeezed and the gas expelled. This experiment on gas which had been so confined nearly a month was made in the presence of the Royal Society. It was stated that the gas when it first issued from the top of the tube was as cold as frosty air, and that it would not take fire from a spark, but required a flame to ignite it.

Some thirty years after the attention of the scientific world was thus called to the nature and properties of inflammable air or gas,—namely, about the year 1765,—we find a proposition made to the magistrates of Whitehaven by the then agent of Lord Lonsdale, to convey this same gas through pipes to light the streets of the town. The magistrates, it appears, refused to entertain the subject, although the proposer, Mr. Spedding, proved its perfect praticability by conveying the gas into his own office and using it for the purpose of lighting.

In the "Transactions of the Royal Society" for the year

1739 is a paper by Dr. Clayton on the subject of distilling pit coal. This paper is an extract from a letter written by the author to the Honourable Robert Boyle, who died in 1691. The letter, therefore, was probably written some time before this, and although not published till 1739, it appears clearly to confer on Dr. Clayton the merit of an earlier experiment on the mode of procuring gas from the distillation of coal than that described by Dr. Hales in 1726.

I shall not quote in detail the experiments concerning the spirit of coal contained in Dr. Clayton's letter to Boyle, as this letter appears in nearly every work on gas which has since been published in this country, and must therefore be familiar to most English readers. Those who may wish to see the complete extract from Dr. Clayton's letter will, however, find it in page 59 of the "Philosophical Transactions" for the year 1739. The author first gives an account of the ditch near Wigan in Lancashire, described by Mr. Shirley, in which the water was said to burn. He proved, however, the fallacy of this supposition, by causing a dam to be made and having the water below the dam scooped out of the ditch. At first the vapour would not take fire, but on digging down about 18 inches the vapour which arose from a shaly kind of coal took fire from a candle, and continued burning. Suspecting from the proximity of coal the true origin of this inflammable vapour, the Doctor proceeds to say, that he procured some coal and distilled it in a retort over an open fire. He describes the products of his distillation as a *phlegm* which first came over (naphtha), afterwards a black oil (tar), and then likewise a "*spirit* arose which I could noways condense, but it forced my lute or broke my glasses." He discovered accidentally that this spirit (the gas) was inflammable. He then proceeded to collect it in bladders, and preserved it in these for the amusement of his friends, before whom he was in the habit of pricking holes in the bladder with a pin, and gently compressing it till the small stream of gas took fire at the flame of a candle, when it would continue burning till all the gas was pressed out. It is curious that the process of exosmose (hereafter explained) was observed at this early stage of experiments on coal gas, for the Doctor says when he filled calves' bladders with the gas, it would lose its inflammability in twenty-four hours; he therefore recommends good thick bladders like those of an ox.

The publication of Dr. Clayton's experiments, although they clearly pointed to the practicability of procuring and storing up an inflammable gas derived by distilling coal, appears to have attracted no further notice at the time. No progress whatever appears to have been made in discovery for many years afterwards.

To the celebrated Dr. Watson, afterwards Bishop of Llandaff, we are indebted for the first notice of the important fact that coal gas retains its inflammability after passing through water into which it was allowed to ascend through curved tubes. This is noticed amongst other results of Dr. Watson's experiments in the second volume of his "Chemical Essays," published in 1767. To this property is due much of the facility with which the manipulations of a gas-making establishment are carried on, particularly those connected with the hydraulic main, and the purification by means of wet lime.

With the exception of Bishop Watson's experiments, the whole subject of procuring from coal a valuable product in the shape of inflammable gas appears to have slumbered for more than half a century, till about 1790 we find an individual, who was afterwards connected with one of the first engineering workshops in the world, turning his attention to the subject in a truly practical form. This individual was Mr. William Murdoch, then resident at Truro, in Cornwall, and afterwards connected for many years with Messrs. Boulton and Watt's establishment at Soho. There can be no doubt as to the exclusive merit of this gentleman, whose claim is unquestionable to the first practical application of artificially manufactured gas to the purposes of lighting. From his own narrations, written with all the earnest simplicity which commonly attends the development of great ideas, it even appears doubtful whether he was acquainted with the papers of Dr. Clayton already alluded to. It is also satisfactory to find that the pre-eminent claim of Mr. Murdoch is most clearly and distinctly confirmed by the celebrated

Dr. Henry, that brilliant philosopher, whose researches into the nature of aëriform fluids have gained for him the admiration of all Europe.

It appears from Dr. Henry's statement, that, in 1792, Mr. Murdoch actually lighted his own house and office at Redruth with gas. He distilled the coal in iron retorts, and conveyed the gas through tinned iron and copper tubes to a distance of 70 feet. He used portable gas, carrying it about with him in a bladder, or in bags of leather or varnished silk, and also in vessels of tinned iron fitted with a small metal tube and stop-cock, through which the gas, issuing from a minute orifice, was ignited, and made to serve as a lantern in travelling backwards and forwards between the mines and his own house. He is said to have excited the unbounded astonishment of the country people, and to have confirmed them in the belief that he was a real wizard, by travelling in a steam carriage lighted up at night with gas contained in bladders. Mr. Murdoch also at this early period made many experiments on various kinds of coal, as the Swansea, Haverfordwest, Newcastle, Shropshire, Staffordshire, and some kinds of Scotch coal. He also tried numerous forms of burners, varying in many ways the shape and disposition of the orifices for the emission of the gas. Thus, in some burners, the gas was allowed to issue from many very minute openings, forming a rose like the head of a watering-can, while in others it was thrown out in long thin sheets, and again from circular openings, on the principle of the argand burner. His attention was also directed to the necessity for purifying the gas, and he certainly adopted the expedient of passing it through water, but does not appear to have made use of lime, the first application of which, to the purpose of purifying, appears due to Dr. Henry and Mr. Clegg. Mr. Murdoch pursued his experiments on the gas from coal, peat, wood, and other inflammable substances, at such intervals of leisure as his numerous other avocations would permit, principally with the intention of avoiding the disagreeable odour peculiar to it. About 1796, Mr. Murdoch communicated to Mr. James Watt, jun., son of the celebrated James Watt, the engineer, his views of employing gas as a substitute for lamps and candles, and suggested that a patent should be obtained for that object. This proposal was not, however, entertained by Mr. Watt, on account of the heavy expenses his father had incurred a short time previously in defending some patents in connection with the steam-engine.*

In 1798 Mr. Murdoch lighted part of the Soho foundry with gas, and exhibited his experiments to a few friends, who, in after years, when his claims to priority for the adaptation of gas were disputed, gave their testimony, and proved the entire justice of his pretensions.

In 1799 a French engineer, of the name of Lebon, obtained a patent in France for procuring gas from wood, peat, &c., and applying it to the purpose of illumination. This circumstance has caused French authors (who ignore the claims of Mr. Murdoch) to invariably award the merit of priority of application to their compatriot.

In 1801, the brother of Mr. James Watt being in Paris, wrote, saying, "that if anything were to be done with Mr. Murdoch's gas, it must be done at once, as there was a Frenchman in Paris who had similar ideas, and proposed to illuminate that city by these means." However, from some unaccountable cause, the patent was never applied for; and it may be assumed that neither Mr. Watt nor Mr. Murdoch had the slightest conception of the gigantic industry they were on the threshold of establishing.

The year 1802 is very remarkable in conjunction with gas lighting, for in that year, on the occasion of the proclamation of peace, a public exhibition of gas-lighting was made at the Soho foundry; and Mr. Matthews, an eye-witness, states, "the illumination of the Soho works on this occasion was of the most extraordinary splendour; the whole of the front of that extensive building was ornamented with a great variety of devices that admirably displayed many of the varied forms of which gas-light is susceptible. This luminous spectacle was as novel as astonishing, and Birmingham poured forth its numerous population to gaze at and admire the wonderful display of the combined effects of science and

* Evidence of Mr. James Watt before Committee of House of Commons, 1809.

art."* Mr. Murdoch, however, had many difficulties to overcome before he attained the perfection which he exhibited on this occasion, but he united sound scientific knowledge, with great practical skill, and his perseverance enabled him to triumph.

In this year M. Lebon, before mentioned, had his house in Paris illuminated by gas, and numbers of people of all classes witnessed it with wonder and amazement. Also at the same period, Mr. Winsor, who afterwards did so much for the advancement of gas-lighting, being at Brunswick, saw an account of the "rapport" or communication of M. Lebon on gas for illuminating purposes, which had been read before the French Institute; and, to use his own words, employed five years after, "the thought struck him like an electric shock." He translated the communication of M. Lebon into German and English, which he published as a pamphlet. He also carried out a series of experiments in connection with gas-lighting by distilling wood, &c., before the duke regent, Charles William Ferdinand, and his court.† And the same year he came to England (undoubtedly entirely ignorant of what had been achieved by Mr. Murdoch), with the intention of carrying the new enterprise into operation.

In 1803 Mr. Winsor first publicly exhibited, at the Lyceum Theatre, in London, the system of illumination by gas. Here he delivered lectures on the subject, which he illustrated by a variety of interesting experiments; amongst them he showed the means of conveying gas from one part of a building to another, and by the employment of different burners was enabled to display the various forms which might be given to its flame. He also proved, in a very elaborate manner, the various advantages of gas-lighting, and its superiority over all other artificial light, all of which time and experience have fully confirmed.

In 1802 and 1803, Mr. Murdoch erected works for the supply of gas to the premises of Messrs. Boulton and Watt; and in 1804, Mr. George Lee, of the firm of Messrs. Phillips

* Matthews' "Historical Sketch of Gas Lighting."

† French translation of Accum on Gas, by F. A. Winsor.

and Lee, of Manchester, had his dwelling lighted by gas, in order to test its salubrity, previously to its adoption in the cotton mills of the above-mentioned firm, and the following year the mills alluded to were so lighted; and Mr. Lee's evidence afterwards contributed considerably towards overcoming the prejudice which existed against gas-lighting, and to demonstrate its advantages and economy. The quantity of light supplied to these mills was equal to that yielded by 2,000 mould candles of six to the pound, or about 2,500 cubic feet per day on the average of the whole year. To produce this quantity he used 7 cwt. of Wigan cannel coal, yielding at the rate of 7,143 cubic feet of gas per ton of coal, considerably less than the quantity made at the present day from the same coal.

In his paper of 1805, which was published in the "Philosophical Transactions" for 1808, Mr. Murdoch does not particularly describe the process which he followed in making the gas, but merely states that the coal is distilled in large iron retorts, and that the gas, as it issues from them, is conveyed by iron pipes into large reservoirs, or gasometers, where it is washed and purified previous to its being conveyed through other pipes or mains to the mills. He describes the burners with some minuteness: these were of two kinds, one on the principle of the argand lamp, and resembling it in appearance; the other a cockspur burner, consisting of a small curved tube with a conical end, having three circular apertures or perforations about one-thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones The gas issuing through these apertures forms three divergent jets of flame, somewhat like a *fleur-de-lis*. The whole of the burners erected in the cotton-mills amounted to 271 argands, each of which gave a light equal to four mould candles of six to the pound, and 633 cockspurs, each of which gave a light equal to two and a quarter of the same candles. The quantity of tallow consumed by each candle was at the rate of four-tenths of an ounce, or 175 grains of tallow per hour.

In his details of the comparative cost of lighting this establishment with gas, as compared with candles, Mr. Murdoch's comparison is very much in favour of the former. Taking an average of two hours per day throughout the year, the expense of candles would be £2,000 per annum, while the cost of gas, including every expense of wear and tear and interest on capital, did not exceed £600 a year. On an average of three hours per day, the comparison is still more in favour of gas, the expense of candles in this case being £3,000 a year, while that of gas, estimated as before, would only amount to £650.

During his experiments, and in erecting his earlier apparatus, Mr. Murdoch tried various forms of retorts, which will be more particularly noticed in the chapter on this subject, so that it may be sufficient to observe that the earliest forms were upright, with various contrivances for extracting the coke which remained after the expulsion of the gas. Many inconveniences attended this form, as well as an intermediate form, in which the retorts were placed in a diagonal or inclined position. In time all the other contrivances gave place to the horizontal retort, which is the mode of setting universally adopted at the present day.

The success of Mr. Murdoch's new mode of lighting the cotton-mills of Lancashire appears to have enlisted a host of ingenious and speculative persons, who entered eagerly upon the course now open before them. About the years 1804 and 1805 we find the subject taken up by eminent chemists, such as Dr. Henry of Manchester, who ably illustrated the mode of making gas in his lectures, and showed how readily and economically it might be used as a substitute for oil and candles. At this time also we find Mr. Clegg, an able mechanician, also engaged in the same establishment as Mr. Murdoch, where he entered as a pupil of Messrs. Boulton and Watt, devoting all his energies to the mechanical appliances connected with the successful application of gas.

Mr. Northern of Leeds, Mr. Pemberton of Birmingham, and Mr. Accum were actively engaged at this time in experiments on coal gas, the means of procuring it and applying it to lighting purposes. Many of the contrivances and suggestions of these gentlemen were highly ingenious, and they each exhibited before the public gas-lights produced from apparatus of their own erection. The apparatus was of course on a very limited scale, and it does not appear that any intermediate process was practised between the retort and the burner, except that of washing the gas by passing it through water so as to condense and cool it before entering the gas-holder.

Mr. Clegg appears to have struck off in the same direction as Mr. Murdoch, and to have embarked about the same time in the erection of private gas-works for cotton-mills and other establishments. Thus he was engaged in lighting the cotton-mill of Mr. Henry Lodge at Sowerby Bridge, near Halifax, at the same time that Mr. Murdoch was erecting his works at Messrs. Phillips and Lee's mill. Indeed, Mr. Clegg, jun., states, on the authority of his father's journal, that the mill at Sowerby Bridge was lighted a fortnight earlier than the one under Mr. Murdoch's direction.

In the following years, 1807 and 1808, Mr. Clegg proceeded to erect gas-works at various other mills, and at the Catholic College at Stonyhurst, in Lancashire, where he first introduced the system of purifying the gas from carbonic acid and sulphuretted hydrogen by passing it through lime in a separate vessel. Previous to this use of a separate purifier, Mr. Clegg had used lime in the tank of the gas-holder, and applied an agitator to keep it in motion, but the difficulty of removing the saturated lime eventually led to its abandonment, and the adoption of a separate vessel.

In this year Mr. Murdoch communicated to the Royal Society a very interesting account of the successful application of coal-gas to lighting the extensive cotton-mills of Messrs. Phillips and Lee, of Manchester; for this communication, Count Rumford's gold medal was presented to him. The following year Mr. Clegg communicated to the Society of Arts his plan of an apparatus for lighting manufactories with gas, for which he received a silver medal. About the same period he erected a gas-apparatus for the manufactory of Mr. Harris, at Coventry.

In 1804 Mr. Winsor obtained a patent for "an improved oven, stove, or apparatus, for the purpose of extracting inflammable air, oil, pitch, tar, and acids, from, and reducing into coke and charcoal, all kinds of fuel, which is also applicable to various other useful purposes."

"A metal, brick, or earthen stove, oven, retort, or vessel, is so constructed to reduce by means of fire and heat all raw fuel of any kind into coke and charcoal, without any, or little, consumption of the fuel, by which operation the smoke being extracted from all raw fuel, is thus conducted through cold air or water into a condenser, where, after being sufficiently cooled and purified, it undergoes a natural chemical resolution into tar, pitch, oil acid, ammonia, and inflammable gas or air.

"The inflammable gas or air may be led in a cold state through tubes of silk, paper, earth, wood, or metal, to any distance, in houses, rooms, gardens, places, parks, and streets (and other places), to produce light and heat, or for any other purpose, such as for increasing and multiplying force and power."

This was the first patent obtained in connection with gas-lighting.

Having this patent, Mr. Winsor described himself as the discoverer, inventor, and patentee of gas-lighting, and agitated the necessity of forming a company for its full development, so that the streets, shops, and private dwellings should enjoy its advantages; but gas-lighting, like every other great innovation, was looked upon by the public with excessive distrust. In the event of its success, several branches of industry and commerce were doomed to suffer; many interests were, or supposed to be, at stake; some of the chemical properties of gas were unknown; great doubt existed as to its safety, and fears as to its salubrity; indeed, the danger of explosion was magnified to the extent that it was asserted, and believed, that a town could be destroyed by the explosion of the main pipes in the streets; and interested parties, in order to prevent the establishment of gas-lighting, did not scruple to appeal to the naval glory of the nation, and this shortly after Nelson had achieved his great victories. "If," said the opponents of the new light—"if this become successful, then our naval supremacy is gone, for at present we obtain principally our artificial light from the whale fisheries:

these are the nurseries of our best sailors; so if we destroy the one, the other must be affected; if the fisheries no longer exist, our navy must degenerate."

These objections and arguments were put forth frequently by the journals; and Mr. Winsor, who by this time had become intimately associated with gas-lighting, and in a manner constituted himself its champion, met them with that extraordinary courage, perseverance, and zeal which so strongly characterised him; but it is to be regretted that although a gentleman of superior intelligence—with the great qualities already awarded him—he lacked the scientific knowledge so essential for the fulfilment of his undertaking, and unfortunately he was not aware of this deficiency. He boldly combatted all possible objections with unexampled ardour, but often committed the most egregious errors, at one time asserting that our atmosphere in its pure state was too powerful a medicine, and that a mixture of coal-gas rendered it more salubrious; again, that gas would not explode when intermixed with air, and that its adoption would purify the atmosphere; whilst the prospectus issued by him contained most extraordinary, exaggerated, and fabulous accounts of the enormous profits to be derived from gas-lighting. All this combined to retard his progress, and had he been of a less sanguine nature, his task would have been comparatively easy. These errors often brought down upon him the greatest ridicule, in which some of the leading scientific journals took prominent part; but, undaunted, he still persevered.

At length, after having struggled, during four years, single-handed, and, as it were, against the opinion of the world—having by his letters, pamphlets, lectures, &c., proved the advantages of gas—Mr. Winsor succeeded, in 1807, in obtaining a capital of £20,000 by means of subscribers, preliminary to the formation of a company; which sum was intended to demonstrate the practicability of manufacturing and supplying gas on a large scale; also for the purpose of forming the company, and obtaining a royal charter.

Mr. Winsor then occupied extensive premises in Pall Mall, on the site of the present Carlton Club. On the basement he had gas manufacturing and other apparatus to illustrate his lectures, demonstrating the practical utility of gas for lighting, heating, and cooking, also its safety and salubrity; the public, on certain days, having free access to take cognisance of the process. From these premises a pipe was laid in Pall Mall to the corner of St. James's Street westward, and to the Haymarket eastward, with lamp-posts at short intervals, including several in front of Carlton House, the residence of the Prince Regent; and thus Pall Mall was the first street ever lighted by gas, and continued so during the sessions of parliament of 1809 and 1810, whilst endeavouring to obtain an Act of incorporation and charter.

The intention of Mr. Winsor, and his subscribers or shareholders, in 1808, was to establish a company, and obtain a royal charter or exclusive privilege for lighting all the British possessions by gas; and for this purpose they proposed a capital of one million sterling.* A memorial was accordingly presented to the king, setting forth the advantages which would result from gas-lighting, and the production and general employment of coke, praying for the concession; but after the question had been duly considered in Privy Council, it was decided that his Majesty could not grant the charter of incorporation until a Bill had been obtained from parliament authorising the company.

The following year Mr. Winsor and his shareholders again applied, with more moderate pretensions, to be established as the "National Light and Heat Company," but were strongly opposed by Mr. Murdoch; and on this occasion many scientific witnesses were examined before a committee of the House of Commons, who proved incontestably that gentleman's claim to priority of adopting gas for illumination. The evidence given is of the greatest interest; but the errors of a leading witness for the company, and the merits of Mr. Murdoch, caused the application to be refused.

Amongst Mr. Winsor's subscribers were some eminent men of the day, and, like himself, of the greatest perseverance and zeal. They had already been too familiar with difficulties to be discouraged by defeat; and again, in 1810,

* French translation of Accum on Gas, by F. A. Winsor.

they applied to parliament, and succeeded in obtaining an Act of incorporation as the "Gas-light and Coke Company," with a capital of £200,000. But the enterprise was looked upon as so visionary, that it was asserted this Act was granted in order to make a great experiment of a plan of such extraordinary novelty.

The royal charter was granted to the company in 1812; but the privileges accorded by that charter were neither liberal nor encouraging; for by it the company had no exclusive right, so as to prevent any other persons or company from entering into competition with them. The power and authority granted were very moderate; and whilst the company were under severe restrictions, they were confined to the metropolis, and were liable to have the charter annulled if they failed to fulfil their obligation.

The very prominent part taken by Mr. Winsor in establishing gas lighting has often been passed over, whilst his errors, the result of a very sanguine mind, have been displayed with all vigour; and whilst the sacrifices he made have been forgotten, he has been represented as being actuated entirely by selfish motives; but the evidence given before parliament on the subject of gas-lighting in 1809 and 1810 proves beyond doubt the important services he rendered to that art, and that through his instrumentality was the first gas company established. The injustice of the charge of selfish interestedness may be met by the fact that in 1815 and 1816, instead of remaining in England, and profiting by the position his labour and energy had created him, he went to France, there to fight again the battles he had so often fought in favour of gas-lighting; and Mr. Peckstone only does justice when, speaking of Mr. Winsor, he says, "Sanguine in his expectations, indefatigable in his exertions, and zealous in his cause, he directed all the talents and energy he possessed to the one great object, and thus achieved much for the public good; but with all his ardour, his skill, and his exertions, he, like many others, achieved but little towards promoting his own comfort, or the comfort of his family."

The Gas-light Company being thus legally established, they commenced their operations at a wharf and premises in Canon Row, Westminster; and there the new industry was left in the hands of chemists, who, however competent they might have been in their legitimate profession, were void of that mechanical knowledge and skill so essential to their task: in consequence, numerous experiments were made, at the expense of a large portion of the capital invested; and the shareholders, who had hitherto shown such extraordinary patience so long as the enterprise was only in project, now began to lose heart, when they saw so much money sacrificed, and so little done towards commercially realising their hopes and expectations.

At this period, when the practical application of gas appeared doubtful, the company had the good fortune to engage Mr. Clegg, before-mentioned, as their engineer. This gentleman had already acquired considerable experience in erecting gas-works. His genius rendered him capable of surmounting the greatest difficulties he encountered; and he may with justice be said to have established the manufacture of gas.

The main features in the present system of gas-lighting which are due to Mr. Clegg are, the system of wet-lime purification; the hydraulic main, with its contrivance of dip-pipes for isolating the retorts; the mode of attaching the mouthpieces to the retorts; the governor or regulator for adjusting the delivery of gas into the mains; to which must be added the gas-meter in its earliest and most novel form, which was afterwards perfected by Mr. John Malam, aided by Mr. Samuel Crosley, and which will claim particular attention at a future page.

These are the principal parts of the mechanism of gas apparatus introduced by Mr. Clegg, and which have become essential parts of the gas manufacture, while there are many other contrivances of perhaps equal ingenuity and merit which have not been successful. Among these are the rotating or web retort, of which a notice will be found further on; the inferential dry gas-meter, the collapsing gas-holder, and an apparatus for the decomposition of oil, tar, &c. A review of these various inventions undoubtedly places the name of Mr. Clegg in the very foremost rank of those who have advanced the practice and science of gas-lighting.

In December, 1813, Westminster Bridge was first lighted by gas; and in the following year the old oil lamps were removed from the streets of St. Margaret's parish, Westminster, and gas-lights put in their place; this being the first parish which applied for a contract to have the streets lighted with gas.

In the year 1814, when the allied sovereigns visited this country, and a general illumination took place in commemoration of the peace of Europe, the new light was brought into requisition, and exhibited to thousands of admiring spectators, in illuminating a magnificent pagoda erected in St. James's Park. This building was instantaneously lighted up by a simple contrivance; and in a single instant of time 10,000 lights burst forth, and formed an immense and brilliant fountain of fire. In the following year Guildhall was lighted up with gas; and on this occasion the public papers teemed with extravagant praises of the new light. Its mild splendour was described as "shedding a brightness clear as summer's noon, but undazzling and soft as moonlight, altogether forming a magnificent combination worthy the inauguration of the presiding citizen of the great city."

After the founders of the gas company had striven against and overcome the errors of public opinion—had become established—had expended considerable sums in experiments, and incurred great losses in carrying the new science to a successful issue—this done, and the trade being open to all, then arose rival companies in the metropolis, these being the City of London, the South London or Phœnix, and the Imperial. Other companies were also established, in Glasgow, Edinburgh, Manchester, Bristol, Bath, Leeds, Chester, Cheltenham, Macclesfield, Exeter, Birmingham, Rochester; and such was the rapid progress of gas-lighting from 1814, that all the works in these, as in many other towns, were in operation in the year 1819.

From about the year 1815 the names connected with gas-works become so numerous, inventions of all sorts and descriptions multiply so fast, and the records of the Patent Office exhibit such a spirit of invention, that it would be impossible to follow them in anything like detail. I must therefore be satisfied with briefly noticing a few of the successive steps by which the practice and science of gas-lighting advanced until it entirely superseded all other modes of public lighting in the metropolis and other large towns, and even came to be extensively used for domestic illumination in place of candles and lamps.

In 1815 Mr. John Taylor patented the means of obtaining gas from oils, fat, resin, and other oleaginous substances. The superiority of the gas thus obtained is unquestionable. It contains a much larger quantity of olefiant gas than that from common coal, and it had long been known that olefiant gas, containing as it does double as much carbon as ordinary carburetted hydrogen, was by far the most valuable ingredient for illumination in any inflammable gas. The gas from oil would also be free from sulphuretted hydrogen, and other impurities which cause considerable expense in the purification of coal gas. In addition to this, the advocates of oil gas contended that the expenses of production and management would be much less than in a coal-gas establishment, and that the large supply of oil required would afford employment to thousands of fishermen, who would be engaged in the capture of fish suitable for yielding oil in sufficient quantity. Of course all considerations of this nature require to be tested by actual practical experience, and when this was applied to the case of lighting by means of oil gas, the results were widely different from those which had been anticipated in theory. It was found impossible to work the establishments with anything like the same economy as those for producing coal gas, and all the companies, without exception, found it was hopeless to expect any dividend for their outlay. Under these circumstances the oil-gas works were abandoned one by one, and apparatus for distilling coal substituted in their place.

But for some years oil gas was considered to be a formidable rival to coal gas; its vast superiority was supported by some of the first chemists of the day; amongst them were Mr. Brande, Professor of Chemistry at the Royal Institute, Mr. Michael Farraday (who has since acquired a world-wide reputation), then assistant to Mr., afterwards Sir, Humphry Davy, and Sir William Congreve, the government inspector of gas works for the metropolis. According to these gentlemen, the light obtained from oil gas, compared with that from coal gas, was in the proportion of three and a half to one. They also asserted that gas from oil was superior on many accounts to that from coal. Sir William Congreve stated, "the most important feature of the use of oil gas was its safety; as from the very narrow limits of the explosive mixture that can be formed of this gas, it is scarcely possible that an accident can occur."*

Mr. George Lowe, who for many years so honourably filled the post of consulting engineer to the Chartered Gas Company, being at that time at Derby, was the first and most conspicuous person who entered the field to oppose the advocates of oil gas; and his extensive knowledge of the subject fully qualified him for engaging in the contest. His communications to the various scientific journals on the subject, while carrying conviction with them, were always characterised by the peculiar wit and good-humour that those who have had the pleasure of his acquaintance can readily understand.

The evidence given by Mr. Lowe before a committee of the House of Commons in 1823 on oil gas, was the severest blow it had received; for he then convinced the committee of inquiry, by actual experiment, that oil gas was as explosive as that produced from coal; that the light of oil gas was barely double that of the other; and that very similar impurities existed both in oil and coal gas. His testimony on those occasions was so clear and positive, as to carry conviction with it, and sufficient to shake the opinions of those who hitherto had held oil gas in the highest estimation.

In 1819 we find Mr. David Gordon obtaining a patent for compressing gas into suitable vessels fitted with proper valves, and capable of being carried about, so as to render the gas portable. This contrivance, which can scarcely be called an invention, as it had been practised by Mr. Murdoch many years before, led to the formation of the "London Portable Gas Company." However, after carrying on business some

* This was somewhat erroneous, as the force of explosion from a given quantity of gas is in proportion to the carbon combined therewith.

time, it was found that the scheme would not answer, and the company was ultimately broken up. About the same time Professor Daniell, F.R.S., was engaged in an unsuccessful attempt to make gas from resin. It is said that his apparatus was highly ingenious, but the project on trial was soon abandoned, from inability to compete with coal-gas works. The Act for lighting Bristol with oil gas was obtained as late as 1823, in spite of the warnings of several eminent gas engineers that the project would prove unsuccessful. The truth of these warnings was amply confirmed in the course of a few years.

Paris was first lighted by gas in 1820, and although previously strong prejudices existed against the project, yet, when carried out, it produced a corresponding enthusiasm; and, to give an instance, a French author of the period, writing to a friend, describing the new light, said, "where gas-light exists there is no night; where gas-light is, there is continuous day." He also mentioned, in the most glowing terms, the transcendent beauty of the ladies, as seen thereby.

Here, it must be observed, that all the bright prospects, all the enormous profits calculated to be derived from gas enterprises, were far from being realised; for, at the commencement, and for years after, commercially, they failed —few, if any, were successful. The causes of this loss were various; in some instances the main pipes were either so bad, or laid in such a defective manner, that a large portion of the gas escaped. The extravagance of many consumers in burning, which no personal surveillance could control or counteract, was another serious source of evil. If we add the want of experience in the manufacture and distribution of gas, and the amount of misplaced and abused confidence, then we can understand how gas companies were unprofitable. And to such an extent was this kind of property depreciated, that a London company was disposed to sell its plant, &c., to a rival establishment for about one-twentieth part of its cost; a difference of a comparatively insignificant sum prevented the sale being effected.

Such is a brief sketch of the leading historical facts which mark the progress of gas-lighting till within the last thirty years. The chapters which follow will explain the modern system of constructing and working establishments for manufacturing gas from coal. I can only hope, however, to present a fair selection of the various practices and contrivances, which vary very much at different works. A gradual spirit of improvement has characterised the progress of all gas establishments, and improvements made almost imperceptibly, year after year, have brought their efficiency up to a high standard. This is evidenced in a most practical manner both by the increased produce of gas, and by the diminution of price to the consumer. In the metropolis few of the companies now charge more than 4*s.* per 1,000 feet for gas, yet the price a few years ago ranged from 8*s.* to 10*s.* While most of the general arrangements have remained the same, more especially those for which we are indebted to Mr. Clegg, a constant succession of improvements in the subordinate parts has vastly improved the value and efficiency of gas-lighting, thus alike benefiting the companies and the public.

Amongst the most important of these improvements are, the very general adoption of clay retorts instead of iron, the more perfect system of main laying, by which the loss of gas is reduced almost to a minimum, the use of the scrubber, the improvements in purification—in short, a systematic change has taken place, ensuring alike economy in the manufacture and distribution of gas. Again, as connected with the distribution of gas, the modern system of fittings deserves especial commendation when contrasted with the very imperfect mode in which this kind of work was originally executed. The business of the gasfitter—one of considerable skill and nicety—has been, in fact, like many others, created since the general introduction of gas-lighting. When we consider the difficulty of confining in metallic pipes a subtle aëriform fluid of only half the specific gravity of common air, conveying it into all kinds of corners, and all parts of buildings, in addition to the use of innumerable cocks and burners, the delicacy and nicety required in every part of the gasfitter's manipulation are entitled to considerable admiration; while the advantage he has derived from the beautiful invention of welded iron tubes and pewter-drawn tubes, contrasted with every other form of metallic tubing originally in use, adds considerably to his facilities. Gas may now be burnt in private houses without the slightest effluvia or escape from any of the pipes, joints, or fittings, and if properly purified, may be burnt in any kind of room, however highly ornamented by gilding and otherwise, without being in any way prejudicial

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CHAPTER II.

ON THE CHEMISTRY OF GAS-LIGHTING.

In all the contrivances which have been used for producing light from oleaginous or fatty matters, either in lamps or in the form of candles, the various component parts of gas, as the carbon and hydrogen, are always vaporised and put into the form of gas before their combustion takes place. In this point of view every wick burning in any kind of lamp or candle is, in fact, a small laboratory for the production of gas, which is burnt or consumed at the instant of its production. It was reserved for the chemistry of our own day to point out this analogy, as it was reserved for the practical skill of our engineers and machinists to bring to perfection the means of producing this gas on a large scale, of storing it for an indefinite period, and then sending it forth whenever required, into our streets and houses, to communicate light, and enable mankind to pursue their useful and laborious avocations alike when darkness shrouds the earth, as well as in the light of day.

A beautiful action takes place in the combustion of an ordinary lamp or candle, in which the wick surrounded by flame represents a series of capillary tubes to convey the melted matter in the form of gas into flame. This action will be very apparent to any one who will watch the process of combustion in an ordinary wax or tallow candle. First, he will perceive a cup of melted matter around the wick, in which a great number of small globules are seen constantly in progress towards the wick. Many of these globules are also seen standing on the wick, studding it all over like little sparkling diamonds. Let us consider what these globules contain. They are filled with the inflammable gas produced by the heat applied to the melted wax or tallow, but fortunately for the success of this method of burning, these globules do not break and set free the gas until they come into close contact with the flame, when the heat becomes so great that the expansion of the gas causes each little globule to break and add its contents to the already burning flame. How beautiful is this provision! How exquisitely constituted are the properties of matter to cause this beautiful result! In every common candle we behold an apparatus of wonderfully refined ingenuity, in which gas is being enclosed in little microscopic pellicles, which are floated to the base of the wick. There hundreds of these little tiny globules are seen ascending the wick, while hundreds of others are every instant exploding and discharging their contents into the flame, which is thus made up by the instant combustion of gaseous matter at the moment when it leaves the liquid form, through the medium of this intermediate stage, in which it assumes the form of an infinitely small translucent globule.

It is obvious if the gas were to be actually formed at the surface of the small cup of melted fluid already spoken of, the surface being usually half an inch below the nearest part of the flame, that the gas would immediately diffuse itself through the air, and combustion could not proceed. It is only through the property which the gas possesses of taking an intermediate form and not finally assuming its gaseous condition till it reaches the flame, that the effect of continued combustion is preserved.

The daily operations of the gas manufacturer, or manager, are so intimately associated with chemistry, as to render a partial knowledge of that science (at least so far as regards the gases he has to treat with) of the first necessity; it is therefore intended to give a brief outline of the subject.

Chemistry is the science which teaches us the composition of bodies, and the laws regulating the combination of the elements of which they are composed. For the purposes of study, it is usually divided into two branches, viz., organic and inorganic chemistry.

The first branch relates to every living object, from the largest being to the smallest animalcule; likewise all vegetable life, from the most stupendous tree, to the minutest trace of vegetation. These, having organs of vitality, are with much propriety called organic bodies. The other class, which consists of inanimate objects, which neither live nor die, having no such organs of vitality, are called inorganic bodies.

All organic and inorganic bodies, constituting everything accessible to man, consist of, or are composed of, about sixty-four simple substances called *elements*, which are so named because they cannot, by any known means, be decomposed; that is, resolved into simpler kinds of matter. These elements combine with each other in certain relative proportions, and form substances called *compounds.*

Of the elements, about fifty belong to the class of metals, as iron, gold, copper, lead, &c.; but those which immediately interest the gas manufacturer are few in number, being only five, viz. oxygen, hydrogen, nitrogen, carbon, and sulphur, which are of the greatest importance, on account of their vast abundance, because one or more of these exist in almost every substance or compound in nature, and they all influence the manufacture or distribution of coal gas.

To render the combination of the elements and the formation of the compounds intelligible, we may compare the chemistry of our globe to a language having about sixty-four letters, each of which letters represents an element; these letters, in unison, form the words, or compounds, and the compounds comprise the earth and all that is on its surface.

A letter in a language resembles an element in chemistry, inasmuch as neither can be reduced or decomposed into anything less than itself.

Letters combine in various manners and ways to form words; so the elements combine in a similar manner to form compounds.

The nature of the word is dependent on the letters composing it, and on their disposition; so in chemistry, the nature of the compound depends on the composition, and disposition of its elements.

And to continue the comparison, the five elements named may be compared to the vowels, without which no word can be formed; so few compounds exist without the presence of one or more of the elements named.

The elements which comprise a substance or compound are discovered by employing means to separate them from each other, which process is called decomposition, and is the basis of what is termed *analysis*. This decomposition is very frequently effected by the application of heat—thus, the black oxide of manganese (a natural compound, an union of two elements, the one a metal called manganese, and the other oxygen), when submitted to a red heat in a retort, is decomposed, part of the oxygen being separated and expelled as gas, and a lower oxide of manganese is left in the retort. Here it is obvious that the oxygen now existing as gas must have formed part of the solid previously to the compound being exposed to the heat, and if the solid be weighed before and after the process, the loss of weight by the separation of part of the oxygen will be found to be considerable.

Again, with limestone, a compound of three elements, carbon, oxygen, and calcium, or lime, some descriptions of which have almost a flinty appearance, when exposed to a great heat, as when destined for building purposes, loses about from 35 to 40 per cent. of its weight, which is driven off as a compound gas, consisting of carbon and oxygen, forming carbonic acid. The residue, deprived of these, is entirely altered in its nature, being no longer the hard rock, but lime, which crumbles to dust on exposure to the atmosphere. Hence, the elements of these gases must previously have existed as a solid, composing part of the limestone.

The decomposition of coal, by heat, as in the manufacture of coal gas, is entirely a chemical operation. Coal contains all the five elements named, and the result of the decomposition is, that the greatest portion of the hydrogen and the volatile carbon are expelled as gas; a portion of the oxygen and hydrogen form water; the nitrogen, with a portion of hydrogen, constitutes ammonia; a portion of the sulphur and hydrogen comprise the impurity, sulphuretted hydrogen. Another portion of sulphur unites with carbon, and produces the troublesome impurity called bisulphide of carbon. The tar is a compound of several of these elements; and the coke left in the retort is fixed carbon, intermixed with earthy substances and a minute portion of sulphur.

Water is composed, *by weight*, of one of hydrogen and eight of oxygen; by means of voltaic electricity, it may be decomposed into its two component gases, the one being liberated at what is called the positive pole, and the other at the negative pole of the battery. These gases, when collected, are found to be in the exact proportion, *by volume*, of two of hydrogen to one of oxygen. If we, therefore, take into consideration their respective weight and volume, oxygen is found to be sixteen times heavier than hydrogen.

Now, if the gases produced from the decomposition of water are placed in a strong vessel, say a soda-water bottle, so as to fill it, and in the same proportions that they were liberated, on a lighted match being applied to the mouth of the bottle an explosion with a loud report takes place; the two gases ignite, and at the same moment re-unite, forming water, which bedews the side of the bottle. By the first experiment water is resolved into the two gases of which it is composed; and by the second, these, again, are converted into the liquid form—striking illustrations of the truth of chemistry. This is but one of the many instances, where a substance can be decomposed and afterwards again caused to assume its former state.

From the foregoing illustrations it is manifest that oxygen enters into the composition of solids, as when it comprises part of the oxide of manganese, limestone, &c.; that it exists in liquids such as water; and that when separated from its compounds it exists only as gas. Most elements can exist in three different states of aggregation—the solid, the liquid, and the gaseous.

The form of solids and liquids is well known, but that of gases, for the general reader, requires some explanation.

Gases are permanently elastic fluids—vapour or steam convey to us the idea of the bulk of gas. But this, by a diminution of temperature, condenses and becomes liquid; whereas gases, under all ordinary circumstances, are permanent in their state. Smoke issuing from a chimney or elsewhere, is a mixture of several gases, combined with vapour and small solid particles of carbon, called soot.

Gases are of various kinds, and very dissimilar in their properties; and, although frequently invisible, the chemist's art teaches him to distinguish the one from the other with the greatest certainty, so as to render them as palpable to the mind, if not to the eye, as the different solids which surround him. Each description of gas has some distinguishing characteristic, such as weight, odour, colour, power of extinguishing fire or of supporting its combustion, or the manner it acts on particular substances, called tests, signifying testimony.

These tests are substances which are known to change in their appearance and nature, in a peculiar and characteristic manner, when exposed to the action of certain gases or liquids.

Thus, an impurity in coal gas is called sulphuretted hydrogen (which, in ordinary language, may be rendered sulphured hydrogen), being a compound of sulphur and hydrogen ; and when this is allowed to act upon a piece of paper, saturated with the acetate, or sugar of lead, the paper immediately becomes blackened, and ultimately assumes a metallic appearance, occasioned by the sulphur of the sulphuretted hydrogen entering into combination with the lead which was previously in union with the acetic acid.

Thus, the acetate of lead is one of the substances acted upon by the impurity in a perfectly understood manner, and is, therefore, selected as a test for sulphuretted hydrogen. There are, however, several kinds of tests; amongst them is the method of ascertaining the presence of certain gases by means of certain absorbents which cause them to become fixed, and to assume a liquid or solid state. A very general test for discovering the presence of acids or alkalies, is litmus paper, which in its natural state is blue, but when treated with the least quantity of a weak vegetable acid, such as vinegar, becomes red; and this when acted upon by an alkali resumes its former colour. The test generally used to detect the presence of ammonia is turmeric paper, which is of a peculiar yellow colour, but becomes brown when submitted to the action of that compound.

With this introduction, we will consider the properties of the five elements named, and afterwards their combination in forming coal gas and its impurities.

Oxygen.—This is by far the most abundant element in nature, and in its gaseous state forms more than one-fifth part of the atmosphere by which our earth is surrounded. As a liquid, in union with hydrogen, it constitutes by weight eight-ninths of all water; as a solid, it is a portion of innumerable organic and inorganic bodies; and is estimated to form about one-third of the mineral crust of our globe.

Oxygen, when free, that is, when uncombined with any other element, exists only as a gas (all attempts to reduce it to a fluid having failed); and this occurs either when it is emitted by the leaves of plants, &c., or when by the agency of man it is separated from other elements with which nature has caused it to combine, and form certain compounds or substances. This element is the support of all animal life and combustion, and possesses very peculiar properties; for instance, a body which burns in air, when it is immersed in oxygen gas burns with vastly increased splendour; and the wick of a recently extinguished candle, having the least part red-hot, when inserted into a jar of this gas is immediately re-lighted; and a piece of charcoal with the smallest point ignited, when so treated burns with great brilliancy.

Oxygen gas is inodorous, colourless, and rather heavier than air; and it may be termed the aërial food of animal life, for at each respiration a portion of it, intermixed with nitrogen, is received into the lungs, acts on the blood, and is afterwards ejected as a poisonous compound, carbonic acid gas.

Oxygen, or any other natural element, can only be obtained from a compound which possesses it, and by adopting means to separate the required element from the compound. Thus, chlorate of potash, red oxide of mercury, and black oxide of manganese, in common with many other substances, contain a large quantity of oxygen, which is easily separated as a gas by means of heat.

For example, red oxide of mercury is a mixture of oxygen and quicksilver, in the form of a red powder; and if a few grains of this be placed in a test-tube and held over the flame of a lamp or gas-burner, the heat expels the oxygen as a colourless gas, leaving the quicksilver in its fluid state. This is decomposition, and was the means first employed to obtain oxygen by its discoverer.

But a more economical manner of obtaining this gas is by taking a quantity of black oxide of manganese (of which one pound will evolve about 1,400 cubic inches of oxygen), placing it in a cast-iron retort, and distilling similarly to the distillation of coal for the production of gas; the oxygen gas can be collected in a gas-holder, or other vessel, for use when required.* One ounce of chlorate of potash, by careful application of heat, will afford about two gallons of oxygen.

Hydrogen.—This element is also very abundant, and does not exist free or uncombined in nature. It is a constituent of all animal and vegetable substances, forming, by weight, one-ninth part of water, and is a portion of most combustible bodies. Hydrogen gas is colourless and tasteless, and when quite pure is without odour; it is inflammable when issuing from an orifice and intermixing with the atmosphere: burning with a faint violet colour, giving great heat, but very little light.

This gas is the lightest substance in nature, being a little more than one-fifteenth part of the weight of air. It is an invariable component of coal gas, both in a free state and in combination with carbon, constituting certain hydro-carbons, such as light carburetted hydrogen (or marsh gas), olefiant gas, &c.

* As these experiments are attended with danger, the reader should not attempt them without having some instruction on the subject.

Hydrogen, for perfect combustion, requires eight times its weight or half its volume of oxygen, as already demonstrated by experiment, the result of the combustion being water; and in every case wherever artificial light is obtained by burning oil, tallow, gas, &c., this production of water is continually taking place, arising from the hydrogen intermixed with the material being consumed uniting with the oxygen of the atmosphere. The water is distributed as vapour in the atmosphere wherever produced, unless means be employed to condense and collect it. Whenever gas-lights are burned in a shop-window without proper ventilation, the vapours are condensed by the cold glass, an inconvenience which is familiar to all; or a bottle of cold water brought into a room where lights are burning is speedily covered with a dew, caused by the condensation of the vapours by the cold water.

A simple way to obtain this gas is by passing a slow current of steam through a small iron tube ($\frac{3}{4}$ or 1-in. gun barrel) loosely filled with iron borings; the tube is placed across a suitable furnace, or blacksmith's forge, and heated to bright redness; the steam on passing is decomposed into the two elements of water, viz., oxygen and hydrogen—the oxygen combining with the iron, forming the oxide of iron; while the hydrogen gas being set free, can be collected in a holder.

Another convenient method is, by putting a few pieces of zinc into a glass vessel, and pouring on them a mixture of one part of sulphuric acid, and four or five parts of water; the gas then rises in bubbles. In this experiment the zinc unites with the oxygen of the water, and subsequently with the sulphuric acid, and the hydrogen is liberated.

Thus, hydrogen exists in solids forming part of animal and vegetable substances; in liquids, *i.e.* as a component of water, and can be obtained in its gaseous state by decomposing one of its compounds, such as water, &c.

Nitrogen.—This element is so called from its being the basis of nitric acid, and nitre, and is sometimes named azote, from its incapability of supporting life.

Nitrogen constitutes nearly four-fifths of the air we breathe, and serves to temper the effects of the oxygen, which, if alone, or even when in moderate excess of the proportion stated, would be too energetic. It is also a component of all animal tissues, muscles, &c.

Nitrogen gas is slightly lighter than air: it has neither colour, taste, nor smell; it supports neither combustion nor respiration; and is characterised by its negative properties, rather than by possessing any inherent poisonous qualities, such as are peculiar to carbonic oxide, or carbonic acid. Nitrogen is of interest to the gas manufacturer on account of its influence on the combustion of gas; also because it is one of the components of the alkali ammonia which is always generated, during the distillation of coal, in making coal gas.

In order to demonstrate the composition of atmospheric air, let us take a cup containing a small piece of phosphorus, which is placed in a dish of water; the phosphorus is then ignited, and the cup covered by a bell-glass, or a glass shade, the mouth of which is immersed in the water. The phosphorus, in burning, combines with the oxygen of the air enclosed in the glass, producing phosphoric acid, and when all the oxygen is removed by the phosphorus, or has entered into the fresh combination, the phosphorus ceases to burn in the absence of oxygen; the water in the mean time, by the removal of the volume of the oxygen, ascends in the glass. The gas underneath the bell, after the operation, is nearly pure nitrogen, and the bulk will be found to be diminished about one-fifth; this decrease of volume being due to the absence of the oxygen which formerly existed, which has entered into the composition of the flakes of phosphoric acid, and become absorbed by the water.

Carbon.—This is, likewise, one of the most abundant elements, and is extensively distributed in nature as a constituent of all animal and vegetable bodies. It exists in the mineral kingdom in various forms—very largely in the state of coal. It also enters into the composition of some earthy bodies; for, united with lime, it forms marble, chalk, and limestone. The diamond, although unlike any of the substances named, is pure carbon, and is about three and a half times heavier than water.

The carbonaceous incrustation in retorts, the soot produced by the imperfect combustion of oil or gas, lampblack, and charcoal, are all carbon, more or less impure.

Under ordinary temperatures, carbon has no affinity for oxygen, nor is carbon affected by heat, unless oxygen, nitrogen, and a few other substances be present. Thus, the diamond remains unaltered in the hottest furnace if these bodies are excluded; but if oxygen is present, it will combine with it to form carbonic acid at a comparatively low temperature.

The combustion of carbon in air or oxygen, produces light, more or less brilliant, according to the degree of heat to which it is raised.

Carbon alone is never found in the gaseous state, but several gases have the power of combining with it, and conferring on it that property; but as soon as the combinations are destroyed by the abstraction of the other gaseous body, the carbon again becomes solid: a most important property, which requires especial attention in connection with the combustion of gas.

Sulphur.—This exists in large quantities in nature, forming part of the ores of copper, lead, mercury, silver, and other metals. It also issues from volcanoes, in the form of gases, in great abundance, and in its solid state is well known under the name of brimstone. It exists in coal in the bright metallic laminæ which intersect it, these being chiefly a compound of sulphur and iron. Coke, even after having been submitted to a very protracted and high heat, still contains a portion of sulphur, giving rise to the noxious odour occasioned by burning it in confined places. A highly volatile compound of sulphur and carbon is produced in the distillation of coal by the combination of a certain amount of sulphur, with carbon, viz. the bisulphide of carbon.

The peculiar, disagreeable odours of many of the compounds of sulphur are familiar to all, and are the most troublesome of all the impurities of coal gas, the economical removal of which has for several years defied the chemist's skill.

COMBINATION OF THE ELEMENTS.

Having briefly given a description of the various elements in chemistry which immediately interest the gas manufacturer, I will now enter on their combinations to form coal gas, its impurities, and the results of its combustion.

By a law of nature all elements have, in their most minute particles or atoms, an innate attraction for certain others, with which they combine and form compounds. This by chemists is called affinity, and by this law of affinity oxygen and hydrogen combine and form water—these gases in like manner, by the intervention of the electric spark or fire, unite to compose the same liquid. By affinity, carbon combines with oxygen, producing carbonic oxide and carbonic acid. Sulphur combines with hydrogen, and the result is sulphuretted hydrogen. Nitrogen combines with hydrogen, and ammonia is produced. And by this affinity all the various compounds or substances in nature are held together.

For the sake of brevity and general elucidation, chemists have devised a very simple means of describing compounds, and at the same time to express their constituent and quantitive parts. For this purpose instead of writing or naming the elements in full, abbreviations are employed, which are frequently the capital initial letter of the element to be expressed; or when there are two or more with the same initial, then a second small letter is added to make the requisite distinction. In those under notice the initial only is employed, thus—oxygen is expressed, O; hydrogen, H; nitrogen, N; carbon, C; sulphur, S; and these are called the *symbols* of their respective elements. Of course all the others have their corresponding symbols.

Whenever elements combine with each other it is only in a particular and definite manner, which is called their combining quantities or proportions, and this occurs by weight and by volume, which bear a direct relation to each other.

The elements named combine by weight only in the following proportions, or their multiples :—

Hydrogen . .	1
Oxygen . .	16
Carbon . .	12
Sulphur . .	32
Nitrogen . .	14

These numbers are called the equivalents of their respective elements.

When gases combine it is always by measures, which bear a simple relation to each other in the following proportions :—thus, hydrogen combines with oxygen in the proportion of two volumes or bulks of the former with one volume or bulk of the latter gas ; hydrogen and sulphur in like proportions ; nitrogen and hydrogen in the proportion of one to three ; &c.

The chemical expression, or, as termed, formula, of the composition of water is $H_2\,O$, signifying two atoms or equivalents of H (hydrogen), combined with an atom of O (oxygen). As already stated, hydrogen constitutes by weight one-ninth part of water, and by volume two-thirds ; whilst oxygen by weight constitutes eight-ninths, and by volume one-third ; giving a simple illustration of the combining proportions by weight and volume.

In order to give examples of the combination of the elements to form compounds, and the formula employed : —One equivalent or atom of carbon, combined with an atom of oxygen, form carbonic oxide, expressed by the formula C O. One atom of carbon with two of oxygen, expressed $C\,O_2$, constitutes carbonic acid. One equivalent or atom of nitrogen with three atoms of hydrogen, formula $N\,H_3$, produces ammonia. By these means the various compounds of gases are formed and expressed.

The means of ascertaining the specific gravity or weight of gas is ascertained in the simplest manner with the balloon made by Mr. Wright, which is treated on in the chapter devoted to experiments on coal gas.

COMPOSITION OF COAL GAS.

Coal gas when purified is composed chiefly of carbon and hydrogen, and consists principally of a definite compound called light carburetted hydrogen, or marsh gas, combined with a variable mixture of vapours or gases consisting of carbon and hydrogen, called heavy hydrocarbons, the most important of which is known as olefiant gas; carbonic oxide is also one of its constituents. The impurities are sulphuretted hydrogen, ammonia, nitrogen, carbonic acid, and bisulphide of carbon.

Light carburetted hydrogen, or marsh gas, is a compound of carbon and hydrogen, in the proportion of one atom of the former to four atoms of the latter, its chemical formula being $C\,H_4$. It is this compound which constitutes the inflammable fire-damp of coal mines, where it is generated spontaneously; it proceeds abundantly from the decomposition of vegetable substances, and is one of the products of the distillation of coal.

This gas is colourless, nearly inodorous, and does not affect vegetable colours, and, like hydrogen, is permanently gaseous under intense cold or pressure. It is highly combustible in oxygen or air, and explosive to a violent degree if mixed with either of these in the due proportion necessary to convert all the hydrogen into water, and the carbon into carbonic acid. In proportion as the oxygen exceeds or falls short of that quantity, so is the explosive power decreased.

By weight marsh gas contains 12 parts of carbon and 4 parts of hydrogen, or, 100 parts contain—

Carbon . .	75
Hydrogen . .	25

Its density is ·559 (air being 1000), the weight of 100 cubic inches being 17·41 grains.

To obtain this gas, a mixture of 40 parts of crystallised acetate of soda, 40 parts of solid hydrate of potash, and 60 parts of quicklime in powder, is transferred to a flask or retort, and strongly heated, when the gas is disengaged in great abundance.

When marsh gas is burned in the air, if allowed to issue as a large, thick flame, considerable light is obtained; it is possible, however, to burn it without any appreciable light, by causing it to issue, under great pressure, from very minute orifices; but this peculiarity of burning, with or without the emission of light, according to the circumstances attending the combustion, exists with all the gaseous compounds of carbon and hydrogen.

Pure carburetted hydrogen gas may be respired with safety. The unpleasant smell of common coal gas is due to impurities. In its natural forms of marsh gas and fire-damp, it is generally contaminated with nitrogen, and with a small proportion of carbonic acid gas.

	Grains.
A cubic foot of this gas weighs	300
And requires for its combustion 2 cubic feet of oxygen .	1200
	1500
The products are 1 cubic foot of carbonic acid, weighing	817
Water . . .	683
	1500

Olefiant gas, or oil-making gas, is so named from its forming an oil when combined with chlorine or bromine. It consists of two atoms of carbon united to four atoms of hydrogen, its formula being $C_2 H_4$; hence by weight 100 of olefiant gas contain 85·7 carbon and 14·3 hydrogen. Its density is ·981, and the weight of 100 cubic inches 30·57 grains.

Olefiant gas containing double as much carbon as the light carburetted hydrogen, burns with much greater brilliancy, and gives out a very superior light.

This gas may be obtained from alcohol, by mixing with it five or six times its weight of sulphuric acid, placing this in a glass retort, and by the gentle application of heat, the gas distils over, which may be afterwards purified from carbonic acid by agitation with solution of caustic potash. Olefiant gas is combustible and explosive under similar circumstances to light carburetted hydrogen, requiring, however, two volumes more oxygen.

There are other heavy hydrocarbons which enter into the composition of coal gas, having the same nature as olefiant gas, known as propylene, butylene, &c.; these, with the general constituents of coal gas and its impurities, have been very ably treated on in a lecture delivered by Dr. Letheby, and recently published in the *Journal of Gas Lighting*, to which the attention of the reader is especially directed. Olefiant gas is decomposed by passing it through a tube heated to bright redness; a deposit of carbon takes place, and the gas becomes converted into light carburetted hydrogen. If the operation be performed with increased heat, the whole of the carbon is deposited, leaving the hydrogen free. This illustrates very forcibly the deterioration of coal gas by the deposit of carbon in the retorts.

Hydrocarbons.—Coal gas, according to the description of coal from which it is produced, and the mode of distillation, contains from 3 to 30 per cent., by volume, of vapour or gaseous matter (carbon and hydrogen), to which the general name of hydrocarbons is applied; and the illuminating power of gas is in direct proportion to the quantity of hydrocarbon in combination therewith.

If chlorine, bromine, or dry sulphuric acid, be added to a sample of coal gas, or if the gas be subjected to excessive pressure or extreme cold, the heavy hydrocarbons are deposited in the form of oil, the volume of the gas being sensibly diminished in proportion to the quantity condensed.

Dr. Fyfe has for a long period devoted his talents in order to arrive at a positive law, so as to be enabled to estimate the illuminating power of gas by the quantity condensed by chlorine; and more recently Mr. Lewis Thompson has employed bromine for the same purpose. But by these means the volume only of the heavy hydrocarbons is ascertained; and as a knowledge of their density is essential, and is not obtained by this process, therefore this mode of testing can only give comparative, but not absolute, results.

Messrs. Faraday and Coombe have also attempted to define the illuminating power of gas by condensing the hydrocarbon under great pressure, the density of which being ascertained, the value of the gas was estimated accordingly;

but the delicate manipulation would prevent the general application of this operation.

Formerly much importance was attached to the specific gravity of gas as an indication of its value; and it is still the opinion of some eminent chemists, that when gas is free from impurities, this mode of ascertaining its quality or illuminating power is worthy of the greatest reliance.

Dr. Henry was the first to indicate the evaluation of gas for illumination, by estimating the quantity of carbon contained in the condensable portions thereof.

Carbonic oxide, or the protoxide of carbon, consists of one atom of carbon and one of oxygen, its atomic weight being, carbon 12 + oxygen 16 = 28, its formula being C O. Hence it contains by weight of 43 per cent. of carbon, and 57 per cent. of oxygen. Carbonic oxide is prepared in the laboratory by passing carbonic acid over red-hot charcoal or metallic iron, by which half its oxygen is removed, and becomes converted into carbonic oxide. This change also explains the mode of its formation in the process of distilling coal for gas-making purposes. Carbonic oxide contains half its volume of oxygen, is a combustible gas, and burns with a beautiful blue flame, the product of combustion being carbonic acid. This gas is extremely poisonous, even worse than carbonic acid, is colourless, and possesses very little odour. Its specific gravity is ·968, the weight of 100 cubic inches being 30 grains.

This compound exists more or less in coal gas, but seldom exceeding 10 per cent. by volume, and generally much less. It requires one volume of oxygen for combustion, being then converted into carbonic acid.

Carbonic oxide contributes to the heat of the flame, but only indirectly to the light. It is not considered an impurity in coal gas; although the fact of it giving off less heat than hydrogen, whilst it absorbs the same quantity of oxygen, and produces one volume of carbonic acid (a substance always very objectionable), undoubtedly renders it an impurity.

Coal gas often contains a trace of free nitrogen and oxygen; but these, by the best analysis, are generally in about the proportion required for atmospheric air. This is therefore probably due to the admission of air either when changing the purifiers or by undue exhaustion.

IMPURITIES OF COAL GAS.

Sulphuretted hydrogen (hydro-sulphuric acid).—This compound consists by weight of one part of hydrogen gas and sixteen parts of sulphur vapour, its atomic weight being H 2 + S 32 = 34, and expressed by the chemical formula H_2S. By measure it contains two volumes of hydrogen, combined with one volume of the vapour of sulphur, the two being condensed into two volumes. The specific gravity of this impurity is greater than common air, being 1·178. The weight of 100 cubic inches is 36·51 grains.

Sulphuretted hydrogen may be produced for experiments by putting some iron pyrites (a compound of sulphur and iron) and dilute sulphuric acid into a glass retort; heat being applied, gas is disengaged, which is caused to pass through water, when pure sulphuretted hydrogen is obtained. This is a colourless gas, possessing acid properties, reddening litmus paper, and has a most offensive odour, similar to putrid eggs, which indeed contain it; it is very poisonous, and if breathed into the lungs is injurious to life, occasioning suffocating vapours like those arising from the burning of brimstone; it tarnishes metals, changes the colour of most kinds of paint and furniture hangings; and when coal gas possessing this impurity is burned, the sulphur combines with the oxygen of the atmosphere, forming sulphurous acid. Therefore, with all the various evils enumerated, it is of the utmost importance that gas should be entirely free from it, and any establishment neglecting this does a serious injury to its business, as well as to the comforts of gas consumers.

Sulphuretted hydrogen is removed from coal gas by means of lime in solution, the "milk" or "cream" of lime, as in the wet-lime purifiers; or by means of the hydrate of lime (lime slackened and moistened), as in the dry-lime purifiers; or by the oxide of iron, muriate of manganese, &c. The inconvenience occasioned by the lime purification, in consequence of the odour emanating therefrom, also the difficulty of disposing of the waste material, has of late years caused the use of oxide of iron to become very general; and perhaps the economy attending it may have been an inducement. When dry lime is used it is necessary to have the lime greatly in excess, as it ceases to absorb sulphuretted hydrogen long before it becomes saturated. The absorbing action of the lime is said to be much increased by adding hydrous sulphate of soda: this has been proposed by Professor Graham (*Phil. Mag.*, June, 1841), who states that on the addition of the sulphate of soda the action continues till two equivalents of sulphuretted hydrogen have been absorbed by one equivalent of lime. The lime is entirely converted into gypsum, or sulphate of lime, and the whole of the soda becomes bi-hydro-sulphuret of soda, which might easily be washed out of the lime: this bi-hydro-sulphuret may be readily again converted into soda by roasting it, and thus might be used over and over again to mix with the lime in the purifiers.

Nearly all coal contains more or less sulphur—usually in combination with iron, and sometimes with lime in the form of sulphuret of iron (iron pyrites)—or the sulphuret of lime. During the process of distillation these sulphurets are decomposed, part of the sulphur being driven off in vapour or gas, and combining with hydrogen, the product being sulphuretted hydrogen. Previously to purification about 8 feet of sulphuretted hydrogen exist in every 1,000 feet of gas obtained from Newcastle coal.

The presence of sulphuretted hydrogen in gas is ascertained by moistening a piece of unsized white paper with a solution of the acetate of lead, and allowing a stream of gas to impinge upon it, when, if present, the paper is immediately darkened, or blackened, in proportion to the quantity of impurity in the gas.

Carbonic acid is another well-known oxide of carbon, containing two equivalents of oxygen to one of carbon. Its chemical composition is denoted by the formula $C\ O_2$; its atomic weight being $C\ 12 + O_2\ 32 = 44$, and proportions being 72·73 per cent. of oxygen, and 27·27 per cent. of carbon. This gas is readily procured by decomposing any of the earthy carbonates, as chalk or limestone, with a stronger acid, which, forming a new combination with the earthy base, sets free the carbonic acid of the carbonate. Carbonic acid gas is without colour, and though possessing an agreeable pungent taste and odour, cannot be breathed for a moment with impunity, as it rapidly produces the effect of suffocation, insensibility, and death. This gas is familiar to us as the fatal choke-damp of mines, as the fixed air in champagne, bottled beer, soda water, &c., and as the heavy gas which floats over the large vats in breweries while the beer is undergoing the process of fermentation. It is also produced wherever there is combustion, and should always be carried off by proper ventilation.

The specific gravity of this gas is 1·524, the weight of 100 cubic inches being 47·26 grains. Not only is this gas entirely uninflammable, but it instantly extinguishes flame even when diluted with three times its volume of air. The carbonic acid gas, owing to its great affinity for lime, is readily separated either by being exposed to the absorption of hydrate of lime, or that of lime diffused through water, as in the wet-lime purifiers. It is extremely injurious in gas intended for illuminating purposes, as it tends directly to destroy combustion. At the same time the great density of carbonic acid gas would give to any compound containing it a false appearance of value by exhibiting a high specific gravity, and hence its presence may reasonably be expected in gas with feeble illuminating power and considerable density.

	Grains.
According to Dr. Henry, a cubic foot of carbonic oxide weighs	520
And requires for its combustion half a cubic foot of oxygen, weighing	300
The product being carbonic acid	820

The presence of this impurity in coal gas is detected by a solution of lime in water, which must be filtered till quite clear; a portion of which is put into a large test-tube, or wine-glass, and by means of a flexible tube the gas under examination is allowed to bubble through it for about one or two minutes; if the water becomes cloudy or milky, it is a proof of the presence of carbonic acid.

The rationale of this test is that lime is soluble in water, but the carbonate of lime or chalk produced by the action of the carbonic acid and lime is insoluble, and the cloudy appearance indicates the production of the carbonate of lime.

Ammonia is produced during the distillation of coal by the union of hydrogen with the azote or nitrogen which is contained in coal, as in all other organic substances. In forming ammonia, one atom of nitrogen unites with three atoms of hydrogen, the chemical formula being $N H_3 = 17{\cdot}06$, and the proportions by weight being 82·41 per cent. of nitrogen, and 17·59 per cent. of hydrogen. The density of ammonia is ·589, the weight of 100 cubic inches being 18·26 grains. Two volumes of ammonia contain by measure three volumes of hydrogen and one of nitrogen, the whole being condensed to the extent of one-half. Ammonia is produced abundantly in nature from the decomposition of animal and vegetable substances: the gas is colourless and very pungent, acting strongly on the mucous membrane of the nose, eyes, and throat. A great part of the ammonia is separated from gas by the condensing apparatus, combined with water, and called ammoniacal liquor. The ammoniacal liquor is the principal source from which ammonia is procured; and numerous patents have been taken out for improvements in the mode of treating this liquor, in order to effect the production of carbonates, muriates, and other salts of ammonia. The value of ammoniacal liquor as a manure for top-dressing grass lands, and in other applications, has been much insisted on of late years. When diluted with four times its bulk of water and applied by means of cylinder carts or other contrivances for distributing liquid manure, the effect is said to be highly beneficial.

Although the ammoniacal liquor is at present the only source of ammonia in ordinary gas-works, there are other parts of the purifying process in which it may be separated, but not in sufficient quantities to be worth working. Where the breeze condenser is used, certain volatile oils together with ammonia are arrested; also where dry lime is used for purification, some volatile salts of ammonia are absorbed, and certain carbonates and sulphates of ammonia are decomposed, and the ammonia is set free.

Ammonia has strong alkaline properties, and its presence is detected by moistened turmeric paper, which, when exposed to the action of this gas, changes from its yellow colour to a deep red or brown. It is also detected by reddened litmus paper, which changes to blue. But the most minute quantity that may be present is ascertained by filling a glass flask with the gas to be examined, and inserting into it a glass rod previously dipped into muriatic acid, when, if present, a white cloud is formed in the flask—this being the muriate of ammonia.

Formerly the ammoniacal liquor of gas-works possessed but little value on account of the large quantity of water intermixed with it, and in some cases where pure water was used for the scrubbers, the greater portion of ammonia was entirely lost; but at the present day the ammoniacal liquor from the condensation is made the medium of purification by being pumped continuously through the scrubbers, until, by the absorption of ammonia, it attains the desired specific gravity, so to render it a valuable commercial commodity Sometimes acidulated water is employed in the scrubbers to remove the ammonia.

Ammonia in small quantities is not injurious to health, but it acts on some of the metals, as brass and copper of the fittings and meters, and is so far an impurity. Against this, it converts any sulphuric acid formed during combustion into sulphate of ammonia; therefore in this respect it is beneficial, and must be considered so until means are devised of freeing gas from all its sulphur compounds. A very small quantity intermixed with the gas is also considered essential, to prevent the deposition of naphthaline in the pipes.

Ammonia is a gaseous body, and that which is usually called so in the liquid state is ammoniacal gas intermixed with water, which takes up or absorbs about 700 times its own volume of that gas.

Bisulphide of carbon.—This impurity in coal gas until recently attracted very little attention, but it is now found to be most objectionable on account of its very disagreeable odour, its injurious effects, and the difficulty in removing it.

This gas is a compound of one equivalent of carbon and two equivalents of sulphur, or by weight carbon 6, sulphur 32 = 38; its formula is $C\,S_2$. It forms whenever sulphur comes into contact with red-hot charcoal or coke.

No practical method has yet been generally adopted for avoiding this obnoxious compound in coal gas; the substances which have hitherto been employed for the purpose, have at the same time deprived the gas of a portion of its heavy hydrocarbons, and in consequence its illuminating power has been much deteriorated. But there is reason to believe that Mr. Leigh, chemist of the Manchester Gas Company, after some years' labour, has succeeded in attaining the desired object.

A means of preventing to a great extent the formation of this substance is by distilling coal at a moderate heat, and not allowing the charge to be quite exhausted. A few words of explanation will make this palpable. Whenever coke is burned in a confined place, the odour of sulphur is very manifest, and is one of the great objections against the more general usage of this fuel for domestic purposes; proving that after the more volatile gases are disengaged, sulphur must be in combination with the coke or carbon in the retort, and the formation of the bisulphide of carbon is only a natural result.

The means of detecting the presence of this impurity is by passing the gas through a solution of potash and alcohol—when, if present, the liquid, after standing in a cool situation, deposes yellow needle-shaped crystals. The most delicate test known to chemists at present consists in an ethereal solution of Triethylphosphine, discovered some years ago by Dr. Hofmann, which precipitates the merest trace of $C\,S_2$ in the form of beautiful red needles. Apparatus hereafter explained is also very generally employed in gas-works for the purpose of indicating the presence of the compounds of sulphur.

Bisulphide of carbon may be produced by heating to redness, in a close porcelain vessel, some iron pyrites, with one-fifth of its weight of well-burned and dry charcoal. It may be condensed as a colourless liquid, having an acid taste and very offensive odour, which vaporises with great facility, is a remarkable solvent for india-rubber, and boils at 116° Fahr.

Cyanogen.—The property of nitrogen to unite with carbon and form cyanogen has been much studied. Cyanogen is an inflammable gas, burning with a beautiful purple or peach-blossom coloured flame, generating carbonic acid, and setting nitrogen free. It contains one equivalent of carbon and one of nitrogen, its atomic weight being 26, and the formula C N.

Cyanogen exists in considerable quantities in the ammoniacal liquor; and the separation of the cyanides for the purpose of forming cyanide of potassium, prussiate of potash, prussian blue, and other compounds, engaged at one period the serious attention of scientific men, but did not realise their expectations. This compound is not generally classed amongst the impurities of coal gas, but as some chemists of ability have decided it to be an impurity, for that reason it is mentioned here.

CHAPTER III.

COAL USED IN GAS MAKING.

Although there are many substances, such as wood, tallow, oil, resin, &c., from which gas for illumination can be obtained, but as these, on account of their increased cost, are very rarely used, it will answer all the purposes of the present treatise by confining myself simply to coal as the means of obtaining gas.

The origin of this mineral is involved in some doubt, but the theory generally admitted by geologists is, that its formation was caused by the deposit of vegetable matter, which in the course of ages became converted into coal. Some eminent geologists suppose coal beds to have been originally a kind of peat bog, or immense accumulations of masses of vegetable remains, and that subsequently the tracts of country where they existed, by some extensive convulsions of the earth, subsided below their former level, and were covered by various deposits. Others suppose that the trees of primeval forests were carried away by floods and rivers, and deposited in immense lakes, where afterwards they were covered by mud, sand, argile, and such like substances, so constituting the covering strata. It is further conjectured that the vegetable remains, whether of trees, peat, moss, &c., being thus buried, became after many ages converted into coal, and the deposits were converted into rock, shale, schist, marl, &c., which now intersect and cover the various strata of coal.

This assumption is formed from the fact that in all coal there are traces of vegetation, as ferns, and even the trunks of trees; these are so positive in their form and appearance, often with the bark attached, as to leave no doubt of their origin. This is particularly the case with the Boghead Cannel, wherein the trunks and branches of trees are often found, the wood having the nature of that coal, and the bark resembling the caking coal.

There are various other theories which have their supporters, and perhaps one of the most feasible is the supposition that coal was formerly a deposit of carbonaceous liquid similar to petroleum, and that by crystallisation this liquid became coal, such as we find it. Those of this opinion argue that the presence of trees and vegetation might have been accidental, or probably by the design of Providence, in order to assist in the crystallisation of the mass.

The use of coal is comparatively of modern date, for the first colliery was opened in the high grounds in the neighbourhood of Newcastle-on-Tyne in the year 1238. About 1306 coal was employed in London by brewers, dyers, and other branches of industry which required large fires; but the smoke produced from it became so offensive to the resident nobility and gentry, that they remonstrated against its use, and, in consequence, a Royal proclamation was issued, forbidding in London the use of coal as fuel. Some few years afterwards, wood fuel becoming scarce, the population and trade of the city increasing, prejudice gave way to utility, and the force of the proclamation diminished.

The use of coal became afterwards very general, but the extortion and abuse of the dealers therein was so excessive, that by Act of Common Council of the City of London, in 1665, each of the city trades' companies was ordered to lay up large stores of coal in summer, which in winter was to be vended to the poor at as low a price as possible, so as not to sustain loss.

The first patent in conjunction with coal was granted in 1589, for the purpose of smelting iron therewith. Patents were subsequently obtained at various periods, for obtaining oil, pitch, tar, and making charcoal (coke) from coal. In 1781 a patent was granted to the Earl of Dundonald, for "a method of extracting or making tar, pitch, essential oils, volatile alkali, mineral acids, salts, and cinders from pit coals." By this it will be observed, that although the patentee was well acquainted with most of the residues, or results of the residues of the distillation of coal, yet the most valuable constituent, the gas, was entirely lost sight of. A few years after this (1791) a patent was obtained for using an explosive mixture of inflammable air (gas) combined with atmospheric air, to produce motive power—an invention only at the present day being carried practically into operation.

Dr. Thomson divides pit coal into three species: brown coal, black coal, and glance coal. The brown coal is a kind of lignite or imperfect coal found at Bovey Tracy in Devonshire, also in several parts of Ireland, France, Germany, Iceland, &c. It contains a large quantity of bitumen, producing volatile carburets when distilled: the texture is fibrous, with evident marks of vegetable origin: it burns with a bright flame, yielding a peculiar bituminous odour, but does not occur in sufficient quantity to render it of much importance in the manufacture of gas.

There are other classes of lignite which exist in many parts of the world, called bituminous wood, earthy lignite, and common lignite. Common lignite is of interest to the gas manufacturer, on account of its strong resemblance to coal, for which, by an inexperienced eye, it might readily be mistaken; when distilled it gives off an abundance of water, with a small yield of gas of low illuminating power, possessing a most offensive sulphurous odour, which lime purification does not remove. This material contains very little tar, and the residue left in the retorts is simply breeze in cubes. It is therefore useless for the manufacture of gas, and only serviceable for burning lime, bricks, and other out-door purposes.

The varieties of black coal are for the most part valuable for the purposes of the manufacture of gas. They are divided by Dr. Thomson into four sub-species,—namely, caking coal, splint coal, cherry coal, and cannel or parrot coal.

Caking coal, to which variety belong most of the Northumberland and Durham coals, is so named from its melting, by reason of which the separate particles become united together into one pasty mass or cake, which, when used in a common fire-place, requires to be frequently broken up to allow currents of air to penetrate and promote its combustion. This coal is soft and easily broken, is very inflammable, and burns with a lively flame, giving out more heat in an open fire-place than most of the other kinds.

Splint coal, so called from its splintery fracture, is broken with more difficulty than the caking coal, and requires a higher temperature to light it. This is the best description for making coke, and when used in furnaces gives out the greatest amount of heat. To this variety belongs the greater part of the coal used in South Wales for smelting the ores of iron and copper. It is probably the best coal in England for making coke for locomotive engines, and from the experiments of Sir Henry de la Beche and Dr. Lyon Playfair, is the coal which appears to be the best adapted for steam boilers in the Navy.

Cherry coal is about the same hardness as caking coal, and is easily broken; it is also easily lighted, and burns with a bright flame. It burns out quickly, not caking at all, but leaving fully 10 per cent. of ash, while the best Newcastle caking coal leaves only 1½ per cent.

Cannel coal is harder and more compact than any of the other varieties, and is frequently cut into ornaments, which are not inferior in lustre to jet: it is very easily kindled, burns with a bright flame, and does not soil the bars of a grate. Cannel coal is extensively obtained in Scotland, and is also procured from Lancashire, from whence it is brought to the London market, both for use in gas-works, and sometimes, though rarely, for domestic consumption, its cleanliness and cheerful crackling mode of burning being its chief recommendation. Cannel coal is largely exported for the purpose of manufacturing gas; the greatly increased light obtained therefrom renders it a very desirable commodity, particularly when the expenses of transport are great.

Glance coal or anthracite consists almost entirely of carbon, and contains only a very small proportion of volatile constituents. Although extremely valuable as a heat-giving coal, it is almost worthless in the manufacture of gas. It exists in great abundance in the western part of the South Wales coal field, in Kilkenny, in Pennsylvania, and other parts of the world.

All coals are composed nearly of the same ingredients, which, however, vary considerably in their respective quantities, to illustrate which a table of the analysis of a few classes is subjoined :—

	Locality, or Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Welsh Coal.	Thomas's Merthyr .	1·30	90·12	4·33	1·00	·85	2·02	1·68	86·53
	Nixon's Merthyr . .	1·31	90·27	4·12	0·63	1·20	2·53	1·25	79 11
	Hill'sPlymouth works	1·35	88·49	4·00	0·46	0·84	3·82	2·39	82·25
Newcastle Coal.	Newcastle Hartley .	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
	West Hartley Main .	1·26	81·85	5·29	1·69	1·13	7·53	2 51	59·20
	Hasting's Hartley .	1·25	82·24	5·42	1·61	1·35	6·44	2·94	35·60

The carbon in the composition of coal may either be fixed or volatile; by fixed carbon is understood that which does not volatise when undergoing ordinary distillation, but remains in the retort as coke. The volatile carbon is that which passes off as gas, hydrocarbons, tar, &c.

The foregoing table demonstrates this difference very forcibly, for in the Welsh coal upwards of 90 per cent. remain fixed as coke, and as a consequence, this class, although admirably adapted for steam purposes, is useless for the manufacture of gas. According to the same table, the Hasting's Hartley yields about 57 per cent. of volatile carbon, which renders it a good gas-producing agent. But it must be observed that the last mentioned material would, on account of its volatility, be ill adapted for steam purposes, as without the greatest care a large portion of it would pass off as smoke.

The following table, by Mr. Lewis Thompson, and extracted from the "Journal of Gas Lighting," gives the per-centage of volatile matter in various coals:—

	Per-centage of volatile matter.
Boghead	68·4
Old Wemyss	52·5
Lesmahago	49·6
Arniston	45·5
Wigan	37·0
Newcastle Cannel	36·8
CAKING COALS.	
Heathern (Staffordshire)	42·9
Stavely (Derbyshire)	40·9
Silkstone (South Yorkshire)	34·3
Newcastle Gas Coals	27·8 to 31·25

Coals are obtained very extensively in Belgium, France, and other parts of the Continent, likewise in America and Australia, and probably they exist in nearly every country in the world, and even in many places beneath the depths of the ocean.

For the combined purposes of producing good gas and coke of excellent quality, possibly no mineral exists equal to the caking coals of Newcastle-on-Tyne; there is, however, considerable variation in their respective natures; some classes having the superiority for the production of gas, either in quantity or quality, while others give superior coke, and gas of diminished value.

During the process of distillation this coal melts, forming itself into a doughy consistency, and expanding considerably; but gradually, as the gas is expelled, it assumes a brittle homogeneous nature, and has to be broken in order to extract it from the retort.

The average yield of gas from a ton of Newcastle coal is 9,200 cubic feet, of a quality equal to about twelve candles, that is, an argand burner with fifteen holes, consuming five feet per hour, gives with this gas, a light equal to twelve sperm candles, each consuming 120 grains per hour ; or, five feet of gas is equal to 1,440 grains of sperm. With the production stated the quality is seldom superior to this, but is often much inferior. When retorts are heated to a moderate degree, the volume of gas produced is less than that mentioned, but its quality is improved.

A ton of caking coal yields, on the average, 13½ cwts. of coke. When the coal is distilled at a high temperature, the coke is hard and brittle; when distilled at a low temperature, it is soft and friable.

If caking coal be exposed to the direct action of the atmosphere, alike to sun and rain, its value as a gas and coke producing agent is diminished in a most remarkable manner, and the results of many observations justify the writer in asserting that coal, when extracted from the mine, and so exposed for three months, becomes deteriorated in value to the extent of about 10 per cent. Of course the subsequent deterioration is in a very reduced proportion; but under the most favourable circumstances this class of coal diminishes in value by prolonged storage.

Caking coal is generally very small, and when wetted, by accident or otherwise, and stored away in that state, has a great tendency to ignite spontaneously, which circumstance has frequently occurred. Another inconvenience with wet coal is, that when the retorts are charged, the water intermixed therewith is rapidly converted into steam, and carries off a large portion of the heat from the retorts, so facilitating the production of an excess of tar and a diminished quantity of gas; and, on the authority of a late engineer of eminence, the distillation of small wet coals invariably produces napthaline. These are sufficient reasons to cause every precaution to be employed to guard against such contingency.

A very curious phenomenon occurs when coals are piled away and subjected to the action of the weather. In the course of time the iron pyrites become decomposed, and the sulphur distributes itself throughout the heap in regular strata at some distance from each other, the inclination or "dip" being about 30° to the horizon, and the strata running parallel. When the pile is seen in section it presents a very remarkable appearance. The cause of this spontaneous stratification must be left to our philosophers and geologists to define.

For the purpose of producing very superior, or, as technically termed, "rich" gas, the cannel coal obtained in Scotland and the North of England surpasses all other. There is, however, considerable variation between the numerous classes; but that called "Boghead" is the most extraordinary, a ton of this coal produces 15,000 feet of gas of a quality equal to thirty-six candles, it possesses no ammonia, and very little sulphur; but the coke resulting from it is useless, except, perhaps, as a deodorising agent, for which purpose Mr. Lewis Thompson recommended it.

The gas from Boghead is never commercially used alone, but it is often intermixed, like that from the other cannels hereafter mentioned, with "poor" gases from caking coal, in order to bring their illuminating power to the required standard. For this object the Boghead must be distilled in separate retorts, otherwise its residue would deteriorate the value of the coke produced from the other coal.

The coke from nearly every description of cannel retains the form and size of the coal previously to distillation. In its nature it is compact, and resembles charcoal, for which it is often substituted abroad. This coke is sometimes used as fuel for the furnaces; but very often an inferior description of coal is employed for the purpose, and the coke is sold. There is a description of Wigan cannel, also Ramsay's cannel, which gives a coke very similar to the caking coal, enabling it to be used as fuel for the furnaces, and it is generally a more marketable commodity than the coke from other cannels.

The gas derived from most cannel coal is suitable for enriching the "poorer" gases, and for the purpose, as a rule, the best quality is generally the cheapest. Boghead, in consequence of its extensive usage for extracting petroleum oil, has attained a very high price, and at present cannot be employed in many places with advantage; but wherever freights are high it can be recommended. The other classes of cannel, as Leshmahago, to produce the same result, require a larger per-centage than Boghead. For instance, if we suppose the standard of illuminating power of gas required to be increased from twelve candle to fourteen candle gas, the additional illuminating power would be obtained from an admixture of about $1\frac{3}{4}$ per cent. of Boghead coal, whereas it would require nearly 3 per cent. of Lesmahago, and, of course, a considerably greater increase of the other inferior cannels.

The following tables on experiments of the quantities of gas derived from various coals, together with their specific gravity and the weight of gas in pounds, must be interesting to all connected with gas-lighting:—

Experiments on the Quantities of Gas derived from Coal.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
NEWCASTLE COALS.				
English Caking Coal .	8,000	·420	257	Dr. Fyfe.
Newcastle Coal . . .	11,648	·475	423	Mr. Joseph Hedley.
Pelaw, Newcastle . .	11,424	·444	389	Ditto.
Pelton, ditto . . .	11,424	·437	382	Ditto.
Blenkinsopp, Carlisle .	11,200	·521	447	Ditto.
Newcastle	8,500	·412	268	London, 1837.
Wall's End, Newcastle	12,000	·490	450	Quantity made in the revolving web retort; authority, Mr. Clegg.
Pelton	11,000	·430	363	Mr. Lewis Thompson, author of the "Chemistry of Gas-Lighting," in the "Journal of Gas-lighting."
Leverson	10,800	·425	353	
Washington	10,000	·430	330	
Pelaw	11,000	·420	355	
New Pelton	10,500	·415	335	
Dean's Primrose . .	10,500	·430	347	
Garesfield	10,500	·398	321	
Gosforth	10,000	·402	308	
West Hartley . . .	10,500	·420	339	
Hasting's Hartley . .	10,300	·421	333	
Blenkinsopp	9,700	·450	335	

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
NEWCASTLE COALS—*continued.*				
Berwick & Craister's Wall's End . . .	12,507	·470	449	Mr. Clegg.
Pelaw Main	12,400	·420	399	Ditto.
Russell's Wall's End .	12,000	·418	384	Ditto.
Ellison's Main . . .	11,200	·416	357	Ditto.
Felling Main . . .	11,200	·410	351	Ditto.
Pearith's Wall's End .	11,147	·410	350	Ditto.
Dean's Primrose . .	11,120	·410	349	Ditto.
Benton Main . . .	10,987	·400	337	Ditto.
Eden Main	10,400	·400	318	Ditto.
Heaton Main . . .	10,400	·410	326	Ditto.
Pelton	11,000	·430		Mr. F. J. Evans.
Leverson	10,800	·425		Ditto.
Pelaw	11,000	·420		Ditto.
Garesfield	10,500	·398		Ditto.
Gosforth	10,000	·402		Ditto.
Dean's Primrose . .	10,500	·430		Ditto.
PARROT OR CANNEL COALS.				
Boghead Cannel . .	15,000	·752	866	Mr. J. Evans, at Westminster Station of Chartered Gas Company.*
Lesmahago, No. 1 . .	13,500	·642	666	Ditto.
Ditto No. 2 . .	13,200	·618	627	Ditto.
Capeldrae Cannel . .	14,400	·577	638	Ditto.
Arniston ditto . .	12,600	·626	606	Ditto.
Ramsay Cannel . . .	10,300	·548	433	Ditto.
Wemyss ditto . . .	14,300	·580	637	Ditto.
Kirkness ditto . . .	12,800	·562	552	Ditto.
Knightswood ditto . .	13,200	·550	558	Ditto.
Wigan (Ince Hall) ditto	11,400	·528	461	Ditto.
Wemyss Cannel . .	10,976	·670	563	Mr. Wright.
Ditto ditto . . .	10,192	·691	538	Ditto.
Wigan Cannel . . .	9,408	·478	344	Ditto.
Knightswood Cannel .	9,720	·590	439	Ditto.
Lesmahago Cannel 1st experiment .	11,681	·540	483	Ditto.
Ditto 2nd experiment	9,878	·650	492	Ditto.

* Each of the results given by Mr. Evans is the mean of three experiments.

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
PARROT OR CANNEL COALS—*continued.*				
Ramsay's Newcastle Cannel	9,016	·604	417	Mr. Wright.
Lesmahago Cannel . .	11,312	·737	638	Mr. Joseph Hedley.
Welsh Cannel . . .	11,424	·737	645	Ditto.
Wigan Cannel . . .	11,200	·606	520	Ditto.
Ditto ditto	9,500	·580	422	Liverpool New Gas and Coke Company.
Lochgelly Parrot . .	9,123	·567	396	Dr. Fyfe.
Ramsay's Cannel . .	9,333	·598	427	J. Z. Kay, Manager of Dundee Gas-Works.
Ditto ditto . . .	9,667	·731	541	Dr. Leeson, Dr. Miller, and Mr. G. H. Palmer.
Wigan Cannel . . .	9,500	·460 to ·520	357	Dr. Fyfe.
Scottish Parrot . . .	9,500	·640	466	Ditto.
Ramsay's Newcastle Cannel	9,746	·554 to ·580	423	Ditto.
Yorkshire Parrot . .	11,500			Dr. Fyfe.
Wigan Cannel . . .	14,453	·640	708	Mr. Clegg.
Ditto ditto . . .	14,267	·610	664	Ditto.
Scotch ditto . . .	14,000	·580	622	Ditto.
Ditto ditto . . .	13,813	·500	529	Ditto.
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL.				
Derbyshire Deep Main	9,400	·424	308	Mr. Wright.
Brymbo 2-yard Coal .	8,880	·463	315	Ditto.
Powell Coal, 2 cwt. charges every 5 hours	10,165	·459	357	Ditto.
Powell Coal, 1½ cwt. charges every 5 hours	8,250	·470	296	Ditto.

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL—*continued.*				
Bickerstaff, Liverpool .	11,424	·475	415	Mr. Hedley.
Neath, South Wales .	11,200	·468	401	Ditto.
Birmingham Gas Company: Lump Coal from West Bromwich . . .	6,500	·453	226	Birmingham Gas Company. Parliamentary return.
West Bromwich . .	6,500	·455	227	Birmingham and Staffordshire. Do.
Macclesfield	6,720			
Stockport	7,800	·539	322	Parliamentary return
Oldham Watergate and Wigan Cannel mixed	9,500	·534	388	Manchester. Do.
Ormskirk or Wigan Slack	8,200	·462	290	Liverpool, Old Company. Do.
Low Moor mixed with two kinds of Slack	8,000	·420	257	Bradford. Do.
Leeds Coal	6,500	·530	263	Leeds Company. Parliamentary return.
Cannel and common Coal mixed . . .	8,000	·466	285	Sheffield Company. Parliamentary return.
Derbyshire Soft Coal .	7,500	·528	303	Leicester. Do.
Ditto ditto	7,000	·448	240	Derby. Do.
Ditto ditto	7,000	·424	227	Nottingham. Do.
Staffordshire.				
South's	10,933	·398	333	Mr. Clegg.
Second variety . . .	10,667	·395	322	Ditto.
Third variety . . .	10,667	·390	318	Ditto.
Fourth variety . . .	9,600	·320	235	Ditto.
Forest of Dean . . .	10,133	·350	271	Ditto.
Second variety . . .	10,133	·360	279	Ditto.
Welsh Coal.				
First variety	10,000	·385	295	Ditto.
Second variety . . .	10,133	·380	295	Ditto.

In examining the foregoing tables, at first sight one is struck with the apparent discrepancies, in trials on the same coal, existing between the various experimentalists, and if a reason could not be assigned for these, probably our faith in their general accuracy might be shaken ; but taking into consideration the imperfect apparatus employed thirty years back, when many of these experiments were made, and other causes, there is much to admire and little to object to.

Some few years ago the influence of the various degrees of temperature of the retorts, in the production of gas, was not so well understood as at present—low temperatures, small retorts, and eight-hour charges were very common, and as a consequence a comparatively small volume of gas was obtained, with an increase of tar. Therefore it is to be assumed that the variations existing in the quantities produced from the same kind of coal, must have arisen from the temperature of the retort during the operation. Thus, if we refer to the two trials of Lesmahago, by the late Mr. Wright, who was a most careful experimentalist, we find a great difference in the volume of gas produced, which, however, is compensated as near as possible by the specific gravity of the gas. The greater yield no doubt was derived from the increased temperature of the retort. The low production of gas obtained by some of the authorities very probably arose from the retorts not being sufficiently heated, so that a portion of the hydrocarbons were converted into tar.

The variation in the specific gravity recorded is by no means remarkable, on account of the imperfect instrument formerly used for ascertaining it.

The table serves as a guide of considerable importance to the gas manufacturer ; it enables him to estimate the quantity and quality of gas, and gives, by inference, the weight of coke derived from each description of coal. It also enables him to estimate the value of gases obtained from cannel coals, and to determine the quantity from each class of cannel that may be requisite to increase the illuminating quality of gas from one standard to another.

CHAPTER IV.

MODE OF CARBONISING. — TEMPERATURE OF FURNACES. — EFFECTS OF VARIOUS TEMPERATURES ON THE PRODUCTION OF GAS AND TAR.—THE PROPER TEMPERATURE FOR RETORTS.—THE CHARGES OF RETORTS.—FUEL IN HEATING FURNACES.—TAR AS FUEL.—ON THE MODE OF WORKING RETORTS.—INCRUSTATION OF CARBON IN THE RETORTS.—MODE OF CLEANSING.

CARBONISATION OR DISTILLATION OF COAL.

The first process in gas manufacture consists in submitting the coal to the action of a high heat, whereby its destructive distillation, or as generally termed carbonisation, is effected. In practice, this is done by placing the coal into retorts of fire-clay or iron, which are previously heated considerably above its point of ignition.

The retort being charged with coal, is then hermetically closed with a door and luting, leaving no means of escape for the gas, except through the ascension pipe. By these means the coal is decomposed and the gas evolved, and when effectually done the residue left in the retort is simply coke—a substance chiefly consisting of carbon, containing neither bitumen, tar, nor other volatile matter capable of yielding a useful gas for the purpose of lighting.

The gas expelled from the coal passes from the retort A (Fig. 1), up the vertical pipe, called ascension pipe, C; then traverses the bridge, or H-pipe D, down the dip pipe E, into the hydraulic main L—which is a large tube placed horizontally, and extending along the length of the furnaces. B is the mouth-piece attached to the retort; H is the lid or door of mouth-piece; J, the screw for securing the same; F, the furnace; K, the furnace door; and G the ash or evaporating pan.

The hydraulic main is about half filled with water or tar, into which the ends of each and all the dip pipes are immersed, and the gas, as generated, forces its passage through the liquid into the space above, but cannot again return into

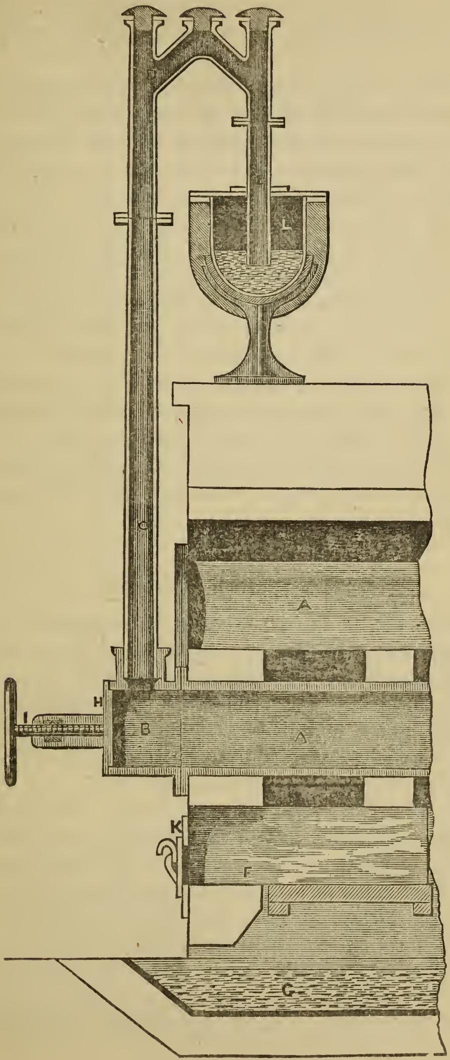


Fig. 1.

the retorts; so that when once arrived in the hydraulic main, it is fairly secured, and ready for the operation of purification.

The reason of this is very simple—for the heat, in expelling the gas from the coal, by the vastly increased volume, creates a pressure or force similar to that of steam when generated from water, the two processes being identical. This pressure being superior to the obstacles which oppose the passage of the gas, such as the dips of the hydraulic main, scrubbers, purifiers, gasholder, and atmospheric pressure, the gas in consequence passes freely as generated; and the column of liquid in the hydraulic main and dip pipe being considerably greater than the pressure of the gas when in the holder, it is thus prevented from returning to the retort.

In the manufacture of gas, the proper means of carbonising coal is of the first importance; ignorance on this point has often entailed considerable and serious loss, when, by a little intelligence, proportionate profits would have resulted. To ensure the necessary degree of heat for the retort is of the utmost consequence.

TEMPERATURE OF FURNACES.

With reference to the heat which it is proper to employ in the distillation of coal for gas-making, it is unfortunate that science has not yet furnished the practical man with any convenient method of estimating high temperatures. Wedgwood's pyrometer, though extremely ingenious, gives all its indications on so small a base line as to require an accuracy and homogeneity in the composition of the clay cylinders employed which is physically impossible. The range of temperature indicated by the Wedgwood pyrometer being more than ten times greater than the range from the freezing to the boiling point of water, has to be expressed within the limits of only $\frac{2}{5}$ths of an inch, this being the extent to which a cylinder of clay contracts between a faint red heat at about 950° Fahr. and the melting point of cast iron at 2800° Fahr. It is true this very small range of $\frac{2}{5}$ths of an inch, divided as it is into 240 parts, is made appreciable by Wedgwood's contrivance of reading off on a base or ruler about 2 feet long, but the delicacy of observing and manipulating with such an instrument is too great to render it available for practical purposes, besides which the cones or cylinders of clay can never be procured sufficiently uniform in structure.

Daniell's pyrometer is, perhaps, superior to any other that has been tried. Its indications are caused by the expansion or contraction of a bar of platinum connected with a lever which acts as an index. The dial on which the index revolves affords room for a greatly increased space to read off the results, but this instrument for practical use is liable to some of the objections against Wedgwood's pyrometer. The recent methods pointed out by Mr. Prinsey for determining high temperatures by means of fusing the metals and their alloys, is far too troublesome and complicated for practical use. The beautiful experiment of obtaining the temperature of a furnace by means of thermo-electric currents is also far too delicate for ordinary use, and until some contrivance more capable of being reduced to daily practice shall be introduced into gas-making, we must be content to be guided in a great measure by the colours presented by the interior of the furnace. Constant observation will, indeed, greatly improve the faculty of estimating high heats by the shades of colour which they present, and at all events enable the observer to compare and adjust the working of his furnaces. The following table of high temperatures, expressed in the colours commonly used, with their corresponding temperatures reduced to Fahrenheit's scale, has been principally compiled from M. Becquerel's "Traité de Physique :"—

Faint red	960°	Fahr.
Dull red	1290	,,
Brilliant red (colour of red oxide of lead)	1470	,,
Cherry red	1650	,,
Bright cherry red	1830	,,
Dull orange	2010	,,
Bright orange	2190	,,
White heat	2370	,,
Bright white	2550	,,
Brilliant white	2730	,,
Melting point of cast iron	2786	,,
Greatest heat of iron blast furnace . .	3300	,,

There are, however, difficulties in appreciating the various degrees of heat by colour; for instance, when heated retorts are exposed to the direct action of daylight, the colour or temperature appears lower than it really is; or when they are enclosed in a dark locality, on the contrary, the temperature seems to be higher than reality. The means of judging the various degrees of temperature by sight is only acquired by continued practice.

The technical name applied to the temperature of retorts is "heat" or "heats;" thus it is expressed "a good heat," "a low heat," or "the heats were down," "the heats were up," &c., terms sufficiently significant to require no explanation.

EFFECTS OF VARIOUS TEMPERATURES IN CARBONISING.

Coal when submitted to a temperature approaching to 600° Fahr.—that is, a very dull red heat as seen in the dark, a degree of heat which slowly chars paper, but does not inflame it—its volatile matter is resolved into tar and oil, and little or no gas is evolved.

Mr. Young, of Bathgate, turned the knowledge of this simple fact to very great advantage, by decomposing Boghead cannel coal at that degree of temperature whereby oil and tar only are obtained, which are afterwards purified, and universally known as paraffin oil. When the operation is properly conducted, the quantity of gas evolved is very small, in some cases perhaps not exceeding 50 feet or 100 feet per ton, the rest of the volatile constituents being condensed into liquid.

In the carbonisation of coal, in proportion as the heat of the retorts increases, so is the quantity of gas augmented, and the tar diminished. The best temperature for iron retorts compatible with their durability and good yield of gas, ranges from 1650° to 1800° Fahr., being cherry-red and bright cherry-red; but with clay retorts, a temperature between dull and bright orange, or 2100° Fahr., is the most suitable, giving vastly superior results in the production of gas than can ever be attained by the use of iron retorts.

Iron retorts, when worked at a low temperature, are of very considerable durability; in this state no deposit or incrustation takes place in them; but these supposed advantages are often very dearly purchased. The attention of the writer was once called by a gas manager to the great durability of his iron retorts, which had been in use upwards of fifteen months, had never required clearing of carbonaceous deposit, and were almost in as good condition as when first fixed. This was all substantially correct; but on referring to the accounts, the yield of gas was ascertained not to have exceeded 6,500 feet per ton; whereas by an alteration of furnaces, so that the proper temperature for the retorts could be attained, the yield was afterwards 9,200 feet per ton. By the low temperature a large portion of the coal was converted into tar, and this in the locality being nearly valueless, the enormous loss can be readily understood.

As stated, the most advantageous degree of heat for carbonising coal is about 2100° Fahr.; but when iron retorts are heated above 1800°, they are speedily destroyed, or "burnt out." Clay retorts on this account have an immense superiority; they can be heated to the proper temperature without the risk of injury; they are of extraordinary durability (their average duration in some works being four years); the quantity of coal carbonised by them is considerably greater, and labour less than when iron retorts are used. These combined circumstances have caused clay retorts to entirely supersede those of iron.

The time the coal remains in the retort is called the charge; thus, if subjected to four hours' distillation or carbonisation, it is termed a four hours' charge; if for six hours, a six hours' charge. The word charge also applies to the quantity, as when a retort is supplied with a certain weight of coal, say 140 lbs. or 2 cwt., as the case may be; they are respectively called a charge of 140 lbs. or a charge of 2 cwt.

The nature of the coal must regulate the quantity and duration of the charge. Some descriptions, as cannels, yield the gas very rapidly; so in Scotland, where this is very generally used, it is found necessary to have small charges of about 1½ cwt. per retort, or less, which is drawn every three hours. With Newcastle coal, which does not yield its gas so readily, $2\frac{1}{2}$ cwt. are very common charges, which is worked off sometimes in five hours, but more generally in six hours.

The coals destined for carbonisation should always be in a dry state; and when by accident they are otherwise, if possible they should be placed along the retort-house and opposite the beds in use, some hours before required, in order to dry them. In addition to the evils of wet coals already enumerated, according to the opinion of Mr. Lewis Thompson the steam is converted into hydrogen, thus impoverishing the gas; but however correct this may appear in theory, from my own observation it does not occur in practice, the heat to which the steam is exposed being insufficient for its decomposition.

FUEL USED IN HEATING FURNACES.

The fuel commonly used for heating the furnace is the coke produced in the retorts after the gas is expelled; the quantity of course varying according to the quality of coal and coke, the construction of the furnaces, and the magnitude of the operation. When Newcastle coal is used, the carbonisation is seldom effected, except in very extensive establishments, with less than 25 per cent., or one quarter of the coke obtained; that is to say, to carbonise a ton of coal, about $3\frac{1}{4}$ cwt. of coke will be required as fuel for the furnaces.

Coal is usually spoken of by weight, and coke by measure. Newcastle coal generally yields about 1 chaldron of 36 bushels, or from 13 to 14 cwt. of coke for every ton of coals. In well-conducted medium size works about one-fourth of the coke made is used as fuel in the furnaces, the surplus three-fourths remaining for sale, as more particularly described in the section devoted to residual products. In small establishments this per-centage of fuel is exceeded; and in very large works the fuel employed is often not more than 18 per cent. of the coke produced.

Some years ago Mr. Croll introduced the system of charging the furnaces with the red-hot coke, as drawn from the retorts; there appears to be considerable saving effected by this, which has induced many engineers and companies to adopt it.

When tar is not a marketable commodity it can be used as fuel with advantage; for this purpose the ash-pit and door are bricked up, but leaving two orifices of about $2\frac{1}{2}$ inches square, the one above the other; the upper being on a level with the line of top of door, the other about 8 inches below this. The furnace being filled with breeze to the level of the bottom of lower opening, a gutter of angle iron, or a gutter in the brickwork itself, inclines in the upper orifice to the interior of furnace, and through this flows a small stream of tar of about $\frac{1}{12}$th of an inch in diameter. When first used, a few pieces of wood are lighted in the furnace, and the stream of tar flowing in, ignites as a flame at the upper opening, whilst a portion of the tar is deposited in front of the lower opening in the form of coke; so that the air entering the orifices becomes highly heated by the flame above, and the combustion of the coke below. Furnaces by this means are kept at an excellent degree of temperature. One great difficulty with tar as fuel is that it acts as a flux on the brickwork, but this is remedied by constructing the furnace expressly for this purpose.

The combustion of tar as fuel is facilitated by allowing a very small quantity of water to drop continuously and intermix with it in the channel; this avoids the smoke which would otherwise pass off by the chimney, and the water itself becoming combustible aids as fuel. By adopting this system no smoke arises, no coke is employed, and the economy in some cases is remarkably important. A cwt. of tar is equal to $1\frac{1}{2}$ cwt. of coke, requiring about a quart of water to be intermixed with it during combustion.

ON THE MODE OF WORKING RETORTS.

The magnitude of the works must always decide the mode of operation. In large establishments, where double retorts are used, being open at both ends, a double set of men is required to work them so as to be enabled to charge the two ends simultaneously. The economy of this, over the old method of setting the retorts back to back in different ovens, is very considerable.

Where double retorts are used, each end is worked with at least three stokers and an extra man for preparing the lids of the mouth-pieces. Others are required for extinguishing the coke, wheeling the coal into the retort-house, clinkering furnaces, and attending to fires. Three stokers, assisted by a man to extinguish the coke, will perform all the work of taking off the lids, raking out the coke, extinguishing and wheeling it away from a bench of seven retorts, in twelve or thirteen minutes; they will then put the proper charge for each retort in the scoop, deliver its contents, and be ready for charging another bench in a further space of seven minutes, while a fourth workman will in the meantime have put on the lids, so that the whole work of discharging and charging the seven retorts will occupy barely twenty minutes.

This extreme dexterity is of course only acquired by long practice, and it must be admitted the labour is very severe; but this is moderated by the time the men have for repose between the charges. The first process, in discharging or drawing, is for one or two of the men to relieve the screws of the mouth-pieces of the retorts about to be discharged, by giving three or four rapid turns; another man instantly gives a knock to each of the cross bars to disengage them from the ears of the lid, and at the same time strikes the lid a blow with a piece of iron or hammer, in order to break the luting, and a light is immediately applied to prevent explosion, which would be likely to crack the retort if of clay. For want of this precaution, many lamentable accidents have happened through the gas exploding when combined with atmospheric air. The men then lift off the cross bar and screw of each retort, placing them on the ground, and then each seizes hold of a lid in both hands, lifting by the projecting ears, and placing it aside to cool, ready for luting for another charge.

Three of the stokers then take up their iron rakes, which are simply rods of $\frac{3}{4}$-inch iron, about 12 feet long, having a handle at one end; the other end being turned at right angles is flat, about 6 inches long, 2 inches wide, and ½-inch thick. These are inserted in the retort, and the red-hot coke drawn to the mouth, whence it drops into the coke vault, where there is a man ready to extinguish by throwing water on it; or when there is no vault the coke drops into iron barrows placed ready to receive it, and wheeled rapidly away when the charge is withdrawn. If the coke were not immediately extinguished it would smoulder, and the surface become covered with earthy ash, which detracts from its appearance and value.

Formerly, in charging retorts, the operation being comparatively very protracted, there was a considerable loss of gas, in addition to the time and extra fatigue to the men. In order to remedy these inconveniences, a method has been contrived for depositing the whole charge in the retort at once; for this purpose an iron scoop is used, this being a semi-cylinder of sheet iron from 8 to 10 feet long and 10 or 12 inches diameter, with a cross handle at the end to assist in lifting and turning it round to empty the coals in the retort.

The charge of coal is placed in the scoop while it rests on the ground, having a bent rod underneath for the purpose of lifting it: one man takes hold of the cross handle, and two others lift the other end by the bent rod and introduce it into the mouth of the retort. The scoop with its contents is then pushed forward to the further end, turned completely over, and immediately withdrawn, leaving the coal in the retort, which is raked into a layer of uniform thickness, when the lid, previously luted and ready, is placed in its position and screwed up as quickly as possible. The operation of charging a retort with the scoop does not occupy more than thirty or forty seconds, so that very little escape of gas can take place. Hence the scoop has come generally into use wherever the works are large enough to supply three men for the purpose of working it. The composition for luting the retorts is made generally of the spent lime from the purifiers, mixed with a little fire-clay or loam, and well worked up with water like mortar. In large works it is prepared outside the retort house and brought in by wheelbarrows as required. In dressing the retort-lid with the luting, the workman uses a trowel, and works a little of it up on a board, and applies it all round the rim, taking care previously to clear off the old luting.

In small works, which do not permit of the necessary men being employed to work double retorts, single retorts, generally about 8 feet long, are used. These are charged by means of the shovel, and the process is necessarily more tedious than the scoop, and the expenses of labour for carbonisation increased.

The beds or ovens of single retorts in very small works are placed side by side, and extend the length of the retort-house. In works of larger magnitude they are placed back to back.

The number of men required to carbonise a given quantity of coal depends on the size of the works. At extensive establishments each man carbonises from five to six tons of coal per day, whilst in small works, where iron retorts are used, often 25 cwt. is not attained. In Scotland formerly, and perhaps at present, it was sometimes the custom for the stokers to be engaged by piece-work.

A very essential point in the carbonisation of coal is to keep the interior of the retorts free from incrustation, and, indeed, as far as possible, to prevent it taking place. This incrustation, as already referred to, is a solidification of the richest parts (the heavy hydro-carbons) of the gas, and when gas is subjected to a high pressure and great heat, these are deposited in great abundance.

It also entails several other disadvantages,—it increases the fuel and labour; by its obstruction renders more retorts necessary, so increasing the capital invested; and wherever it abounds the coke is always of inferior quality. In iron retorts, where the heats are not so high as in those of clay, supposing both to be subject to the same pressure, this deposit does not take place so speedily; but it is always in excess in the hottest part of the retort, which is generally the closed end, and diminishes towards the mouth in proportion to the diminished temperature. It has often been considered that the exhauster was unnecessary wherever iron retorts were used; but wherever the incrustation of carbon occurs, either in iron or clay retorts, it may be taken as a direct proof of the necessity of that instrument.

When clay retorts are at the most advantageous temperature, and the gas in them is under a pressure of 18 or 24 inches (which is not uncommon when no exhauster is used), two or three weeks are sufficient for a very inconvenient accumulation of carbon in the retorts; but when the pressure is diminished by the exhauster to about 1 inch, the same quantity of accumulation would require from three to four months.

The mode sometimes adopted to clear out this carbon (the furnace being heated as usual), is to project from a tube a small jet of steam on to the crust attached to the roof of the retort. The oxygen of the steam combines with the carbon which gradually diminishes, and when sufficiently thin can be easily detached by means of a chisel bar, it being removed from the roof, like an arch without the key; the deposit of the sides breaks away in large lumps.

Others prefer a periodical cleansing by leaving the retorts exposed to the action of the atmosphere, the heats being kept up as usual; for this purpose the door is placed in its position, leaving about an inch space between it and the mouth-piece. The air enters and gradually cleanses the retort. It is always advisable to clear out this deposit before it becomes too thick; if neglected, its accumulation is very rapid.

In all coal, combined with the ash, there are particles of iron, lime, and other substances, which fuse and become slag, or clinker, which deposits itself between the furnace bars and stops the current of air. To effectually remove this the bars should be loose, as hereafter stated; and the clinker is readily detached by means of a suitable bar.

When the ascension pipes are placed too close to the furnaces, or when the wall of the furnace is not sufficiently thick, the pipes are heated to such a degree that the tar in its passage is deposited thereon, as pitch, thereby causing a speedy obstruction.

CHAPTER V.

SITE MOST APPROPRIATE FOR GAS-WORKS.—CONSIDERATIONS IN CHOOSING SITE. — OBSERVATIONS ON THE LOWEST LEVELS FOR SITES.—LEAKAGE OF MAINS.—OBSERVATIONS ON PLAN OF WORKS.—ESTIMATE OF CAPITAL OF WORKS.

CHOICE OF SITE FOR GAS-WORKS.

In the largest class of towns or cities, the site generally chosen for gas-works has been the side of a canal or river, so as to profit by the convenience of water carriage for the supply of coal, purifying materials, pipes, bricks, retorts, and apparatus, also for the economical transport of the residues, as coke, tar, ammoniacal liquor, breeze, waste lime, &c.

Since the establishment of railways, a site contiguous to a line is found, so far as economy of transport is concerned, equally advantageous; whilst it is superior on some accounts, not being, like the canal and river, liable to the contingencies of frost. There is the further advantage in the railway, that the coal is delivered daily and direct into the retort-house ready for use, so avoiding the expenses of unloading the barges, loading the trucks, and wheeling.

The Great Central Company's Works, at Bow, afford an excellent instance of this arrangement. A branch line is laid down connecting the works with the railway which serves for the supply of coal, and the rails are laid actually into the retort-house, the rails being raised a sufficient height above the level of the charging floor to enable the waggons to tilt with perfect ease, and deposit the coal beneath, directly opposite the furnaces where required. Nothing can surpass this arrangement for economy and convenience. The most eligible situation for erecting gas-works close to a railway station is where the railway is on an embankment 12 or 14 feet high. A siding should here be constructed, on which the coal-waggons turn out of the main line and discharge their contents through shoots or other well-known contrivances. The retort-house should be erected as close to the siding as convenient, so that the coal as delivered from the waggons will be quite ready for charging the retorts, and all expense both of carting and wheeling the coal will be avoided. In the north of England this juxtaposition of gas-works and railways is by no means uncommon, and many small towns are reaping the advantage of lighting by gas which might otherwise have long been without so great an acquisition.

In some establishments which adjoin a canal or river, the coal is delivered from the barge into iron waggons containing about a ton each; these are raised by hoists, and deposited on a line of rail, by which they are conveyed, either into the retort-house for immediate use, or to be stored.

There are few things connected with gas-lighting which demand greater care than the choice of site for the intended works. In making the selection due consideration must be given to the probable objections that might be raised on sanitary grounds, and if there is an improving or superior part of the town, this should be avoided. Two London companies, whose works are situated in improving and superior neighbourhoods, were for some years put to great expense, in consequence of the complaints of evils that were said to occur to the neighbourhood from the proximity of their works.

For convenience of communication, and economy in the cost of mains, it is essential that the works should not be too distant from the locality to be supplied. There are other circumstances depending on the relative value of property, the means of acquiring it, the nature of the ground, whether suitable for the economical construction of the edifices, or if liable to be submerged by heavy floods. These are points which demand serious attention.

It has frequently been laid down as an imperative law, that gas-works should always be established at the very lowest level of the district to be supplied, and often in following this impression, an unsuitable site has been chosen, the land has been procured at a fabulous price, and perhaps afterwards the works, from their position, have been the source of continued complaints; whereas by the exercise of proper judgment a more advantageous and suitable site might have been procured at considerably less cost.

The motive assigned for the necessity of so placing gas-works, is that the lower districts are by these means better supplied; and there might be some reason in this, if gas derived its force or pressure from its own ascensive power, but this is not the case, as the pressure is dependent on the holder which expels the gas. Too much importance has generally been attached to this law, and I will give a case in order to prove how one might err in following it.

Gas by its lightness has an ascensive power; and when enclosed in the mains, at the period that there is no draught or supply therefrom, the ascensive power is equal to about 1 inch pressure for every 100 feet rise of elevation. So in a town where the difference between the highest and lowest level is 200 feet, the pressure in the lowest level being $\frac{5}{10}$ths of an inch, that in the highest parts would be $\frac{25}{10}$ths. The loss of gas by leakage from the mains is always in direct proportion to the square root of the pressure of the gas, so if from a certain main the loss be 500 feet per hour, the gas being at $\frac{25}{10}$ths pressure, it would be 400 feet at $\frac{16}{10}$ths, and only 300 feet per hour with a pressure of $\frac{9}{10}$ths. Therefore, in choosing a site, it becomes a serious consideration to avoid as much as possible the high pressure, which existing during the whole of the day, when there is no lighting, would entail a great loss.

Now if in the town already referred to, the works were to be constructed midway between the two levels, with two distinct mains to supply the upper and lower districts, then a maximum pressure of $\frac{15}{10}$ths would be sufficient; and if the general lighting were in the upper part of the town, all other circumstances being equally favourable, great advantage would be gained by placing the works midway. As a rule, it is generally better to place the works in the lower part of the district, but the difference of a few feet in the level will never be of material consequence.

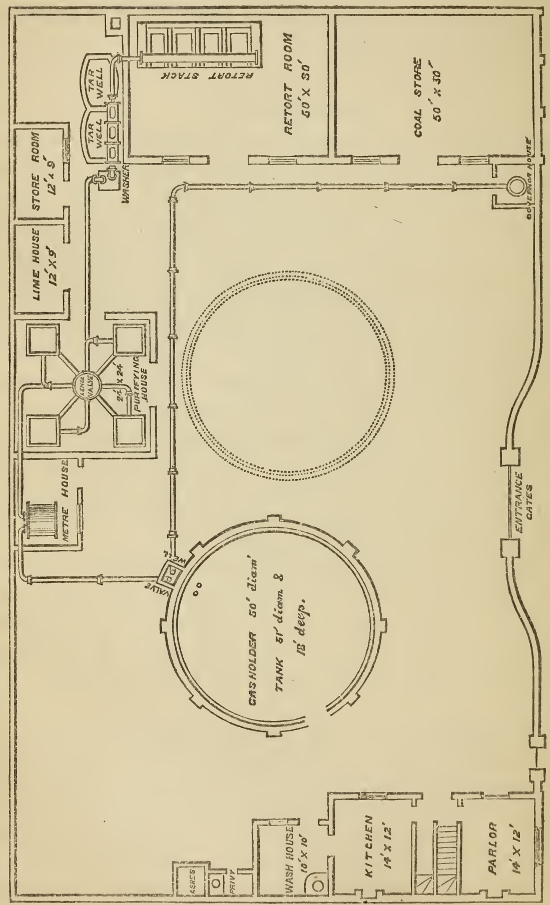
When there is the full supply from the mains, the pressure is not always in relation to the level; but being according to the size of the mains, the highest part of a town, that might have extraordinary pressure when there is little draught, as during the day, might through the insufficiency of the mains, or through an obstruction of naphthaline or water, be almost in darkness at night.

PLAN OF WORKS.

Previously to the arrangement of the plan of works, the nature of the ground chosen for the site should be ascertained. This is readily done by sinking a well to the desired depth of the foundations of intended gas-holders. A guide is then obtained as to the mode of constructing and the cost. Should water be abundant within a short distance of the surface, then cast-iron tanks for the gas-holders must be decided on. Should the substratum be of clay, ordinary earth, or gravel; a brick or stone tank for the gas-holder can be constructed with facility and economy. Should it be "made ground," that is ground which had formerly been transported from elsewhere, then extraordinary precautions in the foundations are necessary; and should rock be encountered the question then arises whether it would be more advantageous to excavate and construct the tank in masonry, or avoid the excavation by erecting an iron tank.

The price of building materials and their nature must also influence the arrangement of a plan of works. In some parts bricks and puddle are abundant and cheap; in other places neither are to be had, unless at an enormous cost for transport, which renders their employment entirely out of the question.

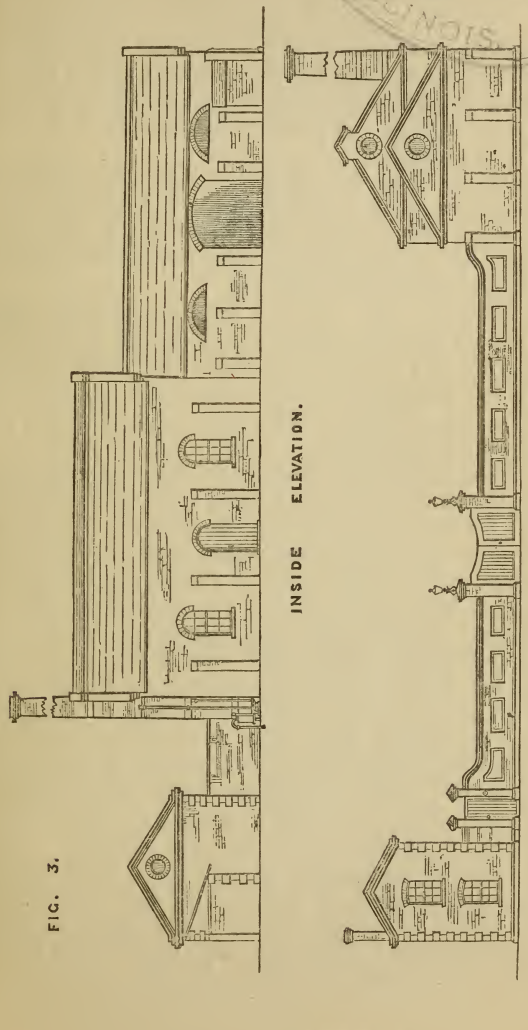
In designing a new works there are a few rules to follow. To construct in such a manner, that at a future period, when required, the works may be increased without much demolition. The retort-house may be so arranged as to be doubled hereafter; the ground so disposed as to admit of extra gas-holders, and sufficient space left for increase of purifiers. The entrance of the works ought to be placed, when practicable, at that part of the site nearest the locality to be supplied.


RETORT STACK
RETORT ROOM 50' X 30'
COAL STORE 50' X 30'
TAR WELL
TAR WELL
WASHER
STORE ROOM 12' x 9'
LIME HOUSE 12' X 9'
PURIFYING HOUSE 24' X 24'
METRE HOUSE
GOVERNOR HOUSE
WELL
VALVE
GASHOLDER 50' diam'
TANK 51' diam &
18' deep.
ENTRANCE GATES
ASHES
PRIVY
WASH HOUSE 10' X 10'
KITCHEN 14' X 12'
PARLOR 14' X 12'

PLAN.

FIG. 2.

FIG. 3.



GAS-WORKS AT St MARY CRAY.— DESIGNED BY ALFRED PENNY. C.E. LONDON.

In the disposition of the various buildings, the manager's or foreman's dwelling should be at the entrance, so that all may be under the immediate notice of the residing responsible person. The offices, store-rooms, and weighbridge—for the purpose of weighing the coal as it enters, and the coke, when sold by weight, as it leaves—should immediately adjoin the dwelling. A plurality of entrances to a works ought to be avoided.

In order to avoid the expense of unnecessary transport the coal-stores, coke spreading floor, and shed for coke, should adjoin the retort-house. Sometimes a part of the coal-store is paved with bricks on edge serving for spreading-floor, and for extinguishing the coke.

The purifying house, tar tank, lime, and purifying material store, are generally separated from the rest of the works, and placed where they may be considered the least offensive. When there is plenty of room the gas-holders are separated from the other buildings; but provision should always be made for future extensions.

Old works, which have been altered frequently from time to time, to suit the demands on them, do not afford the same facilities for excellence of design as those of more modern construction. One of the most perfect plans of gas-works of magnitude, is that of the Liverpool United Gas Company at Wavertree; it is a combination of every advantage, alike for the company and their men, and reflects the highest credit on the engineer, Mr. King. The plan of the new works of the London Gas Company, as also that of the Great Central Company, are both very excellent and worthy of imitation.

The accompanying figure (Fig. 2) represents the ground plan of a small works designed and erected by Mr. Penny, of London, for St. Mary Cray, Kent. Fig. 3 is an elevation of the same. It is a favourable specimen of modern works, and appears to be laid out with care and judgment. These works, in their present form, are capable of manufacturing and supplying about 60,000 cubic feet per diem; with another gas-holder, and an increase in some of the apparatus, double that quantity could be produced. The cost of these, but not including the main pipes, was about £3,200.

The magnitude of gas-works and plant is generally estimated by their annual production; thus a works is described as "ten million," signifying that number of feet per annum, the maximum production in the depth of winter being about 44,000 feet, the minimum, at midsummer, being about 18,000 feet per day. In a works of 50 million per annum, the maximum production is about 220,000 feet per day, and the minimum 90,000, and so on in proportion for the larger establishments.

But there are works of such extraordinary magnitude that the production is estimated by the maximum per diem. The maximum produce of each of the Imperial Company's works is about 5,000,000 feet, making with their three stations a daily production, in the depth of winter, of about 15,000,000 cubic feet of gas.

The capital required for gas-works is variable: for modern works from £600 to £800 per million feet per annum is about sufficient; or if the capital be estimated according to the population, from 15*s.* to 25*s.* per head may be calculated. The capital of old-established works usually surpasses these estimates, and in some instances the excess is very material, arising from the high price formerly paid for the mains, apparatus, and the necessary contingencies attending the first establishment of gas-works. The general improvement in the modern construction of the various apparatus, contributes also to the diminished price.

When gas-lighting is properly developed, which mainly depends on the company supplying according to the quality and price of the gas, and the facilities afforded for its adoption, the average consumption per head is from 2,000 to 2,500 feet per annum. Whenever the consumption of a town is proportionably small, as a rule, it arises from mismanagement on the part of the company.

CHAPTER VI.

ON THE RETORT-HOUSE AND BUILDINGS.

The Retort-house, as its name implies, contains the ovens, or, as more generally termed, "settings" or "benches" of retorts, in which the operation of distillation or carbonisation of coal is conducted. With very few exceptions this is a rectangular building, covered usually with iron principals, and slates or tiles. When economy is a consideration, the roof is of sheet iron, the durability of which is, however, very limited. The width of this edifice in large establishments is from 52 to 70 feet, and from 30 to 32 feet high; the length, of course, depending on the size of works.

A few of the largest establishments have the retort-house very differently arranged to those of the great majority. In the centre, and extending from end to end, are a series of arches built on suitable piers. On these are constructed the ovens or benches, the piers of which correspond with those below. On a level with the furnaces of the retorts there is a stage or firing floor, where the stokers work when charging or drawing the retorts. This is about 8 feet from the ground, and is commonly formed by cast-iron columns and plates, and extends on each side throughout the length of the retort-house, leaving a space of about 2 feet wide immediately in front of the furnaces, through which the coke drops when drawn from the retort, into the space below, which is called the coke-hole, or coke-vault.

The coke-vault possesses some advantages, for where it exists the stokers are not exposed to the continuous heat of the coke when drawn; since it falls immediately below, where it is extinguished by other men. The furnaces are also clinkered from below, which saves the trouble of raking out the fire, thus avoiding the cooling effect of a current of air passing through the oven, an evil which always happens where the furnaces are clinkered from the door; and the convenience of loading the coke direct into the carts from the coke-vault is also a recommendation. The objections to the coke-vault are the expense in construction; the coke in falling breaks, and it is further injured on account of the very limited space for spreading, extinguishing, and storage.

There are few works which have coke-vaults attached to the retort-house. Generally the ovens are built on suitable foundations, ensuring solidity to the structure, and preventing as much as possible radiation of heat from beneath. In these the furnaces are nearly on a level with the ground, and the coke when drawn falls into iron barrows, and is wheeled away to a separate place for the purpose of extinguishing.

In retort-houses having no coke-vault, the tops of the ash or evaporating pans are a few inches below the level of the ground, which is usually paved with fire-bricks on edge. Sometimes cast-iron plates have been tried as a substitute for brick paving, but the metal conducts the heat to the feet of the men with such facility as to render it objectionable.

The benches of the retorts were formerly placed back to back, so that a building containing say sixty single benches, each about 8 feet 6 inches long, thirty of these had their open ends or mouthpieces towards one side of the retort-house, the other thirty having their mouthpieces towards the other side, and a 9-inch or 14-inch wall separated the benches. These are called single settings. Of late years this method has been superseded by dispensing with the partition wall, and so the two single beds form one continuous oven, each retort being about 18 or 20 feet long, open throughout, and having a mouthpiece at each end. These are called double beds or double retorts, and the economy derived from this plan is very considerable, but they can only be employed in large establishments, where there are at least six stokers to charge both ends of the retorts simultaneously.

In small works the retort-house is constructed only for a single row of ovens, which are placed side by side, often extending the entire length of the building. In this case the retort-house is from 24 to 28 feet wide, and from 15 to 18 feet high. The beds are placed at one side, leaving a space of from 13 to 16 feet wide for charging and drawing, also as a deposit of coal for immediate use. In works of the smallest descriptions the retort-house and coal-store frequently form one and the same building; this, however, is objectionable.

In deciding on the dimensions of the retort-house, every consideration must be made, not only of the present requirements of the locality to be supplied, but also that of the future; for gas, even at the present day, is very far from attaining its full development, and it is impossible to anticipate the various future uses to which it may be applied; but the experience of the past demonstrates the necessity of making every reasonable provision for extension. It is also important to have a good margin, and not to estimate the power of carbonisation too highly; for by unforeseen circumstances, the supply of the ordinary coal may be temporarily discontinued, when resource must be had to that of inferior quality, which yields less gas and in consequence requires more retorts.

No definite rule can be laid down for the dimensions of the retort-house; this must entirely depend on the mode of setting. With one kind of setting considerably more coal is carbonised than with another; it depends whether they are single or double, whether the retorts are of clay or iron, the kind of coal employed, and other circumstances.

Mr. Clegg gives for the thickness of the walls in retort-houses built by him, 18 inches from the ground-line to the firing-floor, and 14 inches from the firing-floor to the top: he states, however, that where funds are available, he would prefer increasing each of these dimensions by half a brick, at all events to the height of the coal-store, which reaches to within 6 feet of the wall plate or top of the walls of the retort-house.

There is nothing peculiar in the construction of the walls of the retort-house, more than other buildings of the same height; of course precautions should be taken to secure a good foundation, to extend the base by footings, and where necessary to use pileing or concrete according to the nature of the foundation. On these points no general directions can be given, as the treatment must vary with the special circumstances of the case; the general rule, however, applicable to ordinary foundations will apply here.

The cost of erecting retort-houses will of course vary with the price of labour and building materials in the district.

Brickwork varies, in different parts of England, from £9 to £15 per rod, therefore it is useless to give the prices of any particular district as a standard; but the following examples may be taken as an average :—

A retort-house 32 ft. long, 25 ft. wide, and 16 ft. high, with iron roof, the firing-floor paved with bricks on edge, and square chimney 30 ft. high, cost £280.

In Mr. Clegg's "Treatise on Coal Gas," it is stated, a retort-house 50 ft. long, 24 ft. wide, and 18 ft. high, the roof of wrought iron and common tiles, and with a chimney 70 ft. above the ground, is estimated at £550.

The next example given, is a retort-house and a coke-shed built on one side of it, on lower ground, so that the ground-line on one side was the firing-floor for the retorts, and the falling nature of the ground gave facilities for the coke to slide down the inclined plane into the shed.

This building, which was 70 feet long, including a chimney 90 feet high, but exclusive of foundations, cost . .	£1200
Wrought-iron roof, slated	190
Ventilator of wood, slated	43
	£1433

Mr. Clegg's next example is on a much larger scale, namely, a retort-house 200 ft. long and 54 ft. wide, with coke-vaults on the ground floor. His estimate for this building is as follows :—

Brickwork in outside walls, iron girders, flagged firing-floor, and centre portion for supporting retort benches	£3950
Wrought-iron roof, slated	700
Chimney, 120 feet high	180
	£4830

Mr. Barlow gives the size of a retort-house of 640 ft. in length by 52 ft. in breadth and 24 ft. high.

He estimates the building, including an iron roof covered with slates, at	£16,640
Coal-sheds, to contain 10,000 tons of coal	9,000
Chimney, 120 feet high, with flues lined with fire-brick	450
800 retorts, namely, 400 clay and 400 iron, set complete, with hydraulic main, mouth-pieces, ascension-pipes, dip and bridge pipes, complete, at £17 15*s.* each .	14,200
	£40,290

The following is Mr. Croll's estimate for a retort-house capable of containing 504 retorts, including the chimney, the purifying-house, the coal-stores, and a boundary wall to surround the works.

	£	s.	d.
436 rods 33 feet standard brickwork, at £11 per rod	4797	10	0
793½ yards of concrete, at 6*s*.	237	14	0
Roofing, as per tender	6615	0	0
Iron floor for purifying-house, 26 tons, at £10 per ton	260	0	0
12 tons of beams to support flooring, at £10 . .	120	0	0
504 retorts, as per former estimate, less £899 13*s*. 4*d*. for brick-work and concrete included in the above	6576	9	0
	£18,606	13	0

Particular precaution is necessary in the erection of ovens, either in small or large works; so that sufficient space be left for the expansion of the masonry, if not, there is every probability of the walls being forced out by the expansion or elongation of the brickwork. This precaution is particularly requisite for chimney-stacks, which should always be detached, and any flue into them should enter like a tube, with a slight space around it; by this means, when the brickwork expands, the flue will not press against the chimney. Through want of attention on this point, many excellent stacks have been thrown so far off the perpendicular as to require rebuilding.

In modern large retort-houses, they are built in blocks of about 100 ft. long, having free communication with each other; there is often a ventilating shaft, constructed of wrought iron, with a valve or door, so by this the heated atmosphere of the building is considerably moderated, contributing much to the comfort of the men. And to the honour of many engineers, it must be said, that the comforts of the men employed in their respective companies have had their greatest consideration. In some gas-works libraries are established, in others baths and mutual benefit societies; and there are gas-works that can boast of having a musical band, composed of the stokers and men of the establishment—circumstances alike praiseworthy to the employers and employed.

THE COAL-STORE.

This is generally attached to the retort-house, with every facility of communication for the purpose of transporting the coals. The dimensions of this building must be defined by circumstances. If the railway is the means of transport, then small stores may be sufficient, but should the ordinary means of obtaining the supply of coal be by river or canal, in order to provide against the probability of frost—the store should be ample for a supply of at least two months; and whenever there are increased difficulties in obtaining the supply, it should be augmented in proportion. It is always advisable to have the coal-store sufficiently large, so that in summer, when not required for coal (and coke is abundant), it can be converted into a store for that residue. When employed as a spreading-floor, it should by all means be paved with fire-bricks, as stone is liable to crack with the heat. When not used for that object, ordinary common paving will answer the purpose.

PURIFYING-HOUSE.

The purifying house has, where practicable, the sides open, to permit a good current of air to pass through, and carry off any noxious gases. There should also be a ventilator in the roof, so that in the event of the lutes "blowing," the gas may escape readily at the top. The roof of the purifying-house is usually of wooden principals and tiles. Iron would be very speedily destroyed by the action of the sulphur emanating from the waste purifying material. In some works the purifiers are uncovered, this has the inconvenience of unnecessarily exposing the men at times to the inclemency of the weather, and ought to be avoided by a suitable roofing.

ENGINE, BOILER, AND EXHAUSTER HOUSE.

In the most moderate sized gas-works at the present day the steam-engine is an important auxiliary; formerly the only use for an engine in a works was for pumping water, or for keeping in motion the wet lime purifiers, and in many works of considerable capacity, where neither of these were requisite, a steam-engine did not exist.

The use of clay retorts has caused motive power for working the exhauster, to be introduced into gas-works of all denominations.

The engine, boilers, and exhauster being attended by the same man, are usually in the same building, and more care is usually displayed in this than any other part of a gas-works. The edifice is often constructed with taste, and is no doubt an inducement to the men who have charge of the machinery to keep it cleanly, and in order with the building itself.

STATION METER AND GOVERNOR HOUSE.

These, like the engine-house, should only be accessible to the foreman, &c., and the man in charge.

When there are several gas-holders together, it is not uncommon for the station-meter to be placed close to them, and the valves of the various gas-holders placed in the meter-house. Or on other occasions there is a distinct house for the valves; but more commonly valves are attached to their respective holders. The most compact manner is the former, either when collected in the meter-house or a distinct valve-house. It is true there is some expense attached to this system, but it is much more convenient and secure.

The governor is frequently placed in the same building as the station meter, but more generally a detached building is constructed expressly for it; in large works there are several lines of mains issuing from the works, each of which has its corresponding governor, with the various pressure gauges and pressure registers.

CHIMNEY OR STACK.

The chimney of a gas-works, resembling all others, serves to separate the issuing hot air of the fire from the atmosphere around.

Air when heated, becoming considerably lighter, has an ascensive power dependent on the degree of temperature it possesses; and when highly heated—as when passing from the furnaces—is capable of ascending with great force and rapidity. The column of heated air thus ascending exerts itself, and draws through the furnace bars a quantity of cold air, which intermixes with the fuel, and produces combustion. The cold air is heated, and ascends, producing what is generally termed draught or current. The force of this draught or current is equal to the difference between the weight of the column of air in the shaft, and the weight of a like column of air of the atmosphere outside the stack.

High stacks are constructed principally for the purpose of carrying off smoke or offensive products to a great height, where they are diffused over a large space, and a nuisance which otherwise would exist is prevented. In some chemical manufactories, the stacks are made of great dimensions,—one near Glasgow is 400 feet high. By means of this all noxious gases that may be generated are carried to and issue from the top, without the least prejudice to the neighbourhood.

The largest chimney for a gas-works is that of the Edinburgh Company, and is a fine piece of building, being 329 feet above the level of the ground, perfectly plomb, and without the slightest crack or fissure throughout the height. The current therein, when in ordinary working order, is equal to an exhaust of $2\frac{1}{2}$ inches of water—a strong current in an ordinary chimney seldom exceeding half an inch exhaust. The cost of this stack, with the lateral flues, was upwards of £4,000.

Some engineers attach little importance to high shafts; and in neighbourhoods where the issuing smoke is not prejudicial, small chimneys are employed. At the Great Central Company's works, instead of a main stack for the furnaces, there are a series of small chimneys, each of an internal area of about 3 feet, and sufficient for six benches of retorts. They are built on the benches, each being about 20 feet high, and placed at intermediate distances throughout the length of the retort-house, and give every satisfaction. An advantage with them is, that in the event of an insufficiency of draught, a new chimney is erected in a few days, so supplying the deficiency. This plan is also adopted at other large establishments.

Chimney stacks for gas-works are constructed in various manners, the simplest and cheapest being the square form; but these are unsightly, and, offering greater resistance to the wind, require to be built strong accordingly. Some stacks are made circular, and others octagonal; the latter, when surmounted on a square pedestal, with a neat capital on the summit, have a remarkably good appearance, and the cost does not exceed that of the circular form.

The ordinary chimneys of gas-works vary in height from 35 feet to 150 feet above the level of the ground; their cost for a given height depends mainly on their internal area and the nature of the foundation. The ground being favourable, the price of a square chimney, 35 ft. high, with an internal area of 4 ft., will not exceed £30. An octagonal or circular stack of 8 ft. internal area, and 60 ft. high, under the same conditions as the former, will cost about £85. A similar stack of 10 ft. area, and 100 ft. high, would be £180 to £200.

Chimney stacks, unless when placed in the centre of the beds, should never be built in the retort-house, as they occupy the space unnecessarily. Wherever constructed, they should always be detached, and, on account of their great weight and height, extraordinary precautions are necessary in their foundations. The area of these must be determined according to the degree of solidity of the ground where erected; the softer the soil, of course the greater will be the footings required. The pedestal for the base is usually one-tenth of the height square.

Stacks for gas-works are always lined with fire-brick either for a portion or the whole of the height. Sometimes the lining is detached from the chimney, leaving a space for a current of air to pass between the former and the latter, which prevents the stack cracking. Small chimneys are usually constructed entirely of fire-bricks.

A mistaken notion often prevails, that by materially contracting the stack at the top, the draught is increased; this, however, can only occur when of too great capacity. The stack, although tapering on the exterior, is internally nearly of one uniform area throughout, there being offsets at certain distances, according to the height and form. In erecting, every eight or ten courses should be built with hoop iron; when this is not done, the stack frequently cracks, afterwards demanding the use of hooping on the exterior, which is unsightly.

CHAPTER VII.

ON THE RETORTS USED IN GAS MAKING.

The earthenware or iron vessels in which coal is distilled for the purpose of separating the gas from the solid carbon are called retorts—a name borrowed from the language of chemistry, in which a retort signifies a vessel either of glass, earthenware, or metal, in which distillation or decomposition is effected by the application of heat. The French, in their word *cornue*, have obviously adopted the name of a chemical vessel in the same manner to designate the retorts used in the distillation of coal gas.

The earliest experiments on the form of retorts appear to have been made by Mr. Murdoch, when he erected the gas apparatus at the works of Messrs. Boulton and Watt, at Soho. The retort used there was a circular tube, the diameter of which was equal to a third of its length. This was placed vertically over the fire-grate, and a horizontal pipe from the upper end conveyed away the gas, the open end of the vessel being of course uppermost. The form of these vertical retorts was afterwards varied, as it was found very inconvenient to extract the coke from them, when opened only at the top. The next form of retort was somewhat in the shape of a wine decanter; that is, of larger diameter at the base than at the top. The fire acted on the bottom and sides of this. In the side, close to the bottom, was an opening for extracting the coke, and a vertical pipe went off near the top for carrying away the gas. This form did not answer, owing to the mass of coal lying too much in a heap, and not presenting sufficient surface, so that an outer coat of coke was formed, which prevented the heat from penetrating quickly to the interior.

The next contrivance was that of a cylindrical retort placed diagonally in the furnace. From this the coke could be readily extracted at the lower end, but the heat did not act so effectually as in the next form, which was that of a cylindrical retort placed horizontally. The shape of this last was varied, being sometimes cylindrical in section, sometimes oval or ear-shaped, but the horizontal position and mode of setting were retained.

During a series of years various systems were adopted before an economical mode of retort-oven or setting could be obtained. At first, retorts were set in single ovens, each being heated by a distinct furnace; afterwards, five were heated by three furnaces; subsequently, one fire was sufficient for five retorts; and such is the progress made in this, that at the present day very commonly a setting of nine or ten large clay retorts is heated by a single furnace.

Amongst the various attempts to improve the settings of retorts may be mentioned that of Mr. Brunton, the web retort of Mr. Clegg, and the reciprocating retort of Mr. Lowe.

The novelty in Mr. Brunton's plan was the employment of a short retort, diminishing in size, so as to be considerably narrower at one end than the other. At the narrow end was a lid with a stuffing-box, through which passed a rod attached to a kind of piston inside the retort. Over this was a hopper, capable of containing about 28 lbs. of coal, which was admitted into the retort by drawing a slide or valve placed immediately under the hopper. The retort being charged with coal, the slide was shut, to prevent the escape of gas.

At the wide end of the retort was a shoot dipping into a cistern of water, to prevent the gas escaping at that point. The coal being carbonised, the coke was forced forward by means of the piston, and dropped through the shoot into the cistern of water, from whence it was removed either by rake, shovel, or endless chain of buckets. The piston was again withdrawn to the narrow end of the retort, ready for another charge.

Mr. Brunton claimed great superiority for this description of retort, and about 1840 it excited considerable attention, was tried in several places, but was not a success.

Mr. George Lowe about the same period introduced his reciprocating retorts. In this system the retorts were connected together in pairs, with suitable valves. The object of this was, that "the products alternately of one of two retorts should be caused to pass into and mix with the products of the other retort; by which means, whichever of the two retorts was last charged, the products thereof, during the early part of the working, should pass into the other retort," which, being in a highly heated state, would decompose any tar that might pass, and convert it into gas. This system, after being tried for some time at the Pancras station of the Imperial Gas Company, was abandoned.

Mr. Clegg introduced a system of retort which was remarkable for its ingenuity. This consisted of a kind of endless chain of fire-bars, caused to travel by means of two revolving cylinders set in motion by steam power, in principle very similar to Jukes's self-consuming smoke apparatus or furnace; the whole of this was enclosed, and the upper part of the chain exposed to the action of a high heat. The coal entered by a hopper, and fell on the web or chain, and by the motion of this, was carried to the point of distillation; which done, the coke by the same motion was caused to drop into the receptacle destined for it.

Mr. Clegg's statement of the process with reference to the specific gravity and quantity of the gas was rather extraordinary; but his assertion that the plates absorbed carbon, and were so converted into steel, was decidedly erroneous.

There are two kinds of retorts employed in the gas manufactory, viz. those of fire-clay, and those of cast iron, and in rare cases they are constructed of fire-bricks, built in the manner of an oven. Retorts are single or double: the single retort is closed at one end, and generally from 7 ft. to 9 ft. long; the double retort is open throughout, and is charged simultaneously at both ends.

They are very variable in their shape, being cylindrical, elliptical, in the form of the letter D, &c., depending on the judgment of the engineer.

Formerly cast-iron retorts were universally employed in gas-works; at present they are almost entirely superseded by those of fire-clay. Iron retorts exist now only in very small works, or when combined with settings of clay, hereafter mentioned.

The iron retort, when now used, is the D shape, and single, being about 7 feet 6 inches long, 15 inches wide, and 13 inches high, interior measure, of the uniform thickness of $1\frac{3}{8}$ inch throughout, and weighing about 16 cwt. There is a flange on its end, corresponding to the flange of the mouth-piece, to which it is attached by bolts and nuts, and the joint made perfectly secure with cement.

THE MOUTH-PIECE.

The mouth-piece may be considered a continuation of the retort; but not being embedded in the brickwork, is not exposed to the same degree of heat as that, nor is it instrumental in the distillation of the coal.

The mouth-piece is usually about 10 or 12 inches long, having the same form as, but being considerably thinner

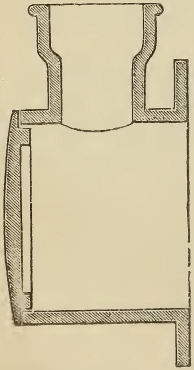


Fig. 4.

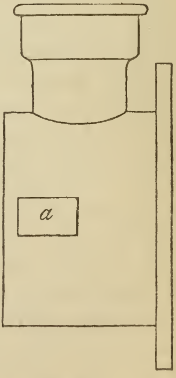


Fig. 5.

than, the retort to which it is attached. There is a socket or flange cast thereon, to receive the end of the ascension pipe, which conveys the gas to the hydraulic main. There are also two pieces called ear-boxes, to which are fixed the ears for supporting the door, or as sometimes called, the lid of the mouth-piece. The cross-piece or screw-key is supported by the ears, and when the retort is charged the lid has a layer of luting around it, and by means of the screw the joint is made hermetically tight.

Figs. 4 to 8, drawn to a scale of $\frac{1}{12}$th, or one inch to a foot, show details of a flanged mouth-piece for a D retort. Fig. 4 is a longitudinal section of mouth-piece, showing the socket cast on it to receive the ascension-pipe, and the lid affixed to

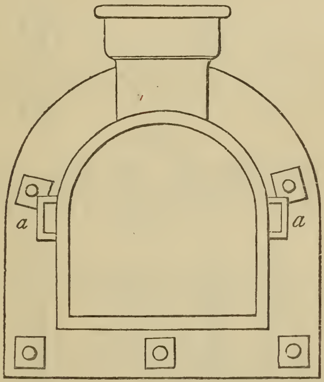


Fig. 6.

the mouth. Fig. 5 is a corresponding elevation, showing the ear-box *a*, cast on each side of the retort to receive the ears, which are usually 14 inches long. Fig. 6 is a front elevation, showing the mouth-piece attached to the retort, but without the lid of the mouth-piece. Fig. 7 is a side elevation, and Fig. 8 is a plan of the mouth-piece attached to the retort, showing also the lid and the mode of securing it to the mouth-piece. *b b* are the ears passing through the ear-boxes *a a*, and secured by cotters, *c c*. *d* is the cross-bar through which passes the screw *e*, which presses on the lid and firmly secures it to the mouth-piece. The ears *b b* are fixed, and the mode of removing the door of the retort is by unscrewing the key, when the cross-bar *d* can be taken

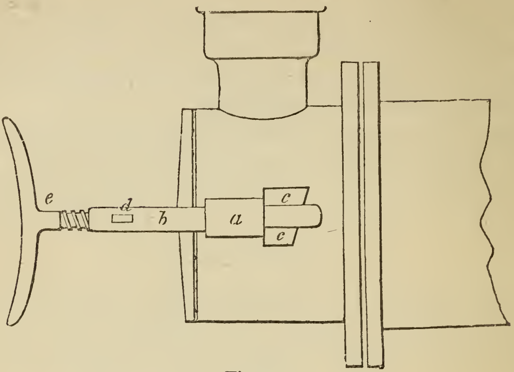


Fig. 7.

away and the door lifted off. The luting usually employed for the edges of the mouth-pieces is a composition of lime-

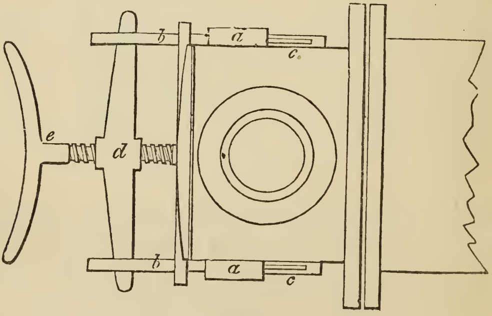


Fig. 8.

mortar and fire-clay or loam, which, on being compressed by the screw, makes a perfectly gas-tight joint.

There are various modifications of the parts connected with the lid, which may be briefly noticed. Sometimes the ear-boxes are so cast as to have no top, in which case they form a simple rectangular notch cast on each side of the mouth-piece. The ears, again, are not always perforated with the holes to receive the ends of the cross-bar, but have sometimes a simple notch in which the ear-bar rests.

There is another method of fastening the lid, in which

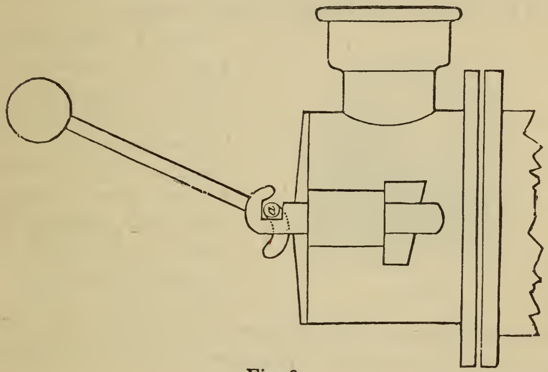


Fig. 9.

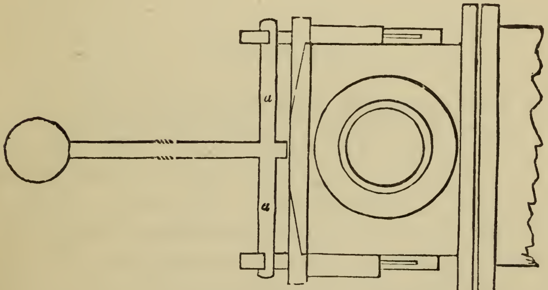


Fig. 10.

the screw is altogether dispensed with, as shown in Figs 9 and 10.

Here the ears form supports for an axis, *a*, which carries a lever formed at one extremity into a sort of eccentric or cam, and carrying at the other end a globe of solid cast iron about 4 inches in diameter. When the globular end of this lever is depressed, the cam presses with considerable force upon the back of the lid, and holds it as effectually in its place as the screw: in addition to which, if required, it is easy to increase the pressure by hanging on to the globular end of the lever an iron ring or other weight.

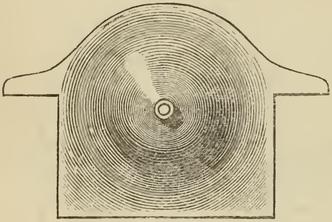


Fig. 11.

Fig. 11 represents a door of a mouth-piece, which is supported in its position, and lifted, by the lugs at the sides. These were formerly of cast iron, but are now of wrought iron plate, about $\frac{1}{4}$ inch thick, and slightly hollowed, to strengthen them. This simple alteration is of great importance, as it relieves the workman from lifting a cumbrous weighty mass, which was one of the most difficult parts of his duty.

IRON RETORTS.

For many years iron retorts were exclusively used, and their general abandonment by gas-works has only occurred within the last twelve or thirteen years. The evils arising from iron retorts are numerous: they are costly in themselves, which is increased by the expense in setting; the price of fire-clay materials, as tiles, shields, bricks for arches, and labour, renders a bench of them expensive. Their durability is also very limited, averaging about seven or eight months, and producing each about 600,000 or 700,000 cubic feet of gas. The average production from clay retorts being nearly four times that quantity.

After having been in operation some time, iron retorts become bad conductors of heat, in consequence of the formation of a coat of peroxide of iron on their exterior necessitating continued cleansing, which, however, can only be effected in some parts of the retort, leaving the other parts covered; and it sometimes happens that the retort is embedded in this non-conducting material, so that the heat cannot penetrate to it.

Another evil is, that the iron becomes changed in its molecular nature, losing considerably its powers of conducting heat, and great care is requisite to protect them with fire-tiles; stout arches are built to prevent the direct action of the heat on them. All this is a cause of a loss of fuel; and with these precautions, care must be employed to prevent them attaining that degree of temperature which would be destructive to them: and this sometimes produces a contrary effect, so that the temperature becomes too low, and a small yield of gas, with excess of tar, is the consequence.

Iron retorts are only useful in small works, where the holders are heavy, or where wet lime purifiers, plunge-washers, and other circumstances exist which produce great pressure, and where an exhauster is not used; or when the retort is continuously heated and cooled, as in experimental apparatus, and auxiliary settings.

Iron retorts expand considerably, and after being worked some time and cooled down, a 7 ft. 6 in. retort will be found to have elongated about 3 inches. If this be put into operation it will again expand, but not in so great a proportion; however, it is not uncommon for a retort, as mentioned, which has been repeatedly heated and cooled, to expand 5 inches in length. Therefore, when used, the ovens of these should be considerably longer than the retort, otherwise the probability is that the front wall of the oven will be bulged out.

When iron retorts are required for future use, previously to being allowed to cool down the carbonaceous incrustation in the interior should be removed; should this be allowed to remain, the retort sometimes breaks in two halves, caused by the iron contracting in a much greater degree than the carbon.

When in separate beds from the furnace, as in the compound settings of iron or clay, their durability is greatly increased, being on the average from eighteen to twenty months; nor do they form the peroxide of iron with the same facility, and this can be diminished to a minimum by a very thin coating of fire-clay on the exterior of the retort.

CLAY RETORTS.

The adoption of clay retorts has undoubtedly been one of the greatest improvements introduced into the manufacture of gas.

As already stated, Mr. Winsor, in 1804, patented a "brick, or earthenware retort or oven," but it does not appear that any application of this was made until 1818, when Mr. John Grafton patented improvements "in employing retorts lined or cased with fire-clay." In 1820 the same gentleman obtained a patent for improvements in clay retorts; in this specification he says, "the Stourbridge clay heretofore used for clay retorts had generally failed in consequence of these retorts being made in one entire piece, which caused them to break in pieces very shortly after the fire was applied;" it continues, "I caused the retort to be made in several pieces," which, indeed, seems to have been the object of Mr. Grafton's invention, and the substance of the specification leads us to believe that clay retorts were being tried previously to this; but if it were so, it must have been on a very limited scale, for neither the works of Accum nor Peckstone, published in 1819, mention anything about them.

It is not very material whether Mr. Grafton was the first or not to introduce clay retorts; it is, however, certain that he has been the direct means of bringing them into general use, for during several years, at great risk and loss, he tried various systems in order to ensure success. Amongst these was the mode of constructing the retort entirely of fire-bricks, built together with fire-clay; these were in the shape of Fig. 12, about 5 feet 6 inches wide and 7 feet long, and capable of distilling from 7 to 9 cwt. of coal at each charge. This description of retort was in operation for many years in several parts of the Continent, where they had been erected by Mr. Grafton. The advantages they possessed were a diminution of labour in charging and discharging,

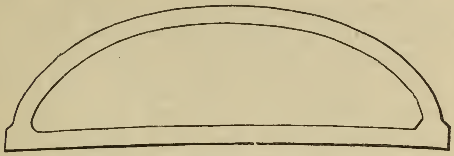


Fig. 12.

and the coke from them was of a good heavy quality, suitable for foundries, &c.; but on the other hand they were very costly in their construction, and required a large quantity of fuel for carbonisation.

The fire-brick retorts of Messrs. Spinney and Clift, described in the former edition of this treatise, were very similar to those just mentioned.

Mr. Grafton afterwards had these retorts made in four or five pieces, similar to the plan now very generally adopted, going back to his original idea according to the specification quoted.

Clay retorts were worked in Scotland for some years previously to their employment in England; they were first applied in consequence of the high heats and short charges necessary in the distillation of cannel coal, which destroyed the iron retorts very rapidly, unless they were well protected with fire-clay materials, so making the settings very costly. The first great trial of clay retorts in London was made by Mr. Croll, at the Brick-Lane Station of the Chartered Company, in 1843. The retorts did not, however, answer the expectations; they cracked, allowing the gas to escape, and this was considered by many at the period as being a fatal objection to their use.

In 1844 Mr. Joseph Cowen, of Newcastle-on-Tyne, obtained a patent for making clay retorts by a new and novel method, and for combining with the clay destined for the retort various substances, such as pounded coke, charcoal, sawdust, &c., which project, beyond doubt, led the way to the present perfection in this branch of manufacture. Probably the idea of Mr. Cowen was that the substances above-named would continue in combination with the retort, when in operation; but the reverse of this took place, for in the course of time the carbonaceous matter so incorporated burned away, leaving the vessel porous; but retorts made in this manner did not crack or break by the heat.

The knowledge of this fact led to trials with other substances intermixed with the clay, and finally to the present system, which is as follows:—In manufacturing clay retorts a portion of fire-clay is burned and reduced to a granulated state; this is then intermixed with just sufficient clay to hold the mass together; the retort is then made by hand—allowed to dry very gradually—and then burned. The retorts so made, although much inferior in appearance to those of clay alone, are all that can be desired. From some peculiarity in the Scotch fire-clay this manipulation was not at first followed; the retorts made therefrom answered the object tolerably well; but those from Newcastle clay, without the granulated burnt clay, will not withstand the heat, for with all the care imaginable in firing they crack and break into numerous pieces.

The advantages of clay retorts are—firstly, their great durability; secondly, the degree of heat to which they may be submitted, which would be destructive to iron, is more suitable for carbonising the coal, producing the greatest quantity of gas, with little tar, and coke of good quality; lastly, they require less labour. These important points have contributed much to the present economy in the production of gas, and the success of gas enterprises.

For some years, however, great prejudice existed against the use of clay retorts; an animated correspondence took place in the columns of the *Journal of Gas-Lighting* between two gentlemen of eminence, the one in favour, the other against them. The arguments unfavourable were, that clay being a bad conductor of heat, would require more fuel for the carbonisation of a given quantity of coal; that the material being porous, the gas would escape to the atmosphere instead of going to the holder; and that by the high heat of clay retorts, the rich hydrocarbons would be deposited therein as incrustation. However, in working, experience has refuted all these objections, and the vast superiority of clay retorts is now universally demonstrated and admitted, not only in this country, but on the Continent and in America.

But clay retorts cannot in most cases be worked advantageously without an exhauster to withdraw the gas the instant it is produced, to prevent it remaining under pressure, exposed to the red-hot surface. Should the exhauster not be employed, and the pressure in the retort be considerable, the heavy hydrocarbons are deposited in great abundance, deteriorating the value of the gas, generating a non-conducting material, which obstructs the interior of the retort, and demanding more fuel for carbonising.

The objection that the clay of retorts is so porous as to permit the gas to pass through, is erroneous, which any one may be convinced of by breaking one of them which has been in use for any length of time, when it will be found that the carbon has perhaps penetrated to the depth of one half or three-quarters of an inch, but shows no signs of having traversed the material. There are, however, some slight fissures or fire cracks which exist in the manufacture, which are speedily stopped after the first two or three charges; but generally clay retorts of good construction, when the exhauster is applied, are not more porous than the best of iron.

As regards the objection that clay is a worse conductor of heat than iron, no one will dispute this; but the opponents of clay retorts did not take into account the vast quantity of this non-conducting material which was employed for the purpose of protecting the iron retorts, nor did they consider the quantity of non-conducting material continually being formed on their exterior. If this had been duly weighed, clay retorts would have had considerably less opposition.

Although the manufacture of clay retorts would appear a very simple process, there is a peculiarity of manipulation in preparing and tempering the clay, and in constructing the retort, which, if not strictly adhered to, results in failure. In first-class fire-brick works a surprising amount of care is taken with the clay, which when extracted from the mine is not considered suitable for the purpose until it has been exposed for many months, and sometimes years, to the action of the atmosphere, which acts chemically on it, and renders it suitable for the object intended. Thus, at the extensive works of Messrs. J. Cowen & Co. of Newcastle-on-Tyne, and probably at many others, there are mounds of some thousands of tons of clay undergoing this process, and to this circumstance may very likely be due the excellence of the goods for which that house is celebrated.

Clay retorts are as variable in their form as the iron ones were. Scotch engineers generally prefer them circular; on the Continent the elliptical are almost universal; whilst in England no definite conclusion on this point has been formed, their size and shape depending on the views of the respective engineers, and not on any positive grounds.

In London the retorts usually employed are the D-shaped, with the corners rounded, otherwise, if square, the increased and uneven thickness would cause them to crack at that part. The form and size universally employed on the Continent is the oval, about 1 foot 8 inches wide, 1 foot 1 inch high, from 7 to 9 feet long, and invariably made in one piece.

The D shape may be slightly preferable on account of the layer of coal when placed therein being of one uniform thickness; against this, probably the circular and oval, being of greater regularity in their thickness, are not so liable to break.

At most large gas-works double clay retorts are used. These are from 18 to 20 feet long, composed usually of four or six distinct pieces, jointed together with fire-clay, having a mouth-piece at each end, and are combined in sets of six, seven, eight, or ten.

At the Imperial Company's works there is considerable economy of space in the retort-house, by placing ten retorts in an oven, in two vertical rows. The upper retorts are charged and discharged by means of a travelling stage. Each of these double beds is capable of carbonising from 7½ to 8 tons of coals, producing from 70,000 to 75,000 cubic feet of gas per day. In the same space, with iron retorts and old settings, of five retorts in a bench, little more than one-third of this result would be obtained.

Clay retorts, like those of iron, are of uniform thickness throughout, averaging about $2\frac{1}{4}$ to $2\frac{1}{2}$ inches. Their mode of setting is remarkably simple, requiring no guard or shield tiles, and in some cases have no arches, which formerly were great obstacles to the distribution of the heat. The mouth-pieces of clay retorts are precisely similar to those of iron, but the sockets and the ascension-pipes are required larger; the latter for clay retorts should never be less than 5 inches internal diameter.

Fig. 13 shows the open end of a clay retort, and Fig. 14

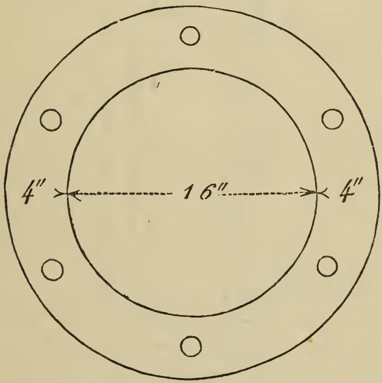


Fig. 13.

shows the mode of attaching the mouth-piece by means of bolts with T-heads let into the body of the retort.

Fig. 13 is a front elevation of the retort, showing the thickness of the part to which the mouth-piece is bolted, also the bolt-holes, $1\frac{1}{8}$ inch in diameter.

Fig. 14 is an elevation showing the mouth-piece attached, with a socket-pipe bolted on, but without the lid, and is similar in its details to that shown for iron retorts.

Fig. 15 is an end elevation of one of the pieces of which the retort is composed, showing the triangular groove of a corresponding ring, for the reception of the fire-clay when making the joint; and

Fig. 16 is a section showing the junction between two pieces of the retort.

In making the joints of clay retorts, or attaching the mouth-pieces to them, the part of the retort should be well

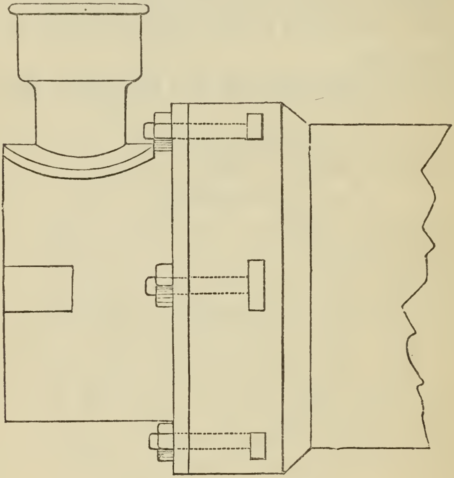


Fig. 14.

wetted, so as to combine with the clay. For connecting together the ends of clay retorts, fire-clay alone is used, formed into the state of mortar. For the joints of mouth-pieces, a small portion of iron cement is often intermixed with the fire-clay. It is essential that these retorts should be allowed to remain a few days after being set, before being fired, to expel any moisture, which would be likely to cause them to crack. The breakage of clay retorts is occasioned sometimes by the stoker failing to apply a light, when in the act of discharging, as soon as the lid is loosened; the consequence is, the gas in the retort becoming combined with air, an explosion is produced, which shatters the retort.

In first-class manufactured clay retorts, when an exhauster is employed, leaving only a pressure of about an inch on them, there is no leakage whatever. In others, of inferior

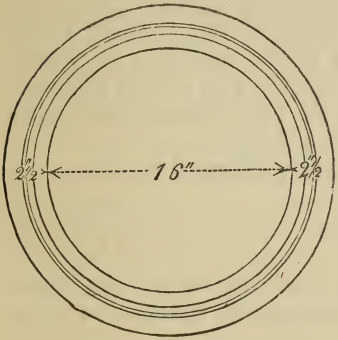


Fig. 15.

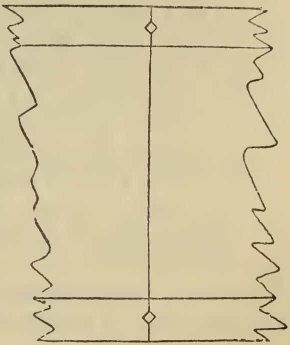


Fig. 16.

make, the leakage will sometimes be considerable; but this, in the course of a short time, is stopped by the carbon of the gas itself, which is deposited in the cracks and fissures; these arising from fire-cracks, and not from the porosity of the material.

In England clay retorts for the sake of strength are generally supported in their ovens at intervals throughout, by walls, as seen in Fig. 19. On the Continent these are always dispensed with—the retorts, usually made in one piece of 8 or 9 feet long, only being supported by the pillars on which they are placed.

In attaching the mouth-pieces to iron retorts, or the ascension pipe to the mouth-pieces, &c., the ordinary iron cement should be employed; this is driven in by means of a caulking iron, and when properly done makes a good sound joint, but is never suitable when exposed to even a very low degree of red heat, for under these circumstances the cement is decomposed, and becomes useless.

The recipes for making iron cement vary considerably Mr. Peckstone says 1 lb. of iron borings or turnings are to b pounded in a mortar into a state of fine dust or powder; these are to be mixed with 2 oz. of sal ammoniac in powder and 1 oz. of flour of sulphur; the whole to be thoroughly incorporated by being pounded in a mortar. When required for use, take one part by measure of the above compound, and mix it with twenty parts of pounded iron borings, adding water to bring the mixture to the consistence of ordinary mortar. This cement may be applied in making all sorts of flange joints, as in securing the mouth-pieces to the retorts, the dip-pipes to the hydraulic main, &c.

Mr. Clegg's recipe is somewhat different: he uses

Iron borings or turnings	32 oz.
Sal ammoniac	1 „
Flour of sulphur	1 „

To be well mixed together, and kept dry for use. When required, water to be added to bring the mixture to a proper consistency.

The French employ for the same purpose a cement called the Mastic d'Aquin, which is thus prepared:—

98 parts of clean iron turnings, pounded and passed through a sieve.
1 part of flour of sulphur.
1 part of sal ammoniac, dissolved in sufficient boiling water to bring the whole mass to the consisteucy of ordinary mortar.

This cement is not prepared till required for use, and should be employed as soon as possible. The iron borings should be sifted, and perfectly free from grease or oil, otherwise if too granulated or greasy a good joint cannot be made.

CHAPTER VIII.

ON RETORT SETTINGS.

The disposition of the retorts in the ovens, or the manner they are placed or set, is called the "setting," and the judicious arrangement of this part of the apparatus in gas manufacture is of the utmost importance; for on this mainly depends alike the economical production of gas, and the use of the minimum quantity of coke as fuel.

Setting retorts comprises the construction of the ovens and furnaces; properly placing, supporting, and protecting the retorts; arranging the passages between them so as to equalise the heat throughout; and making the communication with the main flue. To approach perfection in this, there are several points to be considered.

The foundations of the retort ovens should be solid and sufficiently massive to prevent the loss of heat at that part. Sometimes a series of air-cells or small spaces in the brickwork of the foundations are formed in order to prevent loss of heat by radiation. All superfluous brickwork in the interior of ovens should be avoided, leaving only that necessary for the proper support of the retorts, and, when iron retorts are used, the proper protection to guard them from the injurious action of the heat. Other means to prevent the radiation of heat should, so far as practicable, be adopted; for all heat lost unnecessarily by radiation is so much coke lost without a purpose. The openings or nostrils for distributing the heat from the furnace should always be amply wide. Many instances have occurred where the furnace has been at an intense degree of temperature, yet the retorts above could not attain an ordinary heat on account of the passages or nostrils being contracted. An essential point also is to have complete control over the damper leading to the flue; for if this be too much open, and the draft strong, a great increase of fuel is necessary without any good result. Lastly, whilst due consideration should be had for the comforts of the stokers employed, all useless loss of heat in the retort-house should be prevented, so that the buildings should not have too many openings, as windows, &c.; and when air-shafts or ventilators are constructed, these should be provided with valves, to shut or close according to the weather, or the season of the year.

Formerly in the construction of furnaces for gas-works the steam-boiler furnace was copied, this being of large area, and the fuel placed in a thin layer; but the conditions of the two are widely different. A large area and thin stratum is well adapted for burning coal and generating steam; but the reverse of this is requisite for burning coke and obtaining that high degree of temperature essential for retorts. It is now generally acknowledged that when the furnace is constructed so as to heat comparatively a small quantity of air to great intensity, which afterwards diffuses itself, the best results are obtained.

Fig. 17 shows a section of a furnace of this kind, which was first employed by Mr. Croll twenty years ago, and has since become very general. They are of small area, being

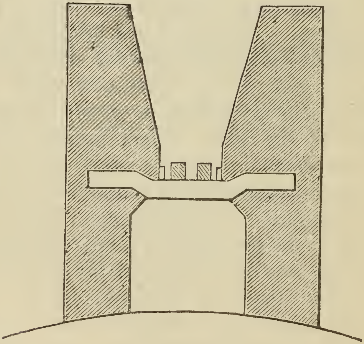


Fig. 17.

at the bottom from 20 to 30 inches long, from 6 to 9 inches wide, and from 10 to 18 inches deep, depending on the size of the ovens to which they are attached, the smallest dimensions stated being sufficient for a bed of five retorts.

There are two bearers of wrought iron built into the brickwork, a short distance from the ends, and on these repose the fire bar or bars. In small furnaces one bar only is used, in large furnaces two are generally employed. These are simply bars of wrought iron of $1\frac{3}{4}$ to 2 inches square, placed loosely on the bearers. By this system the air passes through a thick stratum of fuel, and attains an intense heat; whereas by the old furnace often a large portion of air passed through the uncovered bars without contributing to the heat, but, on the contrary, carrying with it a portion of that from the retorts. Great facilities for "clinkering" are offered by this manner of placing the bars, so that they can easily be shifted, the clinker removed, and afterwards, when replaced, a few lumps of coke are thrown in to prevent the smaller pieces of coke from falling through the openings between the bars, which done, no more breeze passes through than with the old-fashioned method. These furnaces are now very generally employed, and are undoubtedly superior to others.

ON SETTING CLAY RETORTS.

In setting clay retorts there is not that degree of difficulty which exists with those of iron; the complication of fire-tiles, shields, and protecting arch, are avoided. The retorts being placed on proper pillars or supports, the fire from the furnaces acts directly upon them.

There is great diversity of opinion as to the best mode of setting, some engineers preferring six, others seven, eight, nine, and even ten retorts in a bed. Nor does this diversity of opinion confine itself to the number, but applies also to the mode of conducting the heated air. In some cases this passes direct into the main flue above, in other instances the heated air passes over the retorts above, and then descends into the main flue below; but as the two methods are practised in our metropolitan works, it may be inferred that there cannot be much difference in their results.

Fig. 18 represents a section of a bed of ten clay retorts, as used at the Imperial Company's works. In this setting there are ten double retorts, each 18 feet long, and charged at both

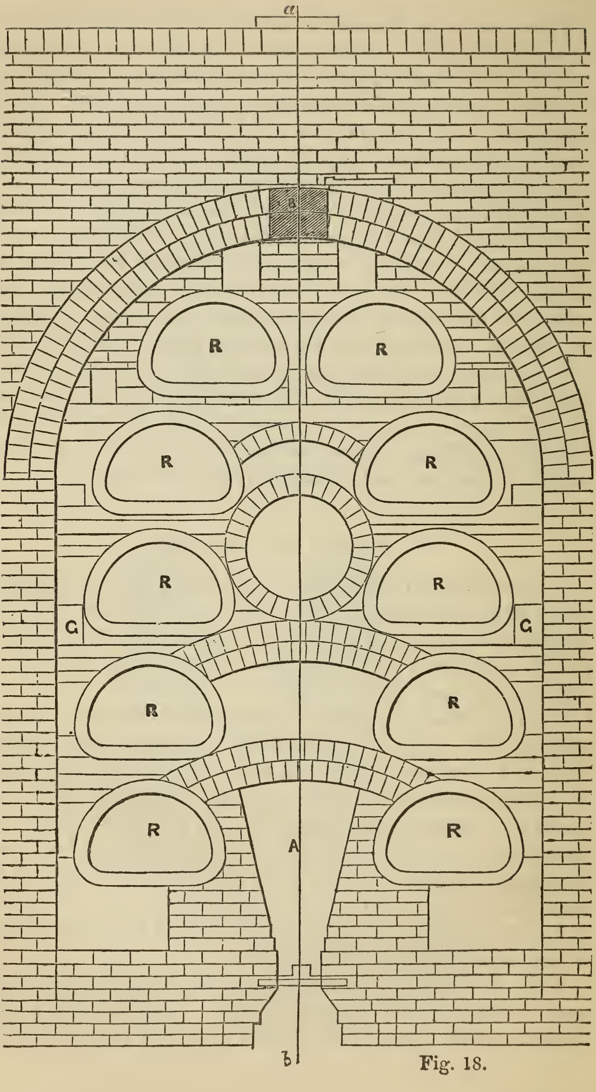


Fig. 18.

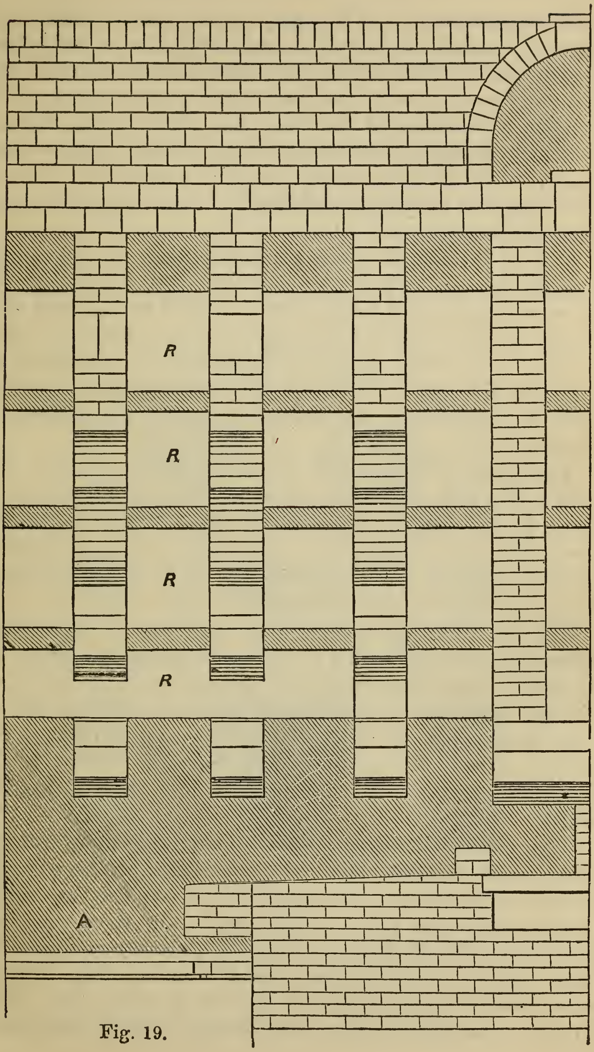


Fig. 19.

ends simultaneously. The upper retorts are charged, and drawn by means of a travelling stage, which is wheeled from one end to the other of the retort-house, wherever required. A is the furnace, having one bar only; R R the retorts; B is the flue conducting to the main flue, there being various openings throughout the whole length for the heat to pass freely. The ordinary charge for this setting is 1 ton 16 cwt., which is sometimes carbonised in five hours, but more generally in six hours.

Fig. 19 is a section of half a double setting of these retorts through the vertical line *a b*, the front wall and mouth-piece, for want of space, not being shown. It will be observed that the brickwork is merely for supporting the retorts, and that the fire acts direct, without any interruption, ascending to the main flue above. These beds are fired with the red-hot coke as drawn from the retorts, producing a considerable economy.

The general opinion is in favour of settings of seven clay retorts in a bed; and where economy of space in the retort-house is not so necessary as at the Imperial Company's works, the settings of seven may be preferable, on account of the whole of the retorts being worked from the ordinary firing floor, and not requiring the travelling stage.

Fig. 20 represents a front section of a set of seven clay retorts as adopted at the Commercial Company's works in London. In this the heated air diffuses amongst the upper retorts, and afterwards descends into the main flue below. The variation in the two systems of upward and downward current cannot be important, otherwise the results would speedily settle the division of opinion as to their respective merits.

The price of a setting of single retorts, including foundations, oven, furnace, door, frame, ash-pan, fire-bars, buckstaves, sight boxes, retort, mouth-piece, two lids, ascension, bridge, dip-pipes, and hydraulic main—in short, the bed complete, with all its accessories—is generally estimated at £17 10s. per retort, so that a bed of seven single retorts, each 8 feet 6 inches long, will cost about £122 10*s*. The average durability of good clay retorts may be considered about two and a half years, during which time the expense for fire-bars, repairs to furnace, &c., will not exceed 20*s.* per retort. The duration of retorts in some of the London works is often four and even five years.

The arch of ovens once properly built will last several years. Taking down retorts, and replacing them with new

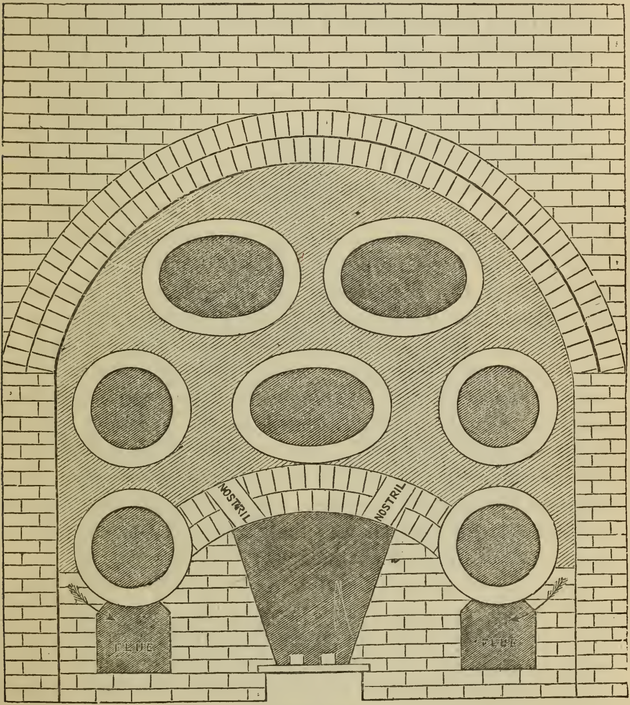


Fig. 20.

ones, including labour, materials, &c., averages £7 10*s.* per retort; so that replacing a setting of seven clay retorts would cost about £52 10*s.* When double retorts are used, the same estimates per mouth-piece are applicable.

The cost of wear and tear of clay retorts in a medium size works may be estimated at 1*d.* per thousand feet of gas produced. In large establishments it will be considerably less than this.

IRON RETORT SETTINGS.

Among the various attempts to improve the working of ordinary iron retorts has been the system of subdividing them into two distinct longitudinal compartments, with the view that any tar that might be formed during carbonisation in the lower part would, in passing through the upper chamber, be converted into gas. This, however, would have the same inconveniences which accompany the production of gas from tar in the ordinary manner, and described elsewhere, with the inconvenience that the hydrocarbons of the gas would be deposited by their prolonged contact with the red-hot retort.

It has also been proposed to construct iron retorts with projecting ribs in the interior, for the purpose of increasing the surface; but this, instead of being beneficial, has tended to encourage the incrustation of carbon. Another method was to glaze iron retorts both internally and externally, which process possessed the advantages that the non-conducting material was not so rapidly formed on the exterior, and the incrustation of carbon was removed with great facility from the interior. These and many other systems have been patented from time to time; but as clay retorts became gradually introduced, so was their great superiority understood, and iron retorts abandoned.

Iron retorts are only useful in very small works, where there is no exhauster, and the pressure is too heavy for clay; or when the settings, as auxiliaries, are subject to being in operation for a short period, and afterwards cooled down, which would cause clay retorts to crack and be useless; or for experimental purposes,—in these cases they may be used with advantage.

When circumstances oblige the use of iron retorts, immediately over the furnace there is an arch or fire slab, forming a kind of table or "bench" to receive the retorts. At each side of this there are openings for the heated air to pass and diffuse itself throughout the bed, also fire-tile shields to protect the retorts from the direct action of the fire.

The accompanying Fig. 21 is a section of a bed of three iron retorts. F is the furnace, C the interior of oven, R R R the retorts, *b b* the fire slabs forming the table or bench, *a a*

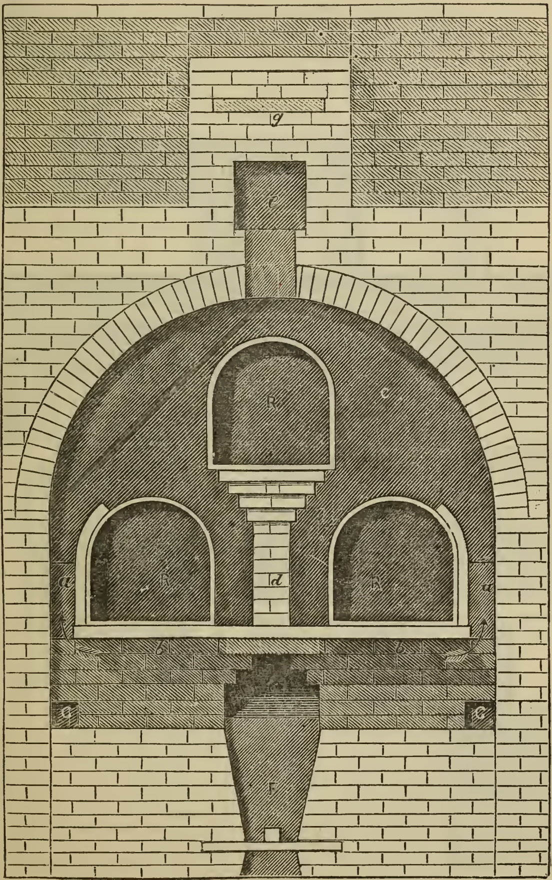


Fig. 21.

the shields for protecting retorts from direct action of fire, *d* the supporting pillars, *e* small flue, *f f f* the nostrils for the passage of the fire, *g* the damper, this being a kind of valve formed of fire-bricks and a fire-slab.

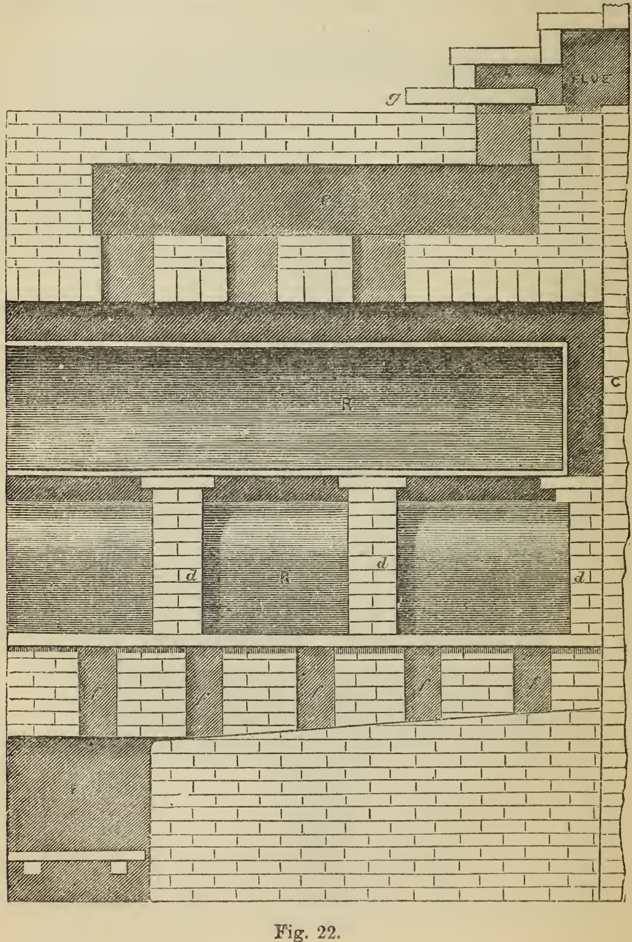


Fig. 22.

Fig. 22 is a longitudinal section of the same, with the corresponding letters of reference ; the front wall for want of space is not shown ; c is the back wall, which divides the two furnaces when they work back to back. When in single beds this wall requires to be of good thickness, to prevent loss of heat.

It is almost unnecessary to say that all parts in immediate contact with the fire should always be of good fire-bricks, for at least a thickness of 9 inches, built with fire-clay, and as thin joints as possible, the bricks being previously moistened. The furnaces should be constructed of the best bricks that can be procured for the purpose. Some descriptions of Stourbridge bricks, others of Wales, called "Dinas" bricks, are reputed to be good for the purpose.

The radiation of heat from the tops of the arches may be greatly prevented by having a good thickness of brickwork, or a layer of sand, ashes, or similar non-conducting material, which is covered by a course of bricks. The front walls of ovens should never be less than 14 inches thick; and when beds in use adjoin those out of action, the latter should be closed in all their parts; the mouths of the retorts, the furnace door, and ash-pit bricked up, and the sight holes and damper securely luted with clay. The end bench of a setting has generally a massive wall as a buttress, which likewise prevents radiation at that point. The beds are also securely tied together by tie-rods and buckstaves.

The following chapter will assist the reader to understand more fully the practice of setting retorts.

CHAPTER IX.

METHOD OF COMBINING CLAY AND IRON RETORTS.

The first conception of combining clay and iron retorts, so that the surplus heat from the former should afterwards be made available for the latter, is due to Messrs. Kirkham and Lowe; but they appear not to have been cognisant of the importance of the system, and it was neglected, if not forgotten.

A short period afterwards Mr. Croll, unacquainted with what had been conceived by these gentlemen, patented a

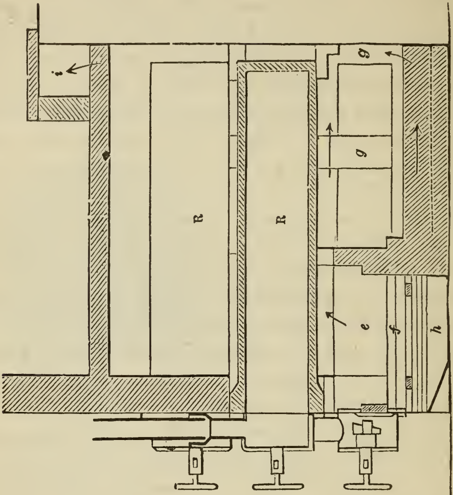


Fig. 24.

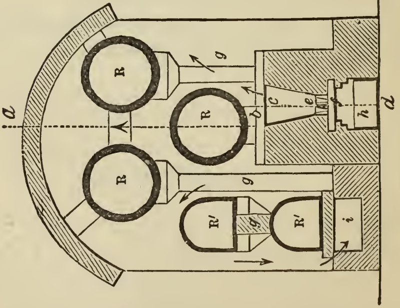


Fig. 23.

similar system, and with the means of properly carrying it to a successful issue.

In applying clay retorts to the carbonisation of coal, they are submitted to a much higher degree of heat than those of iron : the average temperature of the former being about 2100° Fahr., or an orange red; whilst those of iron work most effectively at cherry red, or about 1700° Fahr. Therefore, it is obvious that the waste heat of clay retorts would be available for iron retorts.

When clay retorts alone are employed, the surplus heat passes into the atmosphere and is lost; but when combined with iron, as hereafter explained, this heat is made available, and is ample to maintain iron retorts at the proper degree of temperature alike for the economical production of gas and coke, thus effecting a very considerable economy in the fuel for carbonisation. This principle of combining clay and iron retorts has for a period of years engaged the attention of Mr. Croll, and under his management has been very successfully applied; but, like many other great innovations, has not met with the general approbation it merits, and, if we reflect on the time required to develop the superiority of clay retorts, this will occasion no surprise.

Figs. 23 and 24 demonstrate the system of this improvement in the simplest form as in operation in small works. *c* is the furnace, the fire of which communicates directly with the three circular clay retorts above (R R R); and, after acting on these, passes over to heat the two ◘ iron retorts (R′ R′), and so to the flue *i*. Fig. 24 is a longitudinal section of the same setting, with corresponding letters to indicate the various parts.

Another modification, varying slightly from the former, is shown in the Figs. 25 and 26. In this the clay retorts are immediately over the furnace, and the iron retorts at the sides.

Figs. 27 and 28 represent a setting of this class for works of larger capacity. In this bench there are five clay retorts, each 7 feet 6 inches long, marked R, R, and four iron retorts of the same length, besides one ◘ retort, 5 feet long, 20 inches wide, and 20 inches high, marked R′ in Fig. 28.

Through the courtesy of the editor of the *Artisan*, who has kindly permitted me to copy the admirable plates published in that journal, I am enabled to give, in Figs. 29 to 32, an elevation, cross section, and longitudinal sections of one of

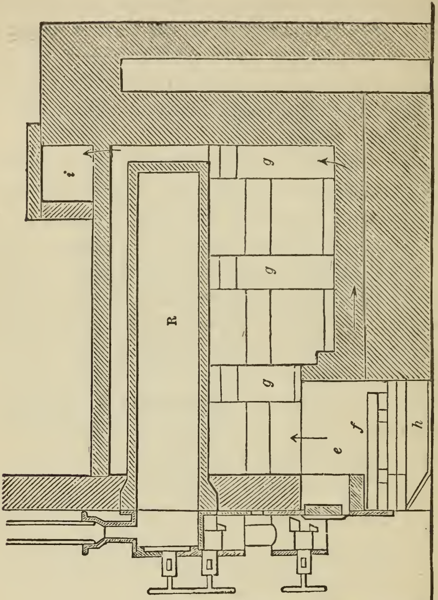


Fig. 26.

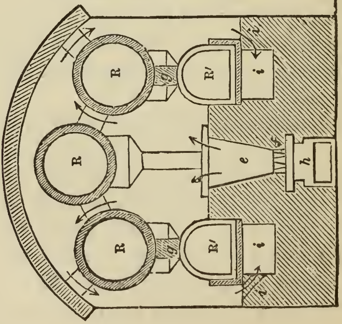


Fig. 25.

Mr. Croll's ovens, showing the mode of combining iron and

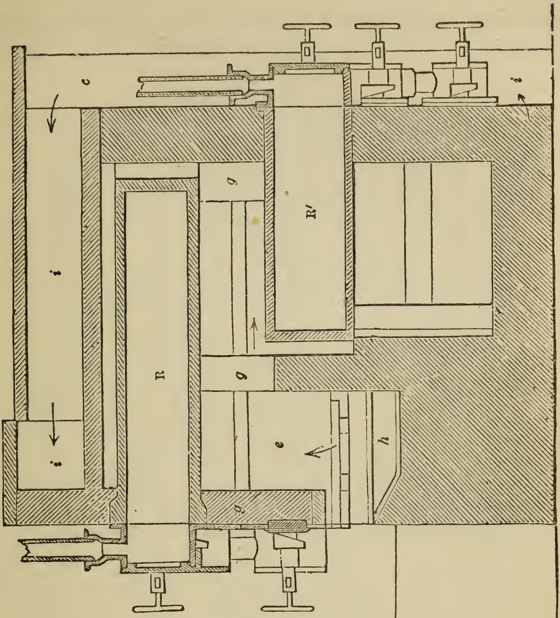


Fig. 28.

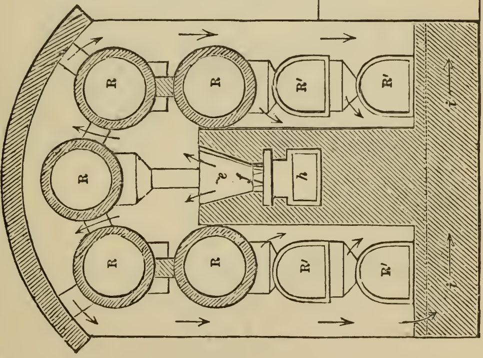


Fig. 27.

clay retorts, as practised by him on a very large scale. These figures are all on a scale of 1 inch to 4 feet. *a a a*, &c., are

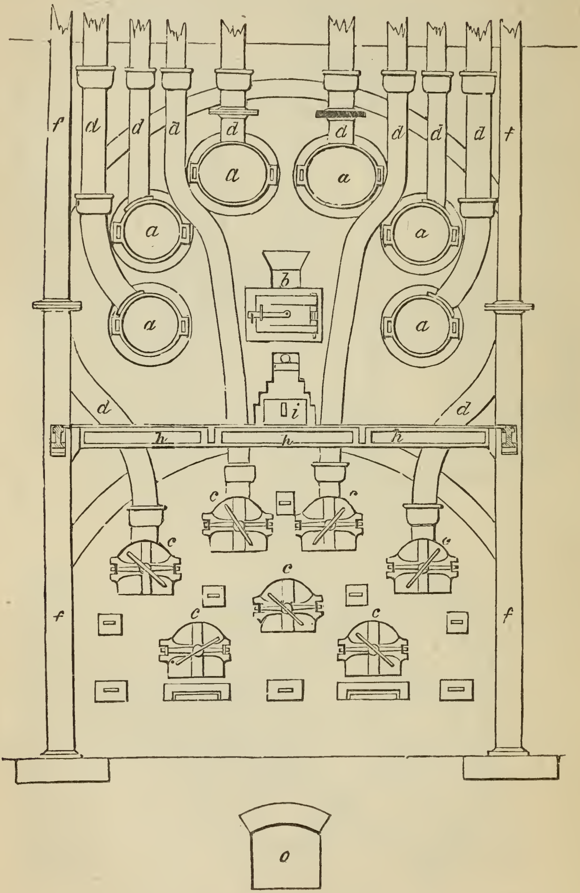


Fig. 29.

the clay retorts, of which the upper two are elliptical, 18 inches by 15 inches, and the other four circular, 15 inches in diameter inside. Each clay retort is made in four pieces, which

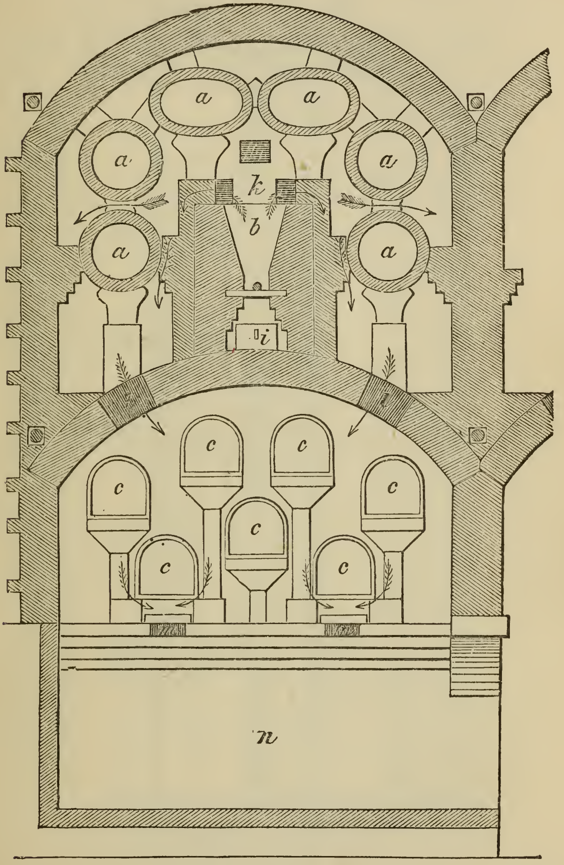


Fig. 30.

are jointed together with fire-clay, as described elsewhere. *b b* are the furnaces at each end of the retorts, which are ranged

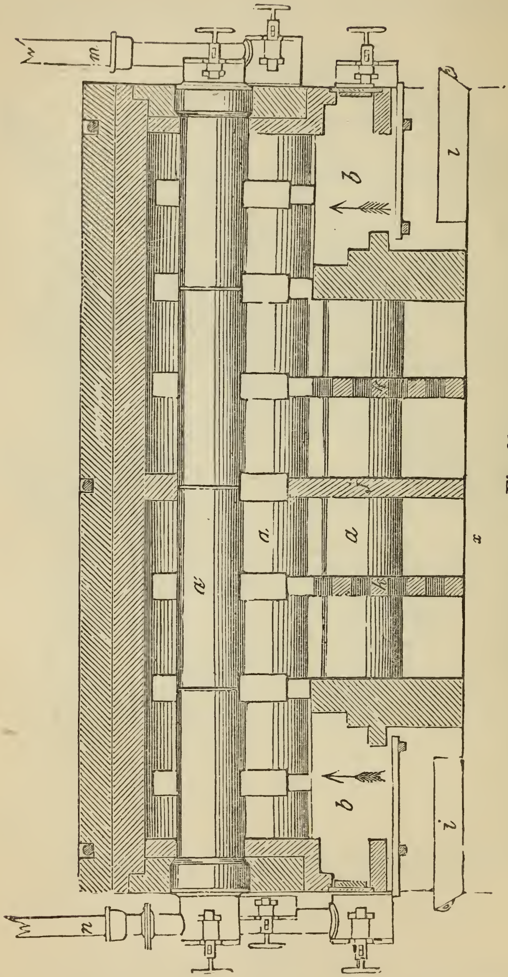


Fig. 31.

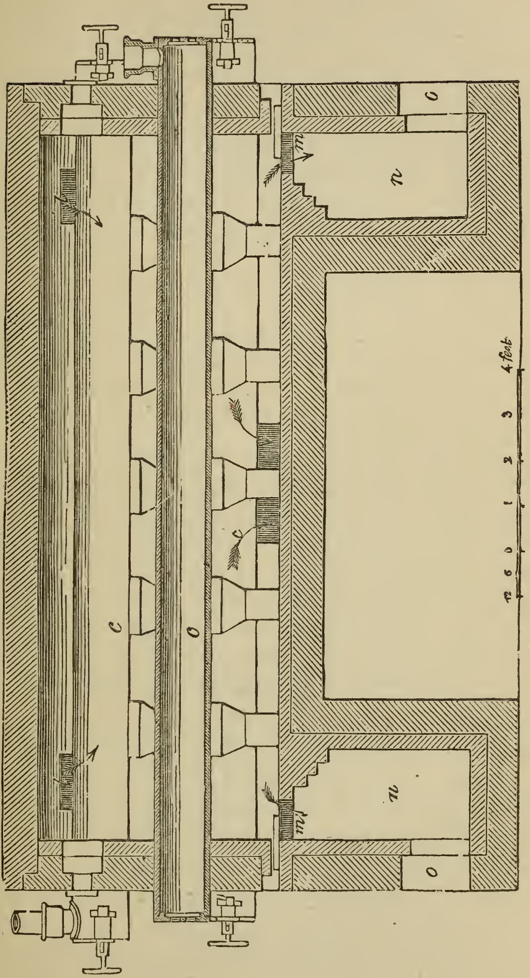


Fig. 32.

so as to receive an equal share of the heat which diffuses itself in the upper oven. *c c c c*, &c., are the iron retorts, set in the lower oven, which receive the heated air through the openings *l l* in the lower arch. *d d d*, &c., are the ascension pipes, which pass up from each end of the clay retorts, and from one end only of those of iron. *f f* are columns which support the hydraulic main. Projections cast on these columns support the girders *h h*, which are destined to carry the firing floor; *i i* are the evaporating or ash-pans; *k k* are the walls which carry the retorts, perforated with holes to allow the heated air to pass; *l l* are the openings or nostrils which admit the heated air from the upper to the lower oven; *m m* are the openings from the lower oven into the horizontal flues *n n*, which are provided with fire-tile dampers to adjust the draught. The horizontal flues lead to the chimney. *o o* are flue-doors for cleaning out the horizontal flues; the whole being drawn to a scale which accompanies Fig. 32.

Fig. 29 is a front elevation of this setting of retorts. Fig. 30 is a transverse section of the same; and Figs. 31 and 32, being jointed together at the line *x*, which is the top of the lower arch, and is common to both figures, will form a longitudinal section at right angles to the face of the bench.

It will be observed from the description given of this method of setting that, independently of the use of clay retorts in combination with iron, and the consequent change in the conduction of heat, there is an important variation from the earlier system.

According to the old method massive brickwork and tiles obstructed the passage of the heat, preventing its radiation through the setting. This was a serious obstacle, which is entirely removed in the combination settings, where the fire impinges directly on the clay retorts, and, after losing a portion of its intensity, passes to heat those of iron. By this method the iron retorts have a greatly increased durability, the average being about eighteen months. If, previously to setting, they have a thin coat of fire-clay on the exterior of about $\frac{1}{8}$th inch thick, they will not require cleaning; this also adds to their durability.

The combination of iron and clay retorts has been very extensively employed by some engineers, producing the most favourable results, the average yield from Newcastle coal being 9,200 feet per ton; and in many instances in works of 25 millions to 100 millions a year, the fuel for carbonising does not exceed 17 per cent. of the coke produced. By one of the modes adopted by Mr. Anderson, 26 retorts are heated by two furnaces, one of which is supplied only by a stream of tar. Wherever coke is valuable and tar not marketable, this plan is of great consequence, 8 gallons of tar as fuel, being equal to about $1\frac{1}{4}$ cwt. of coke.

CHAPTER X.

THE HYDRAULIC MAIN.

This serves the purpose of a series of valves for all the retorts, and if such a contrivance did not exist, each ascension pipe would have to be provided with a separate valve or tap, occasioning considerable labour to shut and open them, every time the coke was drawn and the retort charged. In addition to this, the risk and loss would be very great. But the hydraulic main is self-acting, beautifully simple in its construction, and, with the least care, accident or loss from it is almost impossible.

The hydraulic main is a tube or trunk, usually of cast iron, extending the entire length of the retort ovens, and varying from 12 to 20 inches diameter, and, when made of cast iron, generally from $\frac{5}{8}$ths to $\frac{3}{4}$ths of an inch in thickness. Wrought-iron hydraulic mains, however, now supersede cast iron, on account of their lightness and strength. These are usually made of larger diameter than the cast iron, and put together in longer lengths. (See Figs. 33 to 35 for the details of the wrought-iron hydraulic main erected by Messrs. Cowley and Co. for the Phœnix and other gas companies.)

This is made of $\frac{3}{8}$-inch boiler-plate. The cylinder forming the main is composed of two circular plates and one flat piece on the top, as shown in Fig. 33. The circular plates are made of two breadths, namely, about 3 feet and 2 feet, and

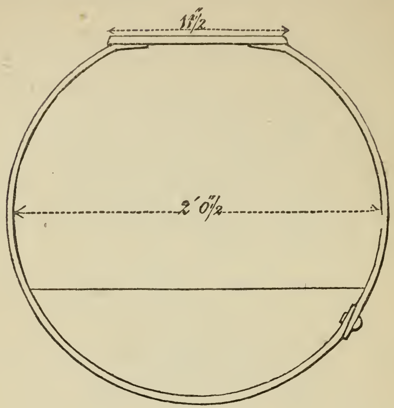


Fig. 33.

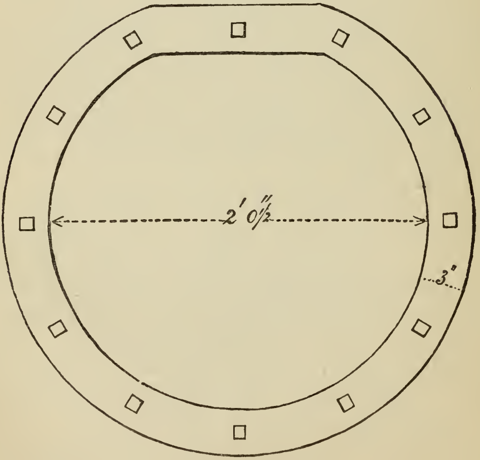


Fig. 34.

about 5 feet 6 inches in length. They break joint with each other, by having their line of division alternately on opposite sides of the main.

The main is constructed in lengths of 23 feet, and at each end of this length there is a flange 3 inches wide, shown in elevation in Fig. 34, which also shows the bolt-holes through which the bolts pass for securing together the separate lengths of main. At the end of each length, and also midway in each length, is a division-plate, 7 inches deep in the centre, shown in Fig. 33. A plan or top view of one length of main is shown in Fig. 35, which exhibits the mode in which the end flange is attached to the main. This flange

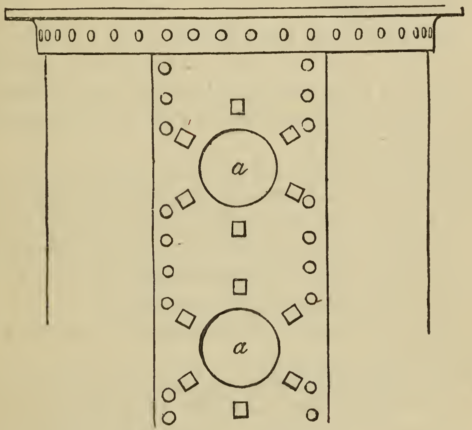


Fig. 35.

consists of 3-inch angle iron, half an inch thick, bent into a circular form, one side being secured to the main by $\frac{3}{4}$-inch rivets, $1\frac{3}{4}$ inch apart all round. The bolt-holes in the face of the flange, shown in Fig. 34, are $\frac{3}{4}$ inch square. The flat top plate is in lengths, of which three correspond to one 23-feet length of main; each length takes seven dip-pipes. Two of the openings to receive the ends of the dip-pipes are shown at *a a*, Fig. 35. These openings are $5\frac{1}{4}$ inches diameter, and 12 inches apart from centre to centre. Each opening is surrounded by six bolt-holes, ⅞ inch square, to receive the bolts for fastening the flanges of the dip-pipes. Figs. 33 to 35 are drawn on a scale of $\frac{1}{12}$th, or 1 inch to a foot. The cost of these mains erected complete is about £17 per ton. Of course the main must be constructed for the settings adopted.

Cast-iron hydraulic mains are generally of such a length as to reach over one bench only, and the joints are made with bolts and nuts, and cement, in the usual manner. In old works the hydraulic main is often a circular tube, but of late years D-shaped mains have frequently been used, with the flat side upwards.

The hydraulic main when first put into action is supplied about half-full with water, but in the course of operation the tar contained in the gas which passes is soon deposited in the hydraulic main, displacing the water, so that the sealing liquid speedily becomes tar.

The end of the dip-pipe, as shown page 63, is immersed to a depth of 3 or 4 inches in the liquid in the main, and during the process of distillation the gas passes from the retorts up the ascension-pipe, through the bridge-pipe, down the dip, bubbles through the liquid into the space above, and from thence to the apparatus for purification.

The action of the dip of the hydraulic main has already been explained.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own retort, and effectually prevents its return. However numerous may be the pipes dipping into the hydraulic main, whether they contain gas or not, and whether the retorts are working or not, it is impossible, under ordinary circumstances, that any gas once arrived above the surface of tar in the main can return back again, each pipe being hermetically sealed by the tar.

The hydraulic main constitutes the first application in the gas manufacture of that beautiful contrivance called the water-joint. It is this contrivance which enables the chemist to store and confine his gases in the receivers of the pneumatic trough, and thus by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtilty, infinitely excels every contrivance of mere mechanical fitting. We shall see hereafter how largely this valuable principle of sealing up the aëriform fluids by means of denser fluids, through which they can pass in one direction but not in the other, has been applied in the purifier, the gas-holder, and, in fact, in every one of the contrivances connected with the collection, storing, and distribution of gas. At present it may be sufficient to point attention to the value of this property derived from the different densities of fluids, which gives both to the chemist and the manufacturer a power over the aëriform bodies which they would in vain strive to obtain by any other means.

The length of the dip-pipe, with the part of bridge-pipe to bridge, should not be less than 3 feet, and is frequently made as much as 5 feet, to prevent the tar overflowing into the retorts which are out of action. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the dip-pipes of those retorts which are not in use, but this distance is seldom equal to 3 feet. As the hydraulic main is generally half-full of tar, its diameter must be so regulated that the tar forced up into the dip-pipes of the retorts out of action will not so far diminish the depth in the main as to unseal the ends of the dip-pipes, because this would simultaneously unseal every one of them, and the gas would immediately escape from the main.

The hydraulic main is sometimes placed on the solid structure of the brick-work over the retorts, but more frequently a little in advance of the ovens, in which case it requires to be supported by columns.

Each length of the hydraulic main is usually provided with a partition, the top of which is level with the surface of the fluid; the object of this is to maintain that surface continually at the same height in every part of the main. Of course where so much depends on the effective sealing of the dip-pipes, every care must be taken to fix the hydraulic main in a perfectly horizontal position from end to end. When the hydraulic main is of cast iron, the holes for the dip-pipes often are cast in it, and the flanges of the dip-pipes are secured to it by nuts and bolts, the joint being made with iron cement, such as used for attaching the mouth-pieces to the retorts; or a hempen or millboard washer, dipped in a mixture of white and red lead, forms a tight and secure joint.

Usually one end of the hydraulic main is closed with a plate fastened with bolts and nuts; a similar plate, provided with an orifice corresponding in size to the exit-pipe conveying the gas to the purifiers, is attached in a like manner to the other end, and on to this is bolted a flanged socket for the purpose of communicating the exit-pipe thereto. Sometimes the two ends are closed, and the exit-pipe is attached to the top of the hydraulic; in this case there is a small pipe attached to the end, at the level of the surface of liquid, in order to convey away the tar and ammoniacal liquor condensed. This is sealed in a similar manner to the dip-pipes before described. When tar is used as fuel it can be taken directly from the hydraulic main, which saves the trouble of pumping, and avoids the necessity of having a reservoir. When so used the tar is very fluid, but care must be taken to limit the consumption, otherwise the main, being exhausted, will deliver only ammoniacal liquor.

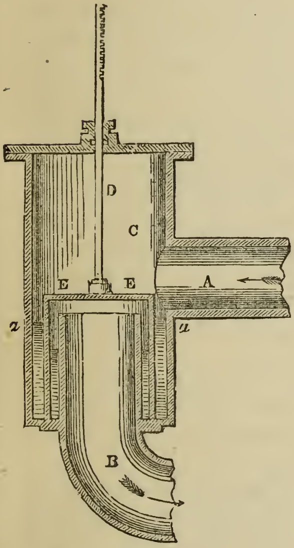
In many works where the exit-pipe is on the end of the hydraulic, this is placed so to carry off the tar and ammoniacal liquor as well as the gas; but it is always considered preferable to have two distinct pipes for the purpose.

VALVES.

In addition to the hydraulic main, which as shown is a series of valves for the retorts, there are two kinds of valves used in gas-works, namely, the hydraulic-valve, which acts on the principle of interposing a column of water in such a position and of such a depth that the gas is incapable of passing through it; and the slide or surface valve, which stops the flow of gas by the close contact of accurately planed metallic surfaces, the contact being preserved by the action of a spring, as will presently be described.

The hydraulic-valve is chiefly used in works between the gas-holders and the mains, while the slide-valves are generally employed in the street mains, and are of great service in stopping the flow of gas when a part of the main is undergoing repair.

Figs. 36 and 37, drawn on a scale of $\frac{1}{20}$th of the full size, show two kinds of hydraulic-valves; and Figs. 38 and 39,



Figs. 36.

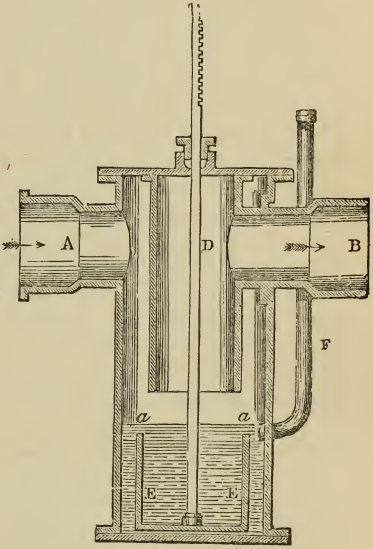


Fig. 37.

drawn on the same scale, show the usual form of slide-valve.

In Fig. 36, D is a cast-iron cylinder, usually for 12 or 14-inch mains, about 3 feet long and 16 or 18 inches in diameter; the other sizes being increased or diminished accordingly. The top of the cylinder has a perfectly air-tight cover with a stuffing-box, through which works the rod D. The gas passes into this cylinder through the pipe A; the cylinder contains water or tar to the level *a a*, or about a foot in depth. The outlet-pipe B, through which the gas passes off to the mains when the communication is open, has its orifice about 3 inches above the level of the tar; E E is an inverted cup which covers the mouth of the pipe B, and can be raised when required by means of a pinion working into the rack on the rod D, or other suitable means. It is evident when the cup is at the bottom and immersed in the water, as shown in Fig. 36, the gas is hermetically sealed up and prevented from entering the pipe B, unless its pressure be sufficiently great to displace the water and cause it to overflow into the pipe B. In this case the gas would escape, but the depth of 12 inches is usually sufficient to prevent this, and to afford a most effectual seal. On the other hand, it is evident when the inverted cup E E is raised above the surface of the tar, the gas will flow uninterruptedly from the gas-holder through pipe A, and thence into pipe B, which takes it off to the main. This kind of valve is extremely simple and efficient, the chief objection to it being that the outlet and inlet pipes are at different levels, an objection which does not apply to the next kind of hydraulic-valve.

Fig. 37 is the section of a valve which is frequently made use of in works, and has the advantage of acting as a receiver or syphon to contain the tar or water which drains off from the gas in its passage.

The outer cylinder is about 3 feet 6 inches long, and about the same diameter as the valve last described, provided as before with an air-tight cover and stuffing-box, through which the rod D passes: A is the inlet and B the outlet pipe, both on the same level; E E is the movable cup, not inverted in this case, but entirely immersed in water or tar when at the bottom of the cylinder, and remaining full of the liquid when lifted up by the rod D to close the open end of the inner cylinder; the inlet-pipe A opens into the outer cylinder, and the outlet-pipe B opens from the inner cylinder. The water or tar should be a little higher than the top of the cup, namely, as high as the line *a a*. On the right-hand side of the engraving is a small pipe, F, with a screwed top, through which the water of condensation is drawn off when it reaches above the level *a a*. Bearing in mind that the inner clylinder is open at the bottom and side, the action of this valve will be readily seen. When the cup is at the bottom, as in the engraving, the gas passes freely from A into the outer cylinder, then up through the inner cylinder, and goes off by the pipe B : when the cup E E is raised, however, the lower edge of the inner cylinder rests on the bottom of the cup, and being of less diameter than the cup, there is an annular space of water all round, equal in depth to that of the cup; this water effectually prevents the gas from passing through it and reaching the outlet-pipe. The dimensions of the inlet-cylinder will depend on the diameter of the main to which the valve is attached, free space being left, inside and outside it, as may be readily understood.

When this kind of valve is used, where it would be inconvenient to have the rod D raised by means of a pinion, the cup is raised by another contrivance. The rod in this case has a thread cut on it, which works through a nut in the bottom of the cup: when the rod is turned, the cup, being at the same time prevented from turning, is raised by the screw until it attains such a position as to seal up the bottom of the inner cylinder. In small valves the rod is lifted by hand.

Hydraulic-valves are now only used in gas-works, and never in the streets. They have the advantage of shutting off the gas very effectually, not being liable to leakage like slide-valves, but have the disadvantage that an accidental excess of pressure renders them useless.

SLIDE-VALVES.

Fig. 38 is a longitudinal section, and Fig. 39 a plan in section, of this kind of valve. A B is the valve case; C is a circular iron disc attached to the rod E, which works through a stuffing-box at the top of the valve case; D is a spring which presses on the disc C, and causes it to be in perfect contact with the rim of the pipe when in its place: the disc is very accurately turned in the lathe, and the rim of the pipe is also truly faced, as well as the part A B, against which the disc presses when raised so as to open the communication between the pipes. It is evident when the disc is placed as shown in the engraving, the passage of the gas is stopped, and when raised by means of a pinion working in a rack cast on E, the passage can be entirely opened. When used in gas-works, the disc is worked either horizontally or vertically, as shown in the engraving, but when employed in the street, the rod E is worked horizontally, by means of a key fitting the axle of the pinion; in this case Fig. 38 becomes a plan in section, and the disc moves laterally instead of vertically, to open the communication between the pipes.

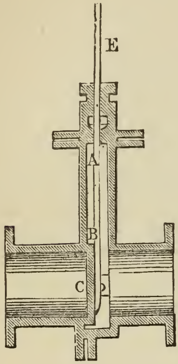


Fig. 38.

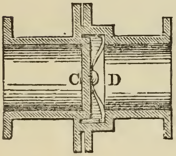


Fig. 39.

Another kind of valve has come into use in gas-works during the last few years: a disc similar to that shown in Figs. 38 and 39 is pressed by a screw upon a faced rim, and when the screw is tightened, the contact is so perfect as to prevent the slightest escape of gas. When the screw is relieved, the disc may be raised so as to afford any required opening for the flow of the gas: the screw may be placed either horizontally or vertically; and this kind of valve is, perhaps, more correct and certain in its action than the spring slide-valve.

Mr. Clegg describes an ingenious contrivance by Mr. Lowe for intercepting the passage of gas in a main where there happens to be no valve in the neighbourhood. This is effected by filling up the main with a bladder distended by common atmospheric air, the mode of proceeding being as follows:—

Supposing a fracture required to be repaired, or a branch pipe inserted, for which purpose the main has to be cut asunder or taken up for a certain length; provide two bladders, each being firmly attached to a piece of $\frac{1}{4}$-inch composition pipe about 1 foot long, and furnished with a stop-cock; then drill a hole $1\frac{1}{4}$ inch in diameter in the main pipe on each side of the place to be operated on, and insert the empty bladder into the main: which is then to be inflated through the tube at the mouth, till it expands and fills up the main, when the stop-cock is turned in order to confine the air. The repairs to the pipes being finished, the air may be let out of the bladders, which can then be withdrawn, and the holes in the main stopped up by screwing in an iron plug.

FURNACE DOOR, ASH-PAN, SIGHT-BOXES, AND BUCKSTAVES.

These minutiæ of a setting of retorts may be described briefly. At the entrance to the furnace there is a cast-iron frame attached by nuts to bolts which are embedded in the brick-work. This frame is usually about from 22 inches to 26 inches square, $1\frac{1}{2}$ inch to 2 inches thick, having a rectangular opening in its centre, of about 12 inches by 10 inches, which is the entrance to furnace. On this frame is cast a fillet for the door to repose on when shut, and two pieces forming part of the hinge of the door; the corresponding parts of the hinge being cast with the door itself. The door is about $\frac{3}{4}$ inch thick, being larger than the opening of furnace so as to allow of a lap of an inch all round: it is furnished in the interior with a bevelled frame, for the purpose of receiving a fire-lump about 9 inches square, and $2\frac{1}{2}$ inches thick, which serves to prevent the radiation, also the destruction of the door by the heat.

The ash-pan, or, as often called, evaporating pan, is a small oblong tank placed immediately under the fire-bars of the furnace, and, as the name signifies, serves to receive the ashes; but its most important office is to contain water, which by the heat of the fire evaporates as steam, and, ascending, plays on the fire-bars, so cooling and preserving them. Afterwards the steam in its passage is decomposed by the fire into its two elements, the oxygen uniting with the carbon, and the hydrogen being liberated, is burned; thus both the constituents of water are made available for the purposes of combustion and heating the retorts. The ash-pan was formerly made of cast iron, but the inconvenience of this cracking has caused them now generally to be made of wrought iron.

The sight-hole or box consists of small cast-iron frame built into the front wall of setting, into which is fitted a plug of the same material: these are circular, square, or oblong, and vary in size from $2\frac{1}{2}$ inches to 5 inches diameter, the most common shape being 3 inches square. The use of the sight-boxes is to ascertain the temperature of the interior of the furnace; they serve for cleansing the exterior of iron retorts, also for removing deposit in the nostrils.

In order to prevent the brick-work being injured by the expansion of the heat, it is bound by tie-bars extending from side to side, and from end to end. These tie-bars pass through iron supports, called buckstaves, when they are screwed up tight, forming a framing for the brick-work, preventing it cracking.

CHAPTER XI.

ON THE PURIFICATION OF GAS.—ON PURIFICATION GENERALLY.—HORIZONTAL CONDENSER.—VERTICAL CONDENSER.—WASH VESSELS.—SCRUBBERS.—WET LIME PURIFIERS.—DRY LIME PURIFIERS.—OXIDE OF IRON.

We have traced the production of gas from the retorts into the hydraulic main, where, as has been shown, it is retained by a beautiful contrivance, which, while freely admitting the gas to enter it from the retorts, opposes a seal hermetically closed against its return into them. Thus collected in the hydraulic main, the gas is capable of being burnt, and was originally used in this state for the purposes of lighting, without any purification. By degrees, however, it was discovered that the numerous obnoxious matters with which it was impregnated rendered it unfit for burning in private houses, and one contrivance after another was adopted to separate these impurities, which are referred to in the chapter on the Chemistry of Gas-lighting, and are now to be more fully treated on.

The process of purification is partly mechanical and partly chemical; that is to say, the tar and ammoniacal liquor are separated by a mechanical process of cooling the crude gas after passing from the hydraulic main, by which process the vapours of tar and ammoniacal liquor in combination with it are condensed and allowed to flow off into separate vessels destined to receive them.

The greater part of the vapours being condensed, means are then adopted to separate the tar held in suspension, also the ammonia which exists as gas, and for this purpose the washer or scrubber is employed.

Another means of removing the ammonia is by Mr. Croll's method of passing the gas through a weak solution of sulphuric acid or chloride of manganese, which process is very effective, and gives a valuable residue. In many works the ammoniacal liquor yielded by the coal is an important agent in the purification of gas.

The other part of the chemical purification is by means of a solution of lime or milk of lime, generally called wet lime purification, or by lime slackened and moistened, called dry lime purification, which absorbs the carbonic acid and sulphuretted hydrogen.

Certain metallic oxides, particularly the oxide of iron, are also much employed for removing the sulphur compounds; and the Rev. Mr. Bowditch has devoted himself to the purification of gas from that troublesome impurity, bisulphide of carbon, by passing the gas to be purified through a chamber filled with lime heated to about 400° Fahr. These and other processes will be treated on in future pages. The impurities being separated, the gas is suitable for the ordinary purposes of lighting, and accordingly passes to the holders, to be stored for use.

THE CONDENSER.

There are two forms of condensers in use, the horizontal and vertical. The horizontal condenser is a rectangular box or chest formed of cast-iron plates, put together with flanges, and perfectly tight joints. Its interior is provided with a series of iron trays, containing each about 2 inches in depth of water, and so arranged that the gas, entering at the bottom of the chest, passes in succession over the surface of the water in each tray, and traversing the whole length of trough ten or twelve times, passes off at the upper side. In the mean time a continuous stream of water enters at the top, and in its descent absorbs a portion of the ammonia, at the same time cooling and condensing the vapours in combination with the gas. This condenser was invented by Mr. Malam, and was formerly very generally used, but is now superseded by the surface or air-condenser and scrubber.

Horizontal condensers are sometimes composed of a series of pipes placed in a horizontal position, and immersed in water.

The other form of condenser, which is very generally employed, consists of a series of vertical pipes, connected in pairs by semicircular bends at the top, and attached to a cast-iron box or chest at the bottom. This chest has a series of divisions, the ends of which are sealed by liquid placed therein, so that the gas in its passage has to pass through the whole series of pipes. The pipes by their contact with the atmosphere radiate the heat acquired from the gas in its passage, and it being in consequence cooled, deposits the vapours as liquid in the form of tar, and water saturated with ammonia, generally called ammoniacal liquor. This condenser is sometimes used with an application of cold water on its exterior, in order to increase the cooling effect.

Fig. 40 shows a longitudinal section, and Fig. 41 a cross section of a vertical air-condenser, with the air-pipes attached to the iron chest, which is filled with water to the line *a a*. The longitudinal section shows that the chest is divided transversely into compartments, each of which contains two pipes communicating freely with each other, the gas passing from

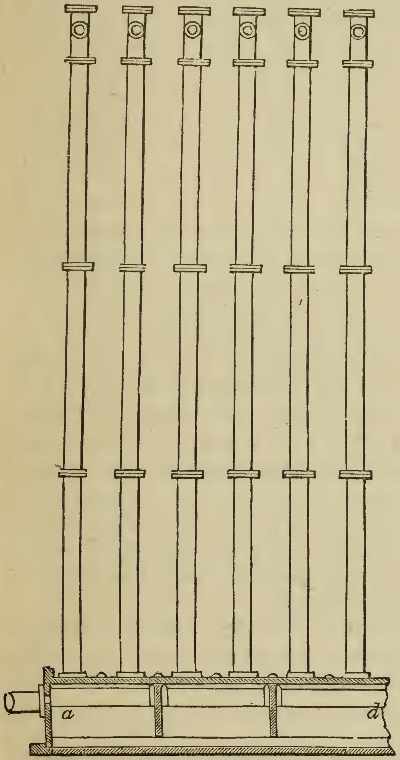


Fig. 40.

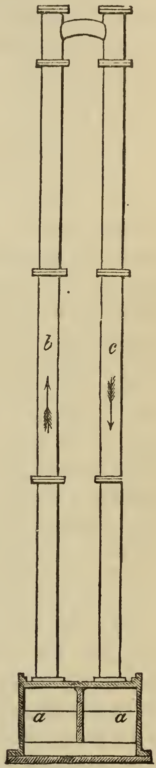


Fig. 41.

one to the other over the surface of the water, and being prevented by the water from going in the opposite direction. The cross section shows that the chest is divided longitudinally into two compartments, each of which receives one row of pipes.

In Fig. 41 the gas entering into the compartment below the pipe *b*, passes up that and down pipe *c*, in the direction of the arrows, into the next compartment, from whence it passes into another pipe, as seen in Fig. 40. So that it has to traverse the whole length of the pipes, which radiate the heat communicated to them by the gas in its passage.

Another form of air-condenser has lately become very general in large works, and consists of an iron chest similar to that described, but of much greater dimensions, surmounted by a series of vertical pipes of great diameter, in which are enclosed others considerably smaller, the two forming an annular space. Through this annular space the gas to be condensed passes, and the interior of the inner cylinder being open to the atmosphere allows a current of air to enter below, which becoming heated, ascends, causing a draught or current; hence the superiority of this system. There are external pipes which communicate the various condensing columns with each other, and so complete the apparatus. The condenser used at the Imperial Gas Works of London consists of ten upright pipes, each 3 feet 6 inches diameter, and 22 feet high, having pipes 24 inches diameter to communicate between the condensing columns. In some works the condenser is replaced, by the pipes from the hydraulic main to the purifiers being attached to the walls of the buildings and exposed to the atmosphere, when a considerable length of pipe is of course requisite.

The researches of Peclet and other French writers on Physics, demonstrate that a far greater extent of cooling surface is required when radiation takes place in air than when the same takes place in water, as when the condensing pipes are in that medium.

It appears, wnere the gas has an excess of temperature of 10 degrees over the atmosphere, that a unit of surface which would radiate 8 parts of heat in the open air, would in water radiate no less than 88 parts of heat; and the following table expresses the proportionate radiation in the two cases for an excess of temperature up to 50°.

Excess of temperature in the gas.	Quantity of heat lost by a square unit of the exterior surface of pipe.	
	When radiating in open air.	When plunged into water.
For an excess of 10°	8	88
„ „ 20	18	266
„ „ 30	29	5353
„ „ 40	40	8944
„ „ 50	53	13437

In examining this table we find a vast difference in the quantity of heat absorbed by water, especially as the excess of temperature rises; and hence it follows that if the system of condensation by simple rádiation into the air be adopted, the extent of surface exposed must be much greater than when water is used; but although this would show a superiority of water as a cooling or condensing medium, yet it is generally believed that there is a certain mechanical effect produced in the gas passing through the series of pipes, which assists materially in the purification. This may be the reason why the air-condenser is so generally used almost to the exclusion of the other. Formerly water-condensers were much employed, now they are seldom seen, practice having proved theory to be incorrect.

The gas in passing the condenser is acted on mechanically, by its various particles coming into contact with the surface of the pipes, and by this friction a large portion of the tar is deposited. The same effect will be observed with the purification; when the exhauster is used the friction assists in the deposit of the tar.

But gas may be condensed to an excess; when this occurs naphthaline is deposited in the mains and services, causing continual annoyance, which is particularly the case in winter, when the condensation should be limited.

Where the system of cooling by radiation in air is adopted, it is very advisable in dry and warm weather to assist the cooling by allowing small streams of water to trickle down on the outside of the condensing pipes: this is effected by having a cistern of water fixed over them. The cooling effect of this water evaporating on the outside of the pipes is greater than if the latter were placed in water, owing to the great quantity of caloric which passes from a sensible to a latent state during the formation of vapour. The more rapidly the vapour is formed, the greater will be the cooling effect, from which it follows that the effect will be greatest when the sun shines most powerfully, and that the condenser should always be exposed as much as possible to the direct rays of the sun.

The evidence taken in 1849 and 1850 before the Parliamentary Committees which sat on the Great Central Gas Consumers' Bill, affords some valuable information on the subject of prices and the general construction of large works. The project brought forward by Mr. Croll, the engineer of the Company, contemplated an annual production of 368,000,000 cubic feet of gas, and the estimate for condensers in a gas-work of this magnitude was £1,237, exclusive of a concrete foundation, which would cost £5 or £6 more.

Mr. Barlow, in his Report to the Directors of the City of London Gas Company, made no objection to this amount, and adopted it in his own calculation. This estimate is equal to ·807*d.* per 1,000 feet of gas per annum, or £1·23 per 1,000 feet of average daily production. Mr. Croll proposed to use for these condensers 128 pipes, each 9 feet in length and 18 inches in diameter; to have a box at top and bottom of each condenser divided into partitions, so that the gas should pass alternately up one pipe and down another in the usual manner.

The entire length of condensing pipe being 1,152 running feet or 5,472 feet surface, if we add 828 feet for the surface of top and bottom boxes, we have 6,300 feet condensing area, or about 4 feet superficial per 1,000 feet maximum production per diem.

These condensers have amply realised all that was anticipated, as upwards of two millions of feet have frequently been condensed by them in the twenty-four hours.

ON THE TAR AND AMMONIACAL LIQUOR-TANK.

The tar and ammoniacal liquor, as condensed, flow from the hydraulic main and condenser to a vessel called the tar-tank. This is sometimes built in the ground in masonry, when it requires to be constructed with all the precautions employed in building the tank of a gas-holder. Or it is formed of cast-iron plates, bolted and cemented together; or it may be made of boiler-plates riveted, to form either a rectangular or circular vessel. In all cases it is desirable that the tar-tank should be covered over to avoid the evaporation and odour which would issue from it; also to prevent the dust and dirt entering and intermixing with the tar.

Whatever kind of condenser be adopted, it is necessary to make provision to hinder the escape of gas through the same pipe which carries the tar and ammoniacal liquor into the tank. The mode of effecting this is shown in Fig. 42, where A B C D represent the tank, and K L the pipe open at

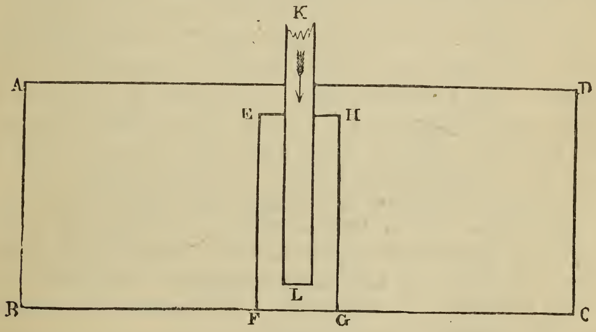


Fig. 42.

the lower end, through which the products of condensation enter. E F G H is a cylinder of larger diameter than K L, open at the top and resting at the bottom on the base of the tank, and filled with water nearly to the top. It is evident that the tar and ammoniacal liquor discharged at L will accumulate in the cylinder, and afterwards flow over into the tank at the top, E H, while the pipe dipping into the water forms an effectual seal against the emission of any gas.

Where an upright condenser is used, consisting of iron pipes connected at the bottom by circular pipes, instead of having the chest described, a modification of the last method is used as follows:—A cylinder, represented by E F G H, is placed under each of the circular bends, with a pipe, K L, leading into it. Immediately above the level of the water in E H, branches off a pipe secured to the cylinder by a flange and leading into the tar-tank, which runs the whole length of the range of condensing pipes, and the products of condensation flow off through this into the tar-tank.

This mode of sealing various parts of the apparatus is very common in gas-works; often a small vessel of this description is placed at the end of the hydraulic main, or at the ends of the air-condenser, so that in the event of a stoppage in the pipes on the works, either through the syphons not being pumped, or other causes, these seals give notice of it by the gas blowing off from there, acting, indeed, as a kind of safety-valve, and preventing any extraordinary excess of pressure.

The capacity of a tar-tank must depend on the magnitude of the works, and the facilities afforded in disposing of the residues. Mr. Peckstone gives the capacity of a tank for a works carbonising about 5 tons a day in mid-winter, at 540 cubic feet, which is rather more than 100 cubic feet for each ton of coal carbonised daily. In estimating the size of the tar-tank it is usual to calculate that each ton of coal produces from 100 to 140 lbs. of tar, and from 10 to 13 gallons of ammoniacal liquor in most instances, and it is proper to have the tank large enough to hold about six weeks' production of the liquids. This agrees very nearly with the estimate just mentioned.

In the tank both the tar and ammoniacal liquor are contained; however, they do not mix together, because the ammoniacal liquor being considerably lighter than the other, floats on the top, the tar being at the bottom. When either of these liquids may be required it is drawn out by means of a pump, with movable suction-hose, which can be adjusted so as to have its orifice either in the ammoniacal liquor or in the lighter or heavier portion of the tar, by which contrivance either liquid can be pumped out as desired.

At most gas-works both the tar and ammoniacal liquor are sold, the price for tar varying from 1*d.* to 1½*d.* per gallon; the ammoniacal liquor is generally sold by contract per annum. At many large and medium size works this is manufactured on the premises into a commercial commodity; usually, on account of the simplicity of the operation, into the sulphate of ammonia.

ON THE WASH-VESSEL.

Figs. 43 to 45, drawn on a scale of 1 inch = 3 feet, show the details of a washer as used in some works between the

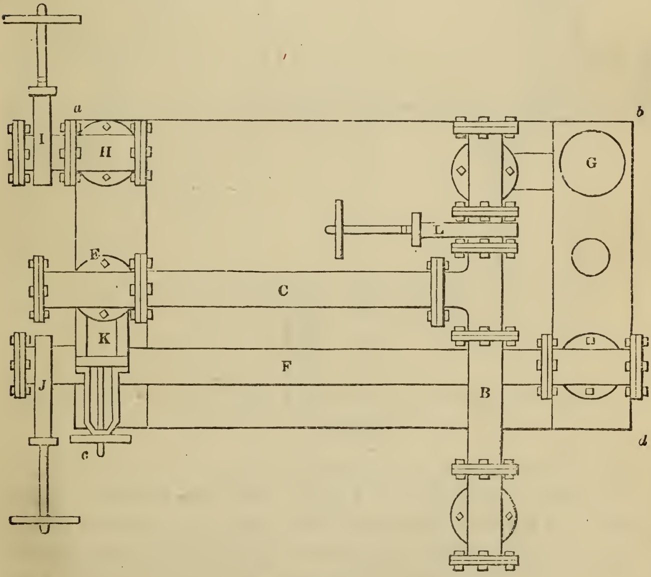


Fig. 43.

condenser and purifiers. Fig. 43 is a plan looking down upon the washer; Fig. 44 is a side elevation, and Fig. 45 a front elevation. In Fig. 43 *a b c d* is the iron vessel termed the washer; it is made of boiler-plates securely riveted together. In Fig. 45 is seen the front elevation of this vessel, which in the engravings is represented about 5 feet wide and 4 feet deep at the ends; the depth in the middle does not exceed 18 inches, as more particularly shown by the outline in Fig. 44. The lower part of the vessel is filled with water to the level *g h* in Fig. 44. The pipes communicating with the condenser, and those by which the gas passes off from the wash-vessel, are all marked with corresponding letters of reference

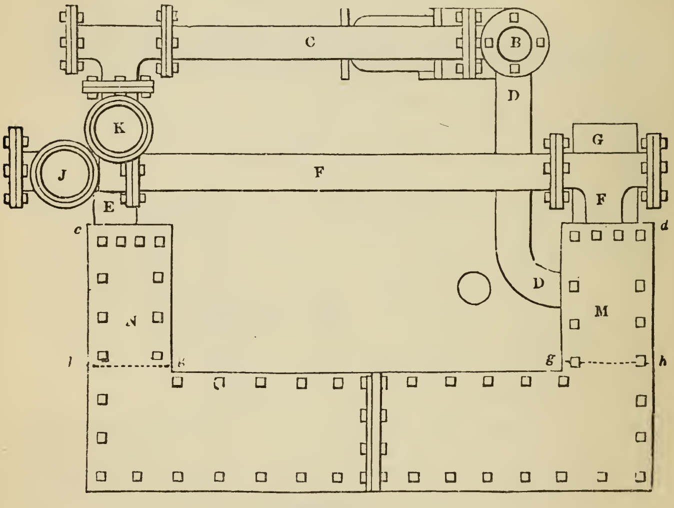


Fig. 44.

in the three figures, and by the aid of these I shall now trace the progress of the gas. Passing from the hydraulic main (see Fig. 45), the gas ascends the pipe A, and proceeds along pipe B. If intended to be passed into the right-hand extremity of the washer, the valve L is kept open, and the gas passes down the pipe D, and enters the space M. Out of this space it has no means of escape, except by displacing the water and passing up at the other extremity of the vessel

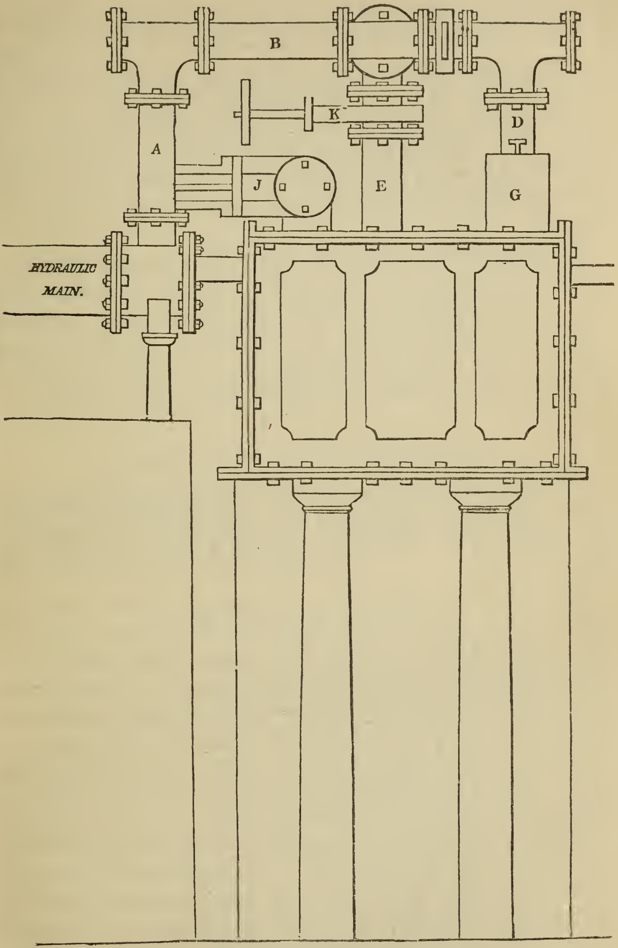


Fig. 45.

into the space N. Arrived here, it passes up the pipe E, and finally goes on through F. If it be intended to pass the gas through the wash-vessel in a contrary direction, the valve L is closed, and the gas then goes from pipe B into C, and descends through the pipe E into N, the left-hand extremity of the washer: it then passes through the water as before, escapes into M, and goes off through pipe F as in the other case. The valves J K L, the use of which will be readily understood from an inspection of the engravings, are marked with corresponding letters of reference in each of the three figures.

This description of washer was very generally employed some years ago, but it was ascertained that, by washing the gas, a large portion of the hydrocarbons were deposited during the operation, and, in consequence, the illuminating power of the gas was diminished, a circumstance which caused the wash-vessel to be superseded by the scrubber.

ON THE SCRUBBER, OR COKE CONDENSER.

This apparatus has now become very commonly employed for the purpose of separating the ammonia from the gas; it also takes up the tar that may have passed over from the air-condenser.

The scrubber is generally a cylindrical cast-iron vessel, its height being from two to four times its diameter, those of large diameter being proportionally short. This vessel is provided with suitable man-holes for the purpose of discharging and charging the apparatus with coke or other porous material, the inlet pipe being at the bottom, the outlet at the top.

In the interior there are two, three, or more flanges for the purpose of supporting the necessary perforated plates, or shelves. On these is generally placed coke so to fill the scrubber, which done the man-holes are closed hermetically. Beneath the lowest shelf there is a chamber for the purpose of receiving any breeze that may be carried there by the water, and the inlet opens into this chamber. A supply of water is caused to enter the centre of the vessel at top, which, in its descent, trickles over the whole mass of coke, and comes in contact with the ascending gas, which yields its ammonia to the water, and the tar is mechanically retained by the coke. Sometimes this vessel is used in the dry state, the coke in that case only abstracting the tar from the gas.

The modern plan generally adopted at large establishments is to have several of these vessels, and the ammoniacal liquor produced by the condensation of the vapours from the distillation of coal flows into a cistern, from whence it is pumped into the scrubbers; and by this repeated operation the ammonia is abstracted from the gas, and the liquid becomes a commercial and valuable commodity. The ammoniacal liquor, as delivered from the air-condenser, possesses little value, on account of the small quantity of ammonia therein; but, when treated as stated, it not only becomes an important purifying agent, but is itself much increased in value. Another advantage of the process is that the hydrocarbons are not deposited by the operation as when pure water is employed. These scrubbers require periodical cleansing; otherwise the tar and coke would form a compact mass, and so prevent the passage of the gas; this being shut off by proper by-pass valves, the coke is withdrawn from the manholes and fresh coke replaced. Cleansing once in three or four months is generally sufficient.

PURIFICATION BY WET LIME.

By the combined action of the condenser and scrubber, the gas is deprived of the ammonia and the tar which existed therewith; there still, however, remains sulphuretted hydrogen carbonic acid, with other impurities; and for the complete removal of the two named, probably wet lime or the cream of lime is superior to all other means of purification.

In this process, the lime, after being slacked, is mixed with water in the proportion of about 48 gallons of the latter to two bushels of slacked lime. It is necessary to mix the lime and water together in a separate vessel, because the prepared lime must be introduced to the purifier in a fluid state. Hence the mixing is commonly effected in a large brick or iron cistern placed at a higher level than the purifiers. In the centre of the cistern is fixed an iron shaft, carrying at its lower end a stirrer or agitator (something like the contrivance used in the mash-tubs of the great breweries), which is caused to revolve by manual labour or steam-power. By means of this stirrer the lime and water are kept in a state of agitation,—the lime being mechanically suspended in the water, when it is allowed to flow into one of the purifiers, having suitable agitators to keep it in a state of solution, otherwise the lime would speedily be deposited, as the water does not chemically combine with or dissolve it.

In large works often two or three sets of purifiers are used, each set consisting of two purifiers. When economy of space is an object, they are sometimes placed one above the other; at other times are placed side by side. They should always, however, be at different levels, as in working them it is usual to cause the contents of the higher purifier to flow into the other, from whence the impure cream of lime is withdrawn. The fresh lime is always admitted into the upper purifier, the crude gas entering the lower, where it becomes partially purified; from thence it passes to the other, and the process is completed. The revolution of the stirrer of the purifiers is effected by the steam-engine (now used in most gas-works), a bevelled wheel on the upright shaft gearing into a similar wheel on a horizontal shaft driven by the engine.

The wet-lime purifier consists of a cast-iron cylinder entirely closed at top and bottom, except where the inlet and outlet pipes join it, and where an opening is required for charging it with lime-water, which same opening is also used for drawing off the charge. To the inside of the cover of this outer cylinder is bolted an inlet cylinder usually made of wrought-iron plate. This inlet cylinder is open at the lower part, and reaches to within a foot from the bottom of the outer cylinder, but has bolted to its lower flange a wide ring or dash plate of sheet iron, the outer diameter being only 8 or 9 inches less than that of the outer cylinder, so that a space of about 4 or 5 inches is left between the outside of the ring and the interior of the large cylinder. These particulars will be more fully understood from the woodcut, Fig. 46, to which reference is now made. A is the outer cylinder and B the inlet cylinder, into which the pipe C opens to admit the gas from the condenser, or scrubber. The gas passes down through the inlet cylinder B, and by its pressure forces its way up through the fluid lime, the surface of which, *d d*, is 8 or 9 inches above the dash plate attached to B: *e* is a hoop of angle-iron attached by bolts to the inside of the purifier, of such a diameter as to allow only half an inch of space to intervene between it and the iron dash plate attached to B. The bottom of the angle-iron hoop is on a level with the dash plate, so that the gas has to find its way through the small space between them: *f*

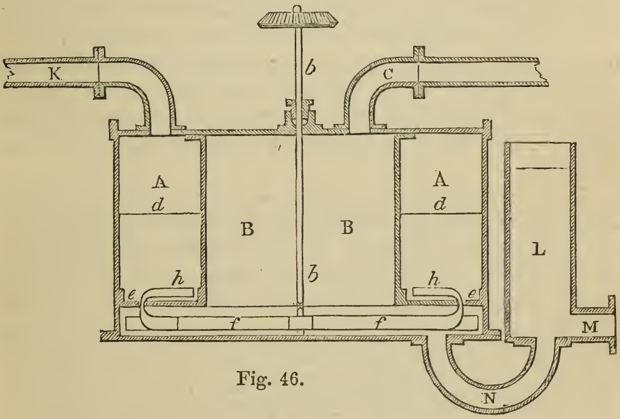


Fig. 46.

is the revolving arm or stirrer keyed on to the shaft *b*, which works in a bearing fixed on the bottom of the purifier, and passes through a stuffing-box in the lid, being worked by a bevel-wheel, as already described for the mixing vessel. To the main arm is attached a band of bent wrought-iron, *h h*, which continues up through the small opening already spoken of, and laps over the dash plate till it nearly touches the inlet cylinder, the object of this being to keep up the agitation and prevent the solid particles of the lime from settling; it also keeps the half-inch opening clear and free for the gas to pass through. K is the outlet-pipe for the purified gas after it has passed through the solution of lime, and reached the annular space between the outer and inner cylinders. L is an outside chamber, and M an outlet-pipe connected with the purifier by a siphon-pipe N; the pipe M is provided with a valve, which is kept closed, except when the contents of the purifier are to be drawn off. The lime-water is conveyed into the purifier through the chamber L, and when it is required to empty the purifier, the valve in M is opened. As the siphon-pipe N must always remain filled with fluid, it is evident that no gas can escape when the lime and water are drawn off. This arrangement is necessary, as when wet-lime purifiers were first used, a serious explosion occurred from the escape of gas along with the spent material. The wet-lime purifiers are variously worked; when four are used, two vessels are employed at one time, and when the lime in the first is incapable of absorbing the impurity, that purifier is put out of action, and the second and third are worked, and so on in succession.

The general impression is that wet-lime purification is the most perfect mode for the effectual removal of carbonic acid and sulphuretted hydrogen. But the operation of discharging the apparatus, together with the residues of the process, are so very offensive to the surrounding vicinity, as to prevent this means of purifying being applied except in instances where the works are quite isolated; and even then the difficulty arises how to dispose of the waste lime. The stench from this is so intolerable as to prevent it being deposited with ordinary rubbish; and I believe no practical method has been adopted of commercially applying it, being used only as luting for the retort doors. Therefore, wet-lime purification is seldom adopted at works established in towns or cities.

DRY-LIME PURIFICATION.

When quick lime is slackened, reduced to powder, and slightly moistened with water, it is called by chemists the hydrate of lime, and is often employed to absorb the sulphuretted hydrogen and carbonic acid from the gas. The process is termed, rather inappropriately, dry-lime purification.

The advantages ensured by this system are,—avoiding the heavy pressure on the retorts, which always exists when wet-lime purifiers are used, in consequence of the gas having to force a passage through a column of water. The residue of dry-lime purification is readily disposed of, being available for agricultural purposes, much used in the formation of compost heaps, and occasionally employed in top dressing; it is also useful as a foundation or substratum for gravel pathways, as it prevents the worms from coming up and disfiguring the walks by heaping up those little spiral coils of earth so distasteful to the gardener. In dry-lime purification no motive power is required, and the odour arising from the residue is not so obnoxious as that from wet-lime purification. These are advantages which have caused this process generally to supersede the other.

The vessels in which the operation is conducted are called purifiers, and consist of two or more vessels acting in conjunction with each other, charged with the hydrate of lime, the gas passing through one or several of these until properly purified.

Dry-lime purifiers are generally rectangular cast-iron vessels, varying from 3 feet to 30 feet square, and from 3 feet to 4 feet 6 inches deep. Sometimes in small works they are made circular; this, however, is not very frequent, and is done for convenience or economy in construction. Each purifier contains a series of perforated shelves, trays, or sieves, supported by suitable bearers of wrought or cast iron, the ends of which are attached to "snuggs" cast on the purifier. In large purifiers there are also pillars placed at intermediate distances to carry the weight of the sieves and purifying material.

The upper part of the purifier is surrounded by a cistern or reservoir of from 6 inches to 24 inches deep, and from 3 inches to 6 inches wide, which is often cast with the purifier and forms part of it, or at other times is attached thereto by bolts and cement, and is for the purpose of containing water to seal the cover. The cover of the purifier is of boiler plate or cast iron, the latter being preferable on account of its durability; but the increased weight is an impediment to its adoption. The rim or border of the cover is rather deeper than the cistern into which it is placed, and is effectually sealed by the water, so preventing the gas escaping from that point.

Often the purifier is divided into two compartments, so that the gas ascends through a set of sieves on the one side, and descends through another set on the other side, answering the purpose of two vessels. In all establishments, however small they may be, two distinct purifiers at least are necessary, to enable the impure lime to be removed from the one whilst the gas is being purified by the other.

The number of purifiers in a work is variable; in the majority of establishments, a set of four is very usual, their dimensions being determined by the capacity of the works—the general calculation when dry lime alone is used being to allow one superficial yard of sieve for every thousand feet of gas produced per diem. Thus, a works producing 50 millions per annum (or a maximum of 220,000 per day) will require four purifiers, each 9 feet square, having six sieves each.

Formerly, the means of changing the passage of the gas to and from the various purifiers, and shutting it off from those vessels, was accomplished by a series of slide-valves attached to the pipes. This plan was exceedingly costly, and was attended with much serious inconvenience. The remedy for this was supplied by Mr. John Malam, whose name is intimately identified with the progress of gas-lighting, and more particularly in connection with the gas-meter. To that gentleman we are indebted for the beautiful modification of the hydraulic valve, by which the gas is received at its first entry into the purifying machinery, made to traverse all the various vessels and pipes in succession, and is at last discharged from thence in almost a pure state, to be stored up in the holder.

The hydraulic valve consists of a cast-iron tank, the diameter and height of which depends on the number and size of pipes connected with the purifiers.

For a set of four purifiers, each being 12 feet square, with 12-inch connection pipes, the tank is about 4 feet 6 inches in diameter, and 3 feet 6 inches deep. In the bottom there are nine holes perforated to permit the pipes to pass freely, and these are attached to the tank by flanges and bolts in the usual manner. The tank has a cover, through which passes a rod working in a stuffing-box, for the purpose of lifting the vessel which regulates the direction of the gas.

Fig. 48 represents a plan of a set of purifiers with hydraulic valve, as constructed by Mr. Walter Mabon, of Manchester. A B C D are the four purifiers (for want of space only part of C and D are shown). The purifiers A and C are inclosed by the covers; those indicated B and D are open, showing the mode of construction and half of the sieves placed ready for receiving the lime. E is the central hydraulic valve, in which meet the various pipes conveying the gas to and from the purifiers; as also the inlet pipe *a* and outlet *o*. The pipes marked 1 3 5 and 7 are the inlet pipes, which convey the gas from the central valve to the respective purifiers; the pipes marked 2 4 6 and 8, convey the gas from the purifiers to the valve.

The vertical pipes in the tank of the valve E are about 18 inches long; and, when in operation, the tank is filled with water to the level of the top of these pipes. In the tank there is a cylindrical vessel, closed at the top, and divided, to within 4 inches of the bottom, into five vertical compartments—*a b c d* and *e*, see Fig. 49. This vessel incloses the nine pipes in such a manner that the inlet and outlet pipes of two separate purifiers are inclosed respectively in the compartments *b c d*. That marked *a* connects the central pipe with the inlet of the first purifier, and the compartment *d* contains the outlet only of the last purifier.

I now propose to trace the progress of the gas from its entrance to its exit to the gas-holder. The tank having been supplied with water, the gas flows by the centre pipe under the cylindrical vessel into the compartment *a*. As it has no means of escape, except by passing down the pipe 1, which leads to the purifier C, it ascends through the layers of lime, and passes down pipe 2 to the cylindrical vessel into the compartment *b*. Here also it can only escape by the pipe 3, and through the lime of purifier A in the direction of the arrows back to compartment *c*, from thence into purifier B, and after traversing the layers of lime, again returns

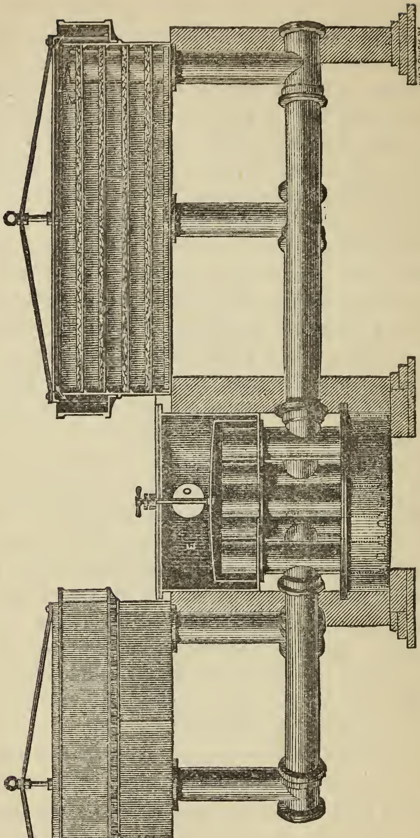


Fig. 47.

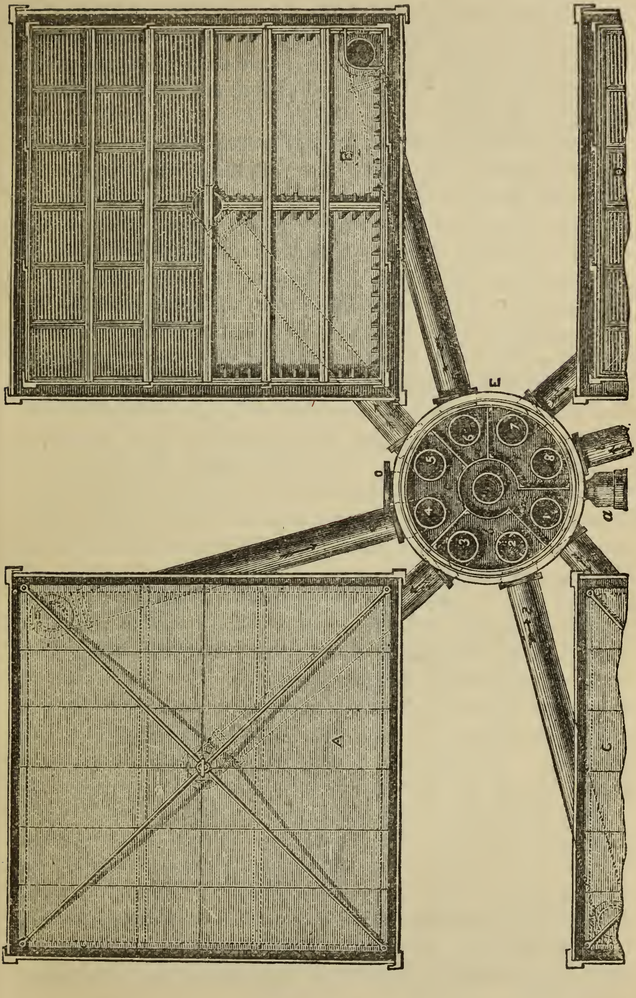


Fig. 48.

to compartment *d*, where there is an opening in the top of the cylinder, through which the gas escapes to the holder by the orifice *o* in side of tank. The compartment *e* contains the inlet and outlet of the purifier D, so that the gas cannot enter therein, and, being out of action, affords the facility of changing the lime.

It will be observed that by this means only three purifiers are in operation, the fourth in the meantime having the foul lime removed and fresh supplied. In order to change the passage of the gas, the cylinder is then raised by the handle of the rod which passes through the stuffing-box until the partitions clear the pipes. It is then turned a fourth of a circle, and allowed to descend into its seat, when the gas first enters the purifier A, from there to B and D, whilst purifier C is thrown out of action for the purpose of changing the lime. By these simple and ingenious means the passage of the gas to and from the purifiers is regulated with the greatest facility.

Fig. 47 represents two of the purifiers just described, —the one in elevation, the other with the front plate removed to show the interior, and a section of the hydraulic valve. There are four sieves for the lime, through which the gas traverses, and, when above the top layer, descends the pipe, as indicated by arrows. The covers of purifiers are strongly stayed, and are lifted by means of a screw or crane. Under the central valve there is a tank, in which stand the pipes; these are open at the bottom; the tank being filled with water prevents the gas escaping. This system has the advantage that no syphons are required to be attended to, and any condensation that may take place in the pipes flows into the tank. The divisions of the cylinder inside the valve are shown in Fig. 49, with the outlet orifice in compartment *d*.

This principle of hydraulic valves is also applicable where there are only two or three purifiers. There is a modification of it manufactured as a slide; and if these are made in a perfect manner they are superior to the hydraulic, inasmuch as when required they can be shifted in an instant, so that no unpurified gas passes, which circumstance always occurs with the hydraulic valve when lifted incidental to changing the position.

On the tops of the purifier covers there should always be valves, or stop-cocks of large dimensions, so as to admit air into the purifier when in the act of raising the covers. Also very small taps with a single jet attached, destined for trying the purity of the gas by means of tests. When the gas is changed from one set of purifiers to the other, the cover of that purifier requiring fresh lime is removed, the waste lime discharged wheeled away, and fresh lime substituted. A very common impression exists, that the lime to be effective should be carefully sifted and reduced to a fine powder; this is erroneous, all that is requisite is to well slacken it; and this done, it should always be moistened to that degree that when pressed in the hand it adheres together in a mass; but if too much wetted it is likely to obstruct the passage of the gas, which should be avoided. A layer of about 2 or 2½ inches thick on the sieves is the most effective.

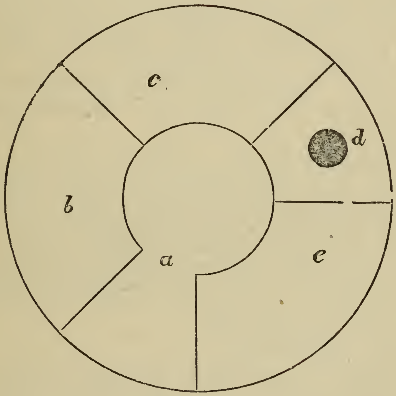


Fig. 49.

On the quality of the lime used will depend the quantity required to purify a given quantity of any particular gas.

Mr. Clegg has fallen into an error in speaking of the qualities of lime best adapted for purification. He rightly gives the preference to that made from the purest limestones, and then observes that the purest lime is obtained from the lias limestones and the lower oolite. Now this is contrary to all received experience, and analysis always shows that the lias limestones, both the white and blue varieties, contain a large per-centage both of alumina and silex. Many of the lias limestones contain as high a per-centage of these foreign ingredients as the septaria, or cement stones, and are, like the septaria, mere argillaceous carbonates of lime. It is, in fact, this union of clay and lime in the same stone which gives to the lias lime its peculiar and valuable hydraulic properties of setting under water, and of setting under all circumstances much more rapidly than the fat or pure limes. The same remarks as to impurity apply in some degree to the lower oolitic limestones, which are all more or less impure, and not nearly so well fitted for the purification of coal gas as the weak chalk limes. I venture to submit the following classification of the best-known limestones of this country, in the order of their purity, and which order also expresses their value for the purpose of purifying gas.

1. The white chalk limestone of Merstham, Dorking, Charlton, Erith, and other parts of the chalk range surrounding the metropolis.
2. The grey chalk limestone, from the lower beds of chalk
3. The blue beds of the upper and middle oolites.
4. The lower, white, and grey limestones of the oolites.
5. The most calcareous and crystalline beds of the carboniferous or mountain limestone, colours grey and bluish.
6. The magnesian limestone of Yorkshire and Derbyshire.
7. The white lias limestone.
8. The blue lias limestone.
9. The Silurian limestones of Wenlock, Dudley, &c., and the coralline limestones of Plymouth and the neighbourhood.

In passing the gas through a succession of either wet or dry lime purifiers, it is important to be able to test the quality of the gas at each stage of the manufacture, in order to determine whether the purifiers are acting properly, to afford a check on the quality of the coal used, and to determine whether it is necessary to turn off one of the purifiers and bring another into work with a charge of fresh lime. The most delicate test for sulphuretted hydrogen is a solution of nitrate of silver in distilled water, made by adding 4 grains of nitrate of silver to 2 ounces of distilled water. The test, however, most commonly used is acetate of lead, made by adding to distilled water as much acetate of lead as it will dissolve. The solution so made may be spread over the surface of a piece of writing-paper with a camel-hair pencil; and when paper so prepared is applied, while the solution is still wet, to a small stream of gas, the shade of colour produced indicates the degree of impurity of the gas. In all works the purifiers should be provided with a stop-cock and a very small single jet burner, so that on turning the stop-cock a minute stream of gas will issue, sufficient to show its quality by the application of the test-paper. The pipe leading into the first purifier is furnished with a similar stop-cock, from which the crude gas issues, when required, before purification. If the test paper be held for a few seconds in front of the small stream of gas containing sulphuretted hydrogen, the paper will be instantly blackened, owing to the union of sulphur with lead, and the consequent formation of proto-sulphide of lead, which is characterised by its black or brownish-black colour. The test varies according to the quantity of sulphide deposited. On applying a fresh surface of the test-paper to the gas from the first purifier, the dark shade is not so intense, as there is less sulphur to combine with the lead, and consequently less of the sulphide is formed. The gas from the second purifier ought to give only a slight shade of colour, while that from the third and last purifier should produce no shade whatever, as it should contain no sulphuretted hydrogen, and therefore produce no decomposition of the acetate of lead. Mr. Clegg recommends that test-paper should be applied every morning to the four descriptions of gas, namely, to the crude gas and to that from each of the three purifiers, and that test-papers should be printed with squares for each kind of gas. The squares should be painted with the solution of acetate of lead immediately before its application to the jet of gas, and the papers preserved as a record of its purity from day to day. Where nitrate of silver is used as a test the shades of colours are produced by a similar decomposition, the metallic silver being in this case deposited on the surface of the paper. The phial in which the nitrate of silver is kept should be coated with tin foil to preserve it from the action of light, which turns the solution black; and if the test-papers are to be preserved, they must for the same reason be kept within the leaves of a book, or otherwise excluded from the light.

The cost of purification by lime is variable; and when practicable, wet lime is the most effective. By these means a bushel of good quick-lime will purify about 20,000 cubic feet of gas; with dry lime only about two-thirds of that quantity will be purified.

Mr. Croll estimated the expense of lime in London at the rate of $\frac{1}{4}d.$ per 1,000 feet. Mr. Barlow's estimate was considerably above this, being ·46*d.* This, with the labour, costing about $\frac{3}{4}d.$ per thousand feet of gas made; but this calculation only holds good in large establishments. The quantity of sulphur present in the coals must also influence considerably the cost of purification.

OXIDE-OF-IRON PURIFICATION

Of late years the oxide of iron has become very generally adopted for the purification of gas. This has not arisen from any superiority of the process, either on the score of economy or effectiveness, but on account of its avoiding that objectionable odour peculiar to lime purification.

The first idea of purifying gas by means of oxide of iron was entertained by Mr. Heard, who had previously been assistant to Mr. Winsor. That gentleman, in 1806, patented a mode of absorbing the sulphur from the gas by mixing lime with the coal in the retort, or by causing the crude gas to pass over lime placed in an iron or other tube and exposed to heat. He also stated that the oxides of iron, zinc, copper, lead, &c., might be used instead of the lime. The admixture of lime with coal in the retorts has recently been tried at some works with the view of depriving the gas of the sulphide of carbon; the result has not been beneficial.

In 1840 Mr. Croll patented the means of freeing gas from sulphuretted hydrogen by causing it to pass through black oxide of manganese, or the oxides of iron or zinc, in powder moistened with water to the same consistency as lime usually employed in the dry process; which materials, after becoming saturated with the impurity, could be again revived by being heated to redness in an oven, and rendered fit for use, so that the same material could be used several times.

By this it appears that the method of purifying now generally adopted was first proposed by Mr. Croll; but on account of the expense, inconvenience, and annoyance of the revivification of the oxide, together with the fact that the system offered no inducement for its adoption, it remained dormant for several years. But as the manufacture of gas increased with such rapidity, so did the nuisance arising from its impurities, giving cause for serious complaints from the public, and it became desirable when gas-works were established in towns and cities to adopt a means of purification that would avoid these evils.

In February, 1849, Mr. Laming patented, in France, a system of purifying gas by means of oxide of iron intermixed with sawdust, which, when saturated with the impurity, was to be exposed to the action of the atmosphere, when it would become revived and again suitable for use—the same material being employed repeatedly. This method, in addition to the economy, possessed the long-desired advantage that very little or no odour emanated from it, which rendered it peculiarly adapted for the majority of gas-works. From circumstances which Mr. Laming has explained from time to time he never applied for a patent for the process in England.

A few months after this, Mr. F. J. Evans, of the Chartered Gas Company, in making experiments with the oxide of iron, accidentally discovered the same principle of revivification of the material when exposed to the air, which he carried practically into operation. And in November of the same year, Mr. Hills obtained a patent, wherein he claimed the repeated renovating or re-oxidising the oxide of iron by the action of air whenever it ceased to absorb the sulphuretted hydrogen, so that the same material might be used over and over again to purify the gas; being substantially the same method as that patented previously by Mr. Laming in France

It is generally admitted by gas engineers, that for the purpose of extracting the sulphuretted hydrogen and carbonic acid, no other system of purification hitherto adopted has equalled the wet-lime or cream-of-lime process. But the intolerable nuisance arising from the residue (technically called "blue billy") is such as to prevent, in many localities, the use of wet-lime purification.

In using the oxide of iron for purification, it is generally intermixed with sawdust, slightly moistened, and placed in the dry-lime purifiers in layers similar to the lime, but of greatly increased thickness; and when it ceases to absorb the impurity, is withdrawn and placed on a paved floor for the purpose of re-oxidation, requiring to be repeatedly turned over and sometimes broken up, so as to expose it to the influence of the atmosphere. Considerable labour is incurred in this, which is compensated by the slight expense of material.

This means of purification removes effectively the sulphuretted hydrogen and cyanogen; but for abstracting carbonic acid, lime must be employed, and, when used after the oxide purifiers, little odour arises from it.

In this method of purifying, the oxide of iron and the sulphuretted hydrogen are both decomposed, the oxygen of the former uniting with the hydrogen, and the sulphur and iron combining to form sulphuret of iron. When the impure material is withdrawn from the purifiers, and exposed to the atmosphere, it liberates a portion of its sulphur, and absorbs oxygen, to form again the oxide of iron; the other portion of the sulphur, being precipitated, combining with the iron. At each revivification the deposit of sulphur is increased, and when it forms about 35 per cent. of the mass, the oxide is no longer serviceable as a purifying agent.

When the oxide of iron is fresh, when withdrawn from the purifier and exposed to the air, it is very liable to ignite. The general mode is to mix a portion of old material with the new in order to prevent this casualty. For the purpose of avoiding the labour in changing the purifying material, it has been proposed to exhaust a portion (about 2 per cent.) of atmospheric air in with the gas, so that its oxygen would revive the purifying material. But if this were practicable, and in such a manner as effectually to absorb all the oxygen, it is certain that the nitrogen of the air would detract from the illuminating power of the gas.

CHAPTER XII.

VARIOUS MODES OF PURIFYING GAS.—THE FIRST MEANS OF PURIFYING GAS.—MR. CROLL'S PROCESS OF SEPARATING AMMONIA.—PURIFYING WITH NEUTRAL SALTS.—MR. LAMING'S PROCESS.—REV. MR. BOWDITCH'S PROCESS.

THE first attempts at purification of gas were by means of lime in the states of solution, hydrate, powder, or heated. After this, numerous other processes were tried, as potash, coke, salt (solid or in solution), various acids, chlorides, alkaline solutions, heath wood, steam, ignited charcoal, and red-hot tubes, and were all patented from time to time as purifying agents. From the abstract of the various specifications, it does not appear that the intention was to profit by the impurities in gas, but merely to remove them, and when we reflect on the value of the ammonia and other residues derived from coal in the manufacture of gas at the present time, we must admire the progress chemistry has made to render these available.

Formerly ammonia was obtained principally from Egypt, where it was produced from the dung of camels and other animals; however, the high price caused its use in any shape to be very limited; but of late years, in consequence of the facilities afforded by gas-works for its production, the use of ammonia in the arts and manufactures has become very extensive, and modern chemistry has demonstrated the vast importance of this compound to agriculture, in which it is largely employed.

MR. CROLL'S PROCESS FOR SEPARATING AMMONIA.

Probably Mr. Croll has been the most extensive manufacturer of ammonia in this country. This originated from a patent obtained by him for the purpose of removing the ammonia from gas, and retaining it in a liquid state as a marketable commodity, so that it could be transported any reasonable distance for the purpose of manufacture. Previously it was very commonly permitted to flow with the liquid of the washer away into the sewer, causing great annoyance, in addition to the waste.

By Mr. Croll's process the gas, after leaving the condenser, is caused to traverse a suitable vessel, which is charged with a weak solution of sulphuric acid, or the chloride of manganese, by which means the ammonia is absorbed from the gas, leaving a valuable compound. The former, when evaporated, producing the sulphate of ammonia, is in large demand as a fertilising agent; the latter, producing chloride of ammonia, or sal ammoniac, is much used in the arts and manufactures, and from it other compounds of ammonia can be obtained. The vessel used is generally circular in form, about 10 feet in diameter and 3 feet deep. The bottom of this is formed by a circle with wooden ribs or radiating bars 8 or 10 inches in depth: this wooden circle completely occupies the bottom of the vessel, and supports a leaden plate 10 inches less in diameter than the vessel, so that a space of 5 inches is left all round it. Diluted sulphuric acid, consisting of 2½ lbs. of acid to 100 gallons of water, are then poured into the vessel up to the height of the leaden plate. The gas to be purified is conducted therein by a pipe which passes through the leaden plate and dips into the acid solution, the divisions by which the plate is supported completely separating and subdividing the gas, so as to bring each portion of it in contact with the solution of acid. By degrees, as the acid becomes neutralised, a regular supply of it is kept up by means of a small reservoir placed outside, from which the acid is allowed to drop or trickle into a funnel, and conveyed by a

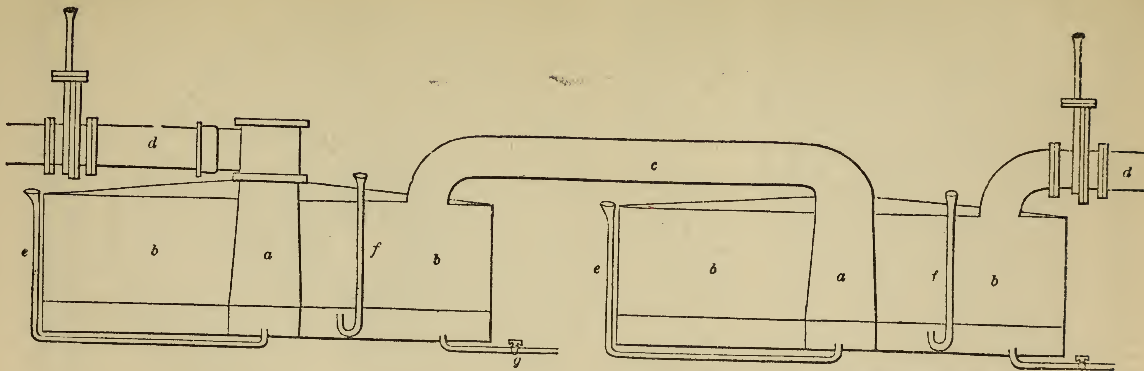


Fig. 50.

small tube down the side of the vessel, and brought in under the leaden plate, as shown in the woodcut, Fig. 50.

The vessel is furnished with another pipe for conveying away the gas to the lime-purifiers, with a small tube for adding supplies of water, and with a discharging-pipe and stop-cock. The original proportion of acid is kept up as nearly as possible until the solution attains, when tried by the hydrometer, a specific gravity of 1,170, which is nearly the point of crystallisation. The supply of acid is then discontinued, the liquor retained in the vessel, and the gas again passed through until the solution becomes neutral, when it is drawn off and evaporated, and yields a pure sulphate of ammonia.

In large works it is preferable to use two vessels for separating the ammonia, in order to insure with more certainty the entire abstraction of all the ammonia, since the gas passing twice through the dilute acid will be better purified than

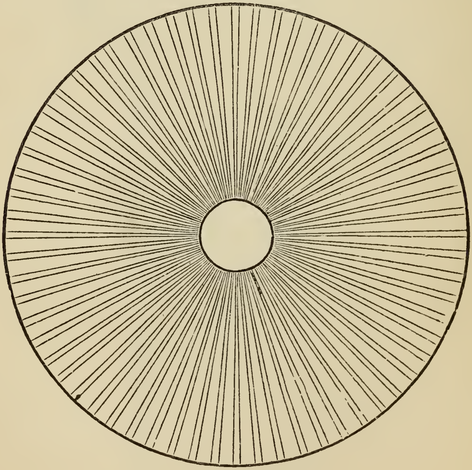


Fig. 51.

if only treated in one vessel, where there may have been an accidental or temporary deficiency of acid. Two vessels of the size here described—namely, 10 feet diameter and 3 feet deep —will purify 500,000 feet of gas in twenty-four hours, and will require to be charged with the acid solution once in two days.

Figs. 50 and 51 show the arrangement made use of by Mr. Croll for purifying the gas. Fig. 50 is a section of one of the vessels, each 10 feet diameter and 3 feet deep. *a* is the inlet-pipe, passing nearly to the bottom of the vessel; *b* is the circular purifying vessel, lined with lead, in order to withstand the action of the acid: the bottom of this vessel is composed of a series of radiating plates of wood, shown in Fig. 51, standing about 8 or 10 inches above the bottom. On the top of these radiating bars of wood rests the leaden dash-plate, as already described. *c* is the pipe leading from one purifying vessel to another, and *d* is the pipe by which the gas makes its exit; *e e* are the pipes, provided with funnels, by which the sulphuric acid is added; *f f* are the pipes for the supply of water, and *g g* are the pipes by which the liquid sulphate of ammonia is drawn off.

The neutral liquor drawn off from the vessels yields on evaporation 80 ounces of sulphate of ammonia per gallon, instead of the 14 ounces per gallon yielded by the ammoniacal liquor separated in the condenser.

This description of the purifying process is taken from a paper by Mr. Croll, read before the Institution of Civil Engineers some years ago. At that time diluted sulphuric acid appears to have been the contemplated purifying medium. The patent, however, also included the use or substitution of metallic solutions.

An impression has been entertained by agriculturists that in consequence of the abstraction of ammonia before the gas enters the dry-lime purifier, the waste or spent lime will be deprived of much of its useful effect, hitherto supposed to be due to the presence of ammonia. Mr. Croll, however, contends that the refuse of dry lime as at present sold by the Gas Companies consists merely of sulphate, carbonate, and cyanuret of lime, all the ammonia being lost by volatilisation long before the lime can possibly be delivered from the works; hence he believes that the refuse lime possesses precisely the same valuable properties as a fertiliser, while the noxious exhalations which accompany the escape of ammonia on the opening of the purifiers are entirely avoided.

The saturated liquor drawn from the purifying vessels after being evaporated leaves sulphate of ammonia in great purity, the quantity of ammonia being equal to 30 parts in 100. The fertilising power of this sulphate is very considerable; and has been attested by numerous agriculturists. It is said, when used as a top dressing on grass lands, to have added half a ton of hay per acre to the produce, and in wheat crops to have increased the weight of the wheat so much as to add considerably to its selling price. About 1 cwt. per acre is said to be a profitable dressing either for wheat or grass land. The manufacture of sulphate of ammonia at the various gas-works is becoming of considerable importance: many tons are already produced weekly from those works where this and other processes are introduced. When an increased production of this valuable article takes place also, the agriculturist will be further benefited by a reduction of price, as in the case of sal ammoniac and carbonate of ammonia, the price of which was formerly 3*s*. per pound, while, since the increase of gas-lighting, and the consequent production in large quantities of ammoniacal liquor, a superior quality of sal ammoniac is sold for one-sixth of that price.

It has been asserted that by this process the rich hydro-carbons are deposited and the gas deteriorated, which circumstance would in reality take place if there were to be an excess of sulphuric acid, but with a weak solution as indicated, the ammonia is effectually removed and the illuminating power of the gas not injured. This method, either as described, or the solution of acid being pumped into the scrubbers, is employed at many works, and amongst them, some of the largest of the Metropolis.

PURIFICATION BY MEANS OF NEUTRAL SALTS.

Recently, Mr. Croll has patented a mode of purifying gas by means of neutral salts, which are combined in a concentrated form at a high temperature; with wood saw-dust, breeze, tan, or other slightly absorbent and cellular matter, and employing such mixture after being allowed to cool in an ordinary purifying apparatus. The salts preferred for the purpose are the sulphate of alumina, the chloride or sulphate of zinc, or the chloride or sulphate of iron or manganese.

This process is in course of trial at several works, where it is highly spoken of, partly for its economy, but more particularly on account of the increased illuminating power of gas when so purified, this increase, according to authentic reports, being equal to 10 per cent.

MR. LAMING'S PROCESS OF PURIFICATION.

A method of purifying gas, patented by Mr. Richard Laming, and which has been adopted by several of the large Gas Companies, will now claim our attention.

This gentleman professes to proceed in a manner analogous to that in which the circulating fluids of the human body are purified. He observes, that the blood in circulating through every part of the system absorbs and carries to the various excretory organs certain superfluous quantities of organic matter, which are required to be expelled from the body. For example, the blood delivers over to the kidneys the two elements of ammonia and those of various acids; and it conveys to the lungs a quantity of carbon, which is there brought into contact with the inspired atmospheric air, and combining with its oxygen is expired in the form of carbonic acid. The blood thus purified from its carbon is again propelled by the action of the heart to the remotest parts of the body, and again becoming loaded with impurities, discharges them by means of the excretory organs, and so the alternate process goes on during the whole period of animal existence.

Mr. Laming practises a somewhat analogous process, by passing the gas through a material which absorbs both its carbonic acid and its sulphuretted hydrogen; and the compounds so formed, when again exposed to the atmosphere, so as to combine with more oxygen, are again converted into a material fit for purification, and may thus be used over and over again in the purifying vessels.

It has long been known, that when gas is passed through ordinary quick-lime, the carbonic acid combines with the lime, and forms carbonate of lime. It is also known, that when gas is passed through either of the sesquioxides of iron, the sulphuretted hydrogen is decomposed, some of the sulphur combining with the iron, and forming sulphuret of iron. Now Mr. Laming, in his method of purification, mixes the quick-lime with the oxide of iron, diffusing the whole through saw-dust or breeze, and hence obtains in his purifying vessel the double compound of carbonate of lime and sulphuret of iron. When this compound is formed, the covers of the purifiers are removed, and the mixture exposed to the oxygen of the air, when the following effects take place. 1st. The carbonic acid, having a very feeble affinity for the lime, quits it, and combining with the iron and with another atom of oxygen forms *carbonate of iron.* 2ndly. The sulphur leaves the sulphuret of iron, and combining with oxygen to form sulphuric acid, unites with the lime, and becomes ordinary *sulphate of lime.* The carbonic acid very soon passes off from the carbonate of iron, which becomes again the oxide, while the sulphate of lime remains unchanged. The sulphate of lime and the oxide of iron are then again placed in the purifiers, and the same changes take place when the gas again passes through the mixture. It will be observed from this description, that the new and important addition which has been made is that of the sulphuric acid, which is formed from the sulphur of the gas combined with the oxygen of the atmosphere. Mr. Laming, however, observes, that instead of waiting for this spontaneous formation of sulphuric acid, it may advantageously be added at the beginning of the operation, or its place may be temporarily supplied by any other acid which is capable of combining with lime, and of being separated from it at ordinary temperatures by carbonate of ammonia.

The principle then of Mr. Laming's purification is the use of sulphate of lime in a state of intimate combination with oxide of iron. Mr. Laming states that muriate of lime, when it can be conveniently procured, will do equally well with the sulphate.

The inventor sums up the account of his process by describing it as based upon a certain set of known affinities, by the influence of which the greatest impurity of the gas, namely, its sulphur, is converted into sulphuric acid, and then combined with the next greatest impurity, namely, the ammonia; while the carbonic acid, which is inodorous, is made to escape into the atmosphere, and is thus got rid of without expense.

In this mode of purification the sulphate of lime is decomposed by the ammonia of the gas, and converted into sulphate of ammonia, which salt accumulates in the mass of used material till it becomes inconvenient, when it is removed by solution. Mr. Laming states in conclusion that his process also removes from the gas its cyanogen and its sulphuret of carbon, which latter is a very injurious compound, and has hitherto very much retarded the admission of gas into private dwellings. The inventor also attributes an excellent effect to the suppression of lime, which is supposed to injure the illuminating powers of coal-gas by its alkaline re-action on the hydrocarbons.

THE REV. MR. BOWDITCH'S SYSTEM OF PURIFICATION.

Great difficulty has been experienced for some years to find an economical and effective means of removing the bisulphide of carbon from gas; and there can be no doubt that this impurity has been increased through the high heats and protracted distillation often adopted in the use of clay retorts, giving rise to many serious complaints on the part of the public.

The process adopted by the Rev. Mr. Bowditch, of Wakefield, is very ingenious. By this, the gas is caused to pass through a layer of hydrate of lime, heated to between 300° and 400° Fahr., when the bisulphide of carbon is decomposed and resolved into carbonic acid and sulphuretted hydrogen, which are removed with facility by the ordinary means of purification. This system has been adopted at several provincial works, and Dr. Frankland's opinion of it is highly satisfactory; that gentleman has stated, that gas so purified does not contain more than 2 or 3 grains of sulphur in the 100 feet of gas. But, according to other good authority, the process is injurious to the illuminating power of the gas, on account of the hydrocarbons being deposed.

Report speaks highly of a method for removing the bisulphide of carbon, adopted by Mr. Leigh, chemist of the Manchester Gas Company. The process is not yet made public, but shortly a description of it may be anticipated, and should it be equal to expectations, will be alike beneficial to Gas Companies and the public.

CHAPTER XIII.

THE GASHOLDER.— CAST-IRON TANKS.— SPECIFICATION OF CAST-IRON TANKS.—MR. STEVENSON'S MODE OF CONSTRUCTING TANKS.—BRICK TANKS.—SPECIFICATIONS OF TANK OF IMPERIAL GAS COMPANY.—A SINGLE LIFT HOLDER.— SPECIFICATION OF HOLDERS.— TELESCOPIC HOLDER AT IMPERIAL STATION, HACKNEY.

THE next subject for consideration is that of the gasholders, or vessels in which the gas is stored ready for delivery into the mains which distribute it throughout the districts to be lighted. These vessels were originally termed gasometers, which name is sometimes even now applied to them, but as they have nothing whatever to do with the measurement of gas, but are mere vessels of capacity or stores, the simple name of gasholder is more expressive and appropriate.

The gasholder is composed of two distinct parts, one of which contains water, and is called the tank, the other is the vessel which contains the gas, being really the gasholder. On the Continent the former is very generally termed the "cistern," and the latter the "bell."

The tank is a large cylindrical vessel, constructed usually, for the sake of economy, of brickwork or masonry, but when the ground is marshy, or when water exists abundantly a short distance below the surface of the earth, which would prevent the construction in masonry at a moderate price, then tanks are made in cast-iron, and, indeed, in small works, are often of wrought iron. In the interior of the tank there are two vertical pipes for the admission and egress of the gas, called the inlet and outlet pipes; the former being in direct communication with the manufacturing apparatus; the latter with the mains which convey the gas to the town. These pipes rise a few inches above the level of the top of the tank, so that the water cannot overflow into them. A series of columns, generally of cast-iron, but sometimes of wood, or brick piers, are placed at equal distances around the tank for the purpose of guiding the holder.

The holder is a cylindrical vessel closed at the top, which is termed the roof, and open at the bottom, made of sheet iron, varying in thickness according to the dimensions of the apparatus, the smaller sizes being constructed of thin material in order to avoid an excess of pressure, whilst those of very large dimensions are made of stout plates for the purpose of obtaining sufficient pressure to expel the gas to the burners. The holder is somewhat less in diameter, but of the same depth as the tank in which it is placed, sometimes being partially suspended by chains which pass over grooved pulleys and counter-balance weights, but more frequently only guided by rollers attached around its lower and upper edges, which work against suitable guides in the tank and on the columns in such a manner as to permit the holder to ascend and descend in the tank with the greatest freedom.

The action of the gasholder is very simple. The tank being filled with water and the holder immersed therein ready for use, there is a space between the surface of the water and the roof of the holder; the gas enters by the inlet pipe into this space, and with the force it acquires in being expelled from the coal pressing on the surface of the water and underneath the roof, and over the whole area of both, causes the holder to rise. Thus, by its own force or pressure, the gas provides room for itself, and in proportion to the quantity entering so does the holder rise out of the water. For instance, a holder having 100 feet area, or about 11 feet 4 inches diameter, in rising 10 feet will receive 1,000 cubic feet of gas, and in descending, the same quantity would be expelled.

Gasholders, although often suspended, are never entirely counterbalanced, having always sufficient weight to give the necessary pressure to force the gas through the mains and burners; and should be so constructed that when the holder is full or at its greatest height, its lower edge will be so far under the water as to prevent the possibility of escape of gas.

The water in the tank serves three purposes; it is the means of resistance for the gas to lift the holder, it prevents the gas escaping or intermixing with the atmosphere, and is the means of expelling the gas when the holder descends.

CAST-IRON TANKS.

When the tank is made of cast-iron the pieces of which it is composed are usually plates about 5 feet long and 3 feet deep, having flanges all round them of 2 or 3 inches wide. The flanges are cast with holes from 6 to 8 inches apart to receive the bolts used for fixing the plates together. The thickness of the plates vary according to the dimensions of the tank for which they are destined; in large tanks, from 80 to 150 feet in diameter, the bottom is formed of plates varying from $1\frac{1}{2}$ to 1 inch thick, and the side plates vary from $1\frac{1}{8}$ to 1 inch thick for the bottom tiers, and from $\frac{3}{4}$ to to $\frac{5}{8}$ inch thick for the top tiers. The plates for smaller tanks are thinner than those stated; for a tank 25 feet diameter and 10 feet deep, they are not required thicker than $\frac{5}{8}$ inch for the bottom and lower tier of sides, and $\frac{1}{2}$ inch or less for the top tier. In all cases it is essential to place iron bands or hoops around the exterior, which are made secure with cotters.

Iron tanks are made of various sizes up to 150 feet in diameter, but seldom more than 25 feet deep. The columns for guiding the holder are generally attached to brick piers by means of holding-down bolts built in the piers. On other occasions, for small holders, brackets for carrying the columns are cast on the tank, but these should always be supported by brick piers.

When cast-iron tanks are erected they require a suitable foundation of concrete, which should be made perfectly level and the bottom plates securely embedded in mortar. Sometimes baulks of timber, placed transversely, are used instead of concrete; but as these are likely to be destroyed by rot, concrete is decidedly preferable.

The flanges of the bottom plates are always cast so as to be on the inside of the tank, which gives great facility for bolting and caulking the joints. The flanges of the sides are generally on the outside, but sometimes, for the sake of appearance, are placed inside the tank, which is, however, very injudicious, for in this case, in the event of a plate breaking, or a joint leaking, after the holder is in operation, it is very difficult to repair.

The introduction of tanks or cisterns formed of cast-iron plates to hold water can scarcely be said to have its origin in gas-works, as the iron troughs or waterways constructed as aqueducts for carrying the water of canals over roads and valleys probably afforded the first examples of the use of iron for such a purpose. Cast-iron aqueducts were common on the canals executed by the late Mr. Telford and Mr. Rennie some time before iron tanks were used in gas-works.*

The following abstract of a specification in Mr. Clegg's "Treatise on Gas Lighting," and specification extracted from the "Journal of Gas Lighting" hereafter inserted, will convey to the reader the mode of constructing cast-iron tanks.

Specification for a Cast-iron Tank 101 *feet in diameter inside exclusive of the flanges.*

"The flanges of the bottom plates to be on the inside, and the others on the outside, the whole of them to project $3\frac{1}{4}$ inches at the least; the bottom of the tank to be 1 inch thick throughout, excepting the outside row of plates, and the row next to it. The outside row to be $1\frac{1}{4}$ inch thick, and the next row to diminish in thickness from $1\frac{1}{4}$ to 1 inch;

* The cast-iron aqueduct which carries the Shrewsbury Canal across the valley of the Tern, at Long Mill, is 186 feet in length. The Pont-y-Cysylte aqueduct on the Ellesmere and Chester Canal is a far more stupendous concern, the cast-iron trough which carries the canal being 988 feet long by 20 feet wide and 6 feet deep. Both these works were executed by Mr. Telford in the beginning of the present century.

the centre plate to be $1\frac{1}{2}$ inch thick; the first tier of side-plates to be $1\frac{1}{4}$ inch, the second $1\frac{1}{4}$ inch, the third $1\frac{1}{8}$ inch, the fourth 1 inch, and the fifth or top tier 1 inch thick, each of the side-plates to be of such a width as to allow of seventy-five in the circumference, each plate to be 4 feet $6\frac{1}{2}$ inches deep, and each tier of plates to be numbered on the casting of them, such numbers to be 1, 2, 3, 4, and 5, beginning at the bottom tier.

"The tank to be bound together with five wrought-iron hoops, each hoop to be 5 inches wide and $1\frac{1}{4}$ inch thick, the tank to be bolted together with full 1 inch bolts, and not more than 7 inches asunder from centre to centre of each bolt, and to be properly cemented together with iron cement; a flange column to be fixed on the centre plate of the tank so as to support the roof of the gasholder when down. The plates of the tank, exclusive of the bolts, cement, hoops, and centre column, to weigh 350 tons."

In cases where it becomes necessary to resort to the use of iron in the construction of tanks, an excellent and economical plan has been adopted by Mr. G. W. Stevenson, of Halifax, by which he entirely dispenses with the bottom plates of the tank, thus saving nearly one-half the metal that would otherwise be required.

The excavation having been made in the usual way, a bed of hydraulic concrete, 18 inches to 24 inches thick, according to circumstances, is laid over the whole of the bottom, and upon this at the outer edge is placed a circle of strong stone kerb to carry the side plates of tank.

The bottom tier of plates has a flange cast on the outside of each plate, which fits loosely into a corresponding groove cut into the stone kerb. After all the bottom plates have been fixed in the groove, the whole of the space between the kerb and plates, as well as the groove, is run quite full with pure cement. As a final precaution against the passage of water, an additional body of concrete is placed on that originally laid down, and close to the face and overlapping the top of the stone kerb.

Where good strong clay can be obtained, the same plan may be adopted in puddle, and Mr. Stevenson has so applied it in tanks upwards of 100 feet in diameter. The cost of a tank, especially of large size, constructed in this manner, is considerably less than when made entirely with iron sides and bottom. It is obvious that this method could be adopted in various ways to suit circumstances, and the material to be employed.

Annular or ring tanks have sometimes, but rarely, been constructed. These, when of cast-iron, consist of two cylinders placed concentric to each other, the space between them being the receptacle for the water and the holder, the bottom of course being plated. A tank of this kind was made for the Brick-lane station of the Chartered Gas Company, and for the Bristol and Clifton Company. A similar tank in masonry, of about 150 feet in diameter, was constructed by Mr. John Manby, in Paris, thirteen years ago, but the expense of this class of construction in nearly all cases prevents the system being adopted.

BRICK TANKS.

When the nature of the ground permits of the tanks being constructed in brickwork or masonry, they are sunk to a considerable depth, so that the top rises about 1 foot 6 inches or 2 feet above the level of the ground; but in some cases, where water prevents the excavation being carried sufficiently deep, tanks of brick or masonry are made to project as much as 6 feet or 8 feet above the level of the surface. When this occurs, they must be remarkably well constructed and of increased thickness; also, for greater security, the part projecting above the ground should be bound with one or more iron hoops, similar to those employed in cast-iron tanks.

Generally the whole of the ground in the centre of the tank is removed, leaving the bottom level; and when puddle can be procured at a moderate cost, the whole surface of flooring of the intended tank should have a layer of about 24 inches of that material, well tempered and trampled down before commencing the building: this, as well as the puddle at the back of walls, to be considered in the dimensions of the excavation.

The thickness of brickwork or masonry for a tank must depend entirely on its size and depth. Small tanks—on account of not having the same column of water to resist against—require walls of less thickness than those of large dimensions. Under ordinary circumstances, for a tank of 37 feet diameter and 16 feet deep, the base of footings should be $3\frac{1}{2}$ bricks wide, with offsets on the outside for 5 or 6 courses, when the wall of tank commences, which should be $2\frac{1}{2}$ bricks thick at bottom, diminishing by two offsets on the outside to $1\frac{1}{2}$ brick thick at top, terminating with a stone coping, or, when strict economy is necessary, a coping of brick on edge.

For a tank 100 feet diameter, and 25 feet deep, the walls should be 4 bricks thick at bottom, diminishing to $2\frac{1}{2}$ bricks at top; the footings being 6 bricks wide at base, gradually diminishing, as before stated, to the course where the wall commences. The bottom of the tank should be worked in with the upper courses of the footings. Piers will also have to be carried up from the footings in order to receive the holding-down bolts by which the cast-iron guide columns are secured.

The nature of the ground, and the material employed, will of course essentially influence a decision as to the thickness of brickwork required in any particular case, also whether concrete be necessary in the foundations. The dimensions above given may frequently require to be exceeded, while very few cases will occur in which it would be safe to diminish them. The whole of the brickwork should be carried up either in Roman cement, or in the very best hydraulic mortar, such as that made from the lias limestone of Aberthaw, Southam, &c. Most of the common mortars when in contact with water will dissolve by degrees, become soft, and in time the joints will be emptied, and the destructive power of the water will soon show itself on the brickwork; therefore cement or hydraulic mortar must be employed. The duration of a tank will materially depend on the perfection of the brick-work, and the complete resistance of the mortar joints is of the utmost importance. It is usually recommended to put in the puddle behind the wall in a more fluid state than it is generally used for canal embankments, dykes, and other hydraulic works, in order that the more compressible part may enter into the pores of the brickwork and form a more complete union with it. The puddle should be used in thin layers of 6 or 9 inches, well cut up, and well worked with water, and trodden down in the usual way. The best material for puddle is not pure clay, which is apt to crack, but clay with a portion of sand or silt, free from stones or other hard masses, and especially free from vegetable fibre of every kind, which would in time decay and leave hollows. The thickness at base of wall above the footings may be 2 feet, diminishing to 1 foot at top. In carrying up the brick-work of the tank, the space between the puddle and the solid ground will become wider, and this must be carefully filled in with earth well rammed in thin courses, corresponding with the progress of the wall. When stone is abundant, tanks can be constructed economically with blocks of about the size of large paving-stones, built in hydraulic mortar, backed with rubble masonry, the walls being rather thicker than when built of brick; a perfectly sound tank can be so constructed without puddle.

The interior of the tank is sometimes flat, at others a mound, cone, or dome is left in the centre. When the ground presents no difficulty, it is cheaper to make the centre nearly flat; but should the foundations be under water, then the mound in the centre has an advantage, as it avoids excavating, concreting, or puddling under water.

But in some localities neither puddle nor bricks are to be obtained, when recourse must be had to the building material of the country, and this, in some of the islands of the Mediterranean and elsewhere, consists almost entirely of freestone, which serves alike for walls, roofs, and often flooring, thus replacing bricks, tiles, and boarding. In such places a more suitable material for gasholder tanks can only be procured at a most extravagant cost; nevertheless, even with this material, a good and sound tank can be constructed without the aid of puddle.

For this object the stone is obtained in suitable blocks, and faced to the required curve, the foundation or flooring being composed of concrete; the wall is built with Roman or

Portland cement, &c., well backed with rubble and hydraulic mortar. When the tank is finished, and allowed to dry, all the interior is well coated with good thick tar, which stops all the pores of the stone.

A natural production from Italy, called Puzzolano, resembling in appearance, when in powder, the red oxide of manganese, is very excellent for rendering ordinary lime hydraulic. Previously to being used, it should be ground to a powder, and mixed in the proportion of one of puzzolano, to three or four of lime slacked, and the corresponding quantity of sand, to be made into mortar. Foundations of concrete with this mixture set under water in a few days, and become as hard as any cement. Puzzolano was used in the construction of Eddystone Lighthouse; but, although much employed on the Continent, it is seldom adopted in England.

The following is a specification, extracted from Mr. Clegg's "Treatise on Gas Lighting," of a brick tank 31 feet 6 inches diameter :—

"*Excavation.*—The ground to be dug out to the depth of 14 feet 6 inches, of such diameter as may be requisite, with such slopes to the sides as will prevent them from slipping in. Should any part show a tendency to slip, it must be immediately shored, and the shores must be maintained so as not to interfere with the building of the walls. The excavation must be kept clear of water till the gasholder is fixed and the scaffolding removed. Well-tempered clay puddle of approved quality to be used for the covering of the bottom of the tank, and for coating the outside of the side walls, in the following thicknesses,—over the bottom of the tank, 2 feet 6 inches; on the side walls, 2 feet 6 inches, reduced to 1 foot 6 inches at the top; the whole to be well trodden in and backed up as finished."

"*Brickwork.*—The bricks to be hard, well-burnt stocks; the whole of the mortar must be of the best hydraulic lime and sharp river sand, well mixed, and thoroughly worked together, and in the proportions of a third lime to two-thirds sand. Two double courses of footings with sets off—of half a brick for each double course; the remaining portion of the wall to be divided into two parts—one 8 feet 6 inches high, and

2 bricks thick, and the other 3 feet 6 inches; the walls to be 1½ brick thick, the last or top six courses to be laid in the best Roman cement; the whole work to be grouted with its respective mortar or cement every four courses. The tank to form a perfectly true circle, neither more nor less than 31 feet 6 inches in diameter in any direction. Seven piers to be built equidistant around the circumference to receive seven stones hereafter described. One pier to be built outside on the main point of suspension, with dry well of 9 inches work of 2 feet 6 inches in diameter, and 3 feet 6 inches deep, for counterbalance weights. Two of the piers to be built at the secondary points of suspension; in these piers holding-down bolts and plates to be built in and run in with Roman cement. Three other piers are also to be formed by carrying up the two-course brickwork in the wall solid to the top for 2 feet 6 inches in width."

"*Masonry.*—Seven squared and tooled stones to be set in cement, 2 feet by 1 foot 6 inches by 6 inches, for inside piers, in which there must be formed holes for six lock nuts; also three stones, 24 inches by 27 inches by 4 inches thick, for the hold-fasts for the girder rods. One square and tooled stone for the cap of the main pier 6 feet by 2 feet by 1 foot, with a portion cut out to allow the balance weight to pass, and holes for the foundation bolts, and cases for the foundation bolts and case of columns. At each of the two secondary points, also squared and tooled stone caps, 3 feet by 2 feet 6 inches and 1 foot thick, with holes for the foundation bolts and case of columns."

According to the same authority, the following is the estimated cost of a tank 36 feet diameter and 12 feet deep.

		£	s.	d.
752⅔	cubic yards of excavation at 1*s*.	37	12	8
107	ditto of puddling, at 1*s*. 6*d*.	8	0	6
246	superficial feet of York flagging under wall, 1*s*. 9*d*.	21	10	6
5½	rods of brickwork and mortar, at £12 10*s*. .	68	15	0
119	cubic yards of puddling and filling in behind wall, 1*s*. 6*d*.	8	18	6
30	cubic feet of Bramley fall stone for base of tripods, 4*s*. 3*d*.	6	7	6
374	cubic yards of earth carted away at 2*s*. 2*d*. .	37	1	10
		£188	6	6

The foregoing details of estimate will serve as a guide of the cost in the construction of a brick tank of moderate dimensions, but when of very great magnitude and depth, the price of some of the items will require augmentation.

One of the most remarkable constructions of this kind is the tank built at the Pancras station of the Imperial Gas Company. The excavation is entirely in London clay, and it was originally intended by the engineer, Mr. Methven, only to build the circular wall, leaving the centre without either masonry or any other protection, relying entirely on the clay in the middle to retain the water. But, on excavating to the depth of about 35 feet, it was found that the soil became of a loamy nature, which rendered it necessary, as a matter of precaution, to cover the lower part of the cone to the height of about 20 feet with three or four courses of brickwork, the upper part, as well as the top of the cone, being clay only. Although of such extraordinary depth and dimensions, the tank is perfectly tight and secure. Herewith is subjoined an abstract from the specification :—

Specification of Brick Tank, 145 *feet diameter and* 45 *feet deep, constructed at the Imperial Gas Company's Works, Pancras Station.*

"The tank, when finished, to be a perfect cylinder of 145 feet internal diameter, and 55 feet deep; the top of coping of tank to be 4 feet above the present surface level.

"The earth to be excavated for the foundation of the wall around the entire circumference of the tank to the depth of 53 feet from the present surface level. The ground to be shored when the excavation shall have reached the depth of 6 feet from the surface, and this shoring to consist of 3-inch planks, placed close to each other around the entire excavation, with strong walling pieces and struts.

"When the wall shall have been completed, the earth in the centre of the tank to be removed to the extent shown on sectional drawing, leaving a cone 6 feet less in diameter at the base than the interior of the tank, and to taper at such an angle as that, at the depth of 15 feet below the finished height of the wall, the cone shall be 30 feet diameter.

"*Brickwork.*—The first eight courses of tank wall and piers to be set in Roman cement. The first, second, third, and fourth double courses of footings to be respectively 5 feet, 4 feet 8 inches, 4 feet $4\frac{1}{2}$ inches, and 4 feet in thickness. The seventh course to commence the net-work of that portion of the wall, which will be 3 feet 7 inches, or $4\frac{1}{2}$ bricks in the thickness, to the height of 10 feet above footings. The remaining height of wall to be reduced as follows, viz.: from 10 feet to 20 feet from bottom of net brickwork to be four bricks thick; from 20 feet to 30 feet in height three and a half bricks; from 30 feet to 45 feet three bricks; from 45 feet to 50 feet two and a half bricks in thickness; and the remaining 4 feet, exclusive of coping, to be two bricks thick.

"There will be sixteen piers, 4 feet 3 inches wide, for the support of cast-iron columns, and built up with the wall.

"Six courses of brickwork in every 5 feet of height, as also the three finishing courses, and the corresponding courses in piers to be set in cement. The brickwork at no part to be carried higher than 5 feet, until the circle up to that level shall have been completed, and properly tempered puddle filled in behind the wall.

"A cast-iron plate and holding-down bolts to be built into each of the piers 10 feet below the level of the coping. The standpipe well to be a true cylinder 15 feet in diameter, the foundation of which will be 63 feet deep from the level of the coping of the tank; the bottom to be perfectly level, and paved with three courses of bricks on edge and set in cement; the footings of the wall to start from the same level as the deepest portion of the wall of tank to and from an integral portion of the same.

"There are to be thirty-two piers of brickwork built in the bottom of the tank for the foundation of rest-stones, the same to form part of the general footings of the tank, each pier to be capped with a stone, a recess of $4\frac{1}{2}$ inches to be left in the face of the tank wall for the insertion of these stones.

"*Stonework.*—In addition to the stones above mentioned, there will be required blocks of stone, 18 inches by 12 by 12 inches, to be inserted in the wall of the tank opposite to and at points equidistant from each pier at the height shown in drawing.

"There are also to be sixteen stones 5 feet square and 18 inches thick to cap piers for the support of the guide columns of the holder. In each of these, four holes are to be pierced for the holding-down bolts. The wall of tank to be surmounted by a coping 12 inches thick, to be bedded in cement. The whole of the stones to be Greenmore or Bramleyfall description.

"*Timber-framing.*—For the support of the roof of the gasholder when down, a wooden frame to be constructed in the manner shown in drawings; the piles, to be not less than 12 inches by 12 inches square, of suitable lengths, and iron shod, are required to be driven into the cone, and to these piles will be attached radiating and circular timbers as shown. The radiating timbers to be let into the top of the piles and properly fastened by $\frac{3}{4}$-inch bolts; the circular timbers to be properly scarfed, let into those radiating from the centre, and firmly secured by wrought-iron knees and spikes.

"*Material.*—The bricks employed on the work to be of the best hard-burnt stocks. The mortar to be composed of one part of fresh burnt lias lime, to three parts of clear, sharp river sand. The Roman cement to be fresh burnt, and gauged in equal proportions with sand as above, the cement to be mixed as it is being used, and no more mortar than sufficient for one day's work to be made at one time.

"The contractor to supply all materials of every description here specified, and to provide all scaffolding, struts, and shoring which may be required, the same to remain his property when the work is terminated.

"*Pumping.*—The contractor, during the progress of the work, to find the necessary pumps and labour to keep the tank dry; to employ competent men to watch at all times, and strut or shore up any signs of slip or yielding of the earth, and to make good at his own cost any damages whatever which may occur from rain or otherwise.

"All superfluous earth or clay, not required for filling in or puddling, to be carted away at the expense of contractor. The puddle to be kept constantly well moistened, and not to be at any point less than 18 inches in thickness, and the earth to be firmly pounded in behind as the brickwork proceeds.

"*Extra Work.*—No extra work to be allowed but such as shall be ordered in writing by the company's engineer, and addressed either to the contractor or his clerk of the works.

"*Terms of Tender.*—The proposed contractor to state the sum for which he will execute the work herein specified according to its true intent and meaning connected with the drawings."

This tank completed cost upwards of £11,000.

ON THE GASHOLDER, OR HOLDER.

There are two kinds of gasholders; the one called the single lift, consisting simply of a cylindrical vessel in the tank as already described and represented in Fig. 52, which has a quarter part removed to show one of the pipes, and the manner the roof is supported. The stand-pipe well is shown in section, with one of the two pipes and syphon at the bottom. The holder is about 42 feet in diameter, and 16 feet deep, and has six cast-iron columns, which serve for guides for the rollers on top of holder, attached to each other at the top by cast-iron girders.

The holder, when raised by the action of the gas, has very little strain upon it, and only when empty, or when it touches the ground, do the roof and sides require any support. For this object roofs are sustained generally by "trussing." This trussing consist of a series of radiating bars of T or flat bar iron, diverging at equal distances from the centre plate, called the "crown plate," to the angle iron or top curb, or angle of the holder. The roof is sustained by a king-post in the centre, which is supported by tension rods from the top curb; there are also suspension rods which carry struts for sustaining the centre of radiating bars. A series of circles of rafters attached to the radiating bars complete the trussing of roof. The sides in large holders have also trussing to prevent the holder "bulging" or "buckling" when on the ground.

In holders of great dimensions the trussing enters for a large portion of the expense; in addition it greatly increases the

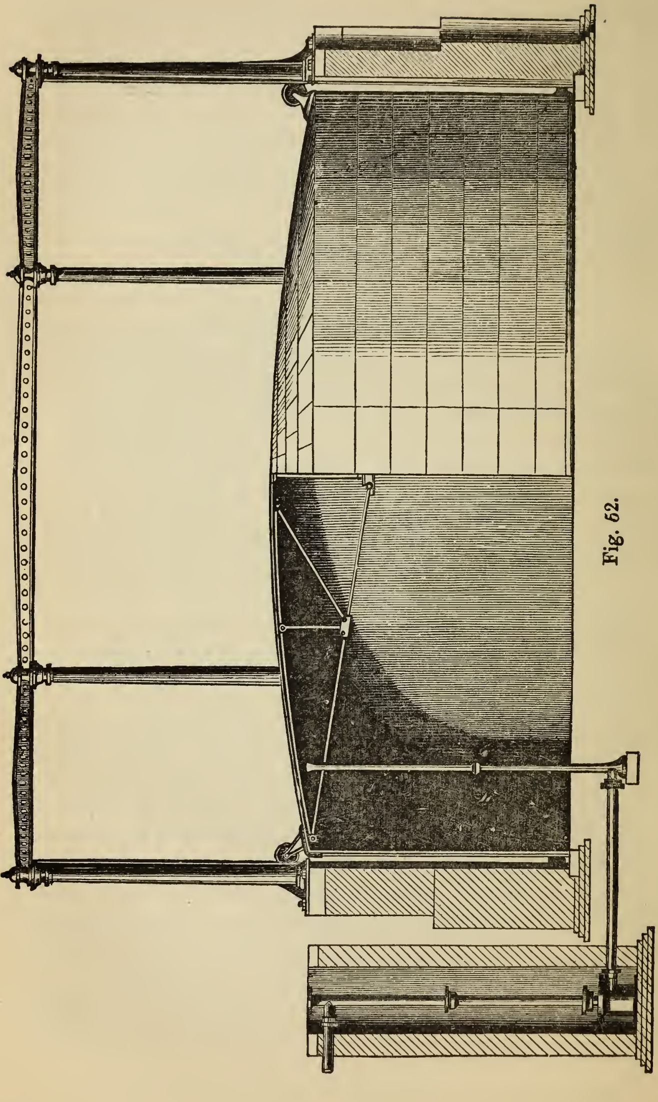


Fig. 52.

weight, and, in consequence, the pressure, which is often by no means desirable. It is a very important consideration in the erection of gasholders, to adjust them so that the pressure of the gas enclosed in them be not much more than the maximum pressure required to supply the town or locality. Whenever an exhauster is not employed, any excess of pressure acts seriously on the retorts, causing a large increase in the carbonaceous deposit in them, the gas being in consequence deteriorated; the fuel and labour are also increased, and the production of gas materially diminished; and even when the exhauster is used, any superfluous pressure on the holder throws unnecessary labour on the engine, and of course requires more fuel.

When holders are suspended by counterbalance weights, the excess of pressure can generally be considerably reduced by placing extra weights, and in many small works, where the holder is not suspended, the loss is of importance. Therefore all small holders, particularly when there is no exhauster, should be counterbalanced in such a manner as to be enabled to give the maximum pressure required in the locality, but no more.

Gas engineers are not unanimous in opinion as to the necessity of trussing the roofs of holders. The majority adhere to the old system of trussing, whilst others dispense with it entirely. In that case, when the holder is empty, or on the ground, its roof is supported by a series of vertical props or pillars with radiating bars in the tank, as described in the specification of Imperial Company's tank. Without doubt this system has several advantages, being simpler, cheaper, and possessing the same durability as when trussed.

A gasholder 100 feet diameter and 25 feet deep, when trussed, weighs about 100 tons, and gives a pressure of about $5\frac{1}{2}$ inches of water, and of this weight about 30 tons consist of trussing. Now, if we suppose a pressure of 3 inches to be adequate to supply a district, it is obvious the extra pressure must be prejudicial. In this case, if the trussing were dispensed with, the holder would be so much lighter as to give only the 3 inches pressure desired, whilst its strength and durability would be retained.

We may, however, assume the pressure of $5\frac{1}{2}$ inches actually necessary in order to supply a given district, when the weight would be indispensable, and under these circumstances it would be certainly wiser to obtain the increased weight by increasing the thickness of the plates of the holder, thereby rendering it of much greater durability, instead of applying the material as trussing. Many eminent engineers now prefer the roofs of gasholders without trussing, and this opinion is gaining ground daily.

The thickness of plates commonly used in the construction of gasholders varies from No. 18 to No. 11 wire gauge, the first of these being less than $\frac{1}{20}$th of an inch in thickness, weighing 1·86 lbs. per square foot, while the other is $\frac{1}{8}$th of an inch, and weighs 5 lbs. per foot. In very large holders plates are considerably thicker than these, in order to obtain the necessary pressure for supplying the district.

The pressure of gas enclosed is dependent on the total weight of the holder containing it, and on the area of its top. The water in the tank being the resisting medium to the pressure, a quantity of this, equal in weight to that of the holder, is always displaced by the latter rising. Thus, by a knowledge of the pressure given by a holder, and the area of the top of vessel, a close approximation of its weight may be ascertained; and, on the contrary, the weight and area being given, the pressure is readily known.

For this, and many similar purposes, the weight of a cubic foot of water is the basis of calculation, this being $62\frac{1}{2}$ lbs.; therefore a column of water exactly 1 foot square and 12 inches high, is equal to $62\frac{1}{2}$ lbs., or a column of same area, 3 inches high, 15·625 lbs., or 1 inch high, 5·24 lbs., &c.

If, therefore, it be required to ascertain the weight of a holder giving a certain pressure, say 3 inches when full, and the sides nearly out of the water, then, on multiplying the area of the top in feet by the weight corresponding to a column of water of the height of pressure, the weight is ascertained. For example, a holder is 11 feet 4 inches in diameter, its area being 100 feet, giving 3 inches pressure, then 100 multiplied by 15·625 lbs. gives $1{,}562\frac{1}{2}$ lbs. as the total weight of holder. Or, the weight being given, the pressure is calculated by dividing the total weight by the area in feet, when the weight of a square foot is found, from which the pressure the holder will give is known, thus reversing the figures just mentioned; 1,562½ lbs. divided by 100 feet gives 15·625 lbs., corresponding to a column of water 3 inches high or that pressure.

By the same means, if it be requisite to know the weight required to be placed on a holder to produce a certain increased pressure, then the weight of column of desired pressure multiplied by the area of top of holder in feet gives the weight. Thus, if the pressure of the before-mentioned holder requires to be augmented say 1 inch, that is, from 3 inches to 4 inches, then the weight of a column of 1 inch being 5·24 lbs. multiplied by the area of top, gives 524 lbs. as the necessary weight. These calculations are approximative; for them to be rigidly exact, the holder should be filled with air, or an allowance made for the specific gravity of the gas. The same rule applies to the weight of governors, pressure registers, &c.

When a holder is nearly at the bottom, and its side plates immersed in water, it becomes somewhat lighter, and in consequence the pressure is less than when it is full and the sides out of the water. Many attempts have been made to remedy this, but the difference is so slight, being 2 or 3 tenths, as to render any means to prevent it quite unnecessary.

Mr. Clegg gives an example of a gasholder 36 feet in diameter and 12 feet deep, made of No. 18 wire gauge for the sides, and No. 17 for the top; total weight of gasholder, 6 tons 5 cwt. 2 qrs. 21 lbs.; tripods, or columns and guide rods, 5 tons 2 cwt. 1 qr. 21 lbs. Total cost of gasholder, including erection, £247 10*s*.

Another example is a gasholder 50 feet diameter and 18 feet deep, containing 35,300 feet; top, No. 14 wire gauge; sides, No. 15 ditto; total weight of gasholder, 12 tons 18 cwt. 2 qrs. 27 lbs.; tripods and guide rods, 11 tons 6 cwt. 3 qrs. Cost, including erection, £541 2*s*.

Another instance is a gasholder 87½ feet diameter and 25 feet high, which cost, including erection, £1,609 10*s*.

The gasholder erected by the Imperial Company for the tank already mentioned, being 142 feet diameter and 55 feet deep, cost nearly £8,000.

The following specifications will, no doubt, be of interest to the generality of readers.

Specification for a Single Lift Gasholder, 40 feet diameter and 15 feet deep.

" *Crown Plate.*—The crown or centre plate of roof of gasholder to be 3 feet 5 inches in diameter, and $\frac{3}{8}$ inch thick, with twelve bolt-holes for receiving the bolts to secure the ends of main bars.

" *Centre Pipe and Truss Cup.*—The centre pipe for trussing to be of cast iron, 4 inches diameter and 6 feet long, the upper end secured to the crown plate with four $\frac{3}{4}$-inch bolts. At the lower end of the centre pipe is to be secured a cast-iron truss cup 2 feet 6 inches diameter, the outer rim of which is to have twelve holes for receiving the ends of tension rods.

" *Main Bars.*—To be twelve main bars of ⊤ iron, $2\frac{1}{2}$ inches $\times$ $2\frac{1}{2}$ inches $\times$ $\frac{3}{8}$ inch; the upper ends of which are to be secured to the crown plate with 1-inch bolts and nuts; the lower ends secured to the top curb; four of the main bars to be prepared at the lower end for securing to both the top curb and also to a vertical stay.

" *Trussing.*—Each main bar to be trussed in the manner shown on diagram; the tension rods to be $\frac{3}{4}$ inch diameter, enlarged at the screw end to 1 inch diameter; the suspension rods to be $\frac{5}{8}$ inch diameter, the upper end formed into a jaw, and secured to the main bar with a $\frac{5}{8}$-inch bolt, the lower end formed into an eye through which the strut will pass; the strut to be $1\frac{1}{4}$ inch diameter, the upper end formed into a jaw and secured to the main bar with a $\frac{5}{8}$-inch bolt, the lower end to be screwed and secured to the tension rods and suspension rods, with two nuts on each.

" *Vertical Stays.*—To be four vertical stays for supporting the sides of the gasholder, of ⊤ iron 3 inches $\times$ $2\frac{1}{2}$ inches $\times$ $\frac{3}{8}$ inch, the upper end connected with the top curb and main bars, and the lower end to be secured to the bottom curb with $\frac{1}{2}$-inch bolts.

"*Top Curb.*—The top curb to be of angle iron 3 inches × 3 inches × $\frac{3}{8}$ inch, curved to a radius of 20 feet, and neatly jointed and secured with proper joint plates.

"*Bracket Bars or Purlins.*—To be three rows of bracket bars or purlins, bolted between the main bars with $\frac{1}{2}$-inch bolts. The first row to be of angle iron 2 inches × 2 inches × $\frac{1}{4}$ inch; the second row to be of angle iron 2 inches × 2 inches × $\frac{1}{4}$ inch; the third row to be of angle iron $2\frac{1}{4}$ inches × $2\frac{1}{4}$ inches × $\frac{5}{16}$ inch.

"*Bottom Curb.*—The bottom curb to be of angle iron 3 inches × 3 inches × $\frac{3}{8}$ inch, curved to a radius of 20 feet, and neatly jointed and secured with proper joint plates.

"*Sheets.*—The roof to be covered with sheets No. 14 Birmingham wire gauge in thickness, and the sides with sheets of the following thicknesses, viz., the top and bottom rows to be No. 14 Birmingham wire gauge, and the remainder of side sheets to be No. 15 Birmingham wire gauge in thickness.

"*Manhole.*—To be one manhole ring, with cover and set-screw, placed in a suitable position on the roof.

"*Rivets, &c.*—The rivets for the sheets to be $\frac{1}{4}$ inch diameter, and 1 inch apart from centre to centre. The rivets for the top curve to be $\frac{1}{2}$ inch diameter, and $1\frac{1}{2}$ inch apart. The rivets for the bottom curve to be $\frac{1}{2}$ inch diameter, and 6 inches apart. The joints of the sheet to have a hemp-string inserted during the time of riveting. Each sheet to be hammered perfectly level before being punched. They are then to receive one coat of linseed oil before being exposed to the weather.

"*Painting.*—The whole of the before-mentioned work to receive two coats of oxide paint in oil during or immediately after erection.

"*Columns.*—To be four cast-iron columns, each 17 feet long, 9 inches diameter at the bottom, and 7 inches diameter at the top; a guide rib to be cast on for the gasholder pulleys to work against; the base to have three holes for bolts.

"*Holding-down Bolts.*—Each column to be secured to the stone-work of tank with three holding-down bolts about

7 feet long × $1\frac{1}{4}$ inch diameter, with cast-iron foundation washers, cotters, nuts, and washers.

"*Guides in Tank.*—Four cast-iron guides in tank for the gasholder pulleys to work against, each guide secured to tank wall with six $\frac{3}{4}$-inch bat bolts run with lead.

"*Girders.*—The top of columns to be connected together with a girder of T iron 3 inches × 4 inches × $\frac{1}{2}$ inch, each trussed with a $\frac{3}{4}$-inch rod and a 1-inch strut; each end of the T iron to be secured to column cap with a $\frac{3}{4}$-inch bolt.

"*Pulleys.*—On each column cap is to be a set of pulleys and fixings for the balance chains to work over.

"*Chains.*—Four sets of $\frac{1}{2}$-inch chains with pins and shackles for carrying balance weights.

"*Balance Weights.*—To supply 40 cwt. of cast-iron balance weights to regulate the working pressure of the gasholder.

"*Pulleys.*—Four sets of pulleys and fixings on top, and four sets of pulleys and fixings on bottom of gasholder, to work up columns and tank guides.

"*Painting.*—The whole of the cast-iron work to receive one coat of oil paint before leaving the works.

"*Scaffolding.*—To supply all necessary scaffolding and tackle for the erection of gasholder, columns, &c., and to fix the whole in a good and workmanlike manner."

The price of this complete, delivered and fixed in London, would be about £296.

Specification of Apparatus, consisting of Gasholder, Condenser, Purifiers, Roof for Retort House, Retorts complete, with accessories for a small works.

"Gasholder to be 35 feet in diameter and 12 feet deep at sides, the centre plate to be 3 feet 6 inches diameter, and $\frac{3}{8}$ths of an inch thick. The crown sheets to be of No. 15 Birmingham wire gauge, and the sides No. 16 ditto, and to be of the best Staffordshire plates. The top and bottom curbs to be of 3-inch angle iron. To have four main bars of 3-inch T iron, four secondary bars of 3-inch T iron. The centre pin to be of $1\frac{1}{2}$-inch iron attached to cast-iron cup. To have four tension rods of 1-inch iron, from centre cup to angle iron, opposite to each column. Eight rollers and frames to be fixed on bottom curb of gasholder at equal distances. Four sets of guide wheels, carriages, and frames, to be properly fitted and fixed, and four suspension chains, with 3 tons of counterbalance weights.

"To provide four cast-iron columns 13 feet 6 inches long, 6 inches diameter at bottom, and $5\frac{1}{2}$ inches at top, with guide rib cast thereon, each to be fastened to pier by four holding-down bolts of 1-inch round iron, and 4 feet long, and to be screwed at one end with nuts. To provide and fix before tank walls are commenced two 4-inch duck's-foot bends; two 4-inch tank syphons, and two flange and spigot pipes, and sufficient socket pipes for inlets and outlets, which are to be fixed when required.

"The gasholder to have two coats of paint before leaving the contractor's works, and to be fixed at the Company's premises, left perfectly gas-tight, and finished in a workman-like manner.

"To provide three cast-iron purifiers, to be 4 feet square internally, and 2 feet 6 inches deep, with 9-inch dips. Three covers for purifiers of No. 8 gauge plate, with lifting tackle and chains complete. The purifiers to be worked by a centre valve so as to allow two purifiers to be used at one time. There are to be four tiers of perforated iron sieves in each purifier to be supported by T iron rafters, the whole to be finished and left in complete working order.

"To provide a cast-iron condensing box, with divisions, and ten 4-inch pipes each 9 feet long; four semi-circular bends, each 1 foot 9 inches long, having suitable bonnets; also to provide sufficient 4-inch pipes to make the connection between the condenser and gasholder, with two 4-inch valves.

"To provide and erect an iron roof 24 feet × 24 feet in the clear for retort house, to consist of four pairs of principal rafters, to be made of T iron properly trussed with wrought iron laths to support slates, and a wrought-iron louvre for ventilation.

"Also to provide and erect the undermentioned castings and iron-work :—

"Six cast-iron D retorts, 7 feet 6 inches long, $15\frac{1}{2} \times 13\frac{1}{2}$ internal measure.

"Six cast-iron mouth-pieces with sockets for same.

"Twelve wrought-iron doors for mouth-pieces.

"Six cast-iron 4-inch flange and spigot ascension pipes.

"Six cast-iron 4-inch H pipes and bonnets.

"Six cast-iron 4-inch dip-pipes.

"Hydraulic main (12 feet) with cover and end plates, to be D shaped, 12 inches by 12 inches, with three cast-iron crutches.

"Six cross bars, screw ears, and cotters.

"Three evaporating pans.

"Three furnace doors and frames.

"Three dead plates and furnace bars.

"Ten cast-iron buckstaves, and the corresponding wrought-iron tie rods screwed at ends.

"Nine sight-boxes and plugs; to provide and fix the pipes to communicate the various apparatus together.

"Set of stoking tools, one iron barrow, one wooden barrow.

"All the above work to be fixed complete within thirteen weeks from day of order, and the whole to be done in a manner satisfactory to the engineer of the company."

The price of this apparatus was £845.

Specification for the Construction of a Gasholder for the Imperial Gas Company at their Pancras Station.

"To be a single gasholder, 142 feet in diameter and 55 feet deep, constructed in a tank 145 feet in diameter.

"The roof to be without trussing or framework, as shown in drawing, and when finished the crown in centre to rise 2 feet above the level of top curb. The top curb to be a circular chamber or girder, in section nearly rectangular, being 18 inches deep at the outer diameter, and $19\frac{1}{4}$ inches at the inner diameter, and 2 feet 6 inches in width. The curb to be constructed of 4-inch $\times$ 4-inch $\times$ $\frac{1}{2}$-inch angle iron; the under and inner sides to be of $\frac{3}{8}$-inch wrought-iron plates, riveted to angle iron with $\frac{5}{8}$-inch rivets. The top to be of $\frac{3}{8}$-inch plates, which will also form the first or outer row of plates of roof; the other side to be $\frac{1}{4}$-inch plates, and will be the top tier of the side of holder.

"The bottom curb to be formed of two circles of $\frac{3}{8}$ boiler-plates 12 inches wide, each riveted to a circle of angle iron 4 inches × 4 inches × $\frac{1}{2}$ inch. One of these to be riveted to the bottom of the $\frac{1}{4}$-inch plate, which forms the lowest tier of side of holder, the other circle to be riveted to the same 12 inches higher up than the former. Two stiffening plates at distances of 2 feet apart are to be inserted between the curb plates at 32 points of the circumference of the gasholder, where the bottom guide-rollers will be attached. These stiffening plates to be fixed to the curb plates and the bottom plates of the holder by $2\frac{1}{2}$-inch × $2\frac{1}{2}$-inch × $\frac{3}{8}$-inch angle iron, riveted with $\frac{1}{2}$-inch rivets, the plates to be $\frac{3}{8}$ inch thick. The angle iron and plates forming the bottom curbs to be butt-jointed with lapping pieces of the same thickness not less than 18 inches long.

"The vertical stays to be in section three sides of a rectangular figure 12 inches wide and 10 inches deep, to be formed of four angle irons 3 inches × 3 inches × $\frac{3}{8}$-inch and $\frac{1}{4}$-inch boiler plate. There will be thirty-two vertical stays, which will be riveted to top and bottom curbs, and to the plates forming the holder.

"The first or outside row of plates of roof to be 3 feet long, and $\frac{3}{8}$ inch thick, riveted to the angle iron of top curb and to each other with $\frac{5}{8}$-inch rivets, $2\frac{1}{2}$ inches apart; the second row of plates to be also 3 feet long and $\frac{1}{4}$ inch thick, riveted to the outer row and to each other by $\frac{9}{16}$ rivets, $2\frac{1}{2}$ inches apart. The remainder of the plates of the roof, except those forming a circle of 30 feet diameter in the centre, to be $\frac{3}{16}$ inch thick, or of No. 7 wire gauge, to be about 5 feet long, and riveted to each other by $\frac{3}{8}$-inch rivets $1\frac{1}{4}$ inch apart. The plates in the centre to the diameter of 30 feet to be $\frac{1}{4}$ inch thick, to be butted together and riveted to each other by means of lapping pieces $3\frac{1}{2}$ inches wide, and $\frac{9}{16}$-inch rivets.

"The top and bottom side plates to be $\frac{1}{4}$ inch thick and riveted to the angle irons of top and bottom curbs with

$\frac{9}{16}$-inch rivets, and to each other and adjoining plates with $\frac{1}{2}$-inch rivets $1\frac{1}{2}$ inch apart. The intervening plates to be No. 10 wire gauge riveted to each other with $\frac{3}{8}$-inch rivets $1\frac{1}{4}$ inch apart.

"There are to be 16 guide pulleys fitted on carriages on top of gasholder, each pulley to be 15 inches diameter, with flanges projecting 4 inches. Each carriage to be bolted to both angle irons of the top curb, also to that on the side of gasholder, by eight 1-inch bolts. There are also to be 32 guide rollers and carriages fitted to both angle irons of bottom curb by six 1-inch bolts.

"There are to be 16 guide columns and girders of the pattern shown in drawings; the columns to be 3 feet diameter at base, diminishing to 2 feet 3 inches under the capital, the thickness of metal not to be more than $\frac{7}{8}$ inch at base, and $\frac{3}{4}$ inch at top; each column to be cast in not more than four lengths, which will be fitted together by internal flanges, the different lengths to be faced true and bolted together by eight $1\frac{1}{4}$-inch bolts. The girders to be bolted to upper side of abacus of column with $1\frac{1}{8}$-inch bolts, and to the entablature with a similar number of bolts. The entablature to be bolted in a like manner to the abacus of column.

"There are to be 64 holding-down bolts of $2\frac{1}{4}$-inch round iron, each 10 feet long from the underside of nut to the top of cotter on the square end.

"All joints of the gasholder to be well coated with red paint both inside and outside, so soon as riveted. The whole of the plates to have, before oxidation shall have taken place, a coat of oil in the following proportions, viz., one part of the best boiled linseed oil, one part of raw linseed oil, and one part of the best turpentine well mixed together.

"The whole of the plates to be of the best Staffordshire quality, free from sand-holes, cracks, blisters, or any other imperfection. The angle iron to be of S G or B B H marks, all rivets and bolts to be made from S C iron. The cast iron to be cold blast, and good, sound, clean castings.

"The contractor to deliver the gasholder terminated and ready for use within nine months from the date of the Company's order, under a penalty of £25 for every week that the completion of the gasholder may be deferred beyond that time.

"The contractor is required to provide all scaffolding, hoisting tackle, &c., necessary for the completion of the work in a manner satisfactory to the Company's engineer.

"Should the work not be conducted to the satisfaction of the Company's engineer, and after notice in writing has been given by him to that effect, to the contractor, in the event of no alteration or improvement being made within 24 hours of the delivery of such notice, the Company shall have full power to employ any number of men and use materials necessary for the completion of the work by the time specified. All expense or loss incurred by the Company in such proceedings, to be borne by the contractor, and to be deducted from any sum which the Company may have in hand of the amount of his contract.

"The contractor to state in his tender the price per ton for wrought and cast iron separately, for which he will construct the gasholder according to this specification. Also a sum for which he will complete the whole without reference to weight, the quality and quantity of iron to be used as herein specified."

TELESCOPIC GASHOLDERS.

When ground is very expensive, telescopic gasholders, which are capable of storing nearly two or three times more gas in a given area than can be done by the single holder just described, are very generally used.

The telescopic gasholder consists of an ordinary single holder surrounded by a cylinder of sheet-iron, similar to the side of holder, and of about the same height. These are both immersed in the same tank, the depth of which is equal to that of the holder or surrounding cylinder. By an ingenious contrivance, the gas entering causes the holder to rise, and when full lifts with it the cylinder, elongating like the tubes of a telescope, from whence it derives its name. To effect this, on the bottom, extending around the holder, there is an annular cup formed by T iron and plates, represented in section by *a b c d* (fig. 53), which, in rising, is filled with water as shown, and is called the water lute. The surrounding cylinder is about 14 to 18 inches larger in diameter than the holder, and is furnished with a similar annular cup (*fe*), but inverted, called the "grip," and when the holder rises to the top, the inverted cup "grips" or hooks into the water lute of the holder, hermetically sealing the two vessels together, on the same principle as seen in the system of purifiers, where a means of preventing the gas from escaping from the cistern around is adopted. The holder in rising lifts with it the cylindrical vessel or "lift," the two reaching a height nearly the double of the depth of the tank. Sometimes there are two cylinders or "lifts," when the storage is increased nearly three-fold for the same area, as compared with the single holder.

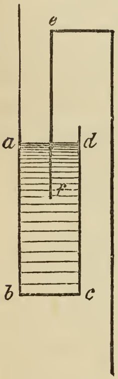


Fig. 53.

In order to insure the proper working of the two vessels together, it is usual to fix on the upper edge of the lower cylinder a series of friction-rollers, the periphery of which presses on the inner vessel, serving to make the motion uniform and to preserve the shape of both cylinders. These friction-rollers are usually from 4 to 6 inches in diameter, about 4 inches broad, and placed 8 or 9 feet apart all round the circumference of the lower vessel. The tank is usually kept full of water, to within an inch of the top. The water lutes vary in depth from 9 to 18 inches, according to circumstances.

It is very essential in telescopic gasholders that the lifts should be partially counterbalanced by suitable weights and chains, otherwise the pressure is very excessive and irregular, on account of the great weight of water in the lute. The counterbalance weights also assist in the regular and effective working of the lifts; but in large holders this is not so important as in those of small dimensions.

But although telescopic gasholders possess advantages where space is difficult to obtain, they should never be fixed where ground is to be had at a moderate price, for in the depth of winter, when a sharp frost sets in, and causes the water in the lutes to freeze, they are excessively troublesome, and require constant attention to break the ice of the lutes in order to prevent an accident. Sometimes, through neglect of this precaution, holders have been disabled and rendered useless.

Another evil with telescopic gasholders is, that when erected near the sea-shore, in a few years the action of the atmosphere destroys the plates in immediate proximity to the lute. It sometimes occurs that there is a leak in the lute, and, in consequence, often a great loss of gas is sustained. Where possible single lift holders should always be employed.

Amongst the largest telescopic gasholders is that of the Imperial Company at Hackney Station, the tank of which is 204 feet diameter, and 41 feet 6 inches deep. The upper lift is 199 feet diameter, the outer lift being 201 feet; when full the holder is 80 feet high, and contains 2,500,000 cubic feet of gas. This holder is supported and guarded by 24 cast-iron columns, each about 76 feet long, 3 feet 1 inch diameter at bottom, and 2 feet 6 inches at top. Each column is surmounted on a handsome pedestal of about 6 feet high, and weighing five tons. Two ornamental girders, curved to the circle, the one placed midway, the other at top of columns, attach the columns together, and a noble capital on each finishes the column. The cost of tank and holder complete was about £41,000.

This is perhaps the finest specimen of gas engineering as applied to holders in existence, and I should have been happy to possess further details in connection with its construction, so to give them a place here. When full, the gas it contains weighs upwards of 35 tons; a balloon of the same capacity, filled with ordinary gas, would carry at least 500 grown persons.

The following is a specification of a cast-iron tank and telescopic holder, extracted from the "Journal of Gas Lighting."

"*Specification of an Iron Tank and Gasholder.*

"*Cast-iron Tank.* — One cast-iron tank of 101 feet diameter, and $22\frac{1}{2}$ feet depth, both inside measure and exclusive of the flanges. The flanges to the bottom to be on the inside, the others on the outside, and the whole of them to project $3\frac{1}{4}$ inches at the least. The bottom is to be 1 inch thick throughout, excepting the outside row of plates and the row next to it; the outside row to be $1\frac{1}{4}$ inch thick, and the next row to diminish in thickness from $1\frac{1}{4}$ to 1 inch. The centre plate is to be $1\frac{1}{2}$ inch thick. The first tier of side plates is to be $1\frac{1}{4}$ inch, the second $1\frac{1}{4}$, and the third $1\frac{1}{8}$ inch, the fourth 1 inch, and the fifth or top tier 1 inch thick. Each of the side plates is to be of such a width as to allow of 75 in the circumference; each plate to be 4 feet $6\frac{1}{2}$ inches deep; and each tier of plates is to be numbered in the casting of them, such numbers to be 1, 2, 3, 4, 5, beginning at the bottom tier.

"The tank is to be bound together by five wrought-iron hoops, which are to be fixed as shown in the drawings, each hoop to be 5 inches wide and $1\frac{1}{4}$ inch thick.

"The tank is to be bolted together with full 1-inch bolts of wrought-iron, not more than 7 inches asunder from centre to centre of each bolt, and properly cemented together with iron cement. A flange column is to be fixed on the centre plate of the tank so as to support the roof of the gasholder when down, and to be of the height and dimensions shown in the drawings. The plates of the tanks, exclusive of the bolts, cement, hoops, and centre column, to weigh   tons; and all to be delivered, and the tank to be erected agreeably to drawings, and to the satisfaction of the committee of management of the company or their engineer, for a sum to be fixed, free of any other charge whatsoever, unless the aggregate weight of the plates shall exceed or be less than six tons of the estimate above stated, in which case the price to be charged or deducted is to be after the rate of £   per ton. The company is, however, to pay for nothing beyond the said excess of six tons, and should the deficiency be more than the six tons, then the company is to be allowed from the price to be paid for the tank after the rate of £20 per ton, for such deficiency, whatever it may be.

"Each of the plates and castings is to be numbered and marked on the inside with its own weight with white-lead paint. The company is to provide good and proper brick or stone foundations, and keep out water; but the contractor is to find and use the necessary materials for scaffolding, also all pulley blocks and falls, and every other material that may be required in erecting and completing the tank.

"The whole of the plates and materials for the tank are to be delivered, and the tank is to be erected complete, on or before the end of thirteen weeks after notice shall have been sent in writing to the contractor from the company, either by hand or by post, that the foundations for the tank are sufficiently prepared for him to begin his work.

"Should the tank not be completed as above stated, then the contractor is to be subject to a fine, to be reserved from his account, of £50 per week from the date at which it is agreed that the tank shall be completed; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the tank without being liable to the contractor for payment, either for the plates delivered or such part of the works as he may already have executed.

"*Hydraulic-room, two* 18-*inch Valves, and six* 18-*inch Quarter Bends.*—One circular hydraulic room with a bottom and top, to be 12 feet diameter and 18 feet deep inside measure, and $\frac{7}{8}$ths of an inch thick throughout, with the requisite flanges. The flanges to the bottom are to be on the inside, and all the others on the outside. The whole to be fixed together with $\frac{3}{4}$-inch bolts fixed in the same manner as in the tank, and completed according to the plan and dimensions described in the drawings.

"Two 18-inch pneumatic lifting-valves, and six 18-inch quarter bends, to be cast agreeably to drawings, and the said valves are to be fitted ready for use. The contractor, on failing to deliver and complete the said hydraulic-room, valves, and bends, to the satisfaction of the committee of management or their engineer, on or before the expiration of the above notice, referring to the tank, is to be subject to a penalty, to be subtracted from his account, of £100; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the said hydraulic-room, valves, and bends, without being liable to the contractor, either for the castings delivered, or for such part of the said hydraulic-room, valves, and bends as he may have already executed.

"*Gasholder.*—One circular gasholder to be made of the best plate and English iron, upon the telescope principle, to the above-mentioned tank. It is to be in two parts, and correspond in diameter and height with the dimensions given in the drawings. The roof and top tier of side plates of the gasholder are to be of No. 11 wire gauge, and all the other side plates are to be of No. 12 wire gauge. Each part is to be 22 feet deep, and is to have a hydraulic joint 15 inches deep and 8 inches wide of No. 10 wire gauge, one part of the joint to be connected with the top of the bottom part. The top edge of the cup, and the bottom edge of the dip are to be bound by half-round iron, 2 inches by 1 inch thick. The roof of the gasholder is to be a dome roof, supported within in the usual way, with sufficient wrought-iron frame-work, and twenty-four trusses, and the requisite intermediate rafter bars, strutted as shown in the drawings. The side of the upper part is to have twelve vertical truss bars, equi-distance from each other in the circumference inside. The lower part is to have twenty vertical plates of flat iron, 3 inches by $\frac{3}{8}$ths of an inch, reaching from the top to the bottom on the inside, with the requisite intermediate bars, strutted as shown in the drawings. The gasholder is to have twenty-four cast-iron guide-pulleys and carriages, twelve of which are to be attached to the upper part and twelve to the top of the bottom part, to work upon guide-rods, and also twelve friction rollers are to be attached to the dip of the hydraulic cup on the top of the lower part of the gasholder, to work between its upper and lower parts; thirty-six friction rollers are also to be attached to the bottom edge of the lower part, to work between it and the tank, all as shown in the drawings. The whole to be of the requisite dimensions to suit their respective places, and the rim of the lower part is to be strengthened with a double wrought-iron curb of angle-iron 4 inches by 1 inch at the root, and a ring of bar-iron 4 inches by 1 inch in thickness. The sheets of the gasholder are not to exceed 4 feet in length by 2 feet 2 inches in height; and the rivets are not to be less than $\frac{1}{4}$ inch in diameter, nor more than 1 inch asunder from centre to centre, their heads showing on the outside. Twelve eye-bolts and shackles are to be attached to the upper edge of each gasholder at equal distances from each other.

"The said gasholder, &c., are to be delivered and executed complete according to drawings, and so as to apply to the said tank, and to the columns and frame after mentioned, and to the satisfaction of the committee of management or their engineer. The contractor is to provide himself with and use the pulley blocks and falls, and every other necessary material for constructing the scaffolding, which he is to erect at his own expense.

"The materials of the gasholder, including friction rollers, pulleys, &c., &c., and all their appendages, are to be delivered, and the whole erected and fitted complete, on or before the end of thirteen weeks after notice shall have been given as above stated in reference to the tank, that the said tank is sufficiently completed to enable the contractor to commence the building of the said gasholder, &c., &c., for a sum to be fixed free of any other charge, such sum to include the price of the columns and frame after mentioned.

"Should the said gasholder, with all its appendages, and also the columns and frame after mentioned, not be completed as above stated, then the contractor is to be subject to a fine of £50 per week, to be reserved from his account, from the date of the period wherein it may be agreed that they shall be completed; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the said works, without being at all liable to the contractor for payment for any part of the works which he may have already executed.

"*Columns and Frame.*—The said gasholder is to have twelve cast-iron columns, and a cast-iron frame to connect them together at equal distances from each other in the circumference, as shown in the drawings.

"Each column is to be composed of four lengths, and when erected to be, including the said frame, about $62\frac{1}{2}$ feet high, from the top of the foundations to the top of the frame, so that the whole frame shall be arranged to one level. The columns to taper from 24 inches diameter at their bases to 16 inches at their tops, and be $1\frac{1}{8}$ inch thick at bottom, tapering to 1 inch at top. The metal of the frame is to be 1 inch thick throughout. Each casting is to be numbered and marked with its weight with white-lead paint.

"Twelve wrought-iron guide-rods of railroad iron, according to drawings, and with the requisite chairs, to be fixed and applied one to each column, and reach from the top of the tank to the under side of the frame; and each column is to have a foundation plate of cast-iron $6\frac{1}{2}$ feet long, 4 feet wide, and 2 inches thick, and four wrought-iron holding-down pins of 2 inches square iron, 10 feet long each, and to be fixed with the necessary lead, as shown in the drawings.

"The columns are to be bound together with a cast-iron frame as mentioned, which is to be composed of twenty-four girders, to be connected in the circumference of the tank from column to column at top, and each girder is to be fitted to its respective columns and to its respective girders. The whole to be properly chipped and secured together with proper screwed bolts, nuts, collars, &c., of wrought iron, cemented together with iron cement. The plan of the frame, and also for the elevation section, bearings, and mode of connecting the columns, guide-rods, and girders, to be according to drawings.

"The said columns and frame, with their appendages, are to be delivered and erected complete, so as to apply to the said gasholder and tank, and to the satisfaction of the committee of management or their engineer, and within the time and under the conditions named in respect to the gasholder."

The earliest gasholders were made in the form of cubes and other rectangular figures, but there were disadvantages in this form, independently in the waste of material required to construct a rectangular figure as compared with that required for a circular figure of the same capacity. The corners and angles of the square figures were also found to require bracing, and other precautions were necessary in order to render the resistance uniform. Wooden tanks were also at one time made for the lifting parts of the gasholder to work in, but this was at a time when gasholders scarcely exceeded in size some of the large vats or backs in use at the great porter breweries. The construction of these wooden tanks was in fact intrusted to the back-makers, who used to guarantee the duration of the vessel for some period of time agreed on. They were, in consequence, generally constructed in a substantial manner, but it is evident that the rapid increase which took place in the size of gasholders required the adoption of a different material from wood. When a deputation from the Royal Society, with Sir Joseph Banks at its head, visited the Gas-Works of the Chartered Company in Westminster about the year 1814, they strongly recommended Government to restrict the Company from constructing gasholders exceeding 6,000 feet in capacity, to be confined in very strong buildings. When Mr. Clegg published his work in 1841, he says, "Gasholders are now constructed to contain 250,000 feet." Since then the capacity of gasholders has been increased tenfold, and there is reason to believe that in the course of a few years even these colossal dimensions will be surpassed.

In the department of gas engineering, there are several manufacturing firms of great eminence, who devote themselves chiefly or wholly to the manufacture of gasholders, and the concentrated attention which the subject thus receives, has undoubtedly led to very favourable results. An engineer, in erecting a works, may receive tenders for his gasholders from a number of well-qualified contractors, who have each their own method of construction, and may, if he chooses, be saved much of the trouble and responsibility of designing these vessels himself.

CHAPTER XIV.

ON THE EXHAUSTER.

Referring again to the composition of gas, which is principally hydrogen and carbon, the first—to use the term of the late Mr. A. Wright*—being the solvent of the latter: when burned, the hydrogen is consumed at the lower part of the flame, leaving the carbon in a state of solid, to combine with the oxygen of the atmosphere, and ignite, and according to the degree of temperature it attains, so will be the amount of light produced from it.

There are various ways to prove that the carbon of gas assumes the solid state, and perhaps the most forcible is to call the reader's attention to the facility with which lamp-black is produced from gas when burned in a close vessel with an insufficient supply of air; by these means, and careful manipulation, as much as 17 lbs. or 18 lbs. of lamp-black may be produced from 1,000 feet of gas. It is obvious, therefore, this weight must arise merely from the solid obtained from the gas.

As already explained, when gas is subjected to a high temperature and great pressure, an incrustation of carbon is deposited in the retorts, this being really the same nature of material as the lamp-black, but more compact and solid. Thus there are two ways of obtaining the carbon in a solid state from the gas—the one in the act of burning, the other when producing it.

During many years the action just mentioned was not understood, and engineers attached little importance thereto, considering it merely incidental to the carbonisation of coal; but we now know this to arise from the decomposition of the hydrocarbons, or olefiant gas, and the deposit of a large portion of the very richest ingredients of the gas in a solid state in the retort, instead of passing to the holder to produce light.

As already stated, it is not only in this deterioration of the

* In the first volume of the "Journal of Gas Lighting" there is a very excellent article on the Theory and Economy of Artificial Light—to which reference is made.

illuminating power of the gas where the loss exists, for the carbonaceous deposit is a very bad conductor of heat, it occupies a large space in the retorts, thereby diminishing the weight of the charge, and its presence undoubtedly reduces the value of the coke when produced therewith. Thus, by this deposit, the gas is deteriorated in value, and more retorts are necessary than would otherwise be requisite, so augmenting the capital and the fuel account; wear and tear and labour are also materially increased.

Mr. John Grafton was the first to understand these difficulties, and to endeavour to provide a remedy for them. That gentleman, suspecting the real cause of the deposit, entered into a series of experiments, by increasing the pressure in the retorts until it became equal to a column of 14 inches of water, whereby, in a single week, an incrustation of 1 inch in thickness was produced; and at the expiration of two months this was so much increased as nearly to occupy one-fourth of the retort. The result of the experiment being that in carbonising 67 tons of Wallsend coal, 10 cwt. 24 lbs. of carbon was deposited as incrustation in the retort, being, in fact, that weight of the very richest portion of the gas lost.

Mr. Grafton afterwards carried out some experiments under different circumstances, by withdrawing or exhausting the gas immediately produced, there being in this case only a pressure of half an inch, or that dip of the fluid in the hydraulic main; when, with the same description of coal, and the same heat as before used, at the end of four months scarcely any deposit took place. The correctness of these experiments are now fully borne out by every day practice.

The earliest form of machine or exhauster used for withdrawing or pumping the gas from the retorts as produced, was a kind of meter wheel; the gas entered this by a hollow shaft, and was expelled at the periphery. This wheel being caused to revolve by steam or other power exhausted the gas from the retorts; but, like many other simple yet great ideas, it required a long time before the merits of the invention were fully understood and appreciated.

There are various kinds of exhausters now employed, and probably the instrument most universally adopted is that manufactured by Mr. Beal, of London. This consists of a cast-iron cylindrical vessel closed at both ends. At one end a shaft (which carries the pulley for the driving belt) passes through a stuffing box. This shaft is placed eccentrically to the outer case, and attached to it is a cylinder of the same length as the case, but considerably smaller in diameter. In this smaller cylinder there are two sliding plates which have the effect of pistons, and when the shaft revolves, these pistons exhaust the gas from the retorts and expel it to the holder.

Mr. Jones, of Birmingham, is the manufacturer of a very ingenious instrument for exhausting gas, many of which have been in use several years without requiring repair.

The exhauster which recommends itself for little friction, is that used by Mr. Methven, of the Imperial Gas Company, and consists of three gasholders, working in separate and distinct tanks, which are nearly filled with tar. These are attached to three distinct cranks on a shaft, placed at equal angles to each other, so that the action may be uniform and regular. Each holder has a rod which works through a stuffing box connected to its corresponding crank above; there are also suitable pipes and clack valves for the ingress and egress to the interior and exterior of each holder. The shaft being put in motion by steam or other power, the cranks raise and depress the holders, which, by the intervention of the tar, pump or exhaust the gas.

Another form of exhauster is very similar to the high-pressure steam-engine, having piston, cylinder, and valves; these are made either as single engine or double engine. That made by Mr. Anderson is of the simplest kind, the cylinder of exhauster and engine driving it, both being on the same foundation plate, and their respective pistons connected by different cranks to the same axle and fly-wheel. The cylinder of the exhauster is about eight times the capacity of that of the engine, and, in consequence, for every foot of steam employed, eight feet of gas are exhausted.

In employing these instruments, great care is requisite to avoid undue exhaustion; should this occur, then atmospheric air from the pipes, or carbonic acid from the furnaces, would be drawn into the holder and intermix with the gas, causing a serious prejudice. According to Mr. Lewis Thompson, one per cent. of carbonic acid intermixed with gas reduces its illuminating power from 8 to 10 per cent.; and, according to Messrs. Audouin and Bérard, six parts of air intermixed with 94 parts of gas, reduce the illuminating power to one half of the light of the same gas when pure; and when 20 parts of air are intermixed with 80 parts of gas, the illuminating power of the gas is entirely destroyed. Therefore it is of the utmost importance to avoid the possibility of intermixing either air or carbonic acid with the gas by excessive exhaustion.

The seal on the dip pipes should not be less than half an inch, nor more than one inch, and care should be taken that no escape exists on the line of pipes between the exhauster and hydraulic main.

Some engineers prefer placing this instrument between the condenser and scrubber; but as the latter apparatus deprives the gas of a large quantity of tar that would tend to clog the exhauster, perhaps a better position for it is after the scrubber, and before the purifiers.

The pressure guage of the exhauster should always be communicated directly with the hydraulic main, so that the pressure therein may be ascertained with the most rigid accuracy. As often practised, the guage only indicates the pressure at a considerable distance from the retorts, so that a partial stoppage in the main, or variation in the production, is likely to cause an error.

In the very earliest days of gas lighting, when the meter was first used, it was employed as a motive power, the gas as produced causing the wheel to revolve, the axis of which protruded through a stuffing box, and gave motion to the purifying apparatus, thus reversing entirely the present and correct method of working.

A great impediment to the employment of an exhauster, in small works, has been the care necessary with a steam boiler, and the chances of danger therefrom. This, however, no longer exists, for gas engines are now made which require no boiler, nor is there the least apprehension of danger, so that any works requiring only half a horse power, can employ it with all possible security.

CHAPTER XV.

ON GAS-METERS: MR. CLEGG'S METER—SIR WILLIAM CONGREVE'S METER—THE WET METER—MOTIVE POWER METER—STATION METER—THE DRY METER.

The whole history of the gas-meter is one of great philosophical interest. At a very early period of gas-lights, it became an object of great importance, both to the manufacturers and consumers of gas, to possess the means of measuring the consumption, in order that a proper adjustment of charges might be made. The system of charging the consumer an annual rent for a certain number of burners, on the supposition that these consumed a given quantity per hour, and were used daily for a certain number of hours, was found to be exceedingly vague and unsatisfactory. It obviously afforded the means of so much fraud, that gas companies were necessarily obliged to leave an ample margin to cover the contingencies of dishonest burning, so that the conscientious consumer was charged heavily to make up for the delinquencies of a large class who were not so scrupulous. Hence it appears perfectly natural that the great array of mechanical talent, which has been from the first so active in the improvement of all kinds of gas machinery, should have directed unwearied attention to the contrivance of apparatus for ascertaining with accuracy the quantity of gas burnt by each consumer.

The merit and honour of having invented and constructed the first gas-meter is due to the late Samuel Clegg, who in 1815 patented "a gauge or rotative gas-meter." This instrument, although very ingenious, was far from being a practical machine, and afterwards underwent various modifications, but never attained that degree of perfection so essential for its general adoption.

About 1817 the very ingenious Mr. John Malam invented another description of instrument for measuring gas, which undoubtedly led to the construction of the meter since so universally employed, and so justly appreciated. On the occasion of this meter being presented by Mr. Malam to the notice of the Society of Arts, Mr. Clegg asserted that it had been copied from him, which serious charge was investigated by a committee of the society, who ultimately, after great deliberation, gave their verdict in favour of Mr. Malam, by awarding him their gold medal for his "invention of a gas-meter, new, ingenious, superior to all others, and likely to be of great benefit to the public." The extraordinary originality of invention since displayed by Mr. Malam has confirmed the decision of the Society of Arts, whilst an admission has been made, in the treatise on coal gas written by the son of Mr. Clegg, under the sanction of his father, that Mr. Malam introduced the "hollow cover," so removing all doubt on the matter.

Among the first instruments proposed for the indication of the quantity of gas passing, was that invented by Sir William Congreve. This consisted of a kind of timepiece attached to the main cock, so that, in the act of turning this on, a pendulum was set in motion, which marked on the dial the time it was open; and when the supply was shut off, this pendulum was stopped. By this means the number of hours the gas had been burning was ascertained in a tolerably accurate manner, but, of course, could not be even an approximation to the quantity; however, it was far superior to the general system of contract, where the gas was left entirely at the mercy of the consumer.

These instruments, at one period, were much used in France, the accounts being made out according to the number of hours indicated by the instrument, multiplied by the number of lights on the premises; and were called *compteurs à l'heure*, or hour meters.

There are two kinds of gas-meters now in use, the "wet" and the "dry" meter; the former is so called because it requires a liquid, as water, to render it effective; the latter derives its name from the absence of such liquid, it being complete in itself.

Each description of instrument has its advocates; for whilst some gas companies countenance only the wet, others will use but the dry meter. Whilst engineers greatly interested in gas companies prefer the one, there are others similarly situated who have directly the opposite opinion; therefore, with those different views, it cannot be expected that a definite decision of their respective merits will be given here: nevertheless the progress made by the dry meter during the last twenty years must be admitted as a strong argument in its favour.

The measurement of gas by meter is as simple, and as positive, as the measurement of liquids by the most ordinary operation; and the volume of the first is capable of being ascertained by the meter with the same precision that liquids are defined by quarts, gallons, &c. There is, however, a very important difference, inasmuch as with liquids, when ordinarily measured, any interruption in the delivery is not material, but with gas the supply must be exact and continuous. The slightest obstruction in the instrument would cause a disagreeable interruption in the supply of gas; consequently the lights would vary, or perhaps be altogether extinguished. Therefore, in addition to measuring, the meter must be self-acting; and, that the supply of gas may be continuous and perfectly uniform, it must be remarkably delicate in its construction.

Let us conceive that the supply of a liquid, as water, ale, wine, &c., in being measured, required to be delivered with the same uniformity as gas; and for the purpose we may imagine a rude self-acting machine, as shown in Fig. 54. Here, it will be observed, there are four vessels of known capacity, attached, at right angles to each other, to axle *a*, with which they revolve. The axle is supported by, and revolves freely in, suitable bearings, which, for simplicity, are not shown. The vessels are filled successively by hand or otherwise, there being suitable mechanical means to prevent them moving until each in succession is quite full. As seen in sketch, vessel No. 1 is being supplied with the liquid to be measured; and No. 4, which has been filled, is emptying itself. When No. 1 is full, by the action of the weight of the liquid contained therein, it suddenly descends, bringing No. 2 in the position to be filled; at the same time vessel No. 1 is emptied; then No. 2, being filled, descends, bringing vessel No. 3 in position to be filled; and so on continuously, causing the vessels to revolve with the axle in the direction of the arrows, so long as there is a supply of liquid.

We will suppose each of these vessels to contain one quart, so that each time they revolve, four quarts or one gallon of liquid must be received and delivered by them ; and in order

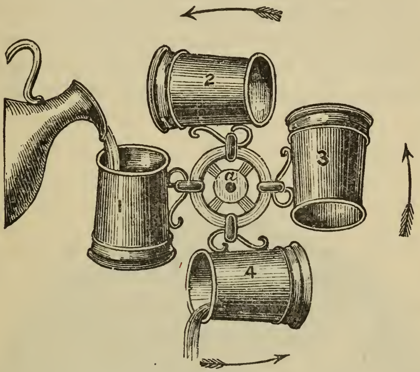


Fig. 54.

to avoid the necessity of continuously counting each revolution of the measures, or, in other words, the quantity received and delivered, we make it a self-recording instrument.

This would be done by fixing on the axle a suitable screw or worm, working into a toothed wheel in communication with a dial : thus, if the wheel had twenty teeth, the measures in revolving twenty times would cause its axle to revolve once, and indicate 20 gallons ; and the motion being further communicated to an index by suitable wheel-work, the quantity passing would be recorded with much greater accuracy than any human supervision could attain.

This supposed instrument is based on precisely the same principle as the gas-meter, for in the latter there are four measuring vessels attached to and revolving with a shaft, which are filled with gas and emptied in succession, and the number of times they revolve, or the quantity of gas received from the company and delivered to the consumer, is indicated on the dial of index.

The annexed figure 55 represents a section of a gas-meter: *m m m* is the outer case; K K K K the revolving measuring wheel attached to axle *a*, which works in suitable bearings shown in Fig. 56. The wheel is divided by the partition plates, *p p p p* (which are slightly inclined, so as to offer little resistance), into four distinct measuring compartments or vessels, Nos. 1, 2, 3, and 4. The wheel is immersed in water, contained in the case, to some distance above the

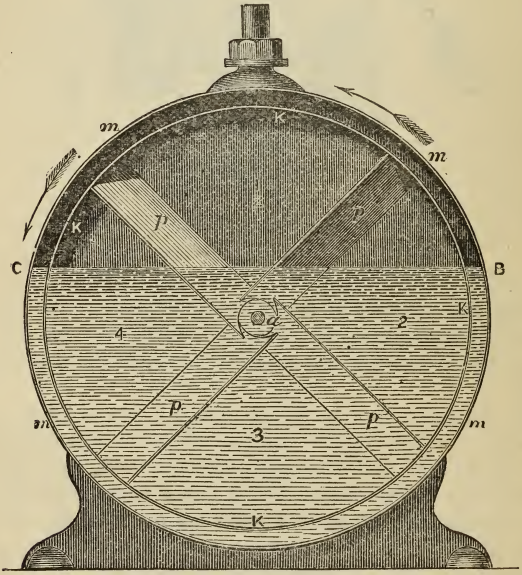


Fig. 55.

centre, as shown by the dotted lines, and by a very ingenious contrivance the gas always enters the vessels in succession at the side B, and by its force presses between the surface of the water and the side of partition *p*, as in the case of the gasholder already described, thereby causing the vessels to be filled; the wheel to revolve in the direction of the arrows; and the gas to be simultaneously expelled from the vessel at the side c; and so on continuously as long as the gas passes. When the chambers arrive at the centre, as No. 1, they are filled with gas, and in that position neither receive nor deliver, but so soon as they pass over the centre, as the wheel revolves, the gas passes by the outlet to the burners.

The similarity between the liquid measure just described, and the gas-meter, must be evident. In the first case the weight of the liquid when filling causes the vessels to revolve and empty themselves; in the other, it is the force of the gas which causes it to fill each vessel in succession, expelling that existing in others on the opposite side, and so causing the series of measuring chambers, or as called, the wheel, to revolve, being, in fact, four gasholders attached to the same axle, which are filled and emptied in rotation.

The measuring wheels of gas-meters are of course made with great accuracy, and vary in size according to the number of lights they are destined to supply. Their capacity is generally calculated so that when the maximum of lights is burning, each light consuming at the rate of 5 feet per hour, the wheel will make 100 revolutions per hour. Thus a meter for ten lights is estimated to deliver 50 feet per hour, therefore, the contents of each revolution of the wheel is equal to half a cubic foot, and it follows that this would have to be filled and emptied, or revolve, two hundred times before 100 feet would be indicated on the dial of the index: by this means the meter registers with unerring exactitude during many years, until rendered useless from decay.

The train of wheel-work giving motion to the hands on the dials is very simple, each pinion working into a wheel containing ten times as many teeth as itself: the ordinary dials register hundreds, thousands, and tens of thousands, the whole of which are actually indicated, while the parts of 100 feet are read by estimation, and the units of feet are indicated on a revolving cylinder in the index-box of meter.

Fig. 56 is a cross section of a meter. *k k* is the wheel or series of measuring vessels enclosed in the case, supported by the axle working in suitable bearings. There is a rectangular box attached to the front of case; on this is a pipe, *a*, for the admission of the gas; the egress pipe is marked *i*; the meter being charged with water to the line *h h*.

Fig. 57 is a front view, showing the details of the contents of square box. *f* is a float similar to that used in water cisterns. On the top of this is attached a valve connected with a lever; and when there is an insufficiency of water in the meter, the float descends, closes the valve, and so obstructs the passage of the gas until the meter has the proper quantity of water. There is a pipe, *c*, the top of

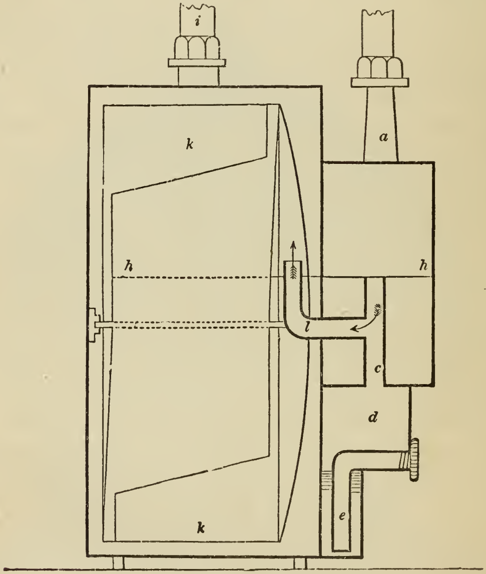


Fig. 56.

which is level with the water line; and any excess of water passes down this into the waste-box, *d*, from whence it can be withdrawn from the pipe *e* by the screw.

The meter being charged with water ready for use, the gas flows through the pipe *a*, Fig. 56, the valve being open, into a square box, and passes by the bent tube *l*, in the direction of the arrows, into the hollow disc or wheel cover, where are situated the entrances to the four measuring vessels, the passages for the egress of the gas being at the other end, or back, of wheel.

Meters, when worked beyond a certain speed, require considerably more pressure to drive them. Under these circumstances they indicate slightly against the company, and have a tendency to inconvenience the consumer by suddenly extin-

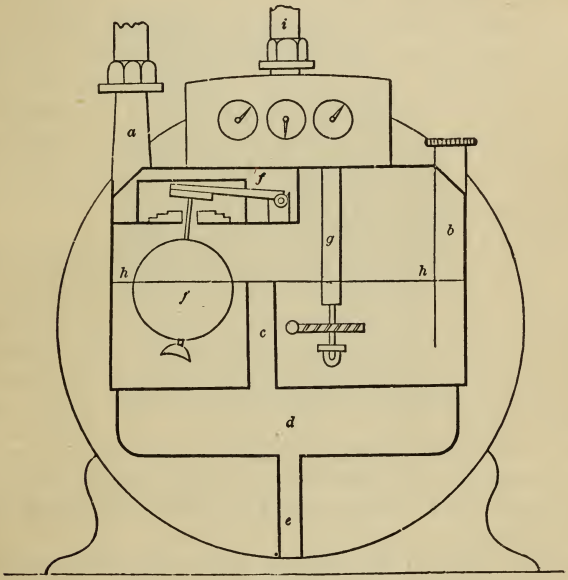


Fig. 57.

guishing the lights, through the float falling and shutting the valve; therefore a meter ought never to supply much more gas than the quantity for which it is destined. The number of burners is not essential; it is the quantity of gas which passes: thus, the meter for ten lights, or 50 feet per hour, will be able to deliver gas for twenty burners, each consuming

$2\frac{1}{2}$ feet per hour, or any number in the same proportion; and, as shown, only indicates the volume of the gas passed.

On referring to Fig. 55 it will be observed that the part of the measuring vessel nearest the axis is defined by the height of the liquid; therefore by the addition of water the capacity of the chambers must be diminished, and by its abstraction they would be increased, the first contingency being detrimental to the interests of the consumer, the latter to the prejudice of the company; and if no remedy existed for these, the gas-meter would be a very imperfect instrument.

In order to prevent the gas passing when there is an insufficiency of water, the meter is provided with the float already described, which shuts off the supply whenever the water is below its proper level, thus protecting the interest of the company; and any excess of water, which would be detrimental to the consumer, falls down the pipe *c* into the waste-box *d*. By these simple means the interests of both buyer and seller are secured.

Formerly the degree of accuracy now attained in ensuring the proper water level, and the rigidly correct registration of the meter, was not considered. Meters at one time were made in such a manner that, although perfectly correct at the proper water line, they could be caused to vary materially either against the company or consumer, by the subtraction or addition of water; but as the instrument was in the custody of the latter, he was always in the position to prevent an excess of water remaining in the meter, and, if so disposed, he could take advantage of the facilities afforded to abstract water; therefore this evil was not favourable to gas companies.

A few years ago the attention of the public was called to this defect in the gas-meter; and, the worst intentions being assumed, considerable agitation existed on the subject, when the intervention of government became necessary; and, accordingly, an Act of Parliament was passed, forbidding the sale of all meters which by any means could be made to vary more than two or three per cent. from the correct standard, which range allowed for a certain amount of evaporation of water from the meter.

Subsequently some manufacturers surpassed the parliamentary conditions, by making gas-meters even more perfect than the Act required, by constructing them to maintain an unvarying water line, so as to measure strictly accurate under all circumstances; which instruments are called compensating meters, signifying that they compensate for any loss of water that may take place. Fig. 58 is a front view of a meter of this class, as manufactured by the firm of A. Wright, Westminster. In the front part of square box

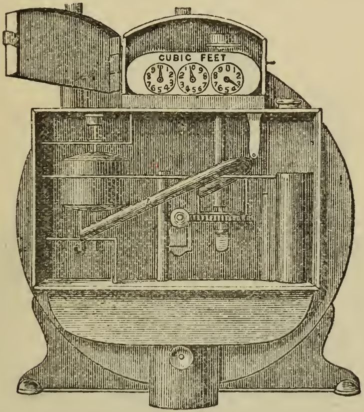


Fig. 58.

there is a separate reservoir, containing water to supply any deficiency in the meter; and all excess of water passes to this reservoir. The supply is effected by the shaft of the toothed wheel, in revolving, giving motion to the scoop A, which lifts a quantity of water from the reservoir, and conveys it to the interior of the meter, so maintaining the surface of the water continually at the same level; and, in consequence, the measurement is strictly correct.

Another means of obtaining the same result is by the beautiful invention of Messrs. Sanders and Donovan, remarkable for its simplicity and ingenuity, and based on truly scientific principles.

Fig. 59 represents a meter with this improvement. B is the outer case on which is fixed a circular case, which replaces the square box already mentioned. A is an air-tight vessel, in reality a float, fixed on axle *x*, working freely in its bearing *a*, so that it can make nearly half a revolution. When there is an insufficiency of water the float hangs in the position shown by the dotted lines, and the plug *b* closes the valve attached to box *c*.

The meter having a proper supply of water, the float slightly changes its position and opens the valve for the

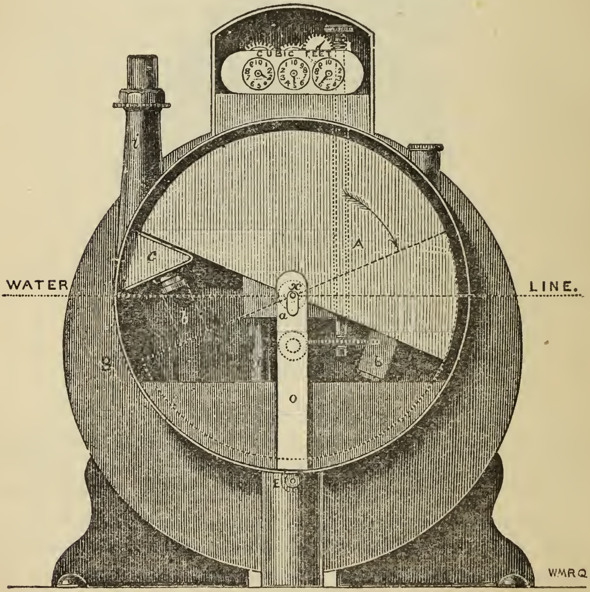


Fig. 59.

passage of the gas ; now, if more water be added to allow for evaporation, the float gradually rises until assuming the position in cut, the level of the water in the meter remaining without the least variation.

In the course of time, any evaporation that may take place is compensated by the float descending in the direction of the arrow, and by means of its bulk maintains the level of water always at the same height, and when it can no longer act, shuts the passage of the gas.

The action of this compensator is a combination of several principles of mechanics, and accomplishes the desired effect without the aid of any motive power from the meter. These instruments are manufactured by the Gas Meter Company, Kingsland Road, London.

Meters are also constructed, where the measuring drum is caused to float, and others have proposed to float the entire meter and case in a separate vessel, but the last has not come into use.

To avoid as much as possible the loss by leakage, it is always the interest of gas companies to have the pressure in the mains as low as possible; and in small towns, where there is no consumption during the day, a pressure of one tenth, in the lowest part of the district, will be sufficient to keep the air from entering. But there are cases where, in order to supply one or two consumers, the pressure has to be kept on continuously, so occasioning great loss by leakage. This is avoided by attaching a motive power meter to the premises requiring gas, when, if the pressure in the main be only one tenth, it can be increased by this instrument so as to give an abundant supply where requisite.

STATION METER.

The station meter is an instrument employed at all well-regulated gas-works, to record the quantity of gas produced, and is as essential to the strict economy of an establishment as the stock-book is to the merchant. This differs from the consumer's meter in some particulars, but is in principle the same. The difference consists in the exterior form, those of small dimensions being cylindrical, whilst the larger descriptions are generally made square, and often very ornamental. The pipes for entrance and exit of gas are at the back, the dial of the index is in the centre in front, the float is dispensed with, and a glass gauge indicates the level of water; in other respects it is identical with the other already described. The index of a station meter, according to its capacity, contains six, seven, or more dials, the hands of which register in succession from hundreds, up to tens or hundreds of millions of cubic feet. In large meters, attached

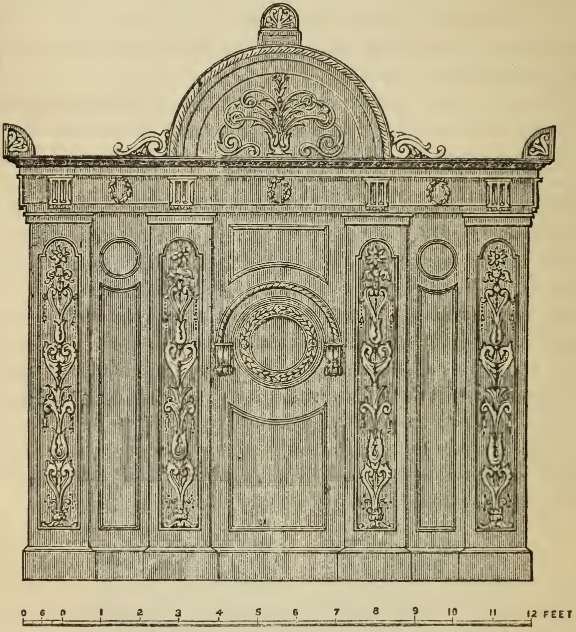


Fig. 60.

to the index is a clock, the hour-hand of which is connected with a rod carrying a spring pencil. Immediately under the clock dial, and in the centre of index, is a disc, which revolves according to the daily production, and on this disc is fixed a sheet of paper, having divisions on its outer circle corresponding with the maximum daily production, which it is intended to indicate. The pencil before mentioned receiving motion from the hour-hand, by the action of the disc revolving, makes a curved mark on the paper, so indicating the number of hundreds or thousands of feet of gas produced per hour. An inspection of the paper so marked shows at a glance any irregularity that may have occurred in the production of gas, affording the superintendent a good check on the workmen during his absence.

Fig. 60 represents an elevation of a Station Meter, by the firm of A. Wright, Westminster, capable of measuring one hundred thousand feet per hour, or two millions four hundred thousand feet per diem. The measuring wheel of this meter delivers 1,000 feet at each revolution. Messrs. Wm. Parkinson and Co., successors of the late S. Crosley, are also extensive and accredited manufacturers of station and consumers' meters, regulators, and other instruments of precision employed in the manufacture and distribution of gas.

THE DRY METER.

This instrument has undoubtedly some important advantages; requiring no water for its action, there is no possibility of the passage of the gas being obstructed by frost, nor are the pipes liable to be stopped by the vapour of the water condensing in them. The dry meter does not demand a periodical attention, like the other, either to add or abstract water, nor is there the probability of the lights being suddenly extinguished from an insufficiency of water.

Such was the prejudice existing against the use of dry meters twenty-two years ago, that very few gas companies could be induced even to try them. It was feared that the flexible material entering into their composition would speedily decay, whereas experience has demonstrated this, when properly prepared, to be the most durable part of the instrument. The dry meter was then considered of such extreme delicacy in its construction, that its durability must of necessity be very limited; however, experience and time have gradually dispelled these notions, and the dry meter has now become a formidable rival to the other, and as a proof of their general adoption at the present day, nearly every wet meter manufacturer constructs them. They are largely employed by all the London and provincial gas companies in the United Kingdom; they are used almost exclusively in the United States; and are now becoming general on the Continent.

The first record of a dry meter is the patent of Mr. John Malam, in the year 1820, in which he adapted a series of bellows combined together on to one common shaft; but the plan was not practicable, nor was it ever carried into effect.

The principle of the dry meter will be best understood by referring to the action of the common bellows. When the upper leaf of this well-known domestic implement is raised, an exhausting power is produced in the interior of the bellows, whereupon the external air raises the valve in the lower leaf, and enters. When the upper leaf is now depressed, the valve is immediately closed and the air expelled through the nozzle of the bellows. If we now conceive the upper leaf to be attached to clock-work, so as to register the number of times which the bellows has been thus filled and emptied, it is evident that, knowing the capacity of the bellows when expanded, we obtain the means of measuring the quantity of air which has passed in and out.

Now, in the dry meter, gas is measured by the alternate expansion and contraction of chambers, which may very aptly be compared to the expanding and contracting chamber of the bellows. These chambers vary in shape in different kinds of meters. For example, in Defries' meter the vessel, or outer case, is divided into three distinct compartments, each of which is subdivided by a square flexible leather partition, strengthened by tin plates, and forms, when extended, a square cone, and by the action of the gas this flexible partition is distended first on one side of its vertical plane and then on the other, so receiving and expelling the gas—the number of times the leather partitions have been distended, or the quantity passed, being recorded on the dial.

Undoubtedly the simplest dry meter, and that most generally employed, is the instrument patented by Messrs. Croll and Richards in 1844. This consists of a rectangular chamber *a a a a*, Fig. 61, which is subdivided by a partition into two distinct compartments. Each of these contains a flexible chamber formed by a metal disc B, a ring attached to partition, and a soft leather belt A, which is secured air-tight around the edge of disc and to the ring. Thus there are four measuring compartments, 1, 2, 3, and 4, as seen in cut. The action of these flexible chambers is similar to a bladder filled with air, which air is afterwards forced out by being compressed between two flat plates.

In the upper part, *b*, of the meter are two slide-valves, *c c*, which convey the gas to and from the several chambers, and

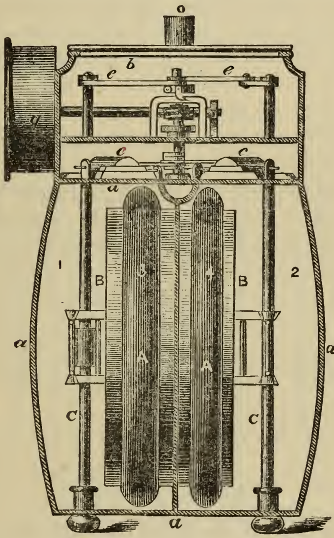


Fig. 61.

are set in motion by a crank in communication with the arms *e e*. These arms are firmly fixed to the rods C C, which receive their motion from the discs B B, to which they are communicated, so that the motion of the discs changes the position of the valves. If we now suppose the gas to be entering chamber No. 4, it would cause the disc B to travel through a certain space, expelling at same time gas from chamber No. 2, and during this period, for the supply to be continuous, the gas would be admitted into chamber No. 1, expelling that from No. 3, so filling and expelling the gas from all the chambers in succession. The flexible chamber being distended to its limits by the action of the valves, the passages are reversed, and by this continued action the flexible chambers distend and collapse alternately, in the first place receiving the gas, which is afterwards expelled to the burners of the consumers.

As already illustrated with the wet meter, the capacity of the measuring vessels being known, the number of times they have been filled and emptied, or the quantity consumed, is communicated to the index *g* by means of wheel-work.

The action of the metallic discs in this meter has been compared to that of the piston in a steam-engine; and there is certainly a considerable analogy if the comparison be made with the horizontal cylinders of a locomotive engine, in which the motion of the piston is precisely the same as that of the discs in this kind of meter. The system of slide-valves for admitting the gas to the inside and outside of the cylinders and to the exit pipe was pronounced by Mr. Clegg to be extremely ingenious, and consists of a double series of apertures, two of which lead respectively to the inside and outside of one chamber, while the third in each series communicates with the exit pipe from each chamber.

CHAPTER XVI.

ON LAYING MAINS AND SERVICES FOR DISTRIBUTING GAS, AND LEAKING IN MAINS.—MAIN PIPES FIRST USED.—VARIOUS KINDS OF MAINS.—CHAMEROY PIPES.—MODE OF MAKING JOINTS.—TABLE OF DELIVERY OF GAS PER HOUR.—CONDENSATION SYPHONS.—PRICES OF MAINS.—MEANS OF DETECTING STOPPAGE IN MAINS.—SERVICES.—LEAKAGE IN MAINS.

THE pipes which convey gas or water through the different streets are called main pipes or mains; and the small pipes which convey the fluid therefrom to the houses are called services.

Probably the first mains systematically laid throughout a town or city, were those of the New River Company, upwards of two hundred years ago, for the purpose of distributing water throughout London.

These were simply trunks of elm trees left on the exterior in their rude state, the interior being bored out to the required size, which varied from 2 inches to 10 inches diameter. One end of this pipe was tapered like a spigot, from which, no doubt, that part of cast-iron pipes takes its name; the other end had a conical seat to receive the spigot, and they were joined together with whitelead, or cement, and "driven home" with a mallet.

This rude state of laying mains existed until the commencement of the present century, when the combined requirements of gas and water led to the production of cast-iron pipes; but such was their excessive cost, when gas companies commenced their operations, that £18 and £20 per ton was the ordinary price. By successive improvements, introduced into this branch of industry, the price has gradually diminished, and at the present day mains are less than one-third of that cost.

At one period, when cast-iron mains were very expensive, several attempts were made to substitute them by pipes of other material. In a city, in the western part of England, an extensive trial was made to transmit gas through brick conduits. Earthenware pipes, similar to the drain pipes of the present day, were also used; and bottle-glass mains were proposed, but never carried into operation. Pipes of earthenware were used on an extensive scale in some of the towns of France: their joints were made with Roman cement, and the services attached by punching a hole therein and inserting the end of pipe, which was secured with cement. It is almost needless to say that this system resulted in complete failure, and several gas companies were all but ruined by resorting to it.

Subsequently a description of main was introduced into France and the Continent, called after the inventor, the

"Chameroy" pipe. These are constructed of tinned or leaded sheet-iron: the pipes, of 2 or 3 inches diameter, being of the thickness of ordinary tin plate, but augmenting in thickness according to the increased diameter, so that a 24-inch pipe is made of about No. 16 gauge plate.

In making these, the sheet-iron is turned round to form the pipe, when it is riveted and soldered; and on the respective ends is cast corresponding male and female screws, made of a composition of tin, lead, and antimony, which are firmly soldered to the tube. The pipe then has a coating of tar internally, and a layer of asphalte intermixed with sand, of from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch thick, according to size of pipe, on the exterior; when laid, they are screwed together with a hempen washer dipped in tallow, forming a very sound joint. Although apparently so very fragile, these pipes are of extraordinary durability, many of them having been interred upwards of twenty years without showing the slightest symptoms of decay; and, undoubtedly, the nature of the material of which they are composed prevents to a great extent the action known by chemists as "endosmose" and "exosmose," which action is considered to exist to a serious extent with cast-iron pipes, and is very detrimental to the quality of gas transmitted through them.

By a law of nature all gases have a tendency to divide, separate, or diffuse themselves, so that the poisonous air of confined places, the vitiated atmosphere of large towns and cities, or gases that may be engendered prejudicial to animal life, are diffused, and fresh air takes their place. This law is so powerful that gas, when confined in pipes, or gasholders, traverses the metal, and atmospheric air enters to replace it; this is what occurs with gas in mains, and the action is called *endosmose* and *exosmose*, derived from the Greek, signifying impulsion, or pressure from within and without. Of course, the more porous the substance confining the gas, the more powerful is this action; hence the necessity of having the metal forming the pipes as compact as possible.

Cast-iron pipes are universally employed in England, and their manufacture is at present brought to a great state of perfection. As ordinarily made, when under 3 inches diameter, they are 6 feet long and barely $\frac{3}{8}$ inch thick; when under 12 inches and above 3 inches diameter, they are 9 feet long, varying from $\frac{3}{8}$ to $\frac{1}{2}$ inch thick; when exceeding 12 inches diameter, they are often made 12 feet and 15 feet long, but rarely exceeding $\frac{5}{8}$ inch in thickness.

These pipes have on one end a socket, sometimes called a "faucet," sufficiently large in diameter to allow the end of another pipe to enter very freely. These sockets vary in length from $2\frac{1}{2}$ inches to 6 inches, according to the diameter of main, the first being for 2-inch pipes; the latter for those 36 inches in diameter. The other end of the pipe is called the spigot, and has a small bead cast on it, which prevents the yarn passing into the interior when the joint is being made. The quality of iron for pipes is of the most vital importance: very soft black iron contains a large proportion of carbon, and this, by long use in the conveyance of gas, is believed to change in its molecular nature, and becomes sometimes so soft, that it can be cut with a knife, with the greatest facility, like the crust of bread.

Previously to being laid, the pipes should be tested separately by means of hydraulic pressure of at least two or three atmospheres; at the same time, a few blows struck along that under examination with a hammer, will detect any fault that may exist. Should there be any cracks or flaws this will be perceived by the water oozing therefrom, and that should be at once rejected. A sound pipe will easily be distinguished from a cracked one by the ringing noise it gives out when struck smartly with a hammer.

The joints of gas and water mains have been made in several ways: the oldest, and undoubtedly the best, is done in the following manner:—The spigot of the pipe about to be laid is placed into the socket of that already laid, when tarred gaskets of spun yarn are, by means of "caulking," driven right into the socket for about half its length, and the remaining portion is filled with molten lead; which, when cold, is caulked, or "set up" with a thick caulking-iron, called a "set;" by this means the ring of lead is wedged sufficiently tight to prevent the possibility of escape of gas.

Sometimes, when more than ordinary care is adopted, the joint is afterwards smeared or painted over with a composition of hot pitch and tallow, which serves to stop any very minute leakages. In making these joints, care must be taken not to have a superabundance of lead on the outer part of the joint, or as termed "too full a joint," for in this case it often happens that in "setting up"—particularly if the workmen be inexperienced—the socket splits; and if he conceals the results of his awkwardness, probably a leakage of consideration may exist during many years. The same casualty is likely to happen if the joint is not "full enough," when the socket is often split by the tool being wedged in. The operation requires great care.

The lead is poured into the joints by means of a belt of plastic clay, attached around the edge of the socket, just leaving sufficient space for the quantity of lead required, a "gate" being left at the top, into which the metal is poured. Another plan for pipes of large dimensions is, to have a flat ring of about 1½ inch wide and ¼ inch thick, the internal part of which fits closely to the pipe. This ring is jointed like a pair of callipers, which it resembles, and the two ends are turned at right angles, with bolt-holes to bolt it together. This replaces the belt of clay, and the interstices around it and the pipe are rubbed over with clay when it is ready for pouring the lead. This system, for large mains, is much to be recommended, for making a good joint, and for the facility with which it can be done.

Mr. Clegg recommends a mode of making joints without lead, by a plan similar to that just described, but substituting tallow instead of metal. This has not been carried into operation: experiments of this nature are dangerous and costly; moreover neither economy nor any other advantage can be claimed for the system proposed.

Mr. Wicksted, engineer of the East London Water-works, proposed a method of making joints of gas and water mains by employing india-rubber rings, which were forced into the sockets; but although strongly advocated by that gentleman, the system has not become general.

A superior plan of jointing pipes has been adopted for some years in Liverpool and Manchester, which is found highly successful when laid in straight lines or in curves of large radius. In this method the socket of the pipe is turned with a slightly conical opening, and the small end turned with a similar conical figure to fit the socket. The two ends of the pipes are covered with a mixture of red and white lead, and being put together, are driven home by blows of a mallet. This system has been applied in many instances with success.

In very large pipes of 4 or 5 feet diameter, the New River Company has recently employed another means of making joints. In this case a bead is cast on both ends of the pipe, there being no socket. There is a collar or belt of cast iron, about 7 inches wide, to fit on the outside of pipe, made in three or more segments, which are jointed together by bolts and nuts. The interior of this belt assumes the shape of, and fits tolerably close on to, the beads of the two pipes to be jointed. Previously to the iron belt being placed, there is a band of felt, of about the same width as the belt, dipped in tallow, placed around the pipes and over the beads, when the cast-iron segments are placed and screwed up, making a good, sound, cheap, and somewhat flexible joint.

In laying mains, the first consideration is the maximum quantity of gas likely to be required for delivery per hour; this decided, then a point in the town where there will be a general divergence of the pipes must be ascertained; the distance between this point and the works being known, the size requisite for the leading main may be ascertained by referring to the very accurate table by Mr. Barlow of the quantity of gas delivered per hour under certain pressures, by various sized pipes, and of different lengths, published in the "Journal of Gas Lighting," of which the following is an abridgment.

The table is calculated on the supposition that the pipes are on a level; if there should be a descent to the part to be supplied, they ought then to be somewhat larger; on the contrary, should there be a considerable ascent, their dimensions may be diminished. The variation of the specific gravity of gases for lighting will not materially influence the sizes of the pipes.

Discharges of Gas in cubic feet per hour through Pipes of various Diameters and Lengths, at different Pressures.

(*The specific gravity of gas estimated at* 400, *air being* 1,000.)

Diameter of Pipe 2 inches.

Length of main in yards . .	150	200	300	500
Quantity delivered with 0·2 inch pressure	441	381	311	241
,, 0·3 ,,	540	468	381	296
,, 0·4 ,,	623	540	441	341
,, 0·5 ,,			492	381

Diameter of Pipe 2½ inches.

Length in yards	150	200	300	500
Quantity delivered with 0·3 inch pressure	943	819	667	516
,, 0·4 ,,	1090	943	770	596
,, 0·5 ,,			861	667
,, 0·6 ,,				731

Diameter of Pipe 3 inches.

Length in yards	500	750	1000	1250
Quantity delivered with 0·5 inch pressure	1054	859	744	666
,, 0·6 ,,		942	815	739
,, 0·8 ,,			942	845
,, 1·0 ,,				942

Diameter of Pipe 4 inches.

Length in yards	750	1000	1250	1500
Quantity delivered with 0·6 inch pressure	1932	1672	1496	1366
,, 0·8 ,,		1932	1728	1576
,, 1·0 ,,			1932	1761
,, 1·5 ,,				2160

DIAMETER OF PIPE 5 INCHES.

Length in yards	750	1000	1250	1500
Quantity delivered with 0·6 inch pressure	2888	2508	2236	1934
" 0·8 "		3174	2828	2596
" 1·0 "			3174	2877
" 1·5 "				3540

DIAMETER OF PIPE 6 INCHES.

Length in yards	750	1000	1250	1500
Quantity delivered with 0·5 inch pressure	4860	4210	3770	3430
" 0·8 "		5320	4740	4340
" 1·0 "			5320	4860
" 1·5 "				5970

DIAMETER OF PIPE 8 INCHES.

Length in yards	1000	1250	1500	1750
Quantity delivered with 0·6 inch pressure	9450	8480	7760	7150
" 0·8 "	10940	9780	8940	6260
" 1·0 "		10940	9900	9237
" 1·5 "			12200	11300

DIAMETER OF PIPE 10 INCHES.

Length in yards	1000	1250	1500	1750
Quantity delivered with 0·6 inch pressure	16500	14800	13500	12500
" 0·8 "	19120	17050	15600	14400
" 1·0 "		19120	17400	16150
" 1·5 "			21300	19600

DIAMETER OF PIPE 12 INCHES.

Length in yards	1000	1250	1500	1750
Quantity delivered with 0·6 inch pressure	26100	23300	21400	19800
" 0·8 "	30200	26900	24600	22700
" 1·0 "		30200	27500	25450
" 1·5 "			33600	31250

DIAMETER OF PIPE 15 INCHES.

Length in yards	1250	1500	1750	2000
Quantity delivered with 0·8 inch pressure	47000	42800	39800	37200
,, 1·0 ,,	52600	48000	44400	41600
,, 1·5 ,,		58700	54300	50800
,, 2·0 ,,			62800	58700

DIAMETER OF PIPE 18 INCHES.

Length in yards	1500	2000	2500	3000
Quantity delivered with 0·8 inch pressure	67600	58800	52300	33800
,, 1·0 ,,	75700	65600	58800	53500
,, 1·5 ,,		80000	71800	65600
,, 2·0 ,,			82800	75700

DIAMETER OF PIPE 20 INCHES.

Length in yards	1500	2000	2500	3000
Quantity delivered with 0·8 inch pressure	88000	76500	68400	62400
,, 1·0 ,,	98800	85300	76500	69800
,, 1·5 ,,		102300	93500	85300
,, 2·0 ,,			108000	98800

DIAMETER OF PIPE 24 INCHES.

Length in yards	1500	2000	2500	3000
Quantity delivered with 0·8 inch pressure	137200	119000	106000	97000
,, 1·0 ,,	155000	135600	119000	108600
,, 1·5 ,,		163000	145500	135600
,, 2·0 ,,			168000	155000

DIAMETER OF PIPE 28 INCHES.

Length in yards	1500	2000	2500	3000
Quantity delivered with 0·5 inch pressure	161000	140000	125000	114500
,, 1·0 ,,	229000	198000	177000	161000
,, 1·5 ,,	280000	241000	216000	198000
,, 2·0 ,,		280000	250000	229000

Diameter of Pipe 30 inches.

Length in yards	1000	2000	3000	4000
Quantity delivered with 0.5 inch pressure	234000	166000	135000	117000
„ 1·0 „	332000	234000	192000	166000
„ 1·5 „		287000	234000	203000
„ 2·0 „			270000	234000

Diameter of Pipe 36 inches.

Length in yards	1000	2000	3000	4000
Quantity delivered with 1·0 inch pressure	530000	372000	303000	265000
„ 1·5 „		456000	372000	322000
„ 2·0 „			428000	372000
„ 2·5 „				416000

To apply this table, let us suppose the maximum consumption per hour in a town to be 10,000 feet, the length of main from works to general divergence 1,500 yards, and the maximum pressure 1 inch, then on reference we find a close approximation to the quantity, and that an 8-inch leading main would be necessary.

The principal leading main having been decided on, in a similar manner approximations must be made of the various quantities likely to be required per hour in each distinct locality, and providing the mains accordingly, taking into due consideration the probabilities of improvement or increase in the various districts.

It is of the utmost importance to have the main pipes sufficiently large; many companies have lost considerably by the escapes of gas caused by the high pressure necessary with small mains; afterwards, when they were increased in size, the loss by escapes was reduced materially, and the company's profits increased in like proportion. The first leading mains that were laid to supply London with gas were 3 inches in diameter, now there are several works which have them 36 inches diameter.

It is very important to have a good map, not only of the site of the works, but of the whole district to be supplied with gas; on this map the course of all mains should be laid down, and the position of all syphons or water receivers should be marked.

In addition to a mere surface plan, a network of levels should be taken over the whole district, and the grades or inclinations of all the mains marked on. The relative elevations of the whole district with reference to some fixed point near the gasholder would be best shown by contour lines of equal heights drawn throughout the district. When the town is nearly all on the same level, contour lines may be laid down at intervals of 2 or 3 feet vertical height, but where the streets are very steep, intervals of 6 or 8 feet would be sufficient. The best rule for laying on the contours is, that they ought to be so frequent as to show by a mere inspection of the map the level of every part of the surface with reference to the fixed datum line.

The admirable surveys of towns made under the directions of the officers of the corps of Royal Engineers, and plotted on a scale of 5 feet to 1 inch, are exceedingly well adapted for the delineation of gas and water pipes. The further information relative to the levels of the streets, the inclination of the mains, &c., will be readily added by a competent person, and will constitute the map a very valuable instrument in the hands of the gas company. There are as abundant examples of the mistakes made by gas and water companies as by commissioners of sewers, for want of proper maps delineating their under-ground works. Much economy and efficacy may be expected where the circumstances of each district as to levels and pressure can be at once ascertained, while on the other hand great losses are frequently occasioned by an ignorance of such particulars. It has been asserted by a writer on this subject that in a street of half a mile in length not less than twelve syphons have been discovered on taking up the main, while one, or at most two, would have been sufficient to drain the main. Blunders of this kind are evidently occasioned by the want of maps to refer to, showing the works already executed, and which would have rendered unnecessary the repeated reconstruction of the same works.

Mr. Clegg recommends, wherever practicable, that the main pipes should be connected to each other by cross pipes, which produce the effect of equalising the pressure of the gas at every point. Where this is not practicable, and where the irregularities of the district to be lighted are considerable, he recommends the use of a governor to reduce the pressure in the higher districts. It is generally considered that a governor is necessary when a difference of level equal to 60 feet exists, so that there are many towns which would require several governors in order to make the pressure more uniform in the mains.

Generally the mains are laid in or near the centre of the road, but when the streets are very wide they are often laid on each side near to the houses, the latter plan being adopted to avoid the expense of long services. Gas in its passage from the works carries with it a quantity of vapour of water; this depending on the degree of condensation to which it has been submitted in the manufacture, or on the temperature of the water in the tanks of the gasholder, which influence the amount of vapour intermixed with the gas. The vapour existing from either of these causes, in its passage through the pipes underground is condensed, and if no provision were made the water would eventually obstruct the pipes and stop the passage of the gas; therefore water receivers (or *syphons*, as generally, although improperly, called) are placed at certain intervals to collect the liquor caused by condensation. Of necessity the mains must always incline into these syphons, to enable the water to drain into them, which is afterwards pumped out when desirable.

These syphons are cylindrical vessels of cast iron, closed at top and bottom, having a socket on one side and spigot on the other, cast therewith, so that they may be connected to the main, of which they form a continuation. In the centre of the upper plate, or cover, is a $\frac{3}{4}$-inch pipe, which descends to nearly the bottom of the syphon, and a similar pipe, screwed on to this, and having a cap thereon, continues to nearly the level of the ground, where it is surmounted by a box, or trap, generally of cast iron. On opening this trap, the cap of the syphon pipe can be unscrewed and a pump attached, so that any water in the vessels is easily removed. These vessels vary in size according to the main to which they are attached. Having the principal levels of a town, the position of the various syphons is easily decided, unless some unforeseen obstacle presents itself, such as sewer, water-pipes, &c., which may render a slight alteration necessary. The syphons should be as few as possible consistent with the perfect drainage of the mains, thus avoiding unnecessary expense in placing them, unnecessary labour in trying them, and the probability of some of them being neglected.

Much is often said of the large quantity of gas condensed in its transit; this is decidedly erroneous, for if the vast condensation existed, which many pretend, it would be made apparent by the liquid deposited in the syphons. That this liquid arises from the condensation of vapours carried off with the gas is made manifest by the fact, that in summer, when the production of gas is at the minimum, the condensation in the syphons is at the maximum, arising from the heat of the holder and the gas therein, which causes a large quantity of vapour to pass off into the mains. Another proof that this does not arise from the condensation of the gas is the nature of the liquid itself, which is neither more nor less than ammoniacal liquor. Therefore, with every confidence, we may say that the loss from condensation in mains, in the ordinary way of manufacturing gas, is not equal to one-thousandth part of the whole; but when gases are so produced that the hydrogen does not chemically combine with the carbon, or when subjected to severe cold, then the deposit of the latter by condensation is often very considerable.

Leakage in mains is a continuous and serious source of loss to a company; therefore, gas mains should never be laid with undue haste; the operation requires the utmost care, for on this greatly depends the success of the enterprise.

An excellent plan to preserve pipes and to prevent leakage to some extent is to immerse them when hot into a vessel containing thin pitch, afterwards placing them erect to allow the surplus to drain off, taking care previously to paint over the part of the spigot that enters the socket, as well as the interior of the socket, with loam intermixed with water to form a paste, allowing this to dry previously to immersion. The loam breaks off when the pipe is cold, leaving that part for making the joint entirely uncovered; if this were not done the pitch might prevent the joint being sound.

The position of the works in relation to the locality to be supplied, together with the size of the leading mains, must determine the pressure at which the gas should be delivered; thus, a town and works being on the same level, if the mains are ample, the gas having a pressure of 1 inch to $1\frac{1}{2}$ inch at the outlet of works should be sufficient for the supply of the whole district.

Some extraordinary instances have occurred where, either by error or necessity, the works have been situated at the highest part of the district; when this happens the pressure must be increased very considerably, in order to supply the lower districts.

When the works are situated very low, sometimes, for the sake of economy, the gas may issue at an exhaust of $\frac{3}{10}$ths or $\frac{5}{10}$ths of an inch, this being dependent on the position of the nearest light to be supplied. When mains are obstructed either by the deposit of naphthaline, or by water accumulated in consequence of not having drainage, a portion, or perhaps the whole, of the district is often without a proper supply of gas, occasioning the manager much annoyance and trouble. The way to discover the point of the main so obstructed is of the greatest simplicity.

To detect where a stoppage exists in a main, recourse must be had to the pressure-gauge; with this the pressure should be taken on the line of main when in *full lighting*, at various intervals of say 100 or 200 yards, commencing from the works. This may be done on the public lamps or on the premises of a consumer; but it is imperative that no light be burned on the same service during the trial, as this would cause a variation from the true pressure on the main, caused by the friction of the meter, or the gas passing through the pipes.

Following the line of main, and noting the pressure at each point where tried, if the decrease of pressure be gradual, this will be due to the friction of the gas in passing; and should it gradually decrease until insufficient for supplying the lights, then the main is too small for the quantity of gas delivered. But should the decrease of pressure between one point and another, say in a distance of 100 yards, be sudden and excessive, then it may be concluded that an obstruction exists between these two places. This ascertained, perhaps it may be necessary to fix air-pipes, these being simply $\frac{1}{2}$-inch or $\frac{3}{4}$-inch short pieces, screwed into the main, closed by a plug or cap, which are placed at various parts where the stoppage is suspected, with a block over them, and during full lighting the pressure is again tested on these air-pipes, when the stoppage may often be detected within a few yards. The remedy then is to cut the main, and remove the naphthaline, if that should be the cause; or should the stoppage arise from an accumulation of water, the main must either be relaid or a syphon placed.

The porosity of cast iron has long been a well-ascertained fact, and numerous experiments have been quoted to show that under high pressure even water may be forced through its pores and made to appear as a damp film on the outside of pipes. It is also certain that ordinary cast-iron pipes are permeable by gas, as the soil in contact with gas-pipes is almost invariably found to be saturated with gas, nor is the saturation confined to the joints, but continuous throughout the length of the pipes. These facts render it evident that great attention should be paid to the quality of the cast iron of which the pipes are composed, and that the pipes themselves should be tested by a pressure of water, as in the case of water-pipes. Much greater attention is also now paid to the joints, which are made in a very superior manner to those formerly in use, as the success of an establishment is principally dependent on the soundness of the mains.

Subjoined is a table of the average weight of pipes, and their price per yard at various rates per ton; also an average price when laid in ballast at an ordinary depth. The price for paving must vary with the locality: often in London the ground opened has to be repaved in part or entirely a second time, which of course increases the expense.

TABLE OF WEIGHT AND COST PRICE OF CAST IRON MAIN PIPES.

Diameter in inches . . .	2	2½	3	4	5	6	8	10	12	14	16
Weight per yard in lbs. .	22	28	34	51	68	80	120	170	212	236	268
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Cost per yard at £5 per ton	0 11¾	1 2½	1 6	2 3½	3 0	3 7	5 4	7 7	9 6	10 6	12 0
,, ,, £5 10*s.* ,,	1 1	1 4½	1 8	2 6	3 4	3 11	5 10	8 4	10 5	11 8	13 2
,, ,, £6 ,,	1 2¼	1 6	1 10	2 9	3 7	4 3½	6 5	8 9	11 4	12 8	14 4
,, ,, £6 10*s.* ,,	1 3¼	1 7½	2 0	3 0	3 11½	4 7¾	7 0	9 10	12 4	13 8	15 6
,, ,, £7 ,,	1 4½	1 9	2 1½	3 2	4 3	5 0	7 6	10 8	13 3	14 9	16 9
,, ,, £7 10*s.* ,,	1 6	1 10½	2 3½	3 5	4 7	5 4	8 0	11 4	14 2	15 10	18 0
,, ,, £8 ,,	1 7	2 0	2 5	3 7	4 10	5 8	8 6	12 10	14 9	16 10	19 2

AVERAGE PRICE PER YARD FOR LAYING MAINS IN BALLAST, INCLUDING CARTAGE, LEAD, EXCAVATION, FILLING IN AND LEVELLING GROUND.

Diameter of pipe in inches . . .	2	2½	3	4	5	6	8	10	12	14	16
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
	0 8	0 9	0 10	1 1	1 4	1 8	2 3	2 9	3 6	4 9	5 6

SERVICES.

Services are the pipes which convey the gas from the company's main to the consumers' premises. Those in England are universally of iron tube, called gun-barrel, which in some description of soil is of great durability, therefore cannot be superseded by anything better; but there are other localities, such as towns which are on the sea-shore, having a sandy soil, where it is speedily destroyed.

Whenever gun-barrel is used, it should always previously be heated, and have a good coat of tar to prevent it oxydizing; the workman when using it should only screw it by the socket, otherwise he will scrape off the pitch, exposing that part of the pipe to the destructive influence of the damp, &c.

On the Continent, generally, lead pipe is used for services; its durability is very remarkable, but it requires more care in laying, in order to keep it even; for that purpose it is usual to place a lath of about ½ an inch thick and 3 inches wide underneath it, which serves as a bed for the pipe, and prevents the uneven places, which would otherwise form and retain the water.

The holes in gas mains should always be drilled: the clumsy and shapeless manner in which some men gouge them out is often the cause of great loss to the company.

Services should always be laid with a declivity towards the main, so that water cannot lodge in them; if this happened, it would cause at first oscillations of the lights, and afterwards a complete stoppage in the supply. Sometimes services are stopped by naphthaline, water, rust of iron, &c., which is effectually removed by the service-cleaner of Messrs. Hulett and Co. This instrument is a kind of force-pump, and when applied to the obstructed pipe it is immediately cleared.

The oscillation or jumping of lights is due to a portion of water deposited in the pipe through which the gas passes; the pressure of the gas at one moment forcing a passage for itself through the water, and at another moment being obstructed by the water. When services cannot be laid with an incline into the main, a syphon should always be placed to collect the condensation; this is formed with a tee-piece, with a short piece of pipe, and bends in a very simple manner; syphons are also made expressly for the object.

On the Continent, generally, there is a main-tap on the exterior of premises attached to the service supplying, for the purpose of shutting off in the event of fire. These taps were also formerly used for turning on and off the supply daily to contract consumers: at sunset a workman of the company turned on to each house, and again went his rounds at the various hours, according to the respective contracts, to shut off the gas. By these means such serious loss as was incurred at one time by gas companies in England, where the supply was kept on continuously, was prevented.

Galvanised gun-barrel resists very effectually the action of rust. The increase of price is an obstacle to its use; but in certain soils it is invaluable on account of its durability, and preventing loss of gas by decay of the services.

ON THE LEAKAGE OF MAINS.

This is a subject of great importance, and one which varies so much under different circumstances as to produce great influence on the returns of gas companies. Where every degree of foresight and economy has been exercised in the actual manufacture of the gas, it may afterwards be so much diminished by leakage between the gasholder and the meters of the consumers as to reduce the profits of the company to an alarming extent; indeed, in some instances has been ruinous. The amount of leakage is variously estimated at from 10 to 25 per cent. Many gas managers insist, with every reason, that when the mains and services are properly laid, and other necessary precautions taken, the loss by leakage should not exceed 10 per cent. Mr. Croll, in his parliamentary evidence, estimated that one-sixth of the whole gas sent out would be absorbed by leakage and stealage; but in this must also be included the loss of gas occasioned by laying new mains, services, and alterations, which loss at times is very great, and demands the serious attention of engineers to prevent it.

Mains are now laid in a very superior manner; and the oldest gas-works are those in which the most extensive leakage prevails. There is also reason to suppose that the pipes are now cast in a superior manner, the metal being closer and more solid in texture, so as not to admit of so much leakage as that which prevails in porous and imperfect castings.

It has been remarked that Professor Graham once found 25 per cent. of atmospheric air intermixed with the gas in its passage, which has been assumed to arise from the action of *endosmose* and *exosmose* before described; but it is difficult to imagine this to have been the cause. More probably the main was opened in a very low part of the district, where there was no pressure, and the air entering there was intermixed with the gas under examination. Gas often enters water-mains under similar conditions, there being a leakage in the water-main at the highest part of the district, also in the gas-main adjoining; the gas is drawn into the water-pipe by a partial vacuum being formed therein, occasioned by the water escaping through a valve, or otherwise, at a part in the lower district.

The effect of excessive pressure on the gas when delivered into the mains tends considerably to increase the leakage; and when the proper supply cannot be maintained without this, the more promptly the mains are replaced by those of larger and proper magnitude the greater will be the profits to the company. Sometimes the expense deters many from carrying the improvement into operation; but sooner or later it must be done, and often by deferring it is postponed until too late. For after consumers have complained repeatedly of insufficiency of supply, without redress, an opposition company makes its appearance; and in some instances, after strong contention, the opposing has bought up the original company. A gradual stoppage in a leading main will have a similar effect as if the main were insufficient in size.

The losses by leakage will be diminished materially by following the instructions in the article on "Laying Mains" —by proving the pipes previously to being laid—by stopping their pores with bitumen—by coating the joints of the pipes afterwards with a flexible, impermeable composition—by drilling, instead of gouging, the holes for the services—lastly, by making the service and main layers fully understand the valuable article they have at their control, and to adopt every means to prevent its loss.

Sometimes the burners of the public lights deliver considerably more than their stipulated quantity, and give, through the excess of pressure, diminished light; or, as it occurred in a London company's district a few years ago, the meters had been so terribly neglected and decayed, that many of them did not register, whilst others only indicated a portion of the gas which passed. These and similar losses are generally put to the account of leakage. Cases like these are by no means uncommon

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CHAPTER XVII.

ON APPARATUS FOR INDICATING AND RECORDING PRESSURE: PRESSURE GAUGE. PRESSURE INDICATOR, AND REGISTERING PRESSURE GAUGE.

PRESSURE GAUGE.

As already stated, when coal is distilled the heat decomposes it, and the gas is expelled in a manner analogous to the production of steam from water; the gas, when confined under ordinary pressure in a holder, assuming a bulk about 250 times greater than that of the coal from which it emanated, and if not retained by this means, dividing or diffusing itself to an indefinite extent. When gas is so confined the gasholder may be so counterbalanced as to prevent it issuing; therefore, there being no weight, there would be no pressure, and by further counterbalance air would enter and intermix with the gas.

The pressure of gas depends on a number of circumstances, such as the weight and area of holders, the size of pipes through which it passes, the means of purification, the seal or dip of hydraulic mains, and other obstacles which may be presented to its free passage; and it is essential to the strict economy of a gas establishment that the pressure existing in all the parts of the manufactory, as well as in the mains for distribution, should be known. For this purpose a simple instrument called the "pressure gauge" is employed, which consists in its simplest form of a glass tube about $\frac{5}{8}$ inch internal diameter, and 6 or 8 inches long, bent in the form of the letter U, with the two legs approached as near as possible to each other. Between the two tubes is a scale, the centre being marked zero, and the space above and below is subdivided into inches and tenths of inches. The gauge is filled with water to the line marked zero on the scale, and when not influenced by the pressure of the gas, the water, of course, stands at the same level in both tubes.

When required for use, one end of the gauge is attached to the pipe through which the gas is passing, when the pressure of the gas causes the water in one of the tubes to be depressed, and to be elevated in the other, the difference between the two water levels, as read on the scale, being the pressure of the gas. For example, if the water be depressed half an inch below the point marked zero, and elevated the same distance above, the pressure will be $\frac{10}{10}$ths; the scale may be dispensed with, and the difference of levels taken with an ordinary measure, and the pressure so ascertained.

These gauges are often made with two straight tubes connected at top and bottom by a small chamber. The advantages of this system are, that the tubes are easily taken apart, and can be readily cleaned; they can also be made much stronger. The bent tubes are very liable to break.

In many establishments the maximum pressure in the town does not exceed 1 inch to $1\frac{1}{4}$ inch, a minimum pressure of $\frac{5}{10}$ths being obtained in the lowest parts of the district, which is sufficient and ample. In others, however, perhaps from the position of their works or the size of mains, or the elevation of the locality supplied, much greater pressure is required. For ordinary purposes, as when ascertaining the pressure in the mains of the town, a gauge 5 or 6 inches long is sufficient.

The pressure in the streets may be ascertained by attaching the gauge by means of a flexible tube to the lamp burners, or, if more convenient, on the premises of a consumer, but taking care that there is no supply from the same service. This operation is only done occasionally in the event of stoppages, or the mains being too small, in order to ascertain the defect.

In gas-works, where the pressure is often equal to from 18 to 30 inches of water, caused by the weight of holders, the dip of washers, the smallness of mains, or perhaps from obstructions in the pipes, then gauges are made to suit the circumstances, and as the greatly increased length would prevent them being placed in many situations, mercury gauges are often employed; these are constructed precisely similar to the water gauge, but the tubes are much narrower, being only about $\frac{1}{4}$ inch in diameter, and contain mercury instead of water.

Mercury, at ordinary temperatures, is a fluid about thirteen and a half times heavier than water; it consequently requires a proportionate amount of force or pressure to raise a column a given height. Or a given variation in the two levels of a mercury gauge indicates thirteen and a half times that pressure in water; so that instead of requiring a water gauge 40 inches long, a mercurial gauge of 3 inches will be sufficient.

There are other means of indicating pressure, by closed vessels being divided into two distinct compartments, and water being able to pass freely from the one to the other. In one of these compartments is placed a float, with a rod attached to it, passing through the cover of vessel, which is provided with a scale. The gas enters one compartment, and depresses the water therein, consequently elevating it in, the others, by which means the float is raised and the pressure shown on the scale by a pointer on the end of rod attached to float. This principle is applied in various ways, sometimes with a dial in the centre, or with a pointer and semicircular scale, and instruments of this class are often made very ornamental.

The gauges above described only indicate the pressure acting on them at a particular moment, and leave no record; but there are other instruments employed which not only indicate but record rigidly throughout the day and night the pressure which has acted on them. Of these there are two kinds—the one called the Pressure Register or Indicator the other the Registering Pressure Gauge.

THE PRESSURE REGISTER OR INDICATOR.

This instrument in France is called the spy, "*le mouchard,*" signifying its duty to keep watch over and record the manner the workmen attend to their duty in the delivery of gas to the districts. Its action is automatic and continuous, requiring the application of a clock to indicate the various periods of time, whilst means are adopted to record the pressure.

This instrument consists of a tank of cast-iron or tinned plate, of about 3 feet deep and 16 inches diameter, in the centre of which rises to about midway a vertical pipe in connection with the main. The top of the tank has a domed cover, on which is a receptacle for a vertical revolving cylinder of about 16 inches long and 5 inches diameter, the whole being surmounted by a clock, attached to the cylinder in such a manner as to cause it to revolve once in the 24 hours. In the tank there is a gasholder of about 14 inches diameter and 16 inches high, having a float throughout its length to give it the required degree of buoyancy when immersed, but which gives increased weight on rising. The holder has proper rollers and guides to enable it to rise and descend with every freedom. Attached to the top of the holder there is a rod which passes through the centre of cover of tank, and on the top of this rod is a spring pencil for the purpose of recording.

Around the vertical cylinder is coiled a sheet of paper, which is marked into twenty-four vertical divisions, to indicate the hours of day and night, corresponding with the clock above. There are also a series of horizontal lines corresponding with the pressure, commonly being forty or fifty tenths, which are numbered, commencing from the bottom marked zero. The tank being supplied with water to the desired height, if there be no pressure the pencil will remain at zero; but if the gas be admitted, say at a pressure equal to 2 inches, the holder rises, and with it the pencil, which records on the horizontal lines of the coil of paper, and the vertical lines indicate the period that such pressure existed. By these means the slightest irregularity, if only existing for a minute, is recorded on the paper.

THE REGISTERING PRESSURE GAUGE.

The registering pressure gauge, represented by Fig. 62, is a much smaller and cheaper instrument than the former,

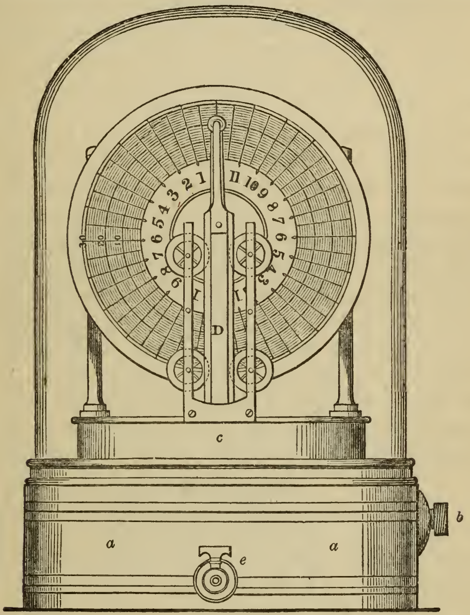


Fig. 62.

and was invented by the late Mr. A. Wright. Its size renders it very portable, its moderate price permits its being adopted by works of all descriptions, and it is largely used by gas companies to record the pressure existing in different parts of their districts.

This instrument consists of two concentric cylinders, the outer one, or case, *a a*, being about 16 inches diameter, and

10 inches deep, closed at its base, also at the top over the annular space between it and the inner cylinder, *c*. These cylinders communicate with each other only through a small space left between the lower edge of the inner, and the bottom of the outer cylinder. The case is surmounted by a clock enclosed in a glass shade. The clock, instead of having an ordinary face, is provided with a metal disc which carries a circular sheet of paper divided by twenty-four radiating lines corresponding with the hours of day and night; also having a series of concentric rings according with the various pressures. A float carrying a rod, D, and pencil similar to that of the Pressure Register, is placed in the inner cylinder, which is open at top. When required for use, water is poured into the vessel *c* until about half full. Gas being then admitted to the upper part of outer cylinder by pipe *b*, depresses the water in the annular space, and elevates that in the inner cylinder, precisely as in the gauges described, thereby lifting the float, causing the pencil to make a mark, high or low, in agreement with the pressure acting.

Fresh sheets or discs are required daily, which should all be dated, and as they may become very important records, should be carefully preserved. These instruments are very essential—they serve to correct irregularities, to prevent blame being imputed in improper quarters, and point out when any complaint arising from irregularity of pressure has been made, not only at what station, but at what precise hour, and under whose management this has occurred. These records serve in the most delicate manner to check the pressure, and enable the superintendent to adjust it to the requirements of the district during the successive stages of the twenty-four hours, in which a remarkable variation takes place in the quantity of pressure required. For instance, there are some works which throughout the day scarcely require a greater pressure than three-tenths of an inch, though towards the time of lighting up the streets, shops, and private houses, the pressure requires to be increased to 3 or even 4 inches, and this continues till the hour when many of the shop lights and private house lights are extinguished. Another diminution occurs about twelve o'clock, when most of the public-house lights are put out, and few lights continue burning except the street lamps. The night pressure is further diminished to its minimum about the hour when the street lamps are extinguished, and continues at its minimum low state throughout the day.

There is a modification of this instrument for the use of gas-works, which records the action of the exhauster, being very useful to prevent undue exhaustion, to which cause must undoubtedly be attributed the great variation existing from day to day in the quality of gas supplied by companies, as recorded by the chemical inspectors.

CHAPTER XVIII.

THE GOVERNOR AND REGULATOR.

The governor is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gasholder and the main pipe in order to regulate the pressure of gas admitted into the latter, and acts quite independently of any irregularity due to the unequal action of the gasholders or to other causes. The governor is also important in another point of view, viz., where a town has great variation of elevations, and where, without some contrivance to prevent it, the pressure of gas in the higher levels would be very excessive and alike prejudicial to the company and consumer.

This instrument is a single-lift gasholder and tank, having a peculiar valve in connection therewith, so that the pressure is always regulated according to the weight placed on its holder. The tank is made of cast-iron, its dimensions being dependent on the size of the mains for which it is destined, and the manner in which the apparatus is made.

Fig. 63 is a view of a governor, the tank and a part of the holder being in section, in order to show the interior; *a a* is a cylindrical tank, having the columns *b b* to support the bridge *e e*, in the centre of which is a guide for the flat rod *d*. The holder *g* is made of tinned iron, has a conical plug suspended in it, and works very freely in the tank, being guided by rollers at its lower edge and the flat rod *d* above. The inlet pipe is exactly in the centre, and has a conical-seated flange at top; the outlet pipe being concentric to it, rises considerably above the level of water.

The holder is provided with an annular float, *o o*, of such buoyancy, that when the tank is charged with the proper

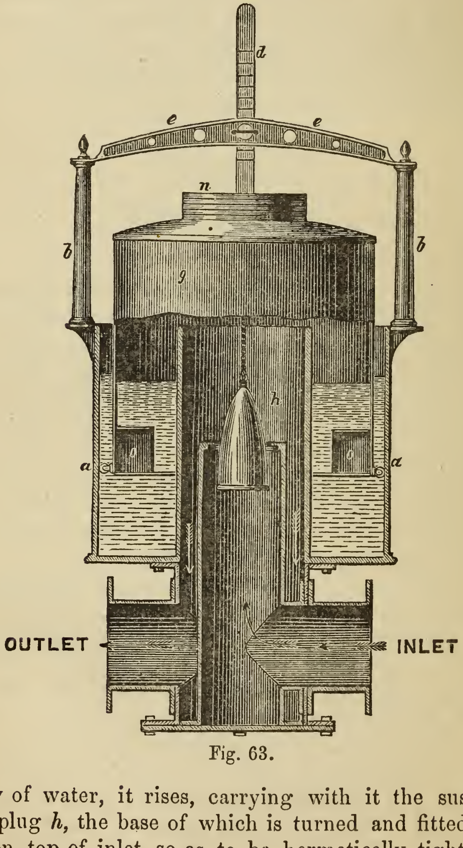


Fig. 63.

quantity of water, it rises, carrying with it the suspended conical plug *h*, the base of which is turned and fitted to the flange on top of inlet, so as to be hermetically tight. The action of the instrument is very simple, for being supplied with water to the proper height, and supposing the weights *n n* to be taken off, the holder ascends, lifting with it the conical plug, which, when at the top, stops the supply of gas. Under these circumstances the governor is destined to give no pressure. Now, if a pressure of $\frac{10}{10}$ths be requisite on placing weights on the holder equivalent to that pressure —no matter whatever variations may take place in the pressure in the works, or the quantity of gas being consumed in the town—the same pressure is strictly maintained by the governor; if the quantity supplied be great, the holder descends with the plug, and so increases the size of orifice; and should the quantity passing be small, the holder rises, and the plug closes the aperture, so that this simple machine delivers at all times any quantity of gas at the pressure desired, according to the weights on the holder.

Another modification, called Wright's governor, is to substitute the float by a pillar lever-beam and counterbalance weights, the variation of pressure being obtained by adding or subtracting weights; in other respects this instrument is precisely like the other.

No gas works should be without a governor; in some instances, where the whole pressure of works is left on the mains continually, it would repay its purchase-money in a month by the saving effected in gas from diminished leakages. In many works the foreman, or stoker, has continually to regulate the pressure during the hours of lighting by means of a valve, giving much trouble, and the work is done very imperfectly.

When there are great variations of levels in towns, governors are sometimes placed on the mains; but for this purpose they are fixed on the principal main only; and the branch mains from one governor should be disconnected from those of another. Thus, if the highest level of a town be 200 feet—by placing a governor at an elevation of 50 feet, and another, say 100 feet, and the third at 150 feet—the pipes supplied from the governor at each level should be quite detached from the others, otherwise the instrument would be useless.

Another mode of governing the pressure of gas, is by means of a loose diaphragm of leather affixed to the top of a cylindrical vessel—having the conical plug and flange pipe similar to that before described—the pressure being varied by weights as before.

Mr. Stevenson, of Halifax, has placed several of these on mains, and he speaks very highly of their efficiency.

THE REGULATOR.

This instrument is precisely the same in its construction and action as the governor; but is considerably smaller, being sometimes made only to supply one light, as for the street lamps, or for establishments of any magnitude, as private dwellings, shops, manufactories, &c.

There is considerable economy in private establishments by employing the regulator, inasmuch as it diminishes the pressure to the degree where the greatest amount of light is obtained from a given quantity of gas; it likewise equalises any irregularities that may exist in the pressure from the company's mains, and prevents loss of gas and smoke. The regulator is also very important for street lamps: it prevents waste, and the burners being suitable, the maximum amount of light is obtained from the gas. A metropolitan company, which uses these instruments generally to its public lights, has set an excellent example; and perhaps there is no place anywhere better lighted than their district.

The street lamp regulators are indispensable wherever there is a heavy pressure on the mains. The instruments are sometimes made with a leather diaphragm, on the principle already mentioned. They were first made by Mr. Ford, of London; Messrs. Wright, Sugg, and others, are also manufacturers. Their cost is about 3*s.* 6*d.* each.

Another kind of regulator for street lamps and private consumers is the "Mercurial," manufactured by Messrs. Hulett and Co., London. This, in principle, is the same as the water-governor, the difference being that mercury is used to replace the water. These are, undoubtedly, more durable than leather regulators, many of them having been in operation thirteen years, without requiring the least attention or repair, and are now, apparently, in as good condition as when they were first fixed.

CHAPTER XIX.

EXPERIMENTS ON COAL GAS. — ON THE INFLUENCE OF TEMPERATURE AND BAROMETRIC PRESSURE ON GAS.— MODES OF EXAMINING AND COMPARING GAS.—TESTS FOR IMPURITIES IN GAS.

For the perfect analysis of gases a high degree of chemical knowledge is essential, and this subject forms in itself a very important branch of chemical investigation. Into this we do not propose to enter, but shall merely notice a few of those simple operations which the manager of every establishment for the manufacture of gas should readily be able to perform, in order to satisfy himself and others of the value and purity of his gas, and to afford the means of rectifying errors.

For this object it is propósed in this chapter to explain the means of examining gas, by its weight or specific gravity, by means of the photometer, and by the condensation of the hydrocarbons; and although there may be some repetition, it is intended to give the various tests for ascertaining the purity of gas.

Gas is materially affected by three causes, namely, the temperature, and barometric pressure to which it is subjected, which influence its volume; and the amount of humidity combined therewith, which influences its weight. Gas is exceedingly elastic, and expands or contracts very sensibly with every variation of temperature, this expansion or contraction being at the rate of $\frac{1}{460}$ part for every degree of Fahr., or at the rate of nearly 2 per cent. for 10°, or nearly 20 per cent. for 100° difference of temperature to which it may be subjected. Thus 100 feet of gas at 40°, when its temperature is increased to 140°, expands and becomes nearly 120 feet; and the temperature again being reduced to 40°, the gas assumes its former volume.

This variation of volume is illustrated by partially filling a common bladder with gas or air (for they are alike in volume, and possess the same properties of contracting and expanding, according to temperature), the neck of the bladder being well secured so that gas cannot escape, when, if it be held before a fire, the heat expands the gas enclosed therein, until the bladder becomes full and distended. If it be afterwards allowed to cool, on the gas attaining its previous temperature and volume, the bladder assumes its former collapsed state. Therefore it is usual in strictly defining the volume of gas to take a standard degree of temperature, viz., 60° Fahr., to which the proper corrections are made. Gas also contracts and expands by variations of the barometric pressure, concerning which a few words may be said. The air which surrounds our globe constituting our atmosphere is as tangible as the water on its surface, and is estimated to be from 40 to 45 miles high or thick. It is therefore obvious that, like all matter having what is termed weight, the air in the lowest parts, as at the surface of the earth, or at the level of the sea, has to bear the weight of the whole of the superincumbent mass above, so that at the lowest point it is necessarily compressed and reduced proportionably in bulk; whilst on the top of high mountains, or when ascending with a balloon, the thickness or weight of air being diminished, the atmosphere in those places is subject to diminished compression, when it is expanded in proportion to the elevation. Gas, following the same law, is compressed or expanded according to the elevation where it exists: thus, at about five miles high, a given quantity expands to about twice the volume it would possess at the level of the sea. Or, a balloon containing 200 feet of gas at that elevation, when reaching the earth would by reason of the superincumbent pressure of the atmosphere be compressed into a space of 100 feet only.

There is also another influence, according to the ever-varying state of the weather, whereby gas, in any given locality, is rendered more or less compressed or compact.

These influences of the atmosphere are ascertained by means of the barometer, which is illustrated in its simplest form by taking a glass tube of about 33 inches long, having a bore of $\frac{1}{8}$ or $\frac{1}{4}$ inch diameter; this being closed at one end, it is entirely filled with mercury. A cup containing a portion of mercury being at hand, the open end of the tube is firmly closed by the finger, when the tube is inverted and held perfectly vertical, and the end immersed in the mercury contained in the cup, when, on the finger being removed, the column of mercury falls to a point according to the weather or the elevation of the locality where the operation is conducted. Under ordinary circumstances, the distance between the level of the mercury in the cup, and the top of column, is 30 inches, which is the standard of comparison for gas, which column is supported entirely by the pressure of the atmosphere. If we suppose the tube and the cup to be fixed, with a scale of inches and tenths of inches attached to indicate the height of the mercury, then we realise the construction of the barometer. By these means the degree of compression that gas is subjected to is known, and the proper corrections made to arrive at the given standard. The increase or decrease of volume is about $\frac{35}{10,000}$th parts every variation of one-tenth of an inch of mercury.

As examples of the necessity of these corrections, a volume of gas, when the mercury in the barometer is 31 inches, occupying 1,000 cubic feet, the barometer being 28 inches, would expand to 1,100 feet, or a difference of 10 per cent. The city of Madrid is about 2,000 feet above the level of the sea, and owing to the diminished pressure of the atmosphere, the yield of gas from a given quantity of coal averages there about 8 per cent. more in volume than would be obtained under precisely similar circumstances in a works nearly on a level with the sea.

The moisture in gas can be readily understood by our every-day experience of its presence in the air, and it is almost needless to state that this moisture increases very considerably the weight of gas.

With these preliminary observations we will proceed to describe the means of ascertaining the specific gravity or weight of gas, which is always defined by comparison with a like quantity of air; this being assumed equal to 1,000, the weight of a like quantity of gas under examination being known, its specific gravity is determined; thus, if a given quantity of air weighs 1,000 grains, and the same quantity of gas weighs only 470 grains, then the specific gravity of the gas under examination will be 470

ON WEIGHING GAS.

A method of weighing gas is to exhaust a globe of known capacity, such as are sold by philosophical instrument makers, fitted with a cap and stop-cock for the purpose. By means of an air-pump the globe is exhausted of all the air it contains, when it is very accurately weighed; this done, it is filled with the gas under examination, and re-weighed, when the difference between the weight of the globe when empty and when filled with gas will of course be the weight of the gas. In defining the value of gas, or ascertaining its specific gravity, it is always compared with a certain quantity of atmospheric air, as stated of a mean temperature of 60° Fahr. and barometric pressure of 30 inches; under these conditions 100 cubic inches of air weigh 31·017 grains. Whatever be the capacity of the globe, the weight of 100 cubic inches of the gas can be readily calculated when the weight of its contents are known. Then as 100 cubic inches of air of mean temperature and pressure weigh 31·017 grains, say as 31·017 is to the weight of 100 cubic inches of the gas, so is unity, or the specific gravity of air, to the specific gravity of the gas. Or another method may be adopted, which is independent of the capacity of the globe, and does not require that capacity to be determined at all. Weigh the globe when filled with gas, also when filled with air, and when exhausted; from these three separate weights, that of the air contained in the globe may be ascertained as well as that of the gas which it contains. Then the weight of the gas divided by that of the air is equal to the specific gravity. In performing the operation of weighing gases, however, many precautions are necessary, and many niceties of manipulation must be practised; for instance, the gas must be reduced to mean pressure and temperature, and corrections must also be made for moisture both in the gas and the air, unless the gas has been previously dried, which is now the practice of the best chemists.

The accompanying table, by the late Mr. Wright, gives the corrections for the bulk, or volume, of gas under various degrees of pressure and temperature, the standard adopted being barometric pressure of 30 inches, and temperature of 60°, which on reference is 1,000. First, referring to the pressure, we find by this table that 933 feet of gas at 30 inches would expand and become 1,000 feet when the barometer is at 28 inches, or 1,033 feet of gas at standard would be compressed into 1,000 feet when the pressure of the barometer was 31 inches.

Then as regards temperature, it would require 1,058 feet of gas of standard temperature to occupy the space of 1,000 feet when the thermometer is at 32°. Or 944 feet of gas at 60° would become expanded to 1,000 feet when the temperature becomes 90°. Therefore the table is of the greatest importance in determining the precise value of gas under all the ordinary variations of pressure and temperature.

Mr. Wright also contrived an ingenious apparatus for taking the specific gravity of gas by means of a balloon capable of containing when full 1,000 cubic inches of gas. This is sometimes gauged by a ring, so to limit the size of the balloon, but a more accurate way is to measure the gas through a good dry meter (the wet meter being objectionable on account of the moisture therefrom intermixing with the gas), when the specific gravity can be ascertained with remarkable accuracy.

There is great prejudice against the use of dry meters for experimental purposes, arising from the supposition that they are not capable of measuring very small particles; this, however, is erroneous, as a well-constructed dry meter should measure the most minute quantity with the greatest accuracy.

The following are Mr. Wright's directions for performing the experiment, with the table which he has compiled for correcting the temperature and pressure of the gas according to the standard generally made use of, as already stated.

Expel the air from the balloon by folding in the form in which it is first received, ascertain the weight of the balloon and car, fill the balloon with gas, insert the stopper, and put as many grains * in the car as will balance it in the air; add the number of grains which it carries to the weight of the balloon, and deduct the amount from the tabular number corresponding to the degree of temperature indicated by the thermometer, and the pressure indicated by the baro-

* The weights used are not troy grains, 100 of them being equal to 30·5 grains troy. They are each equal to a cubic foot of air, when the barometer is at 30 inches, and thermometer at 60°.

meter; divide the result by the tabular number due to the temperature and pressure of the gas, to ascertain which allow the gas to blow upon the bulb of the thermometer until the mercury is stationary, and the three first figures are the specific gravity.

EXAMPLE 1.

Temperature of the air, 70° }
Barometer . . . 28·5 in. } Tabular number 932.
Temperature of gas . 56° }
Barometer always the }
same as air . . 28·5 in. } Tabular number 958.

Weight of balloon and grains in car, 560.

```
                              932  Tabular number for the air.
                              560  Weight of balloon, &c.
                             ----
Tabular number for the gas  958)3720(388  Specific gravity.
                                2874
                                ----
                                 8460
                                 7664
                                 ----
                                  7960
                                  7664
                                  ----
                                   296
```

EXAMPLE 2.

Temperature of the air, 40° }
Barometer . . . 30·5 in. } Tabular number 1058.
Temperature of gas . 62° }
Barometer always the }
same as air . . 30·5 in. } Tabular number 1013.

Weight of balloon and grains in car, 560.

```
                              1058  Tabular number for the air.
                               560  Weight of balloon, &c.
                              ----
Tabular number for the gas  1013)4980(491  Specific gravity.
                                 4052
                                 ----
                                  9280
                                  9117
                                  ----
                                   1630
                                   1013
                                   ----
                                    617
```

NOTE.—This table will also be found convenient for correcting the quantity of gas made, as indicated by the station meter; the quantity, being divided by the tabular number due to the temperature and pressure, will give the amount as if the gas had been at 60° Fahrenheit and 30 inches barometer.

TABLE

FOR CORRECTIONS OF TEMPERATURE AND PRESSURE OF GAS.

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
28·0	988	984	980	976	971	968	964	960	956	952
28·1	991	987	983	979	975	971	967	963	959	955
28·2	995	991	987	983	979	975	971	967	963	959
28·3	998	994	990	986	982	978	974	970	966	962
28·4	1002	998	993	990	985	981	977	973	970	966
28·5	1005	1001	997	993	989	985	981	977	973	969
28·6	1009	1005	1000	996	992	988	984	980	976	972
28·7	1012	1008	1004	1000	996	992	988	984	980	976
28·8	1016	1012	1008	1003	999	995	991	987	983	979
28·9	1020	1015	1011	1007	1003	999	995	991	987	983
29·0	1023	1019	1015	1010	1006	1002	998	994	990	986
29·1	1027	1022	1018	1014	1010	1006	1002	998	993	989
29·2	1030	1026	1022	1017	1013	1009	1005	1001	997	993
29·3	1034	1029	1025	1021	1017	1012	1008	1004	1000	996
29·4	1037	1033	1029	1024	1020	1016	1012	1008	1004	1000
29·5	1041	1036	1032	1028	1024	1019	1015	1011	1007	1003
29·6	1044	1040	1036	1031	1027	1023	1019	1015	1010	1006
29·7	1048	1043	1039	1035	1031	1026	1022	1018	1014	1010
29·8	1051	1047	1043	1038	1034	1030	1026	1022	1017	1013
29·9	1055	1050	1046	1042	1038	1033	1029	1025	1021	1017
30·0	1058	1054	1050	1045	1041	1037	1033	1028	1024	1020
30·1	1062	1057	1053	1049	1044	1040	1036	1032	1028	1023
30·2	1065	1061	1057	1052	1048	1044	1039	1035	1031	1027
30·3	1069	1064	1060	1056	1051	1047	1043	1039	1034	1030
30·4	1072	1068	1064	1059	1055	1051	1046	1042	1038	1034
30·5	1076	1071	1067	1063	1058	1054	1050	1045	1041	1037
30·6	1079	1075	1071	1066	1062	1057	1053	1049	1045	1040
30·7	1083	1079	1074	1070	1065	1061	1057	1052	1048	1044
30·8	1087	1082	1078	1073	1069	1064	1060	1056	1051	1047
30·9	1090	1086	1081	1077	1072	1068	1063	1059	1055	1051
31·0	1094	1089	1085	1080	1076	1071	1067	1063	1058	1054

TABLE

FOR CORRECTIONS OF TEMPERATURE AND PRESSURE OF GAS (*continued*).

BAR.	THER. 52°	54°	56°	58°	60°	62°	64°	66°	68°	70°
28·0	948	944	941	937	933	930	926	922	919	915
28·1	952	948	944	940	937	933	929	926	922	919
28·2	955	951	947	944	940	936	933	929	925	922
28·3	958	955	951	947	943	940	936	932	929	925
28·4	962	958	954	950	947	943	939	936	932	928
28·5	965	961	958	954	950	946	943	939	935	932
28·6	969	965	961	957	953	950	946	942	939	935
28·7	972	968	964	960	957	953	949	945	942	938
28·8	975	971	968	964	960	956	952	949	945	941
28·9	979	975	971	967	963	960	956	952	948	944
29·0	982	978	974	970	967	963	959	955	952	948
29·1	985	982	978	974	970	966	962	959	955	951
29·2	989	985	981	977	973	969	966	962	958	954
29·3	992	988	984	981	977	973	969	965	961	957
29·4	996	992	988	984	980	976	972	969	965	961
29·5	999	995	991	987	983	979	976	972	968	964
29·6	1002	998	994	991	987	983	979	975	971	968
29·7	1006	1002	998	994	990	986	982	978	975	971
29·8	1009	1005	1001	997	993	989	986	982	978	974
29·9	1013	1009	1005	1001	997	993	989	985	981	978
30·0	1016	1012	1008	1004	1000	996	992	988	984	981
30·1	1019	1015	1011	1007	1003	999	995	992	988	984
30·2	1023	1019	1015	1011	1007	1003	999	995	991	987
30·3	1026	1022	1018	1014	1010	1006	1002	998	994	990
30·4	1029	1025	1021	1017	1013	1009	1005	1002	998	994
30·5	1033	1029	1025	1021	1017	1013	1009	1005	1001	997
30·6	1036	1032	1028	1024	1020	1016	1012	1008	1004	1000
30·7	1040	1036	1031	1027	1023	1019	1015	1011	1007	1004
30·8	1043	1039	1035	1031	1027	1023	1019	1015	1011	1007
30·9	1046	1043	1038	1034	1030	1026	1022	1018	1014	1010
31·0	1050	1046	1042	1037	1033	1029	1025	1021	1017	1013

TABLE

FOR CORRECTIONS OF TEMPERATURE AND PRESSURE OF GAS

(continued).

BAR.	THER. 72°	74°	76°	78°	80°	82°	84°	86°	88°	90°
28·0	912	908	905	901	898	895	891	888	885	881
28·1	915	912	908	905	901	898	894	891	888	884
28·2	918	915	911	908	904	901	898	894	891	888
28·3	922	918	914	911	908	904	901	897	894	891
28·4	925	921	918	914	911	907	904	900	897	894
28·5	928	925	921	917	914	910	907	904	900	897
28·6	931	928	924	921	917	914	910	907	903	900
28·7	935	931	927	924	920	917	913	910	907	903
28·8	938	934	931	927	924	920	917	913	910	906
28·9	941	937	934	930	927	923	920	916	913	910
29·0	944	941	937	934	930	926	923	919	916	913
29·1	948	944	940	937	933	930	926	923	919	916
29·2	951	947	944	940	936	933	929	926	922	919
29·3	954	950	947	943	940	936	933	929	926	922
29·4	957	954	950	946	943	939	936	932	929	925
29·5	961	957	953	950	946	942	939	935	932	928
29·6	964	960	957	953	949	946	942	939	935	932
29·7	967	963	960	956	952	949	945	942	938	935
29·8	970	967	963	959	956	952	948	945	941	938
29·9	974	970	966	963	959	955	952	948	944	941
30·0	977	973	969	966	962	958	955	951	948	944
30·1	980	976	973	969	965	962	958	954	951	947
30·2	983	980	976	972	969	965	961	958	954	950
30·3	987	983	979	975	972	968	964	961	957	954
30·4	990	986	982	979	975	971	968	964	960	957
30·5	993	989	986	982	978	974	971	967	963	960
30·6	996	993	989	985	981	978	974	970	967	963
30·7	1000	996	992	988	985	981	977	973	970	966
30·8	1003	999	995	991	988	984	980	977	973	970
30·9	1006	1002	998	995	991	987	984	980	976	973
31·0	1009	1006	1002	998	994	990	987	983	979	976

The preceding table contains no correction for moisture, nor is this commonly considered necessary in practice if the experiments are made in a dry room at some distance from the gasholder, or vessel in which the gas has been standing over water; nevertheless a few words will be said on the subject, so that if desirable the proper corrections may be made.

CORRECTIONS FOR MOISTURE IN GAS.

It has been ascertained by careful experiments that 100 cubic inches of permanent aqueous vapour, corrected for a temperature of 60° and a mean pressure of 30 inches, weigh 19·29 grains. If we then know the proportion of aqueous vapour absorbed by gas at different temperatures when in direct contact with water, we shall have the means of determining, from the known volume and weight of the moist gas, the volume and weight of the dry gas. Professor Faraday, in his "Chemical Manipulations," gives the following table, which is founded on the experiments of Dr. Dalton and Dr. Ure, and which ranges through most of the temperatures at which gas is likely to be weighed :—

TABLE SHOWING THE PROPORTION BY VOLUME OF AQUEOUS VAPOUR EXISTING IN ANY GAS STANDING OVER OR IN CONTACT WITH WATER AT THE CORRESPONDING TEMPERATURES, AND AT A MEAN BAROMETRIC PRESSURE OF 30 INCHES.

Temp.	Proportion of vapour in 1 volume of gas.	Temp.	Proportion of vapour in 1 volume of gas.	Temp.	Proportion of vapour in 1 volume of gas.
deg.		deg.		deg.	
40	·00933	54	·01533	68	.02406
41	·00973	55	·01586	69	·02483
42	·01013	56	·01640	70	·02566
43	·01053	57	·01693	71	·02653
44	·01093	58	·01753	72	·02740
45	·01133	59	·01810	73	·02830
46	·01173	60	·01866	74	·02923
47	·01213	61	·01923	75	·03020
48	·01253	62	·01980	76	·03120
49	·01293	63	·02000	77	·03220
50	·01333	64	·02120	78	·03323
51	·01380	65	·02190	79	·03423
52	·01426	66	·02260	80	·03533
53	·01480	67	·02330		

It is easy from this table to determine the quantity of aqueous vapour present in gas of any given temperature which is standing over water, or which has been in contact with water; for it is only necessary to multiply the volume of the moist gas by the number corresponding to the temperature, in order to find the volume of aqueous vapour which is present.

Suppose 120 cubic inches of moist gas at a temperature of 70° weighing 22 grains under mean barometric pressure, then the volume of vapour present is equal to $120 \times \cdot 02566 = 3 \cdot 079$ cubic inches. This volume corrected to a temperature of 60° will have to be deducted from the whole volume of gas corrected to the same temperature.

Now 120 cubic inches at 70° are equal to

$120 \times \frac{460 + 60}{460 + 70} = 117 \cdot 74$ cubic inches at a temperature of 60°. Hence $117 \cdot 74 - 3 \cdot 079 = 114 \cdot 66$ cubic inches, the volume of dry gas at mean temperature. Then to find the weight of this volume of dry gas we must deduct from the whole weight of 22 grains the weight of 3·079 cubic inches of aqueous vapour, which is equal to $3 \cdot 079 \times \cdot 1929 = \cdot 5939$ grains. Hence we have $22 \cdot - \cdot 5939 = 21 \cdot 4061$ grains as the weight of 114·66 cubic inches of dry gas. From this it follows by simple proportion that 100 cubic inches of the dry gas corrected for temperature and moisture will weigh

$$\frac{21 \cdot 4061 \times 100}{114 \cdot 66} = 18 \cdot 67 \text{ grains.}$$

Then as 100 cubic inches of air at mean temperature and pressure weigh 31 grains, the specific gravity of the gas will be

$$\frac{18 \cdot 67}{31} = \cdot 602.$$

There are some advantages in operating on the moist gas, because the volume can be measured before passing it into the globe in which it is weighed; and in this case no error will be made even if the globe be not perfectly exhausted, or if the globe be not quite filled with gas, the only thing necessary being the increase of weight due to the gas actually admitted as measured by a graduated jar before transferring it to the globe. This measurement cannot so perfectly be made when the gas is dried beforehand, in which case the globe must be perfectly exhausted and perfectly filled with gas, when, its capacity being known, the specific gravity can be arrived at as before.

The simplest method of drying gas is to pass it through a tube filled with some substance having a powerful attraction for water. The tubes used are about half an inch in diameter, and from 12 to 20 inches long. Chloride of lime will answer well as a desiccating material for gas which does not contain much ammonia. The chloride of lime should be heated and fused in an earthenware crucible, a temperature below that of visible redness being quite sufficient for the purpose; then poured upon a clean metallic or stone surface, and, as soon as it has solidified, broken up and put into stopped bottles. This chloride being divided into a mixture of large and small fragments is to be introduced rapidly into the tube, until the latter is nearly full; the apparatus is then ready for use.

The tube may be connected with the jar, gasholder, or other vessel containing or evolving the gas, or in any convenient way; and so much gas should be passed through as effectually to expel all the common air before the globe or vessel to be filled with the dry gas be attached. That being done, the gas should be allowed to pass slowly, 100 cubical inches having from 10 to 20 minutes allowed for passing through such a tube as that described, though if the period be lengthened no injury is occasioned. If the tube be of smaller diameter, more time should be proportionably allowed.

Chloride of lime will not answer for ammonia, or for sulphurous and some other acid gases. Potash, or carbonate of potash, answers perfectly well for ammonia, but not for acid gases. Sulphuric acid is a very excellent desiccant for many gases, and may be used in a tube by first curving the tube, then filling it with fragments of glass or rock crystal, and afterwards pouring in so much concentrated oil of vitriol as shall moisten the fragments but not cause obstruction to the passage of the gas. By moving the tube a little from time to time the acid is made to pass from place to place; it becomes mixed, and it remoistens the fragments, which from the previous quiescent state of the apparatus may have drained considerably. This substance is effectual with almost all ordinary gases except ammonia.*

ON THE BROMINE TEST.

There are substances which possess the property of reducing certain gases to a liquid state,—thus a solution of potash absorbs carbonic acid; the solution of the acetate of lead absorbs sulphuretted hydrogen; and chlorine and bromine condense the hydrocarbons existing in gas. Therefore, if a suitable graduated tube be employed, the volume of gas absorbed or condensed is known by the diminished volume of the mass. On this principle the means of ascertaining the quantity of olefiant gas, or hydrocarbons existing in gas, are determined, and its quality as an illuminating agent, under some circumstances, may be defined.

The method of ascertaining the amount of condensation produced in coal gas by the addition of a single drop of bromine, is now much preferred to the use of chlorine, which presented some difficulties in estimating the volumes to be mixed.

The chlorine test, however, in the hands of a skilful operator, is a very beautiful experiment. It requires one measure of chlorine gas to be passed into a jar inverted over water, and containing two measures of coal gas. This mixture will cause a diminution of volume in the gas, and an oily liquid will be formed by the hydrocarbons or olefiant gas uniting with the chlorine. The chlorine ought to be in excess; and the remaining portion having been removed by the addition of a few drops of a strong solution of potash, the diminution of volume which the coal gas has sustained will

* Faraday's "Chemical Manipulations," p. 390.

be a measure of its value, by indicating the proportion of olefiant gas contained in it.

For the purpose of testing gas with bromine a glass tube is used about 3 feet long and half an inch diameter inside. This is closed at one end and bent at the other into a small semicircle, so that the straight part of the tube is about 33 inches long, the remaining 3 inches being occupied by the bend. The straight part of the tube is graduated into hundredths towards the closed end as far as twenty-five divisions, or one-fourth of the length; this graduation serving to show the diminution in the volume of gas effected by the bromine.

The tube is to be filled with water, and the curved or open end placed over an orifice from which the gas is allowed to flow. After passing up through the water the gas begins to displace the latter, and must be allowed to do so till the gas exactly fills the tube from the zero division or the beginning of the graduation to the top of the tube. The curved end of the tube remains filled with water, which acts as a seal and prevents the escape of gas. It is then necessary to add a few drops of a solution of potash to remove any carbonic acid which may be in the gas. A portion of bromine about the size of a small pea is dropped into the open end of the tube, and the thumb being placed firmly on this open end, the tube is to be shaken several times in order to bring the bromine into perfect contact with the gas. After this the thumb may be withdrawn under water, and a few drops of a solution of potash added, in order to remove from the tube the vapour of bromine contained in it. To effect this removal the thumb is to be again pressed on the open end of the tube, and its contents agitated by again inverting the tube once or twice. The open end of the tube is then to be placed in water, which will now rise considerably above zero, and after remaining at rest for some time, the height of the water may be read off on the graduated part of the tube. The division so read off will of course represent the condensation of the gas in parts of 100.

Some of the inferior gases are not condensed by bromine to the extent of more than 3 or 4 per cent. while some of the rich and highly illuminating cannel coal gases are condensed as much as 30 per cent.

This process cannot, however, be regarded as satisfactory under all conditions, inasmuch as it only gives the *volume* of the hydrocarbons, without their *density;* and it follows that if the one be considered without the other, the experiment can have no value.

With caking-coal gas, each per centage of condensation or diminished volume is considered equal to three candles, so that 4 per cent. condensation would indicate twelve candles; but an admixture of cannel gas renders the experiment entirely worthless.

Cannel gas, when examined by the process, gives no positive result, without the specific gravity of the condensed matter be ascertained, when, the *volume* and *weight* being known, the value of the gas is determined. Therefore, under some circumstances, the bromine test cannot be relied on; and, although exceedingly beautiful in operation, it must give place to other and more definite means of estimating the illuminating power of gas.

ON THE COMPARISON OF GASES BY MEANS OF THE PHOTOMETER.

The method of estimating the illuminating power of gases in measures of which the unit is a single wax candle consuming a known weight of wax per hour, is a test of great beauty and simplicity. By many of the most experienced gas engineers this test of the value of a gas is preferred to all other methods of comparison. It has been justly said that the specific gravity of a gas is not a correct test of value, because this may be due to the presence of carbonic acid; but when the actual lighting power is tried by the photometer, if the standard should fall short of that which might be expected from the specific gravity of the gas, then the presence of carbonic acid may be fairly suspected.

The earliest method of comparing the lighting power of gas with that of candles, or any other standard, was that proposed by Count Rumford, and commonly known as the method of shadows. For this purpose a simple apparatus was designed, and named after its inventor, the Rumford photometer. This consists simply of a black box opened at each end, which ends were presented to the two lights under examination. In this box a white space is painted to receive the shadows made by intercepting the light from a gas-burner and a candle, placed at such distances as to give shadows of precisely the same intensity. When the distances are so adjusted that the shadows are precisely similar in colour or intensity, then the lighting powers of the two flames are proportionate to the squares of their distances from the substance intercepting the light and throwing the shadow. Thus, if the gas-burner be 9 feet and the candle 3 feet from the centre of the photometer, the squares being 81 and 9, their light will be in the proportion of these numbers to each other, the gas giving the light of nine candles. Or if the gas give a shadow equal to that of a candle placed at one-fourth of the distance, it is equal to sixteen candles, and so on. In general terms, let d be the distance from the candle to the intercepting body of photometer, and x the distance from the gas-burner to the same photometer, then when the shadows are alike, the illuminating power of the gas is equal to the square of x divided by the square of d, that of the candle being unity. When the distance of the candle is fixed at 10 inches, it will only be necessary to cut off two figures from the square of the gas-burner's distance to find the number of candles to which the gas is equal. Hence the distance of the gas-burner being 24 inches, while that of the candle is 10 inches, then the square of 24 is equal to 576, and the light given by the gas is 5·76 candles.

Although the method of comparison by shadows is still highly spoken of by some who have practised it for many years, and have acquired a habit of great accuracy in discriminating the depth of shadows, it is not in general use at the present time, the Rumford photometer having been superseded by an instrument invented by Professor Bunsen, of Marburg, and first introduced in this country by Dr. Lyon Playfair, who described it to Mr. King, of Liverpool. The comparison made by the Bunsen photometer is not one of shadows, but is a comparison of transmitted light passing through a transparent surface, with reflected light striking on an opaque surface. This comparison is made by interposing between two lights a disc of paper with an annular space made transparent, and surrounding a small part in the centre which is opaque. Now, if any light whatever be placed behind a disc of this kind, the transparent ring will be illuminated, while a dark circle will appear in the centre. If another light be now placed in front of the paper at such a distance as to cause the reflection from the opaque circle to be greater than that transmitted through the transparent ring, the centre space will be more illuminated than the ring. Again, if the light in front be placed at such a distance that the reflection is less than the transmitted light, then the central spot will appear darker than the ring, and be distinctly visible. When, however, the light is so placed that the light reflected and that transmitted are exactly equal, then the centre spot is invisible, as the whole surface of the paper appears alike, and no difference is observed between the central spot and the annular space which surrounds it. When this condition is obtained the lights are to each other as before, in the ratio of the squares of their distance from the disc.

Photometers made on this principle of comparing lights by means of a disc of this kind placed between them are now made by Mr. Wright and Mr. Sugg, both of Westminster, and by Messrs. Hulett and Company, who manufacture the photometers known as Church and Mann's.

The composition at first used for making the paper transparent was melted spermaceti, but Dr. Fyfe recommends spermaceti dissolved in oil of naphtha till it acquires a consistence which is solid at natural temperatures, but is liquefied by the application of a very gentle heat, such as by holding the vessel for a few minutes in the warm hand. He applies the mixture when fluid, leaving in the centre a circle uncovered about the size of half-a-crown. After this the paper is held horizontally over a lamp, and very cautiously heated, so as to make all the inequalities disappear. Dr. Fyfe prefers the fine cream-coloured letter-paper for the purpose of the disc.

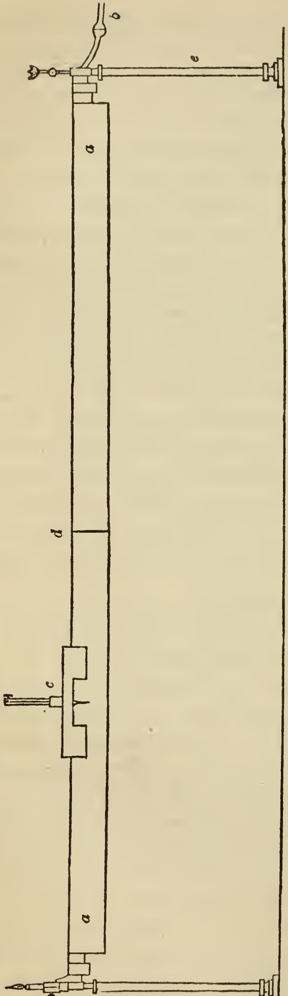


Fig. 64

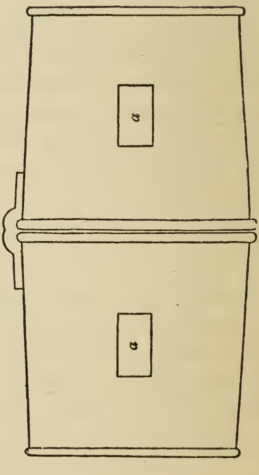


Fig. 65

Fig. 66.

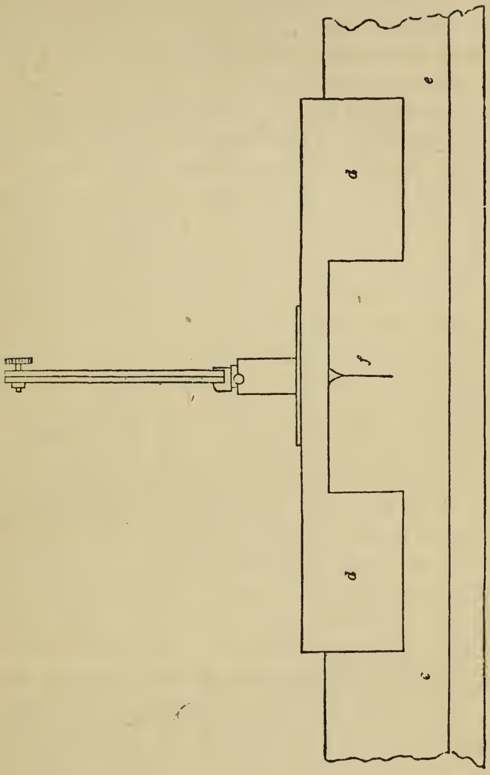
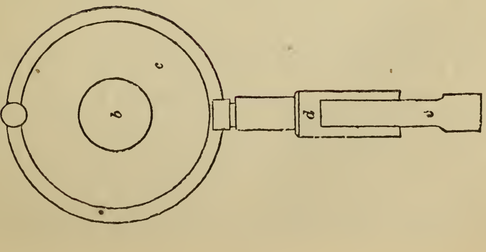


Fig. 67.



Figs. 64 to 67 show the Bunsen photometer as constructed by Mr. Wright. Fig. 64, drawn on a scale of $\frac{1}{20}$th of the full size, is an elevation of the photometer : *a a* is a straight bar of wood carrying at one end a support for a candle, and at the other a support for the gas-burner, which can be screwed on when required. These supports are so placed that the lights are exactly 100 inches apart from centre to centre. Sometimes a meter is fixed at one end in place of the pillar *e*, and the burner is screwed on to a short pipe which passes up from the meter ; in other cases a flexible tube *b* is used for conveying the gas to the burner after passing through an experimental meter so made, that by an observation of a minute the gas consumed in an hour is indicated : *c* is the movable carrier supporting the disc, which can thus be placed in any position on the bar : *d* is the centre of the bar from which the divisions commence, the first division in the centre being marked 1 for one candle. The bar is divided into a scale towards the end where the candle is placed, which scale indicates candles and tenths of a candle, as far as nine candles. From 9 to 20 the spaces indicate half-candles, and from 20 to 36 they indicate only whole candles.

Fig. 65, on a scale of $\frac{1}{4}$th the full size, is an elevation of a blackened shade, which is placed over the disc in order to exclude any radiated light, and render the determinations on the disc more delicate. It consists of two short wide tubes made slightly conical, and united at top by a hinge, which allows them to be separated at the base. The shade is open entirely through, in the direction of its axis, and when placed over the disc, the surface of the latter is seen by the observer through the small spaces *a a* in the side of the shade.

Figs. 66 and 67, on a scale of $\frac{1}{4}$th the full size, are an elevation and side view of the disc and carrier. The disc is merely a circle about 4 inches diameter, inserted between two flat metal rings which are kept close by a small screw. The opaque space in the centre *b* is an inch and a half in diameter, and *c* is the transparent part surrounding it. In these figures *d* is the carrier, *e* is the divided bar, and *f* the pointer marking the division over which the disc stands.

The following table shows the distance on the scale of the whole candles up to 30 candles; the fractional parts may be tolerably well ascertained by dividing the intermediate distance.

No. of candles.	Distance of division from centre of candle. Inches.	No. of candles.	Distance of division from centre of candle. Inches.
2	41·42	17	19·52
3	36·61	18	19·08
4	33·34	19	18·67
5	30·90	20	18·26
6	28·99	21	17·96
7	27·43	22	17·57
8	26·12	23	17·25
9	25·00	24	16·95
10	24·14	25	16·67
11	23·16	26	16·40
12	22·40	27	16·14
13	21·71	28	15·90
14	21.09	29	15·64
15	20·52	30	15·41
16	20·00		

The photometer made by Messrs. Hulett and Co., of London, has the disc always fixed at a distance of 10 inches from the candle; this has the advantage that the beam being shorter it is more portable and occupies less space in the apartment where placed.

THE WEIGHT OF GAS PRODUCED FROM COAL.

In considering the quantity of gas produced from a ton of coal, the real value is determined by its volume and its specific gravity, so that the most convenient mode of expressing the quantity is to give the weight of the gas produced, this being a compound of the quantity and the specific gravity. The latter being known, the following rule will give the weight of any quantity.

Rule.—Multiply the quantity in feet by the specific gravity, and strike off the three right-hand figures, then multiply the remainder by the decimal ·0753, then strike off the proper decimals, and the remainder is the weight in pounds. Thus, if 100 lbs of coal give 400 cubic feet of gas, of specific gravity 420—then 420 × 400 × ·0753 = 12·65 lbs. of gas.

The following comparison of the specific gravity of gas, with the illuminating power as shown by candles, is an average deduced from the results of the best experimenters :—

No. of candles.		Specific gravity.	No. of candles.		Specific gravity.
12	equal to	·400	26	equal to	·600
14	"	·425	28	"	·640
16	"	·450	30	"	·670
18	"	·475	32	"	·700
20	"	·500	34	"	·730
22	"	·530	36	"	·770
24	"	·560			

For further details on the experiments on coal gas and the mode of analysing, the reader is referred to the "Analysis of Gas," for practical men, by A. Wright.

ON TESTS FOR ASCERTAINING THE PURITY OF GAS.

The managers of many works unfortunately attach but little importance to the purification of the gas they supply; and it is a lamentable fact that, notwithstanding the progress which the science of gas-lighting has made of late years, and the amount of practical chemical skill which has been applied to the subject, there are yet many towns in England where the gas is so bad and so imperfectly purified as to be quite unfit for consumption in private houses, and where people are afraid to introduce it, well knowing its injurious effect on many articles of value exposed to its influence.

This is an evil which must act seriously against the interest of any gas company, for it prevents the proper development of their business, causing continuous complaints and dissatisfaction; and when we consider the small expense incurred in purifying, it becomes a matter of astonishment how it can possibly be neglected. By the adoption of the following tests, every manager has the means of assuring himself of the purity of the gas manufactured; and every care should be adopted to make it of such a quality as to withstand such tests.

Tests for Sulphuretted Hydrogen.—Test papers for detecting sulphuretted hydrogen are prepared by moistening common writing-paper with a solution of acetate of lead or nitrate of silver, the latter being the most delicate test. The gas under examination is caused to impinge on the moistened test-paper for about a minute, and should this become darkened in colour, it is a proof of the presence of this impurity. It may also be detected by passing the gas through solutions of either of these. Another method, sometimes practised, is to pass the gas into pure distilled water, then to add a single drop either of the acetate of lead, the nitrate of silver, or the chloride of bismuth: if any sulphuretted hydrogen be present, it will immediately show itself by blackening the water.

Test for Ammonia.—This being an alkali, the test papers to be used must be either yellow turmeric paper, or litmus paper first reddened by solution of vinegar or any other weak acid. If the original blue colour of the litmus paper be restored by the gas, or the yellow colour of the turmeric be turned to brown, it indicates the presence of ammonia.

Test for Carbonic Acid Gas.—Paper steeped in the blue tincture of litmus is rendered red both by carbonic acid gas and by sulphuretted hydrogen. In order to distinguish accurately which of these impurities is present, a solution may be made of pure barytes in the tincture of litmus. If the gas be passed into this solution and only sulphuretted hydrogen be present, no change will be produced, but should carbonic acid gas be present, a precipitate of the carbonate of barytes will immediately fall down. Carbonic acid may also be detected by causing the gas to blow or bubble through lime-water, and if this become cloudy or milky, the presence of this impurity is established.

Test papers of turmeric, litmus, or acetate of lead, are to be purchased at many operative chemists in the form of small books, about 3 inches long and $\frac{5}{8}$ inch wide, each book containing about 24 leaves. They are exceedingly convenient, and no works should be without them.

A very useful little instrument is made by Mr. Wright, for the purpose of detecting sulphuret of carbon in gas. The presence of this compound of sulphur had long been suspected, and, as it cannot be detected by the ordinary test papers which are used, has often escaped observation. Every combination of sulphuric acid, however, being highly injurious in coal gas, it is important that every possible pains should be taken to remove this impurity. This apparatus is equally useful for detecting sulphuretted hydrogen or any other compound of sulphuric acid.

The arrangement consists of a simple apparatus for condensing the products of combustion from an ordinary gas

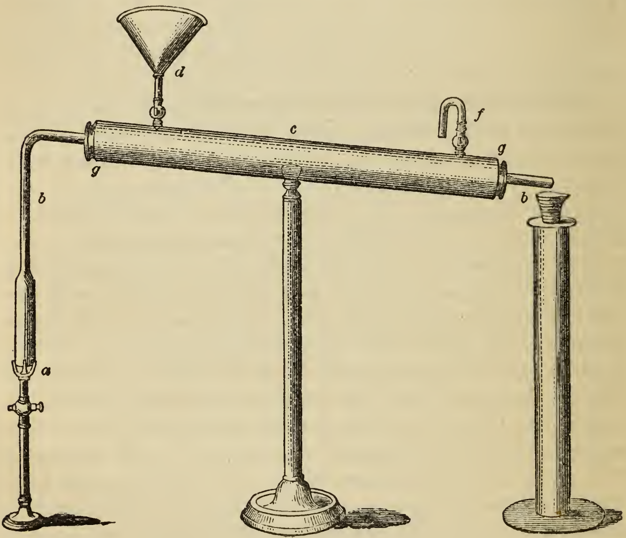


Fig. 68.

flame, and of applying to the liquid so condensed a salt of barytes, which immediately precipitates the sulphur, when present in ever so small a quantity.

In fig. 68, *a* is a small jet flame over which is a chimney, gradually contracted into a small tube, *b b*, half an inch in diameter, which tube is bent and carried through a metal cylinder *c*, about 18 inches long and 2 inches diameter. This cylinder is kept full of cold water, which is retained by means of screwed caps, *g g*, at each end, being provided with small India-rubber washers, which make a perfect joint at each end of the tube. *d* is a funnel for filling the tube with water, and *f* is a siphon by which it overflows when the tube is full. The vapours which escape from the combustion of the gas at *a* pass through the tube *b*, in which they are condensed, and drop in the state of fluid into a glass placed to receive them, while the carbonic acid escapes at the same open end of the tube. The water which drops from the tube is generally colourless, nearly tasteless, but with a peculiar and not unpleasant odour.

When a drop of the nitrate of baryta is added to the water thus condensed from the combustion of ordinary gas, a flocculent white powder immediately discolours the water, being the sulphate of baryta. This is considered by competent authorities the very severest test to which gas can be subjected.

To obtain the whole of the sulphur present some ammonia should be placed around the jets of gas, in a vessel for the purpose. The vapour of ammonia will pass up the tube, and combining with the sulphurous acid, the whole of the sulphur compound will be condensed in the water in the form of sulphate of ammonia.

Dr. Letheby employs a similar method, but has introduced an air condenser; this is a glass vessel capable of holding about one gallon; into this the products of combustion are conveyed, and there condensed, to be afterwards analysed. The difference between the two apparatus being, that in the former the condensation is caused by contact with water; in the latter, by radiation or contact with the atmosphere.

CHAPTER XX.

ON THE MODE OF BURNING GAS.—EFFECTS OF PRESSURE, ETC. —ADMIXTURE OF AIR ON GAS.—LIGHT OBTAINED.— CARBURISATION OF GAS.

When coal gas is ignited as it issues from a burner or orifice, its hydrogen is consumed at the lower part, producing the blue flame characteristic of it, and the carbon being sufficiently heated is liberated in a solid state at the upper part of the flame, if properly consumed, where it combines with the oxygen of the atmosphere, again therewith resuming the state of gas as carbonic acid; and according to the degree of heat attained by the innumerable particles of carbon, so will be the amount of light emitted by the gas.

Whenever the flame of gas is unduly cooled, or when the gas is intermixed with a portion of atmospheric air, or when it issues from the burners under great pressure, the light obtained from a given quantity is very materially reduced, and when either of these contingencies is carried to an extreme, no material light is obtained from gas.

To illustrate the first affirmation, I have only to call the reader's attention to a large flame issuing from a stand pipe, frequently seen in London and other places where public works are being carried on at night. In this a volume of gas issues, giving at one moment, when the weather is calm, the light of thirty or forty candles; but at the next instant, when a strong gust of wind blows upon it, a small blue flame only is perceptible, the gas giving no appreciable light. It may be supposed that the supply of gas is interrupted by the wind, and the loss of light due to this cause. This, however, is not the case, for experiment will prove it to be about uniform alike in the calm and under the influence of the wind; therefore, when a flame is extremely cooled, gas gives no available light.

The second affirmation, that when gas is intermixed with atmospheric air the light is diminished, is witnessed daily in igniting gas, when often an intense blue flame issues, but giving no light: this being occasioned by the admixture of air therewith. According to Dr. Letheby, the following are the proportions of light given by different quantities of air being intermixed with gas, supposing the light from gas unmixed with air to be 100 :—

	Light.
2 per cent. of air in gas	90
5 " "	70
7 " "	52
10 " "	34
20 " "	12
40 " "	1
50 " "	0

These results do not correspond entirely with the experiments of Messrs. Audouin and Bérard, already referred to, which may arise from the especial manner the gas was consumed, or perhaps from its quality. However, the pernicious effect of an admixture of air with gas is fully demonstrated, and requires the utmost attention to avoid it either in the production, transmission, or consumption of gas.

The affirmation, that the light given from gas is influenced according to the pressure with which it is emitted from the burners, requires to be illustrated by experiment; and for the purpose let us take an argand burner, having fifteen holes of such dimensions as to permit 5 feet per hour to issue with a pressure of about $\frac{1}{10}$th inch, when with ordinary gas from Newcastle coal we would obtain a light equal to about twelve candles. Now, if we reserve the same form and size of burner in every respect, but diminish the size of the holes so that a pressure of $\frac{5}{10}$ths is necessary to expel the 5 feet of gas per hour, then the light will only be equal to five and a half candles; and if we further diminish the size of the holes, so that $\frac{40}{10}$ths pressure will be required to expel the 5 feet, then that quantity of gas produces a blue flame, but no material light. With a fishtail burner, consuming at a low pressure 4 feet per hour, the light of seven candles may be given, but by increasing the pressure to expel 8 feet per hour from the same burner, the light is then diminished, and with 15 feet per hour there is very little light. All descriptions of burners are liable to this variation; and it is a most important consideration to all connected with gas lighting, but more particularly to the manufacturers of burners.

There is another important consideration in the consumption of gas, namely, its power of giving light. Gases are very variable in this respect, as the following table demonstrates.

Table of Light yielded by various descriptions of Gas, when burned under favourable circumstances, and at the rate of 5 feet per hour.

Anthracite, and some lignites, equal to from 3 to	10	candles.
Newcastle average	12	„
Knightswood Cannel	18	„
Ramsay's „	20	„
Wigan „	20	„
Arniston „	22	„
Lesmahago „	24	„
Boghead „	36	„

This variation in the luminosity of different kinds of gas is due to the quantity of carbon they relatively contain, which carbon separates at the moment of ignition from the hydrogen in very minute, solid particles, and, by intermixing with the oxygen of the atmosphere, assumes a state of incandescence; and, according to the number of these solid particles of carbon in gas, so is the amount of light to be derived from it. But it is essential for the carbon to attain the necessary degree of heat to combine with its equivalent of oxygen. In the event of the supply of this being deficient, the carbon then passes off in the solid state, distributing itself on the ceilings of apartments, the atmosphere, &c., as smoke. Therefore, for the perfect combustion of gas, the proper supply of atmospheric air requires the greatest attention.

There is, however, another action takes place when the particles of carbon are cooled below the point necessary for their incandescence. In this case the carbon does not assume the solid form, but unites with the oxygen the same instant it leaves the hydrogen; thus, as Mr. Wright observed, passing from an union with one solvent (if the expression may be used), to unite with another solvent, and is completely consumed before it has been submitted to the high temperature essential for the separation of the carbon.

Thus for the economical consumption of gas there are various points for consideration, which, however, are resolved into two simple questions; the one, to avoid an excess of atmospheric air with the flame, the other, to ensure a sufficiency of this to combine with the carbon of the gas.

Having attempted the explanation of the contingencies in the combustion of gas, it now becomes a question to consider the mode of obtaining the maximum of light from a given quantity.

For this purpose, as a rule, the best results are obtained when the gas issues from the orifices of argand burners at about $\frac{1}{10}$th inch pressure; but fishtails and batswings, to burn advantageously, require a pressure of $\frac{3}{10}$ths or $\frac{4}{10}$ths. The holes of burners destined for poor gas should be large, so that the minute particles of the carbon in the gas when issuing become heated to the necessary extent to produce light. The holes of burners destined for rich gas should be small in proportion to the richness of the gas, in order that the particles of carbon may unite with their equivalents of oxygen from the atmosphere, and give light instead of passing off in the solid state as smoke. The orifices of the interior and the exterior of argand burners should be adjusted according to their relative sizes and quality of gas.

Burners, whether argand, batswing, fishtail, or jet, give the maximum of light only with one particular consumption; and this depends on the quality of the gas,—for example, the maximum of light from 12-candle gas, with an argand, is when it has 30 holes, and consuming about $7\frac{1}{2}$ feet per hour. The richer kinds of gas are consumed in smaller quantities.

An argand burner, with 15 holes, varies in the following extraordinary manner:—

When consuming	5	feet per hour,	the light	is equal to	12	candles.
,, diminished to	$3\frac{1}{2}$	,,	,,	,,	4·5	,,
,, ,,	$2\frac{1}{2}$	,,	,,	,,	1·2	,,
,, ,,	$1\frac{1}{2}$	,,	,,	,,	0·2	,,
,, ,,	1	,,	,,	,,	0·02	,,

The other burners follow the same law; for instance—

A fishtail consuming	5	feet per hour,	the light	is equal to	10	candles.
The same reduced to	$3\frac{1}{2}$	,,	,,	,,	5·5	,,
	$2\frac{1}{2}$	,,	,,	,,	2·4	,,
	$1\frac{1}{4}$	,,	,,	,,	0·6	,,

All burners require to be made especially for the quality of gas they are destined to consume; therefore, a particular standard burner, or fixed rate of consumption for all classes of gas, is erroneous; for an argand burner, which may be well adapted for burning 12-candle gas at 5 feet per hour, would be ill adapted for burning the same quantity of 14 or 16-candle gas, and still worse for the richer qualities. Therefore, it would appear that the Act of Parliament which defines the mode of testing the illuminating power of gas by restricting the holes of an argand to 15, and the consumption to 5 feet per hour, is prejudicial to gases of higher illuminating power; for, in the event of gas, say of a quality equal to 16 candles, being so consumed, either a large portion of it would pass off as smoke, or the holes would have to be so contracted in size as to prevent the quantity issuing except under an increase of pressure, both circumstances being unfavourable to the richer gas.

As gas is generally employed either in places where the standard of quality is 12 candles, or in Scotland, where it is 24 candles, the average light yielded from each burner is about 12 candles. Perhaps, therefore, in estimating the value of gas, the correct manner would be for the richer gases to be brought to the standard of the poorer, by defining the quantity necessary to give the light of say 12 candles, which might be taken as a standard. According to this method, and adopting the table already mentioned as correct,

5	feet of	Newcastle	gas	would be equal to the standard, or 12 candles.
$3\frac{1}{3}$	,,	Knightswood	,,	
$2\frac{1}{2}$	,,	Lesmahago	,,	
$1\frac{3}{4}$	,,	Boghead	,,	

Of course the intermediate quantities could be readily defined according to the required standard of gas.

It is generally believed that for poorer gases the argand burner is superior to the others, and for richer gases that the fishtail is the most suitable. The latter has the great disadvantage that, under excess of pressure, gas passes off imperceptibly without giving light. Notice of this is given with the argand and batswing by the smoke engendered, when the evil may be corrected.

No general rule can be laid down for the sizes of the holes of the various burners,—this must be obtained by experiment, by regulating the holes so as to cause the required quantity to issue at the low pressures already referred to. The external and internal supply of air to the argand, as also the length of the glass chimneys, require great care in defining them. The slits of batswing burners should be always at least as deep as the diameter of the nib, so to form a good deep flame. The angles of the holes of fishtails require particular attention in drilling; in experimenting, the results of these are very variable.

CARBURISATION OF GAS.

There is a method of enriching gas by causing it to pass, just previously to its combustion, through the vapours of carbonaceous liquids, as naphtha, spirit of petroleum, &c., whereby additional particles of carbon are communicated to it, and held mechanically in suspension for a brief period until ignited. This process is called carburisation.

This system was first patented by Mr. Lowe in 1831, when he proposed to produce carbonic oxide, and enrich it with "the vapour of essential oil (liquid hydrocarbons) or other illuminating material," and the following year the same gentleman patented the means of "increasing the illuminating powers of coal gas, by impregnating it with the vapours of naphtha, commonly called spirit of coal tar, or with any other hydrocarbonaceous liquid, by any convenient method."

Since that period various patents have been obtained from time to time for analogous processes—these being for combining the volatile hydrocarbons with atmospheric air, hydrogen, and other gases; but the only manner of applying the system economically is, as proposed by Mr. Lowe, by intermixing these vapours with gas. Some years ago this was tried on an extensive scale, under the directions of the patentee; and although gas was at that period twice its present price, it did not succeed.

Within the last three or four years the same principle has been revived with all pretensions to originality, and it must be admitted that great efforts have been made to render it successful; for the hydrocarbon liquid is prepared expressly for the purpose, the apparatus employed are probably much superior to those formerly in use for the object, and there is, moreover, greater confidence in the issue; but there still remains a strong doubt as to its ultimate success.

The main difficulty existing against the carburisation of gas is the irregular evaporation of the liquid; a portion of which, when first placed in the carburating vessel, is remarkably volatile, and passes off in abundance, requiring burners with small holes to prevent the formation of smoke. By degrees, when the most volatile vapours have evaporated, the gas in consequence not being enriched, a difficulty arises from the smallness of the burners, which, as already explained, give, for the quantity of gas consumed, a very diminished light.

I subjoin an account of two experiments made in order to ascertain the rate of evaporation of liquid hydrocarbon. The material chosen was the spirit of petroleum, as light as it could be procured, being about 700 specific gravity. A portion was placed so as to fill a test-tube 4 inches long and half an inch wide, having a scale of the same length attached to it, and divided into fractional parts of inches, for the purpose of appreciating the amount of evaporation. The first hour the evaporation was $\frac{1}{8}$th of an inch, or $\frac{1}{32}$nd part of the whole; the second hour it was about $\frac{1}{12}$th of an inch; and at the end of twenty-four hours was $\frac{5}{8}$ths of an inch. The second day the evaporation was less than $\frac{1}{2}$ an inch, and at the end of fourteen days it amounted to $2\frac{1}{4}$ inches, and in a month had increased to nearly 3 inches. Continuing the experiment, at the end of four months, there still remained $\frac{1}{2}$ an inch, or $\frac{1}{8}$th of the whole of the liquid, which was highly carbonaceous, but not volatile. The temperature of the apartment in the meantime had varied from 45° to 75° Fahr.

The other experiment was with 3 lbs. of the same material placed in a suitable vessel in such a manner as to expose a large surface for evaporation; and on passing atmospheric air therethrough by means of a motive-power meter, a very large and rich flame, giving off abundance of smoke, was the result. This at the commencement, when adjusted to 5 feet per hour, gave a light equal to sixteen candles, but speedily the flame became perceptibly less; in a short time it was diminished to a remarkable extent; after twenty-six hours merely a blue light was obtained, and at the end of forty-eight hours no flame whatever existed, as all the volatile constituents at the temperature of the atmosphere had evaporated; on reweighing the residue, barely one-half of the total quantity had been available. This clearly demonstrated how easily people may be deceived by a carefully prepared experiment; for, at the commencement, the air was so highly charged with carbon as to occasion the greatest surprise, but as this was of such short duration, on account of the very small quantity of the highly volatile material, the experiment was very deceptive, and the process of carbonising the air utterly useless.

These experiments are highly instructive as regards the carburisation of gas; they show the great irregularity in the evaporation, also that a portion of the liquid will not evaporate with sufficient rapidity under ordinary temperatures, and they show that a portion does not evaporate. If, on the contrary, the liquid evaporated regularly, even although it might require a comparatively high temperature for the purpose, then the carburisation of gas would be a very valuable adjunct to gas-lighting, as it would give to ordinary gas all the advantages of cannel, producing less heat for a given quantity of light, securing better ventilation, and the agreeable glow produced by the light of rich gas, which is an advantage much to be desired.

There are, however, several firms established in London and elsewhere for carburating gas; they supply the apparatus and liquid; they undertake the exchange of the non-volatile for the volatile liquid; and, indeed, attend to the entire process, taking all trouble and responsibility from the gas consumer who adopts the system.

The process of carburisation was tried for one or two years on the public lamps in the City of London; and, according to the estimates of the projectors, a considerable economy was to be effected, together with a great increase of light. To obtain these advantages, it was necessary to change the ordinary burners, consuming 5 feet per hour, and replace them by others consuming only 3 feet, which of course diminished very materially the account of the gas company; but, as the sequel will clearly prove, was not an economy. The carburising apparatus being placed in the lanthorns, were unsightly, besides throwing great shadows. The gas at one period, when supplied with fresh naphtha, issued with a smoky flame, rendering in a single night the glasses dirty and obscure; but in the course of a short time the naphtha was useless, when, on account of the very small burners, the gas was consumed under a great disadvantage, and the light given was diminished to a serious extent. After a long trial it was renounced, on account of the difficulties it possessed and the absence of the economy anticipated.

CHAPTER XXI.

THE RESIDUAL PRODUCTS FROM THE DISTILLATION OF COAL.

COKE.

The most important commercial commodity of these is the coke, which is an excellent fuel for household purposes, and much used in the arts and manufactures. The breeze or small of this is generally sold for the purpose of brick-making, but where fuel is dear it is often intermixed with a small portion of tar, and subjected to great pressure in suitable moulds, and so formed into blocks or bricks. These are afterwards placed in ovens and submitted to a moderate degree of temperature, in order to expel the volatile matter, as water and naphtha, when a very good artificial coal is produced.

The coke obtained from caking coal is much superior to that from cannel coal; although the latter is very compact in its nature, it is very small, and comparatively possesses little value. The coke from cannel coal is sometimes reduced to powder, and intermixed with tar, compressed, and evaporated, and makes a very good substitute for charcoal, and is called by the French "*charbon de Paris*," Paris charcoal. The coke from Boghead cannel is useless as fuel, but is sometimes employed as a deodorising agent.

TAR.

Although not the most valuable, this is the most interesting of the residual products from coal. As already demonstrated, when the retorts are at a low heat this is produced in abundance, and probably with very careful manipulation coal could be carbonised without any material quantity of tar being produced.

Among the first attempts to profit by this residue, was one to distil and convert it into gas, and the experiments connected therewith were sufficiently satisfactory to induce a large expenditure to carry it into practical operation; but this, whenever attempted, has always terminated in failure. The difficulties attending the operation are various: the tar cannot practically be decomposed with the required regularity; it speedily obstructs the ascension pipes from the retorts with a solid mass of pitch; the gas when produced from it has a great tendency to form itself into naphthaline, which stops the mains; and it is also believed that it does not chemically combine with gas produced in the ordinary manner, and in consequence is deposed in its passage through the pipes. With these difficulties, the distillation of tar for the production of gas has for some years been abandoned.

The products from coal tar are very numerous; by careful distillation it yields naphtha suitable for burning in lamps, or for dissolving India-rubber, making varnish, &c.; benzole is also obtained from it; this is useful for extracting oils and grease from woollens, and a later residue of the distillation of tar is the dead or heavy oil much used for preserving railway sleepers and other timber exposed to the action of the soil and atmosphere. Amongst the other volatile results is paraffin oil, used very extensively in lamps, also an excellent oil for lubricating machinery. Paraffin for candles, excelling for whiteness and beauty the best wax, is also extracted from tar. The various dyes known as magenta, aniline, and rosoline, are all obtained from gas tar, and according to the opinion of many chemists much of the worth of this important material remains to be discovered.

The volatile parts of tar being expelled, pitch, used as a substitute for asphalte, is obtained, which is employed for paving, or rendering walls or floorings impermeable to moisture. The pitch upon being distilled in suitable retorts gives off the best dead oil for preserving timber, and a very excellent coke for foundry purposes is produced, this being exceedingly compact and hard, and does not possess the least sulphur, the presence of which is always injurious to iron when smelted.

AMMONIA.

This is also an important residue in the distillation of coal. It is sometimes obtained in the manner already described in Mr. Croll's process, at other times taken direct from the condenser to be manufactured; but more generally the liquid of condensation is concentrated by being pumped repeatedly over and over again into the scrubbers, where it absorbs the ammonia from the gas, and when sufficiently saturated is withdrawn and manufactured, so by this means serves as a purifying agent, and at the same time becomes more valuable.

The simplest mode of manufacturing the ammoniacal liquor is to put slacked lime into a boiler, which is afterwards charged with the liquor, and when heat is applied the vapours of ammonia are caused to pass over into a vessel containing sulphuric acid, and this when neutralised is evaporated and produces sulphate of ammonia, of which there is a very large demand for agricultural and other purposes. This process is adopted by many works at the present time.

Volatile alkalies, the carbonate of ammonia, muriate of ammonia, or sal-ammoniac, as well as all the other compounds, are produced from the gas-works' residues. Trials have been made to prepare Prussian blue and madder dye therefrom; the first has been carried into operation, but does not produce the same brilliancy of colour as that ordinarily found in commerce.

WASTE LIME FROM PURIFIERS.

The residue obtained from the wet lime purifiers has such a disagreeable odour that even its transport through the streets is the source of serious annoyance. It has been proposed to extract the sulphur from this, as well as the dry lime, by roasting it in ovens; but all who have adopted it agree that the system is not profitable. The wet lime residue is disposed of generally by mixing it with loam for luting the retort doors, for which purpose it is suitable.

The dry lime sometimes finds a ready sale, being in some descriptions of ground very valuable as a fertilising agent. The residue from the oxide of iron purification is generally repurchased by the firms supplying the material, who, it is stated, derive considerable advantage from it.

CHAPTER XXII.

EXPLOSIONS OF GAS.

When lighting by means of gas was first proposed, the fears of explosions were the strongest arguments against its adoption, and several scientific men of the period attempted to reduce these casualties to a positive law, by asserting that a gasholder containing 15,000 feet of gas would in exploding be as destructive as ten barrels of gunpowder. As a further proof of the slight knowledge of the nature of gas at the time, Sir William Congreve, with other learned gentlemen, when acting as a royal commission of inquiry on the subject of gas explosions, recommended that gasholders should be exceedingly limited in their dimensions (not to surpass 6,000 cubic feet each), and, further, that they should be surrounded by strong walls, to confine the disastrous effects of explosion should it occur.

We can look with satisfaction to the advancement science has made in connection with this subject, for now we know, instead of gas being so terribly destructive, that when unmixed with atmospheric air or oxygen, it is as harmless as regards explosion as the water in the tank beneath it; and if it were possible to insert a lighted torch, or taper, into a holder containing gas, instead of the gas exploding, the flame would be extinguished. In other words, gas unmixed with oxygen suffocates flame, and in this state cannot ignite or explode.

That explosions by gas have occurred, and do sometimes even now happen, is well known, but these have been, and are, so remarkably few in number, that the extraordinary safety of gas lighting is as fully established as the safety of railway travelling under the most careful supervision; however, by treating on these accidents, and describing their causes, is to adopt the proper step to prevent them.

Explosion is an instantaneous ignition of a mass, and that mass may be solid or gaseous; thus, a mixture of charcoal, sulphur, and nitre in certain proportions, and prepared in a particular manner, form gunpowder, which ignites instantaneously, and the increased volume, occasioned by the solid assuming the gaseous state, is the cause of the force or power attending the combustion. There are numerous other solid compounds even more explosive than gunpowder, but the simple mention of this will be sufficient as example.

Certain gases, like the solids, when intermixed in due proportion, are likewise capable of instantaneous combustion; for instance, hydrogen when intermixed with oxygen, as before stated, in the proportion, by volume, of two of the former and one of the latter, ignites, producing explosion; and coal gas when combined with air in certain proportions is also explosive, this being due to the hydrogen and carbon composing it entering into combination with the oxygen of the atmosphere, producing water and carbonic acid gas; and the nearer they approach to the proper proportions for the perfect formation of these compounds, the greater is the force of explosion. A mixture of seven parts of air and one of gas is considered to be the most explosive compound, but this must depend on the quality of the gas. Mixtures of less than three of air to one of gas, or more than eleven of air and one of gas, do not explode.

Explosions from gas are exceedingly rare. By a Divine ordinance, the odour arising from gas is generally so repulsive as to awaken in the minds of the most callous a desire to avoid the inconvenience, and in so doing the danger is averted. However, there are circumstances where this notice by odour is not manifested, as where from the lightness of the compound it ascends in the atmosphere above;

but when in dwellings or other buildings the slightest odour of gas is noticed, it should always be attended to.

At one period or other, in some of the largest cities of the United Kingdom, as well as those of the Continent, gas-works have been the scenes of explosions. This has often arisen from a new gasholder, when nearly terminated and ready for use, having, from a very simple oversight, been communicated with the manufacturing apparatus; and it has afterwards happened that through a leaky valve allowing the gas to pass, or perhaps by some careless person thoughtlessly opening the valve, the gas has entered, intermixed with the air in the holder, and the accidental production of a light has caused the disaster. Therefore, when new holders are constructed they should either not be communicated with the manufacturing apparatus until quite terminated, or the pipes should be "logged," or sealed with water, so that no gas can possibly enter until quite ready for use.

But explosions of this nature have occurred when the holder was being first filled with gas; one of the most remarkable took place a few years ago, by which the engineer was killed. This arose from a defect in the construction, and want of ordinary caution on the part of the unfortunate sufferer. The facts are simple, for the holder on being charged with gas at the commencement of the operations contained a considerable quantity of air, the two forming an explosive compound, and by a singular fatality it happened that the holder was so far bound, or set, as not to give any pressure. The engineer, desirous of judging the quality of gas, very imprudently tried it at an open orifice of about $\frac{1}{4}$ inch diameter; the consequence was, the flame entering, the explosive compound in the holder ignited, and produced the disaster. Had the gas been tried by an argand or fishtail burner the accident would not have occurred, the holes in these being too small to permit the flame to enter.

Explosions have taken place in station meters when newly erected, just previously to their use, this arising from causes already mentioned—by leaky valve, or by unnecessary meddling on the part of the workpeople. On one occasion which came under the writer's notice, a calamity of this kind occurred from the mixture taking fire through the men making the joint with overheated lead. And this suggests the varied opinions as to the possibility of a spark igniting gas. The general opinion is that gas cannot be ignited by that means; and, indeed, it is difficult to be done, but by chance a spark may be produced of sufficient heat to inflame gas.

Accidents have frequently occurred when laying mains; often occasioned by a bladder-valve, which has permitted a small portion of gas to pass into the main beyond it, where the explosive compound was formed, and by the merest hazard a neighbouring light has produced the calamity; therefore, in laying mains, when practicable it is always better to have a sheet-iron temporary valve, which is done by having the spigots of two pipes together where the stoppage is desired, and a thin sheet of iron between them, which may be clayed or cemented round to prevent the leakage of gas. The plate can be removed when requisite, and a temporary or permanent joint made with a running socket.

An erroneous impression exists that if a gasholder were to be rent by accident, and the gas ignited, whenever the holder touched the ground, and there being no pressure, that the contents would explode. This is incorrect, for, no matter the size of the opening, when the pressure ceased the gas would be extinguished; but from this moment danger would commence, for a portion of the gas remaining in the crown would gradually issue, and air take its place, so by degrees an explosive compound would be formed.

An explosive compound of gas when under pressure only ignites at the exterior of the pipe; but if the pressure be taken off, the flame enters, and it explodes.

In illustration of these assertions, I will relate a few experiments entered into by myself in order to be convinced of some of the circumstances under which explosions take place. The most suitable and available vessels for the purpose were old tin-plate meter cases of the larger sizes. These were entirely closed except at the outlet and the bottom, or emptying plug. In the first, a 50-light, the gas was allowed to flow through for a considerable time, when the bottom plug was replaced and a light applied to the outlet. The gas then burned with a flame the diameter of the pipe, and about 18 inches high, but this quickly diminished until it died out or was extinguished. This was tried several times with the same result, thus proving that when gas is enclosed in a vessel, the moment the pressure ceases the flame is extinguished. But by allowing the vessel to remain some time, and afterwards applying a light, it was shattered to pieces; which arose from a part of the gas having gradually escaped, in the meantime air entering and combining with the remainder, so forming an explosive compound.

Another similar vessel was again charged as before, but in this instance the bottom plug was left open, and on applying the light the flame was considerably higher and more vivid than in the former experiments, caused by the gas ascending by its lightness, air entering by the lower orifice to fill the place of the gas ascending. Gradually the flame became dimmer and dimmer, and at last changed to a deep blue, when it suddenly entered like an inverted cone, and explosion took place, shattering the meter case, and throwing its ends a distance of several yards.

On another occasion, on making a trial with a very small holder containing 2 feet of explosive compound, with a pressure of $\frac{5}{10}$ths, the gas issuing from a $\frac{1}{4}$-inch orifice, it ignited with a very intense blue flame; but on taking the pressure off the holder and applying the light, explosion occurred, lifting the holder from its place, and throwing the water of the tank in every direction.

I need hardly say that these experiments require great care. Thin tinned iron vessels are sufficiently strong; and as the *débris* is thrown a considerable distance, too much caution cannot be exercised. When a cylindrical vessel is subjected to explosion the ends generally give way, whilst the sides remain intact.

The explosion of gas was formerly considered to be due to the hydrogen in combination therewith, which assertion was maintained by Sir William Congreve. However, it is now established that the richest gases are the most destructive when exploding.

An explosive mixture always possesses a very powerful odour of gas; this is sufficient to indicate to any one that a light should not be approached; and under these circumstances, when in dwellings, ordinary precautions only are requisite; above all to have no lights near, and to open the doors and windows, the upper part of the latter especially, as gas by its lightness ascends, and will readily escape thence. The main tap should be turned off, and a careful inspection made, when perhaps a burner will be found turned on, or an hydraulic joint without water, or some other defect which can easily be remedied. No one should ever apply a light where there is an odour of gas in the upper part of an apartment; many little mishaps have occurred through neglecting this precaution. Should there be any escape which can only be detected by flame, the gas ought to be turned off for two or three hours, and the other precautions being adopted, the light may be applied the moment the main tap is turned on; but it is always better and safer to detect escapes in dwellings without the employment of a flame, it requiring only a little more patience.

Meters are sometimes mysteriously destroyed by explosion, even when fixed in their places. The syphon plug when not sealed by water, and the tap of a burner being left open, are sufficient to permit air to enter and form the explosive compound, and a light being applied to an orifice without a burner, the flame enters, but does no injury beyond rendering the meter useless.

Of the few explosions that have occurred in gas-works, the majority have arisen from having the pipes in vaults and tunnels, or perhaps from open spaces existing under some of the apparatus, generally with the view of seeing to the perfect condition of the pipes, &c. From this originated the first two accidents of the kind, which befell Mr. Clegg, forming a very powerful argument against the use of subways, proposed some time ago, for containing gas mains; and if these were unfortunately to be carried into operation, all the extravagant fears of danger which existed at the introduction of gas would certainly be realised.

It is well known that mains as now placed, even in isolated places where there is little traffic, are sometimes unaccountably broken, and this when entirely protected from the effects of severe cold or frost by the depth they are laid. It is also well known that cast iron, and even wrought iron, have a tendency to become brittle when exposed to the action of frosty weather; therefore we may reasonably suppose that, if mains break as now placed, accidents of this nature would be considerably more frequent if they were placed in these subways and subjected to the action of frost.

In the event of a pipe breaking as mains are at present laid, the gas may percolate through the earth and be lighted on the surface, or even a portion may find its way into the sewer, in both cases giving timely notice for reparation; but if such an event occurred with a pipe when enclosed in the subway it is difficult to imagine the consequences; an explosion under these circumstances would cause houses to totter to their foundations—probably shatter the subway containing them; and in the midst of all this, the only possible means of remedying the evil would be to shut the valves which communicate with the broken pipe, and so put the district in total darkness, thus increasing the terror of the inhabitants, and offering facilities for committing depredation with impunity.

There are minor objections against the use of subways, such as their excessive cost, and the difficulty of attaching services, which could only be done with safety by shutting off the supply in the neighbourhood, and this, to use the mildest term, would be a very serious inconvenience. These and many other reasons are sufficient to prevent subways for gas ever being successfully employed; they may be tried, and may be used under certain circumstances, but can never be carried into operation successfully in the streets of a city.

On the occasion of a fire occurring near a gas-works, the public journals generally fall into error by assuming the contents of the gasholders to be explosive, and conjecture the amount of damage that would arise from this event occurring, the excitement being much increased by this mis-statement. Gasholders when in use, that is, containing ordinary gas, cannot by any means explode, even although the plates forming them were to be made red-hot by the flames: all that could occur is that the gas, expanded by the heat, would issue in detached flames, but no explosion could take place. Another common error, when an edifice, as a theatre, takes fire, is to turn off the gas to prevent explosion, and this is done sometimes at the risk of putting the audience in darkness to find their way out in the best manner they can. Nothing is more absurd; for supposing, at the worst, the fire to melt the pipes in the building, and the gas to issue, the same flame which melted the pipe would ignite the gas, so that explosion is not possible under these conditions. A good system is to have a valve or valves on the exterior of all public buildings of resort, which, in the event of a fire unfortunately occurring, can be shut off after all the people have left the building, so preventing the destructive effects of the flame should the gas ignite, and the loss of gas.

CHAPTER XXIII.

ON WATER GAS, OR THE HYDROCARBON PROCESS OF GAS-MAKING.

If, as already stated, the steam or vapour of water be passed through a red-hot iron tube, it is decomposed, and hydrogen gas given off in considerable quantities: 10 lbs. or 1 gallon of water will yield 210 cubic feet of hydrogen gas, which, although possessed of considerable heating power, is quite worthless for illuminating purposes.

Hydrogen gas, however, has been successfully applied for heating stoves, and when the jets of this are made to burn in a stove filled up with loose fragments of platinum-foil, a very cheerful-looking fire is produced, well known to the public from its frequent exhibition at the Polytechnic Institution of London by Professor Bachhoffner, under the name of Bachhoffner's polytechnic fire.

No systematic manufacture of hydrogen gas has been attempted on the large scale for the purpose of heating, although it has been proposed on various occasions. Several patents have been taken out for producing hydrogen gas from water, and bringing it into combination with the rich gases derived from oil, resin, tar, naphtha, cannel coal, and other materials which yield highly illuminating gases. Among those who have obtained patents of this kind are Messrs. Donovan, Lowe, Manby, Val Marino, Radley, White, Croll, Webster, Barlow, and Gore.

Although the processes indicated by all these patents differ very slightly from each other, if indeed they are not in some cases perfectly identical, the only one which was carried out in a really practical manner was that of Mr. Stephen White. Under the patents of this gentleman the towns of Ruthin, Southport, Warminster, Dunkeld, together with many mills and factories in Lancashire, were lighted with hydrogen produced from water and combined with the gas from resin or cannel coal, and called the hydrocarbon process.

About twelve years ago, when this treatise was first presented to the public, the hydrocarbon process was in great favour, and very sanguine expectations existed of its success. Amongst its ablest supporters were Dr. Frankland and the late Samuel Clegg, both of whom were entitled to the utmost confidence—the former on account of his profound chemical knowledge and the general accuracy of his opinions—the latter for his great ability and having been so intimately and honourably associated with gas-lighting from its earliest date.

At the period mentioned, some sanguine minds gave the most extraordinary accounts of the process in question. Mr. Clegg's statement of the process was undoubtedly of a very extravagant nature, for he assigned 75,000 feet of 12-candle gas as the produce of one ton of Boghead coal when so treated, and it is inconceivable how he could have fallen into this error, inasmuch as this production is literally impossible, for the weight of that quantity and quality of gas would be about 1 ton 1 cwt., whereas the whole of the volatile portion of a ton of Boghead coal, together with the weight of the hydrogen intermixed with it to form 75,000 feet of gas, would be under 15 cwt.; therefore if the quantity stated were obtained, it could not be of the quality indicated.

However, the process was so well supported as to induce many companies to make trials on an extensive scale; amongst these were the Manchester and South Metropolitan, and during several months, the engineers of these establishments did their utmost to ensure success; but experience and time proved the fallacy of the system, and the results of these extensive experiments only made evident the impracticability of the hydrocarbon process. Whilst the towns before mentioned which were supplied by these means, instead of yielding profit, as was afterwards the case when coal gas was adopted, suffered one continuous loss.

The causes of this signal failure were various. Firstly: The production of hydrogen by the decomposition of water is very costly; under the most favourable circumstances much more fuel being required to produce a given quantity of gas from water than from coal. Secondly: Hydrogen when so produced and intermixed with rich hydrocarbons, forms merely a mechanical mixture—no chemical affinity existing between them—and, in consequence, the hydrocarbons were deposited in the pipes before the gas reached the consumers' burners, whereby it was so much impoverished and deteriorated as often to be next to worthless as an illuminating agent. Thirdly: It was impossible to regulate the supply of steam in proportion to the heat of the retort where it was destined to be decomposed; so that when there was an excess of steam, nearly the whole passed off merely superheated without being decomposed, to be afterwards condensed into water; so, under these circumstances, the rich gases were delivered without the proper quantity of hydrogen, and of course a beautiful light was the result. On other occasions, when the water was successfully decomposed, the hydrogen being in excess, the gas would be exceedingly poor, possessing little illuminating power. Thus, one night the light would be of great brilliancy, and the next of the worst description. This irregularity was very fatal to the method.

But one of the greatest objections was the cost of wear and tear. Clay retorts, although most suitable on account of being capable of sustaining that degree of heat essential for the decomposition of water, could not be employed because of the leakage, the hydrogen being much more penetrating than coal gas. Therefore iron retorts only could be used; and these, by the combined action of the heat and the oxygen absorbed by them from the water, were speedily converted into a kind of plumbago; they also thickened to a great extent, thus presenting a large mass of non-conducting material, which not only increased the fuel to an enormous degree, but the retorts were of very short duration, so that the wear and tear and fuel account added considerably to the many other disadvantages.

One of the great arguments of Dr. Frankland in favour of the hydrocarbon process was, that the hydrogen swept out the whole of the carbon, and instead of this being deposited in the retorts, it was carried to the burners for consumption. This might probably be a consideration at that period, but the improvements in carbonising coal, by the employment of the exhauster, have reduced this deposit to an unimportant amount.

It may be stated that the zeal, energy, and perseverance displayed in endeavouring to carry this process to a successful issue, merited a better result; but the system was erroneous, and a striking instance of the highly successful experiment of the laboratory being commercially worthless when carried into practice.

Hydrogen gas was employed by M. Gillard in another manner. In this instance the gas issued from an argand burner surmounted by a platinum wire cage which reached a little above the dull hydrogen flame; the wire cage became incandescent, and a cylinder of intense light was formed around it over the whole surface, the light being obtained simply by the incandescence of the platinum wire. Narbonne, and two or three other small towns in France were lighted for some time by these means, but the great expense of hydrogen caused it to be renounced. The light by this process, although intense, was neither agreeable nor useful. With the view of obtaining hydrogen more economically, M. Gillard erected a cupola similar to those in iron founderies; this was filled with coke or charcoal, ignited, and the fuel brought to a state of incandescence by a fan or blower; after which (all passage to or from the atmosphere being closed) steam was admitted at the lower part, and passing through the volume of fuel was decomposed, when the hydrogen and carbonic acid with which it was impregnated were withdrawn by an exhauster from the upper part of the cupola. From time to time the supply of steam ceased, and air was furnished by the blower as before, to bring the fuel to the proper degree of temperature for the decomposition.

This plan, although much more economical than the retort system, did not succeed; the expense of manufacture was still very excessive. Therefore it may be concluded that the production of hydrogen gas by the decomposition of water is neither advantageous nor economical, and whether applied to be intermixed with rich gases, heating platinum wire, or being intermixed with oxygen to produce the hydro-oxygen or lime light, cannot at the present time compete with coal gas.

CHAPTER XXIV.

ON THE RATING OF GAS-WORKS IN PAROCHIAL ASSESSMENTS.

After many years of strife and contention, during which extravagant statements have undoubtedly been put forth on both sides of the question, a more rational and sober series of conditions appears to have been agreed upon. The principle is at least firmly established that every property, however great, and however extensive may be its ramifications, is to be rated on the rental which a tenant would give for it as a whole from year to year, deducting therefrom such expenses as will necessarily be incurred by the owner in order to command such a rental.

In the following discussion I wish to guard myself from any imputation of advocacy on either side of the question. All my inclinations lead me to lean to the side of public companies associated together for purposes of enterprise, and who at the same time are frequently entitled to rank as public benefactors. I cannot, however, conceal from myself the fact, that a great deal of misplaced indignation has been displayed of late years by public companies and their organs on the subject of rating. They seem to have been especially irritated at seeing their property assessed on the same principles as other descriptions of property, and have sought to introduce exceptions and modes of dealing with their particular case which do not appear warranted by the law as it now stands.

I shall not discuss the justice of the present law of rating, but simply endeavour to give, as clearly as I am able, my view of the manner in which it should be carried out, and the way in which gas property should be rated in proportion to other property in the same parish. If powerful joint-stock companies possessing a large interest in the soil, such as railway, canal, gas, and water-works companies, would consider for a moment the number of separate individuals which their gigantic concern displaces, and reflect how large an amount a parish would derive from the separate rating of so many individuals, they would see less reason than at present to complain of the injustice of parochial rating. From a parliamentary document which appeared a few years ago, it appears that the London and Birmingham railway proper, 112 miles in length, was rated to the relief of the poor on a net rateable value of £134,159. Now, this rateable value applies to an expenditure of at least four millions sterling in works, buildings, and other stationary property which is clearly rateable, so that the value on which the railway is rated would be about 3·3 per cent. on the fee-simple of the property But conceive the same amount of four millions sterling invested in buildings of any description, and it will be admitted by most persons who have attended to the subject that such a rating is far below that which would be applied to buildings; and that, in fact, a rateable value equal to 6 or 7 per cent. of the value is by no means unusual. While, on the one hand, it is highly unjust for public companies to be rated for a mere local purpose at a higher proportionate rate than other properties, it is also manifestly unfair that they should escape local taxation to a greater extent than any other kind of property.

In proceeding to rate any description of property extending into many different parishes, such as a gas-work, a railway, a canal, or a water-work, it is necessary first to determine the net rateable value of the whole, and then to apportion this net rateable value amongst all the parishes in which the works are situate. I shall first consider the mode of ascertaining the rateable value of the property as a whole, and then proceed to the method of subdividing or apportioning this amongst the parishes.

Now, in order to arrive at the rateable value of the whole, we are clearly to be guided by the words of the Act 6th and 7th William IV. chap. 96, which enacts that property is to be assessed first at that rent which it might reasonably be expected to let for from year to year, and then that the net rateable value is to be found by deducting from this annual rent such expenses for insurance, repairs, &c., as will enable the property to command such rent. The exact words of the Act, which is commonly called the Parochial Assessment Act, are as follows:—"That no rate for the relief of the poor in England and Wales shall be allowed by any justices, or be of any force, which shall not be made upon an estimate of the *net* annual value of the several hereditaments rated thereunto; that is to say, of the *rent* at which the same might reasonably be expected to let, from year to year, free from all usual rates and taxes, tithe commutation rent charge, if any, and deducting therefrom the probable average annual cost of repairs, insurance, and other expenses, if any, necessary to maintain them in a state to command such rent."

The first thing therefore in rating a gas-work is to determine the rent at which it may be expected to let for from year to year, and here immediately and directly arises the necessity for a reference to the company's balance sheet, in order to find out the profit which the company is making. It has happened in the absence of such a document, when access to the company's books has been refused from some cause or other, that valuers have been required to form an estimate of the annual value from independent calculations of their own, in which the cost of manufacturing the gas is deduced from certain data real or imaginary, and a profit assumed as the amount realised by the company. I shall not stop to inquire into the mode of so estimating the profits of a gas-work, although when the amount of coal carbonised is known, the selling price of gas being given, the locality and other circumstances taken into consideration, a tolerably fair approximation may be made. I am only desirous at present to establish, as a foundation to proceed upon, that the profit realised by the company in any one year is the basis or ground-work from which the rateable value must be derived.

This point should be clearly settled at the outset, because it has been contended more or less ever since 1836, when the Parochial Assessment Act passed, that such a mode of assessment was unfair with respect to railways and similar works. It has been said that in seeking to ascertain the profits of a railway company you are seeking to rate them on *profits*, which is expressly forbidden by a short Act which is passed every session for the purpose of exempting stock in trade from liability to be rated. But on the other hand it is to be observed, that the inquiry into profits is rendered necessary in order to ascertain what the property would let for, and this is precisely that which is directed to be ascertained by the Parochial Assessment Act. The necessity for inquiring into profits is supported by every example that can be brought to bear on the subject.

In the case of rating ordinary houses the gross annual value is a very simple affair, because the house has generally a tenant who does exactly pay a rent for it, and even if in the landlord's occupation, the value to let is easily inferred from comparison with similar houses; but when we come even to the most simple case of premises deriving a peculiar value from situation, manufacturing power, or any other circumstances, we require to know immediately the amount of profit which annually arises from such circumstances. Thus we may know perfectly well, without any inquiry into profits, what all the houses in any particular street will let for; but suppose one house to be fitted with a billiard-table from which the tenant derives a profit, we shall require to know the amount of this profit before we can estimate the additional value which is conferred by the billiard-table.

The same remark applies to peculiar situation and to manufacturing power, as where machinery exists on the premises. In all these cases, where the landlord holds or occupies the property himself, we ought to know the profit which he derives before we can possibly estimate the value of the property to let from year to year.

Admitting then that the profit must be inquired into, there are two ways of arriving at this—either by taking it from the company's books of account, or making an independent estimate of what the profit ought to be. In the case of railway companies, the business carried on is so extensive and complicated that as a matter of necessity the parochial officers and persons acting for them are compelled to take the profit from the accounts of the company, usually from the accounts published for their half-yearly meetings. In the case of gas companies, however, some of which are not under the most efficient management, it is not unusual for valuers to make their own estimate of the profits on certain known *data*, which are perhaps admitted on the part of the gas company. I shall not at present enter into the mode of estimating the productive power, and consequently the profit of a gas company, but suppose that this has been ascertained by one or other of the means pointed out, and that the profit is found to consist of a certain sum which remains after deducting the total expenditure of the year from the gross receipts during the same period.

We have now arrived at the profit made by the company whilst the works are in their own occupation, but this is not the sum which a tenant will give for them, because he must not only have a certain sum left for himself as a remuneration for his time and superintendence, but must have interest for the capital employed to carry on the works.

The amount and nature of these arbitrary allowances for the tenant have given rise to great disputes, and the utmost variety of opinion is entertained on the subject. It appears to be an admitted principle on all sides that the tenant is to be allowed a certain amount of capital to carry on the works, that is, to pay for coal, lime, wages, &c., until his returns are received for gas and coke sold; and also that he is to be allowed for capital corresponding in amount with the present value of such machinery as comes under the denomination of stock in trade, and which cannot be rated as forming a part of the premises, or an hereditament attached to the soil.

On the part of the gas company the whole yearly expenditure is first deducted from the gross receipts, including such items as wear and tear of retorts, loss by meters, rates and taxes, directors' and auditors' salaries, bad debts, &c. The balance which remains is then subject to what are termed arbitrary allowances for tenant, in which his capital is made to consist of the following items :—

1. Capital required to enable him to carry on the works, usually estimated by valuers for the companies at about half the gross expenses for one year.

2. The present value of the meters, retorts, and other stock in trade.

On the capital so arrived at, it is assumed that the tenant would require 5 per cent. for interest and 12½ per cent. for profit, which amount is therefore deducted from the gross value as an arbitrary allowance to the tenant.

On the other hand, the parties usually employed to value for the parishes, contending that directors' and auditors' salaries being already allowed for in the expenses, make this a set-off against the remuneration of the tenant. Considering further the perfect security for payment which the Act of Parliament gives to most gas companies, the means which they have of enforcing payment, and the small amount of risk incurred in carrying on their business, they contend that such an allowance of 17½ per. cent. for capital is excessive, and ought not to be more than 10 or at most 15 per cent. Then as to the amount of capital, they seem to have generally allowed the retorts to be stock in trade, but not the meters, which they consider fixtures to the mains, and therefore subject to be rated.

An example of estimates formed on these varying principles will be shortly given, from which it will be seen how widely these arbitrary deductions vary according to the views adopted by the valuers.

I now come to the class of deductions comprised under the head of statutable allowances, comprehending all those (such as rates, taxes, insurances, and repairs) which are necessary to enable the premises to command the rent assumed. Here the valuers for gas companies have sought to bring in charges for repairs, or rather for restorations, which are said to be necessary, in addition to those which appear in the annual current accounts. For instance, they claim an annual allowance for the repair of buildings, although the accounts include every farthing which has been expended in such repairs.

They also claim an allowance for insurance of buildings beyond any amount which is actually paid for such a purpose. Besides which they claim an allowance of 2 per cent. on the value of all their trade fixtures and utensils, and of $1\frac{1}{2}$ or 2 per cent. on the value of all the mains, for the reproduction of these when worn out. The valuers for parishes, on the other hand, entirely dispute these allowances, and contend that the current expenses provide for such reproduction by having everything renewed as fast as it is worn out and requires to be replaced.

Some years ago, in the rating of railways, very extravagant allowances were claimed, on the same principle, to cover the reproduction of the rolling stock and of the permanent way. It was, however, frequently suggested that if any provision were necessary for such a purpose, the railway company should itself set aside a sum annually, by way of sinking fund, to cover such an expense when found necessary. In certain cases where no such fund was set aside by the railway company, the allowance for reproduction was refused on the rate being appealed against. There is still, however, a difference amongst railway engineers as to the necessity for a depreciation fund. The London and Brighton Railway Company, acting probably under the advice of their able chairman, Mr. Lang, who possesses a vast amount of practical experience and valuable statistical knowledge, has been in the habit for some years of setting aside a sum out of its receipts to form a depreciation fund. On the other hand, such a fund has been declared altogether unnecessary by one of the most eminent and accomplished railway engineers of the day, who has devoted himself to every question of railway politics with an energy and industry peculiarly his own. I need scarcely say that I allude to the originator of the broad gauge, who has publicly declared that the current accounts of the Great Western Railway include such expenses as are necessary, from time to time, for keeping in perfect order both the rolling stock and the permanent way, and that no annual reserve in the shape of a depreciation fund is necessary for their maintenance.

I am aware that there are many rating cases which are tried on appeal at quarter sessions, where an intimation is given by the bench that some allowance for depreciation should be made to the company beyond that which appears in their accounts. In addition to this, in the valuing of houses, manufactories, and many other descriptions of property, where no accounts of repairs have been kept, or where it appears clear that a charge for restoration would accrue suddenly at some future time, and cannot be provided for by annual repairs and restoration, it may be necessary to calculate on sound principles what the allowance should be for such a purpose. It will not be sufficient in such a case to assume any mere arbitrary allowance on the cost, such as $1\frac{1}{2}$, 2, or 5 per cent., all of which sums have been claimed for reproduction, but it must actually be ascertained what sum under the given conditions of the question will be an equitable allowance for the purpose. There are two elements which must be assumed in any case of this kind; first, the value of the object to be restored, and the period or distance of time at which the restoration is to be made. The value must not be the original value of the object when first erected, but its value at the time of making the rate; and when once the sum to be set aside annually is determined, it will be the same year after year, because, although the value of the object will diminish yearly, so also, in the same proportion, will diminish the number of years during which the annual sum is to be set aside. The principle I am now contending for is this, that the annual sum to be set aside is that sum which at compound interest will amount in the assumed number of years to the whole sum required at the end of that period to effect the restoration. For instance, suppose a building or any other object whose present value is £1,000 should be assumed to last thirty years, when an amount of £1,000 must be employed to restore it; then, I say, the annual sum to be put aside is that which at compound interest, at 3 per cent., will amount in thirty years to £1,000. Now, it appears from the tables of compound interest that £1 per annum invested at compound interest during thirty years will amount at the end of that time to £47. Hence it follows, if we divide 1,000 by 47, we shall have the sum which, being invested annually at compound interest, will at the end of that time produce £1,000. Then $\frac{1,000}{47}$ = £21 5*s.* 8*d.*, the sum to be invested annually. This would amount to rather more than 2 per cent., which is the proper allowance when the duration is estimated at thirty years.

When a period of twenty years is taken for the duration of an object, an allowance of nearly 4 per cent. must be made.

When the period is 30 years, 2 per cent.
„ 40 „ 1·3 „
„ 50 „ ·88 „

The following estimate, made by Mr. Lee, of the net rateable value of the Phœnix Gas Company, forms a good example of the mode usually adopted by the valuers of gas companies for assessing the rateable value. This valuation was made in 1849 on the occasion of an appeal by the Phœnix Gas Company against the rate in the parish of Greenwich.

	£ s. d.	£ s. d.
Net balance for 12 months, taken from the company's books		21,964 12 0
Arbitrary deductions to arrive at the gross estimated rental.		
Floating capital employed by tenant, assumed equal to six months' expenses	33,210 0 0	
Present value of meters, the cost being £25,000	15,000 0 0	
Present value of retorts	7,525 0 0	
Total amount of tenant's capital	£55,735 0 0	

	£ s. d.	£ s. d.
Brought forward		21,964 12 0
5 per cent. for interest on £55,735 is .	2,786 0 0	
12½ per cent. for tenant's profit on £55,735	6,966 0 0	
Amount of interest and tenant's profit for one year .		9,752 0 0
Gross estimated rental		12,212 12 0

Statutable deductions.

Rates and taxes previously deducted in arriving at net balance; annual repairs of buildings previously deducted.

	£ s. d.
Insurance on buildings, value £65,054, at 5*s*.	162 0 0
2 per cent. for reproducing the following:—	

	£ s. d.
Trade fixtures, value	39,672 0 0
Utensils	12,945 0 0
Mains in the stations	6,271 0 0
Street mains . . .	105,760 0 0
	£164,648 0 0

	£ s. d.	£ s. d.
2 per cent. on £164,648	3,292 0 0	
Total deduction for renewal and insurance . . .		3,454 0 0
Net rateable value of the whole property, the value being £278,998		£8,758 12 0

It appears that the valuers for the parish during this appeal did not treat the production of the Phœnix Gas-works as a whole, but confined their estimates to the production of the Greenwich Station alone, whereas the company has also manufacturing stations at Vauxhall and at Bankside. In consequence of this, no comparison can be made between the net rateable values arrived at by the two parties, treating the works as a whole. Mr. Penfold, however, in his work on Rating, has published a statement of net rateable value for the whole works, founded on the basis of the company's own rental, and on arbitrary allowances, according to Mr. Barlow's statement of expenses for manufacturing gas. This statement is taken from an able Report made by Mr. Barlow in 1849 to the Directors of the City of London Gas Company. In his Report, Mr. Barlow analyses with great minuteness the prospects of the Great Central Gas Consumers' Company. He investigates the cost of every item of gas manufacture under two distinct heads, *production* and *distribution*, making the total cost of production amount to 20·64*d*. per 1,000 feet of gas made, and the expense of distribution equal to 13·51*d*. per 1,000. Mr. Penfold, considering Mr. Barlow as the especial advocate of the then existing companies, and interested in proving the cost of gas-making to be as high as possible, considers such statements fair evidence as against any gas company on the question under discussion.

Using the data before explained, Mr. Penfold makes the net rateable value of the whole of the Phœnix Company's gas-works	£18,312
And substituting Mr. Croll's cost of manufacturing gas, as given in evidence before the Central Gas Committee, he makes the net rateable valuable of the whole	28,455
Mr. Lee's valuation of the rateable value being . .	8,758

We shall present one other case in which the author was himself engaged, and Mr. Lee valued for the gas company. This was the case of the British Gas Company and the parish of Ratcliff. Mr. Lee's valuation in this case was nearly on the same basis as in the Greenwich case, except that the estimates claimed only 1½ instead of 2 per cent. for the reproduction of the mains. The following is Mr. Lee's valuation :—

	£	s.	d.	£	s.	d.	£	s.	d.
Cr.									
Total rental for gas-light				21,188	0	0			
Cash for coke and ammonia				4,514	0	0			
Total receipts for 12 months							25,732	0	0
Dr.									
Coals, 12,322½ tons used (at 14*s*. 10½*d*.) . . .	9,153	0	0						
Lime used for purifying	267	0	0						
Working process wages	5,092	0	0						
Wear and tear of retorts, &c.	2,020	0	0						
Meter repairs and fixing £882									
Meter rent received 400									
Loss	482	0	0						
Carried forward	17,014	0	0				25,732	0	0

	£	s.	d.	£	s.	d.	£	s.	d.
Brought forward	17,014	0	0				25,732	0	0
Rates and taxes (last year, 1848)	650	0	0						
(Rates in 1849 are larger.)									
Office expenses and clerks' salaries	742	0	0						
Directors' salaries . . .	500	0	0						
Ordinary law expenses .	70	0	0						
Interest on borrowed capital . . . £1,395									
Bad debts and over-charges	400	0	0						
							19,376	0	0
Net balance for 12 months . . .							6,356	0	0
Deductions to arrive at the gross estimated value 5 per cent. on the capital* necessarily employed by a tenant	11,500	0	0						
Ditto on the present value of meters (the cost being £5,640) . .	3,640	0	0						
Ditto on the present value of retorts (cost £4,680)	2,420	0	0						
Amount of tenant's capital	17,560	0	0	£	s.	d.			
5 per cent on the above is				878	0	0			
Amount of tenant's profit, being 12½ per cent. on the above £17,560 capital				2,195	0	0			
Amount of interest and tenant's profit for 12 months							3,073	0	0
Gross estimated rental of the whole property							3,283	0	0
Statutable deductions.									
The rates and taxes are before deducted.									
Annual average repairs of buildings .				390	0	0			
Insurance on buildings				106	0	0			
For renewal or reproducing trade fixtures and utensils, their value being £16,847 (meters not included), at 2 per cent.				336	0	0			
Carried forward				832	0	0	3,383	0	0

* The capital here assumed is considerably more than six months' expenses, and is nearly equal to six months' gross receipts.

	£	s.	d.	£	s.	d.
Brought forward	832	0	0	3,383	0	0
For renewal or reproducing the mains on the stations, and the street mains, their value being £24,453, at 1½ per cent.	367	0	0			
Total of repairs, insurance, and renewal . . .				1,199	0	0
Net rateable value of the whole property . . .				£2,184	0	0

It being considered that this rateable value was too small, having regard to the magnitude and capacity of the works, the author was called in by the parish at the suggestion of Mr. Penfold, who was one of the arbitrators, and after going through the works and minutely considering the Company's evidence to see what parts could be adopted as reasonable and fair, the result of his investigation was the following estimate :—

NET RATEABLE VALUE OF ALL THE WORKS AND MAINS.

	£	s.	d.	£	s.	d.	£	s.	d.
Gross revenue, as per statement A							24,172	17	3
Production account.									
Coal, as per evidence . .	9,153	0	0						
Labour of distilling 12,322 tons of coal, as per statement B	2,261	5	0						
Wear and tear of retorts, as per statement C . .	1,333	13	0						
Expense of lime for purifying, 12,323 bushels, at 4*d*.	205	8	0						
	12,953	6	0						
Less residual products, as per statement D .	4,601	13	4						
				8,351	12	8			
Cost of distribution, as per statement E				3,276	7	3			
Statutable allowances, as per statement F				1,219	18	0			
Arbitrary deduction for interest and tenant's profit, £10,000, at 15 per cent., as per statement G				1,500	0	0			
							14,347	17	11
							9,824	19	4
Deduct rates and taxes, as per company's statement .							650	0	0
Net rateable value of the whole property . . .							£9,174	19	4

A.—Estimate of Gross Revenue.

12,322½ tons of coal carbonised per annum, each ton assumed to yield 9,200 cubic feet of gas.

			£	s.	d.
Then 12,322½ × 9,200 = ...		113,367,000			
Less one-fourth for leakage		28,341,750			
Total quantity to be sold		85,025,250			
From this deduct consumption of 1,264 public lights, each at 50 feet per night, making 1,264 × 50 × 365 = . .	23,068,000				
Deduct also quantity used in works, as per evidence . .	1,000,000				
		24,068,000			
Private consumption		60,957,250 at 6s.	18,287	2	0
Receipts for public lights, as per company's evidence .			5,885	15	3
			£24,172	17	3

B.—Estimate of Expense for the Labour of manufacturing Gas from 12,323 tons of Coal.

	£	s.	d.
Salary of superintendent	£200	0	0
Foreman, at 36s. per week	93	12	0
Two foremen of stokers, at 30s. per week each	156	0	0
Twenty ordinary stokers, at 24s. each	1,248	0	0
Wheeling coal, 12,323 tons, at 3d.	154	1	0
Two purifying men, at 24s. each	124	16	0
Valve man, at 28s.	72	16	0
Storekeeper	80	0	0
Coke clerk	80	0	0
Gatekeeper	52	0	0
	£2,261	5	0

C.—Wear and Tear of Retorts.

In this estimate it is assumed that each retort will be worn out, and require to be taken down and reset, after producing 700,000 cube feet of gas. Hence the number of retorts required per annum will be $\frac{113,367,000}{700,000} = 162$ retorts, which are assumed to be of cast iron, weighing 16 cwt. each.

	£	s.	d.
Hence 162 retorts, at £5	810	0	0
Taking down 162 old retorts, breaking the connections, and renewing old materials, 162 at 4s.	32	8	0
Carried forward	842	8	0

	£	s.	d.
Brought forward	842	8	0
Bricklayers' wages for re-setting retorts, 162 at 12*s.* 6*d.*	101	5	0
Fire-clay and fire-bricks used in re-setting retorts, and in repairing furnaces, 162 at 20*s.*	162	0	0
Making good connections to hydraulic main	26	0	0
Bolts and cement for new connections, wear and tear of ash-pit pans, furnace-doors and bars, ears and cross-bars, barrows, scoops, shovels, brooms, &c., 162 at 10*s.*	81	0	0
	1,212	13	0
Allowance for contingencies, defective retorts, &c., 10 per cent.	121	0	0
	£1,333	13	0

No deduction is here made for the sale of the old retorts.

D.—Residual Products.

Total coal used	12,322 tons.
Making	12,322 chaldrons of coke.
Used for carbonising, one-third	4,107
Remaining for sale	8,215 chaldrons.

	£	s.	d.
8,215 chaldrons, at 10*s.*	4,107	10	0
100 tons of coal will yield 8 chaldrons of breeze, to be sold for brick-making, at 3*s.* per chaldron.			
Hence $\frac{12,322 \times 8}{100} = 985$, at 3*s.*	147	15	0
Each ton of coal will yield 10 gallons of gas tar.			
Hence 123,220 gallons, at 1*d.*	513	8	4
	4,768	13	4

Deductions.	£	s.	d.	£	s.	d.
Filling 9,200 chaldrons of coke and breeze, at 3*d.*	115	0	0			
Labourers delivering tar and ammoniacal liquor	52	0	0			
				167	0	0
				£4,601	13	4

E.—Expenses of Distribution.

	£	s.	d.
Lighting and repairing 1,264 public lamps, at 20*s.* . . .	1,264	0	0
Collection and bad debts, at 3 per cent. on rental of £24,000	720	0	0
Law expenses, stationery, and incidental expenses, 113,367 at 1*d.*	472	7	3
Engineer, secretary, clerks, and inspectors	820	0	0
	£3,276	7	3

Engineer	£200
Secretary	200
Two clerks	150
Three inspectors	270
	£820

.—STATUTABLE ALLOWANCES.

	£	s.	d.
Insurance of buildings, and annual repairs of buildings and apparatus	500	0	0
Renewal or reproduction of trade fixtures, valued at £17,644, at 2 per cent.*	352	18	0
Renewal of mains, valued at £24,453, at 1½ per cent.*	367	0	0
	£1,219	18	0

G.—ESTIMATE OF CAPITAL REQUIRED BY A TENANT.

	£	s.	d.	£	s.	d.
Coal in stock, 2,000 tons, at 15*s*.				1,500	0	0
One year's consumption of coal	9,153	0	0			
One year's wages for manufacturing, as per statement B	2,261	5	0			
One year's wear and tear of retorts, as per statement C	1,333	13	0			
One year's expenses of distribution, as per statement E	3,276	7	3			
One year's maintenance of works, repairs, insurance, &c.	500	0	0			
	16,524	5	3			
Deduct one year's receipts for sale of coke	4,601	13	4			
	£11,922	11	11			
The tenant would have to provide for half-a-year's payment, or $\frac{11,923}{2}$				5,961	10	0
Assumed value of retort, as per evidence				2,420	0	0
				£9,881	10	0

DIVISION OF THE NET RATEABLE VALUE BETWEEN THE SEVERAL PARISHES.

We now come to the second branch of inquiry: namely the mode of apportioning the net rateable value, as deter-

* These allowances were made because in former cases they had been decided at quarter sessions. The amounts being small, it was not thought advisable to complicate the case by contending for the principle of a sinking fund, which, as already explained, is the proper way to estimate costs of reproduction.

mined for the whole gas-works, amongst the several parishes through which the mains extend. Here again we find quite as great a variety of opinion as on the other subject. Even the judgments delivered by the Court of Queen's Bench, the highest court of appeal to which rating cases have been carried, seem to have undergone some change year after year since the passing of the Parochial Assessment Act. It appears to be clearly decided, in the case of the Queen *v* Cambridge Gas Lighting Company, that the rateable value is not to be divided in proportion to the *receipts* for gas in each parish; and Lord Denman, in his judgment in this case, quoted a parish through which the New River passed, and in which no profits accrued to the Company, yet the New River works in this parish were rated, and properly so, at £300, because the apparatus in the parish contributed to the whole value to let, although no receipts within the parish itself were derived from the apparatus lying within it. So it will often happen in the case of gas-works that mains may pass through a parish without any service-pipes being affixed to them, without supplying any gas in the parish, and consequently not yielding any receipts. But the works are nevertheless to be rated in this parish because they carry gas which passes through them for the supplying of other parishes where the company receives payment for its gas. Some of the judgments even seem to have inclined to the opinion, especially in the case of railways, that the total rateable value should be divided in proportion to the mileage or length of line passing through each parish. This division however, would usually be very unjust alike for railways, gas-works, and all similar undertakings. In each case the most remote and thinly inhabited parishes would reap far more than their share, while metropolitan parishes, and chiefly those nearest to the principal termini or principal sites of manufacture, would be injured in a proportionate degree. Other decisions, however, and those of a more recent date, have supported an opposite principle,—namely, that of dividing the net rateable value of the whole in proportion to the quantity of apparatus in each parish. Lord Denman, in his judgment in the case of the Queen *v.* the

Cambridge Gas-Light Company, speaking of the division amongst the parishes, says, "We are aware of no rule which can be laid down as to the amount, except that it must be in proportion to the quantity of apparatus situate in each parish."

In the next case of importance, namely, that of the Queen *v.* the South-Western Railway Company, a somewhat clearer principle was expressed; and in the case of railways it was decided that the division should be in proportion to the earnings in each parish, having first deducted from the net rateable value of the whole the rateable value of the stations, which are separately rated in the parishes in which they are situated. Now in the case of a railway this mode of division is quite practicable, and no parish would be excluded from its just proportion of the whole assessment, even though no receipts are actually taken in it. Suppose a parish situate between two stations A and B, then the whole of the traffic passing from A to B and *vice versâ* will pass through the parish. The parish accordingly will be entitled to its proportion of the receipts taken for traffic between A and B in proportion to its length, so that the case is amply provided for in which a parish has no station, and in which consequently no receipts are taken by the Company.

The case is equally simple when the parish contains a station; the net rateable value here being a proportion according to the mileage of the receipts between the station in the parish and that on each side of it, with the addition of a sum for the station itself. It would lead us too far out of our way and be altogether inapplicable in this work to go further into the mode of dealing with the railway stations, and separating their rateable value from that of the railway proper; and we must therefore confine our attention more immediately to the case of gas-works. Here, however, the same general principle prevails for separating the works,—that is, all the rateable apparatus at the head-quarters or manufacturing establishment from the pipes or mains extending through the streets. No satisfactory or even practicable mode of doing this has ever been suggested, except that arising from the cost or value of the *works* as compared with that of the whole property, *works* and *mains together*. We shall suppose the net rateable value of the whole to have been arrived at, and, in order to find the separate part of this chargeable to the works and to the mains, we must have an estimate of the present value of the works and of the mains separately. Then we have this proportion :—

As the present value of the works and mains together is to the net rateable value of the whole, so is the present value of the works to the net rateable value of the works. In the same way the net rateable value of the mains is found by substituting the present value of the mains for that of the works in the third and fourth terms of this proportion.

The principal station or manufacturing site of a gas establishment is commonly at least equal in value to that of the mains, so that in this simple mode we get rid of half the rateable value by apportioning it to that parish in which the manufacturing station is situate. If there be more than one station the division is equally simple, each station being debited with its proportionate rateable value according to its present worth, as compared with the worth of the whole property.

We have yet a further sum, however, to divide amongst the mains, and perhaps this division has given rise to more contention than any other question connected with the rating of gas-works. In the case of the Phœnix Company and the Parish of Greenwich, the Court of Quarter Sessions decided that the division was to be made in proportion to the square yards of ground occupied by the mains in each parish. Now, with great submission to the learned Bench of Magistrates, this decision was simply absurd, because the square yards of ground occupied are neither a measure of the quantity of apparatus, nor a measure of the earnings, nor a measure of the capacity of the mains. This mode of distributing the rateable value has the effect of giving an enormous advantage to the remote parishes, and in a proportionate degree injuring those which are nearest to the fountain-head, and which first distribute the gas before it can be taken out of the mains.

Another principle of division which has been adopted is also fallacious, but not to the same extent—namely, that of dividing the rateable value according to the cubic yards of main in each parish. This principle makes a perfectly correct division according to the quantity of apparatus, but not according to earnings, which by the latest decision is clearly intended to be the basis of the subdivision. The error is of the same nature as the one allowed by the Quarter Sessions in the Phœnix case—namely, one of excess for the remote parishes, at the expense of those near the centre of distribution. The principle, in fact, of dividing according to cubical capacity of the mains is only correct on the supposition that a main of a given area will deliver the same quantity of gas at all distances from the gasholder, which we know is very far from being the fact. Every one knows that a 12-inch main within 100 yards of the gasholder will pass a great deal more gas than the same main at the distance of a mile. The principle in question would also require this theoretical condition—namely, that the mains at the extremities of the company's district should be attenuated to such dimensions as just to deliver the gas required for present consumption with the requisite pressure; but this is notoriously not so, for with a view to extensions the mains are purposely not so much contracted as they otherwise might be. The effect of all this is, that this mode of subdivision does not give to the mains their proportionate value as parts of the apparatus in the arterial parishes, and gives too much value to those at a distance. It divides the rateable value in proportion to quantity of apparatus, not with reference to earnings, nor with reference to capacity for earning, or contributing to the whole earnings of the concern.

I am now bound to explain the mode in which I propose to subdivide the rateable value amongst the mains, for which purpose I must have the cubical contents of all the mains, the cubical contents in the particular parish, the quantity of gas supplied in that parish, and the annual receipts for that gas. Then I should calculate the size of main which would be required simply for the delivery of the quantity of gas consumed in the parish, and consider the extra size of the main entitled to a further allowance for contributing to the earnings of the parishes lying beyond. Thus, I would say—

As the whole receipts are to the rateable value of the whole, so are the receipts in the parish to the rateable value of the mains in respect of receipts within the parish.

Then, to find the additional rating for the part contributed by the mains towards the receipts in other parishes, I would say—

As the cubical contents of all the mains is to the extra cubical contents of main in the parish beyond what would be necessary for the supply of the parish, so is the rateable value of all the mains to the extra rateable value of mains in the parish. The fourth terms in each of these proportions being added together would give, as I conceive, the whole rateable value of the mains in any parish.

I am afraid of extending this subject of rating to too great a length, as it might be wearisome to many of my readers. At the same time, the subject possesses much interest for gas companies, who would in many cases fare better if they did not attempt to shroud this affair in such impenetrable mystery. This air of mystery is often apt to occasion a suspicion of far greater profit than that really derived. In all such cases fair play to the parishes is to be insisted on; let each have its proper share, and let each have such means of information as will enable its officers to make assessments on a sound basis.

It has not occurred to me now for the first time, considering the many complicated interests which have to be assessed in these days of progressive improvement, that it would be desirable if some public officer were appointed to make an assessment every year of the property in gas-works, canals, railways, &c., rateable to the relief of the poor. Such an assessment would require to be varied every year, but the principle of division once settled would be permanent. A vast amount of litigation would be thus saved, and in the end all parties would find it much more satisfactory than the present blindfold system.

INDEX.

THE END.

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