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A

PRACTICAL TREATISE

ON THE

MANUFACTURE AND DISTRIBUTION

OF

COAL-GAS;

ITS INTRODUCTION AND PROGRESSIVE IMPROVEMENT,

ILLUSTRATED BY ENGRAVINGS FROM WORKING DRAWINGS,

WITH GENERAL ESTIMATES.

BY

SAMUEL CLEGG, JUN.,

CIVIL ENGINEER.

MORDEN COLLEGE BLACKHEATH

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TO

MY FATHER,

THIS WORK

IS APPROPRIATELY AND AFFECTIONATELY

DEDICATED.

488

PREFACE.

In presenting the following work to the public, I may preface it by a few words, stating the reasons which have induced me to compile it. I am acquainted with no work which, following the progress of the science of Gas-lighting from its first invention down to the present day, and including the numerous improvements which have of late years œconomized the production of gas, and facilitated its application to the wants and convenience of society, affords to the engineer the practical statements and details which he requires in the management of Gas-Works. I have endeavoured to meet this want; and in order to render my work useful, I have made it essentially *practical*; adding, by way of Introduction, a brief sketch of the origin and progress of the invention. I may here observe, that my principal inducement to write this work has been the great advantage I have enjoyed in having access to, and the free use of, my father's manuscripts and notes—the result of his long labours and experience in this department of our profession. To him I am indebted for a great mass of valuable materials. I need only add, that I have spared no pains to verify all my statements and calculations, and to obtain, from the best sources, the information I required.

S. C.

16 *Sidmouth Street, Regent Square,*
April 10*th*, 1841.

ERRATA.

Page 39, line 27, *for* barometric-gauge *read* pyrometric-gauge.
— 42, — 2, *for* C *read* C'.
— 95, 3rd line from bottom, *for* meter *read* thousand.
— 112, line 16, *for* B *read* A.

CONTENTS.

LIST OF PLATES.

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A PRACTICAL TREATISE

ON

THE MANUFACTURE AND DISTRIBUTION

OF

COAL-GAS.

HISTORICAL SKETCH OF THE INTRODUCTION OF LIGHTING BY COAL-GAS.

In the earliest ages, and prior to the time from which records of extraordinary events have been handed down to us, the existence of an inflammable air appears to have been known. The perpetual fires and sacred lamps, regarded with superstition by the ancients, were fed by inflammable air issuing from fissures of rocks or springs of petroleum. The choke and fire-damp, so fatal in the experience of miners, was in modern times discovered to be the same gas, now so valuable for the purposes of illumination.

Although both its useful and injurious properties appear thus to have been long partially known, no investigation of its nature was made, at least none published, until the end of February, 1659, when Mr. Thomas Shirley communicated to the Royal Society some experiments upon the gas issuing from a well near Wigan in Lancashire. This paper will be found in the Philosophical Transactions for June, 1667, and has also been published in former works on gas-lighting; but as these works may not be in the possession of the majority of my readers, I shall here quote the interesting narrative in the quaint language of the author.

"*Description of a Well and Earth in Lancashire, taking fire by a candle approached to it.*

"This was imparted by that ingenious and worthy gentleman, Thomas Shirley, Esq., an eye-witness of the thing now to be related in his own words, viz.:—

"About the latter end of February, 1659, returning from a journey to my house in Wigan, I was entertained with the relation of an odd spring situated in one Mr. Hawkley's ground (if I mistake not), about a mile from the town, in that road which leads to Warrington and Chester.

"The people of this town did confidently affirm that the water of the spring did burn like oyle; into which error they suffered themselves to fall for want of due examination of the following particulars.

"For when we came to the said spring (being five or six in company together) and applied a lighted candle to the surface of the water, 't is true there was suddenly a large flame produced, which burnt vigorously; at the sight of which they all began to laugh at me for denying what they had positively asserted; but I, who did not think myself confuted by a laughter grounded upon inadvertency, began to examine what I saw; and observing that this spring had its eruption at the foot of a tree growing on the top of a neighbouring bank, the water of which spring filled a ditch that was there, and covered the burning place lately mentioned; I then applied the lyghted candle to divers parts of the water contained in the said ditch, and found, as I expected, that upon the touch of the candle and the water the flame was extinct.

"Again, having taken up a dishful of water at the flaming place and held the lighted candle to it, it went out; yet I observed the water at the burning place did boyle and heave like water in a pot upon the fire though my hand put into it perceived it not so much as warm.

"This boyling I conceived to proceed from the eruption of some bituminous or sulphureous fumes, considering this place was not above thirty or forty yards distant from the mouth of a coal-pit there; and indeed Wigan, Ashton, and the whole country for many miles' compass, is underlaid with coal. Then, applying my hand to the surface of the burning place of the water, I found a strong breath, as it were a wind, to bear against my hand.

"Then I caused a dam to be made, and thereby hindering the recourse of fresh water to the burning place, I caused that which was already there to be drained away; and then applying the burning candle to the surface of the dry earth at the same point where the water burned before, the fumes took fire and burnt very bright and vigorous; the cone of the flame ascended a foot and a half from the superficies of the earth: the basis of it was of the compass of a man's hat about the brim. I then caused a bucket full of water to be poured on the fire, by which it was presently quenched, as well as my companions' laughter was stopped, who began to think the water did not burn.

"I did not perceive the flame to be discoloured like that of sulphureous bodies, nor to have any manifest scent with it. The fumes, when they broke out of the earth and prest against my hand, were not, to my best remembrance, at all hot."

The next mention we find of the presence of an "elastic inflammable air" in coal is in the account of some experiments made by Dr. Stephen Hales, for the production of elastic fluids from a great number of substances, and are related in the first volume of his "Vegetable Statics," published in 1726.

In 1733 Sir James Lowther communicated a paper to the Royal Society upon the damp air issuing from the shaft of a coal-mine near Whitehaven. After his men had sunk the pit to the depth of forty-two fathoms, instead of finding water as they expected, they were surprised by a rush of air, which caught fire on a candle being held towards it: it burned very fiercely with a flame about one yard in diameter, and two yards high, which frightened the workmen so that they immediately went up the pit, after extinguishing the flame by beating it out with their hats. The steward of the works being made acquainted with the circumstance, went down the pit himself, and again lighted the air, which had increased in volume; it burned fiercely as before, the flame being blue at the bottom and more white towards the top: they then extinguished it in the same manner, made a greater opening in the black stone bed, and again fired the air: the flame was a full yard in diameter and about three yards high, and soon heated the pit to so great a degree that they made all possible haste to put out the flame, which this time could only be effected with the assistance of a spout of water. It was found necessary to make a tube to carry off the inflammable air; this tube projected four feet above the top of the pit, and through it the gas discharged itself, without sensibly diminishing in its strength or lessening in its quantity during the two years that elapsed between the sinking of the shaft and Sir James Lowther's report to the Royal Society. Bladders were filled with gas from this tube, which were carried away, and the gas burned through a small pipe inserted in the bladder.

The Rev. Dr. John Clayton, dean of Kildare, made some experiments on the "spirit of coal"; he was one of the first who actually distilled coal in a close vessel, and burned the gas thus obtained from the bladders in which it was collected. These experiments are related in the Philosophical Transactions for 1739, in an extract from a letter by the Rev. Dr. John Clayton, as follows.

"Having seen a ditch within two miles of Wigan, in Lancashire, wherein the water would seemingly burn like brandy, the flame of which was so fierce that several strangers have boiled eggs over it; the people thereabouts, indeed, affirm that about thirty years ago it would have boiled a piece of beef; and that whereas much rain formerly made it burn fiercer, now, after rain, it would scarcely burn at all. It was after a long-continued season of rain that I came to see the place and make some experiments; and found accordingly, that a lighted paper, though it were waived all over the ditch, the water would not take fire. I then hired a person to make a dam in the ditch and fling out the water, in order to try whether the steam which arose out of the ditch would then take fire, but found it would not. I still, however, pursued my experiment, and made him dig deeper; and when he had dug about the depth of half a yard, we found a shelly coal, and the candle being then put down into the hole, the air catched fire and continued burning.

"I got some coal and distilled it in a retort in an open fire. At first there came over only phlegm, afterwards a black *oil*, and then, likewise, a *spirit* arose which I could no ways condense; but it forced my lute and broke my glasses. Once, when it had forced my lute, coming close thereto, in order to try to repair it, I observed that the spirit which issued out, caught fire at the flame of the candle, and continued burning with violence as it *issued out* in a *stream*, which I blew out and lighted again alternately several times. I then had a mind to try if I could save any of this spirit, in order to which I took a turbinated receiver, and putting a candle to the pipe of the receiver, whilst the spirit arose, I observed that it catched flame, and continued burning at the end of the pipes, though you could not discern what fed the flame. I then blew it out and lighted it again several times; after which I fixed a bladder, squeezed and void of air, to the pipe of the receiver; the oil and phlegm descended into the receiver, but the spirit, still ascending, blew up the bladder. I then filled a good many bladders therewith, and might have filled an inconceivable number more, for the spirit continued to rise for several hours, and filled the bladders almost as fast as a man could have blown them with his mouth, and yet the quantity of coals distilled was inconsiderable. I kept this spirit in the bladders a considerable time, and endeavoured several ways to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders and pricked a hole therein with a pin, and, compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising, because no one could discern any difference in the appearance between these bladders and those which are filled with common air."

During the long period that elapsed between the years 1739 and 1792, many experiments were made upon inflammable air, merely as a subject of philosophical curiosity, without their being attended by any useful or practical results.

To the talent of Mr. Murdoch we owe the first introduction of gas as a source of œconomical light, and to him must be awarded the great merit of having first arranged an apparatus for the production of gas, so as to render it useful to mankind. Of the value of the adaptation of gas to purposes of illumination no one can doubt: gas-lighting must indeed be placed amongst the great and various improvements which ingenuity has introduced into the arts of civilized life.

It is not many years since our streets were dimly lighted by miserable oil-lamps, that only served to make the surrounding gloom more perceptible; the shades of night offered an easy escape to depredators, by whom the metropolis was infested. Now, on the contrary, by the brilliant lustre of the gas, night is rendered as secure as day, and the inhabitants may pursue their various avocations by its cheerful light, prolonging the period of their usefulness and activity. Those only who have experienced the contrast can appreciate the immense advantage arising from the present system. When we consider the great increase of pleasure and convenience thus afforded us, we must feel deeply indebted to those highly-gifted and enterprising individuals, by whose talents and industry so great a blessing has been conferred on society.

In the year 1792 Mr. Murdoch made use of gas in lighting his house and office at Redruth in Cornwall, where he then resided. The mines where he was at work being distant some miles from his house, he was in the constant practice of filling a bladder with coal-gas, in the neck of which he fixed a metallic tube, with a small orifice, through which the gas issued; this being ignited, served as a lanthorn to light his way for the considerable distance he had nightly to traverse. This mode of illumination being then generally unknown, it was thought by the common people that magical arts alone could produce such an effect. At this time inflammable air seems to have been similarly used by a French gentleman of the name of Le Bon, who lighted his house and gardens with gas obtained from wood and coal.

In 1798 Mr. Murdoch erected an apparatus for the production of gas at the manufactory of Messrs. Boulton and Watt at Soho. The annexed sketch (Fig. 1.*) will show the description of retort he then used.

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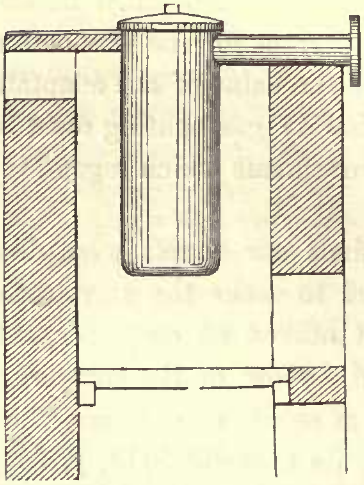
* The figures are drawn to a scale of half an inch to the foot. The same letters refer to corresponding parts in all.

Fig. 1.



In March 1802, on occasion of the general illuminations for the Peace of Amiens, Mr. Murdoch first publicly exhibited the gas-light, by placing at each end of the Soho manufactory what was termed a Bengal light. The operation was simply effected by fixing a retort in the fireplace of the house below, and then conducting the gas issuing from thence into a copper vase. This was the only gas used on that occasion, the rest of the manufactory being illuminated by the usual small glass oil-lamps, and not with the gas, as has been erroneously stated*.

About a year after this the Soho Foundry was lighted, but in a very primitive manner; the gas, as it issued from the retort, was immediately conveyed to a gasometer about eight feet in diameter and six feet deep, and from thence to the burners. Mr. Murdoch afterwards repeatedly varied the form of his retorts; he found it inconvenient to extract the coke from his first, and therefore constructed them in the forms shown in the following figures.

In Fig. 2. A is the retort; B, the pipe that conveyed away the gas; C, the furnace; and D, the flue leading to the chimney. The disadvantages attendant upon this form will be evident; the coal, acted upon in such a mass, became encrusted with an outside coat of carbon, which prevented the effect of the heat from penetrating quickly to the interior.

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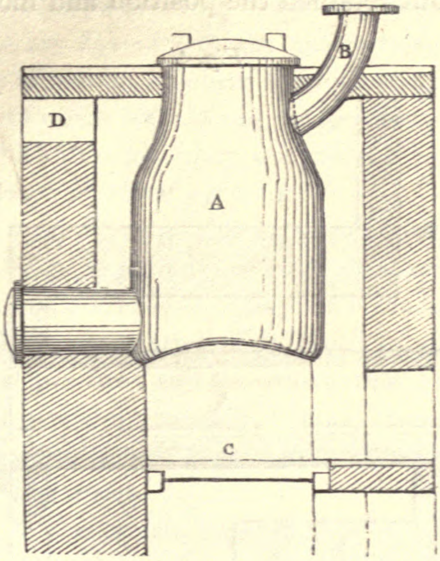
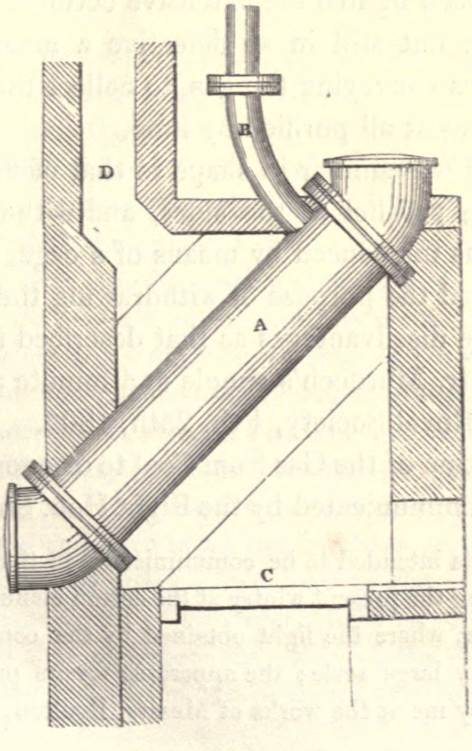
* Mr. Clegg, then a pupil of Messrs. Boulton and Watt, was present and assisted at this illumination.

Fig. 2.



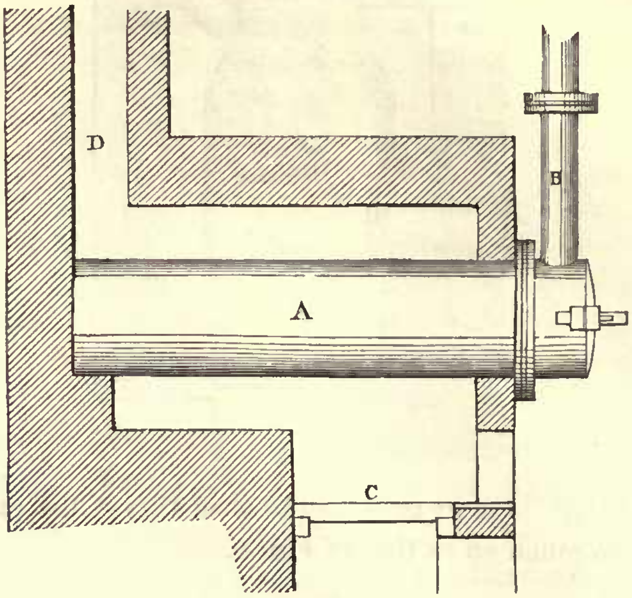
The form of Fig. 3. is more œconomical than that of the retort above-mentioned, but not so much so as that of Fig. 4.

Fig. 3.



Mr. Murdoch varied the transverse section of this last from cylindrical to oval and ear-shaped, but retained the position and mode of setting.

Fig. 4.



In 1805 Mr. Murdoch lighted the extensive cotton-mills of Messrs. Phillips and Lee, of Salford; but still in so defective a manner, that siphons were placed along the pipes conveying the gas, to collect the tar that condensed in them; nor was the gas at all purified by lime.

The retort he used was similar in shape to that of Fig. 2, but made to contain 15 cwt. of coal; parallel at the sides, and without the opening at the bottom. The coal was introduced by means of a cage, lifted by a small crane, which cage also served the purpose of withdrawing the coke. This retort is attended by the same disadvantages as that described in Fig. 2.

The following is Mr. Murdoch's simple and minute account of this apparatus, read before the Royal Society, Feb. 25th, 1805. It is entitled " An Account of the Application of the Gas from Coal to œconomical Purposes, by Mr. William Murdoch, communicated by the Right Hon. Sir Joseph Banks, Bart."

> " The facts and results intended to be communicated in this paper, are founded upon observations made during the present winter at the cotton manufactory of Messrs. Phillips and Lee, at Manchester, where the light obtained by the combustion of the gas from coal is used upon a very large scale; the apparatus for its production and application having been prepared by me at the works of Messrs. Boulton, Watt and Co. at Soho.

"The whole of the rooms of this cotton-mill, which is, I believe, the most extensive in the United Kingdom, as well as its counting-house and store-rooms, and the adjacent dwelling-house of Mr. Lee, are lighted with the gas from coal. The total quantity of light used during the hours of burning has been ascertained, by a comparison of shadows, to be about equal to the light which 2000 mould candles of six in the pound would give; each of the candles with which the comparison was made, consuming at the rate of four-tenths of an ounce (175 grains) of tallow per hour.

"The quantity of light is necessarily liable to some variation, from the difficulty of adjusting all the flames so as to be perfectly equal at all times; but the admirable precision and exactness with which the business of this mill is conducted, afforded as excellent an opportunity of making the comparative trials I had in view, as is perhaps likely to be ever obtained in general practice; and the experiments being made upon so large a scale, and for a considerable period of time, may, I think, be assumed as a sufficiently accurate standard for determining the advantages to be expected from the use of the gas-lights under favourable circumstances.

"It is not my intention in the present paper to enter into a particular description of the apparatus employed for producing the gas; but I may observe generally, that the coal is distilled in large iron retorts, which, during the winter season, are kept constantly at work, except during the intervals of charging; and that the gas, as it rises 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, called mains, to the mills.

"These mains branch off into a variety of ramifications (forming a total length of several miles) and diminish in size, as the quantity of gas required to be passed through them becomes less. The burners, where the gas is consumed, are connected with the above mains by short tubes, each of which is furnished with a cock to regulate the admission of the gas to each burner, and to shut it totally off when requisite. This latter operation may likewise be instantaneously performed throughout the whole of the burners in each room, by turning a cock with which each main is provided near its entrance into the room. The burners are of two kinds; the one is upon the principle of the Argand lamp, and resembles it in appearance; the other is a small curved tube with a conical end, having three circular apertures, or perforations, of about a thirtieth of an inch in diameter; one at the point of a cone, and two lateral ones, through which the gas issues, forming three divergent jets of flame, somewhat like a *fleur-de-lis*. The shape and general appearance of this tube has procured it, among the workmen, the name of the cockspur burner.

"The number of burners employed in all the buildings amount to 271 Argands and 633 cockspurs, each of the former giving a light equal to that of four candles of the description above-mentioned, and each of the latter a light equal to two and a quarter of the same candles. When thus regulated, the whole of the above burners require an hourly supply of 1250 cubic feet of the gas produced from cannel coal; the superior quality and quantity of the gas produced from that material having given it a decided preference in this situation over every other coal, notwithstanding its higher price.

"The time during which the gas-light is used may, upon an average of the whole year, be stated at least at two hours per day of twenty-four hours. In some mills where there is over-work, it will be three hours; and in the few where night-work is still continued, nearly twelve hours. But, taking two hours per day as the common average throughout the year, the consumption in Messrs. Phillips and Lee's mill will be 1250 × 2 = 2500 cubic feet of gas per day; to produce which seven hundred weight of coal is required in the retorts. The price of the best Wigan cannel (the sort used) is 13½*d.* per cwt. (22*s.* 6*d.* per ton) delivered at the mill; or say about eight shillings for the seven hundred weight. Multiplying by the number of working days in the year (313), the annual consumption of cannel will be 110 tons, and its cost £125.

"About one-third of the above quantity, or say forty tons of good common coal, value ten shillings per ton, is required for fuel to heat the retorts; the annual amount of which is £20.

"The 110 tons of cannel coal, when distilled, produce about 70 tons of good coke, which is sold upon the spot at 1*s.* 4*d.* per cwt., and will therefore amount annually to the sum of £93.

"The quantity of tar produced from each ton of cannel coal is from eleven to twelve ale gallons, making a total annual produce of about 1250 ale gallons, which not having been yet sold, I cannot determine its value: but whenever it comes to be manufactured in large quantities, it cannot be such as to influence the economical statement, unless, indeed, new applications of it should be discovered.

"The quantity of aqueous fluid which came over in the course of the observations which I am now giving an account of, was not exactly ascertained, from some springs having got into the reservoir; and as it has not been yet applied to any useful purpose, I may omit further notice of it in this statement.

"The interest of the capital expended in the necessary apparatus and buildings, together with what is considered as an ample allowance for wear and tear, is stated by Mr. Lee at about £550 per annum, in which some allowance is made for this apparatus being made upon a scale adequate to the supply of a still greater quantity of light than he has occasion to make use of.

"He is of opinion that the cost of attendance upon candles would be as much, if not more, than upon the gas apparatus; so that in forming the comparison, nothing need be stated upon that score on either side.

"The economical statement for one year stands thus:—

"Cost of 110 tons of cannel coal - - - - - -	£125
" 40 " common - - - - - - - -	20
	145

Deduct the value of 70 tons of coke - - - - - - - £93

The annual expenditure in coal, after deducting the value of the coke, and without allowing anything for the tar, is, therefore, - - 52

And the interest of capital and wear and tear of apparatus - - 550

making the total expense of the gas apparatus about £600 per annum.

"That of candles to give the same light would be about £2000, each candle consuming at the rate of 4-10ths of an ounce of tallow per hour; the 2500 candles burning upon an average of the year two hours per day, would, at one shilling per pound (the present price), amount to nearly the sum of money above-mentioned.

"If the comparison were made upon an average of three hours per day, the advantage would be still more in favour of the gas-light, the interest of the capital and wear and tear of the apparatus continuing nearly the same as the former case; thus 1250 × 3 = 3750 cubic feet of gas per day, which would be produced by 10¾ cwts. of cannel coal, thus multiplied by the number of working days, gives 168 tons per annum, which, valued as before, amounts to - - - - - - - - - £188

And 60 tons of common coal for burning under the retorts will amount to 30

218

Deduct 105 tons of coke at 26*s.* 8*d.* - - - - - - 140

Leaving the expenditure of coal, after the deduction of the coke, and without allowance for the tar, at - - - - - - - - - 78

Adding to which the interest and wear and tear of apparatus as before, the total annual cost will not be more than £650, whilst that of tallow, rated as before, will be £3000.

"It will readily occur that the greater number of hours the gas is burnt, the greater will be its comparative economy; although in extending it beyond three hours an increase of some parts of the apparatus would be necessary. If the economical comparison were made with oils, the advantages would be less than with tallow.

"The introduction of this species of light into the establishment of Messrs. Phillips and Lee has been gradual, beginning at the year 1805 with two rooms of the mills, the counting-house, and Mr. Lee's dwelling-house; after which it was extended through to the whole manufactory as expeditiously as the apparatus could be prepared. At first some inconvenience was experienced from the smell of the unconsumed, or imperfectly purified gas, which may in a great measure be attributed to the introduction of successive improvements in the construction of the apparatus as the work proceeded. But since its completion, and since the persons to whose care it is confided have become familiar with its management, this inconvenience has been obviated, not only in the mill, but also in Mr. Lee's house, which is most brilliantly illuminated with it, to the exclusion of every other species of artificial light.

"The peculiar softness and clearness of this light, with its almost unvarying intensity, have brought it into great favour with the work-people; and it being free from the inconvenience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, as tending to diminish the hazard of fire, to which cotton-mills are known to be much exposed.

"The above particulars, it is conceived, contain such information as may tend to illustrate the general advantages attending the use of the gas-light; but, nevertheless, the Royal Society may perhaps not deem it uninteresting to be apprized of the circumstances which generally gave rise in my mind to its application as an economical substitute for oils and tallow.

"It is now nearly sixteen years since, in a course of experiments I was making at Redruth, in Cornwall, upon the quantities and qualities of the gases produced by distillation from different mineral and vegetable substances, I was induced, by some observations I had previously made upon the burning of coal, to try the combustible property of the gases produced from it, as well as from peat, wood and other inflammable substances; and being struck with the great quantities of gas which they afforded, as well as with the brilliancy of the light and the facility of its production, I instituted several experiments with a view of ascertaining the cost at which it might be obtained, compared with that of equal quantities of light yielded by oils and tallow.

"My apparatus consisted of an iron retort with turned copper and iron tubes, through which the gas was conducted to a considerable distance, and there, as well as at intermediate points, was burned through apertures of various forms and dimensions. The experiments were made upon coal of different qualities, which I procured from distant parts of the kingdom, for the purpose of ascertaining which would give the most economical results. The gas was also washed with water, and other means were employed to purify it.

"In the year 1798, I removed from Cornwall to Messrs. Boulton, Watt and Co.'s works for the manufactory of steam-engines, at the Soho Foundry, and there I constructed an apparatus upon a larger scale, which during many successive nights was applied to the lighting of their principal building, and various new methods were practised of washing and purifying the gas. These experiments were continued, with some interruptions, until the peace of 1802, when a public display of this light was made by me in the illumination of Mr. Boulton's manufactory at Soho upon that occasion.

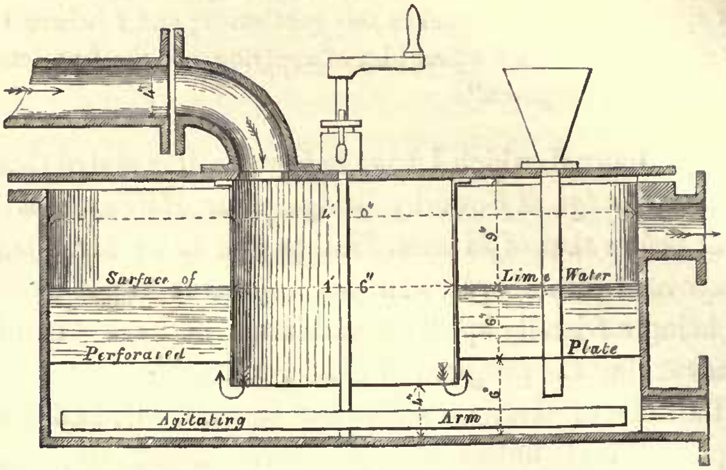
"Since that period I have, under the sanction of Messrs. Boulton, Watt and Co., extended the apparatus at Soho Foundry, so as to give light to all the principal shops, where it is in regular use, to the exclusion of other artificial light; but I have preferred giving the results of Messrs. Phillips and Lee's apparatus, both on account of its greater extent, and the greater uniformity of the lights, which rendered the comparison with candles less difficult. At the time I commenced my experiments I was certainly unacquainted with the circumstance of the gas from coal having been observed by others to be capable of combustion, but am since informed, that the current of gas escaping from Lord Dundonald's tar ovens had been frequently fired; and I find that Dr. Clayton, in a paper in Volume XII. of the Transactions of the Royal Society, so long ago as the year 1739, gave an account of some observations and experiments made by him, which clearly manifests his knowledge of the inflammable property of the gas, which he denominates 'the spirit of coals;' but the idea of applying it as an economical substitute for oils and tallow does not appear to have occurred to this gentleman; and I believe I may, without presuming too much, claim both the first idea of applying, and the first actual application of this gas to economical purposes."

In Mr. Clegg's Journal, which I have before me, it is stated that the cotton-mill of Mr. Henry Lodge at Sowerby Bridge, near Halifax, was lighted with gas a fortnight before that of Messrs. Phillips and Lee; Mr. Clegg had made his men work over-time in order that his apparatus might be the first completed, there being a friendly spirit of emulation between Mr. Murdoch and his pupil in advancing the progress of gas-lighting.

Soon after the mills of Messrs. Phillips and Lee and Mr. Lodge were lighted, it became apparent, that, unless some plan were adopted to purify the gas, it could not be burnt in close rooms, the offensive effluvia proceeding from it in an impure state causing headache, and even in some cases affecting the lungs. To remedy this serious evil, Mr. Clegg, in the next manufactory he lighted, (that of Mr. Harris, of Coventry) introduced lime into the tank of the gasometer, preventing it from settling at the bottom by an agitator, put in motion from time to time. The gas from the condenser was passed partially through the lime and water, and was thus purified. This plan was found to answer tolerably well for a short time, but the difficulty of removing the spent lime from the tank formed a practical obstacle to its further adoption.

Among the various places lighted with gas about this time (1807, 1808), the Catholic college of Stonyhurst, Lancashire, deserves particular mention. This establishment was the first of the kind that adopted the use of gas-lights, and Mr. Clegg received great encouragement in making experiments and improving his apparatus from the liberality and kindness of the Professors of the college. He was well aware that gas could not with safety be applied to lighting private rooms unless it were perfectly freed from sulphuretted hydrogen, and that the method adopted at Coventry would not answer the purpose, on account of the difficulty attending the removal of the lime. Lime-water was therefore introduced into a separate vessel, in which the lime could be easily renewed; the gas was passed through this vessel previous to its entering the gasometer, and was by this means rendered perfectly pure. The vessel is shown in the annexed wood-cut (Fig. 5.).

Fig. 5.



After completing this apparatus, Mr. Clegg invited Dr. Henry to visit Stonyhurst College, in order to examine the method he had there adopted for purifying, and to test the gas. Dr. Henry had previously made some chemical experiments respecting the affinity of lime for sulphuretted hydrogen, but gave it as his opinion that "coal-gas could not be purified from sulphuretted hydrogen, on a large scale, by means of lime." I presume this opinion to have been founded upon the idea of the practical difficulties attendant upon the complete contact necessary to produce combination to any great extent; for his own experiments in the laboratory proved that lime would combine with sulphuretted hydrogen, leaving the carburetted hydrogen free. Dr. Henry refused to acknowledge the efficacy of Mr. Clegg's apparatus for purifying, until he had repeatedly tested the gas; after which he admitted it to be perfectly satisfactory, and capable of being adopted in large manufactories.

In 1808 Dr. Henry communicated a paper to the Royal Society, claiming as his own idea the use of lime-water for the purification of gas from sulphuretted hydrogen in large quantities, without even mentioning the apparatus of Mr. Clegg, who, having consulted Dr. Henry while proceeding with his experiments at Stonyhurst, felt much pain as well as disappointment at this injustice, which was the more unexpected, from the friendship that had subsisted between them. After this, Messrs. Boulton and Watt erected a lime machine at the Soho manufactory.

While these circumstances were passing in the country, Mr. Winsor was lecturing at the Lyceum Theatre in London, claiming the *invention* of gas-lighting, and exhibiting a few lamps in Pall Mall, by way of specimen. Though exceedingly deficient in practical and chemical knowledge, he was indefatigable as a projector; and if we are indebted to Mr. Murdoch for the first practical introduction of gas-lighting, we owe the formation of the first Gas-light Company to Mr. Winsor.

In the year 1809 application was made to Parliament for an Act to incorporate a Company, to be called "The London and Westminster Chartered Gas-light and Coke Company." The object of the persons desirous of forming this Company was to carry out effectually the operations commenced in Pall Mall, but many were the difficulties they had to encounter. Their projects were considered visionary; great prejudices were also entertained against the general introduction of gas-lighting, from the idea of its being fraught with danger; the Act was also opposed by Mr. Watt and Mr. Murdoch, on the plea that the latter gentleman, having been the first to suggest the idea of gas being used as a source of œconomical light, had a right to the exclusive privilege of its application. In consequence of these various objections, the Bill was thrown out. The interest, however, of too many persons was at stake to suffer them to be easily discouraged in their scheme: in the following year, 1810, after again incurring considerable expense and combating much opposition, they succeeded in their object, and an Act was passed, authorizing his Majesty to grant a charter within three years. It is unnecessary to enter here into the details of the stipulation and conditions; they will be found in the printed Parliamentary Reports for the year 1810.

In the mean while, many cotton-mills in Lancashire had been lighted with gas, and, among the rest, the extensive manufactory belonging to Mr. Greenaway, of Manchester, where Mr. Clegg invented and put in practice the hydraulic main. In 1812 he lighted the cotton-mills of Mr. Samuel Ashton and Brothers, at Hyde, near Stockport, where the lime machine and hydraulic main were introduced with increased effect: this latter invention has since been universally adopted, without the slightest deviation from the original plan. Here twelve-inch cylindrical retorts and improved mouth-pieces were first introduced; the mechanism was also first attached to the gasometer for regulating its specific gravity.

In the same year Mr. Clegg lighted Mr. Ackerman's premises in the Strand.

Gas-lights, being then a novelty, created much surprise and admiration ; indeed, a lady of rank was so much astonished and delighted with the brilliancy of a lamp fixed on the shop counter, that she begged to be allowed to carry it home in her carriage, offering any sum for a lamp so far superior to any she had before seen ; this is a proof how little the nature of gas-lighting was at that time understood. The great success of the plan pursued in lighting this establishment was the cause of Mr. Clegg's being engaged as engineer to the Chartered Gas-light and Coke Company.

When the gas apparatus at Mr. Ackerman's had been at work some time, a fear was entertained of its having to be discontinued, from the great complaints that arose of the refuse lime-water running into the main shore. To remedy this evil, the use of cream-lime was substituted ; but this plan was afterwards abandoned, on account of the quantity of lime it required ; it was not then known that a great extent of surface was necessary.

From the time of the formation of the Chartered Gas-light and Coke Company to the year 1813 (when Mr. Clegg was engaged as engineer), the works had been entrusted to Messrs. Winsor, Accum and Hargraves ; it will appear an enigma at the present day, how their attempts to construct a gas apparatus could so utterly have failed ; but it must be remembered that nothing had yet been done to which reference could be made—all was new. Much time and money had consequently been uselessly expended, and at this time, (1813) the Company was nearly on the point of dissolution. Mr. Clegg having been educated an engineer at Messrs. Boulton and Watt's establishment, and having already had much experience in lighting private establishments with gas, it may be conceived that the affairs of the Company were conducted with more skill and judgment than hitherto. But still, though the concern was now put in a better train, many difficulties had to be encountered and overcome, and additional expenses to be incurred, before the Company could expect to receive any return for their immense outlay. The existing apparatus was discarded, being perfectly useless, and new machines were constructed on an improved plan. The engineer had not only to invent the necessary apparatus, but also to instruct the workmen in the use of these inventions ; for where the masters were so ignorant, much knowledge could not be expected from the men.

The great prejudice entertained against the introduction of gas-lighting, not only by the public but also by men of science, seemed at one time to present an insurmountable obstacle to its further progress. Lighting a town with gas was still thought a visionary scheme; Sir Humphry Davy considered the idea so ridiculous, that he asked "if it were intended to take the dome of St. Paul's for a gasometer?" To which Mr. Clegg replied, that he hoped to see the day when gasometers would not be much less. They are now (1841) made 100 feet diameter and 39 feet deep!

The Gas Company at first fitted up and supplied shops and houses with gas free of expense, in order to induce others to adopt the plan; so things went on for nearly two years, with only a few retorts in action. It was strangely believed that the pipes conveying the gas must be hot! When the passages to the House of Commons were lighted, the architect insisted upon the pipes being placed four or five inches from the wall, for fear of fire, and the curious would apply the gloved hand to the pipe to ascertain the temperature. Mr. Maiben (a Scotch gentleman, I believe), who had erected several small apparatus, took out a patent for gas-pipes made of wood and paper. So great was the difficulty of obtaining service-pipes, that they were also formed of old musket-barrels, attached to each other, the muzzle of one being screwed into the breach of the next. It was some time before the manufacturers could be prevailed upon to make welded tubes for gas-pipes: Mr. Russell's patent for welded pipes has now superseded all other methods.

The Insurance Companies also started objections, such as this, "If a burner were by carelessness left open, what would be the consequence?" To obviate this fresh obstacle, Mr. Clegg invented the burner described hereafter, which answered the purpose of overcoming the opposition of the Insurance Companies, though, from the expense of manufacturing such burners, they were never afterwards used.

In 1813 Mr. Clegg commenced the Gas-works at Peter Street, Westminster; the ground on which they were erected was a swamp, nearly on a level with the Thames, and formerly overflowed by the river; it was therefore impossible to sink for a tank, and an iron one was then very expensive; this gave rise to Mr. Clegg's revolving gasometer, which worked with greater regularity and less friction than any other; but the expense of construction was as great as that of an iron tank; it was besides complicated and difficult to repair. The collapsing gasometer was never put into action.

After the works at Peter Street had been some time in operation, Sir Joseph Banks and several other members of the Royal Society were deputed to examine and report upon the gas apparatus. The deputation strongly recommended Government to oblige the Company to employ gasometers containing not more than 6000 cubic feet, secured in strong buildings. As Sir Joseph Banks and some of the other members of the deputation were conversing upon the danger of a leak in the gasometer if a light happened to be near, Mr. Clegg called to a man, desiring him to bring a pickaxe and candle; he then struck a hole in the side of the vessel, and applied the light to the issuing gas, to the no small alarm of all present, most of whom quickly retreated; contrary to their expectation, no explosion resulted from this experiment. This practical proof, however, did not serve to convince them of their error, and the Chartered Gas Company was put to considerable expense in making small gasometers, surrounded by strong buildings.

From the first introduction of gas-lighting the use of large gasometers was considered as highly dangerous. After Stonyhurst had been lighted (where the capacity of the gasometer was 1000 cubic feet), Mr. Wright, the Superior of the College, complimented Mr. Clegg upon his success in lighting the establishment with gas, but suggested as an improvement the alteration of the size of the gasometer; he thought that one of 1000 cubic feet was too unwieldy, and advised that two should be erected to contain 500 feet each. At present gasometers are made to contain 250,000 cubic feet. Telescope gasometers were invented twenty years before they were brought into use; and gasometers without a house to protect them from the weather were thought absurd. The gasometers erected by Mr. Clegg at Chester and Birmingham were much disapproved of on account of their being exposed to the open air; and the Chartered Company for years pursued the plan of erecting buildings over their gasometers.

At the end of 1813, an explosion of a serious nature took place at the Westminster station, owing to a volume of gas escaping from the purifier contained in a vault beneath the retort-house; the gas coming in contact with the flues of the retorts was the cause of this frightful accident. The windows of several houses in the neighbourhood were shattered, and Mr. Clegg was severely injured. The recurrence of such an event was afterwards effectually guarded against, by drawing the refuse lime-water through a bent pipe, always containing sufficient water to seal it. The fear, however, of such an explosion again occurring made the public timid for some time.

On the 31st of December, 1813, Westminster Bridge was lighted with gas.

It soon became an object of attraction, and, while the novelty lasted, was a fashionable promenade. The lamp-lighters were much startled with the new system, and refused to act, and Mr. Clegg had himself to light the lamps for a few nights.

The first parish that applied for a contract to have their streets lighted with gas was St. Margaret's, Westminster; and on the first of April, 1814, the old oil-lamps were removed, and the more brilliant gas-lights substituted in their stead. Hundreds of people used to follow the lamp-lighter in his rounds, to watch his operations. Torches for the purpose of lighting the lamps were afterwards dispensed with, and the hand-lanthorn introduced by Mr. Grafton was substituted.

The contractors who had supplied the oil-lamps were loud in their complaints. One of these, when told by the Board of Guardians that his lamps gave no light, replied that this was not in his contract, which only stated that they were to be *lighted* from sunset to sunrise. This was literally the case,—*lighted* they were, but *light* they gave none.

At the outset it was not easy to overcome the prejudice in favour of the brackets attached to the houses; it was after much altercation between the Gas Companies and the parish authorities that the present posts were allowed. When the Chartered Gas Company had surmounted the principal difficulties, other Companies began to erect gas-apparatus in different parts of the kingdom, —Bristol, Birmingham, Chester, Kidderminster, etc. At the present time there is scarcely a town in Great Britain of any importance that is not lighted with gas. The first retorts erected at Peter Street were much superior to the present mode of setting, as far as regarded the health and comfort of the workmen; a flue was attached over the mouth-pieces, to convey the smoke and flame directly into the chimney, but this flue being found expensive was abandoned. The retorts were set two to a fire, one over the other; this plan required less fuel to carbonize the coal than any since adopted; but again, it was more expensive, and occupied a greater space than the oven plan adopted by Mr. Rackhouse. It would be superfluous to mention the variations in the shape of retorts, with different numbers in an oven, from three to seven. Every Gas Company have a plan of their own; and as long as the coal is allowed to be distilled in bulk, the slight variations in shape and number in an oven is of little consequence.

On the occasion of the illumination for the Peace of June 1814, when the

Allied Sovereigns visited England, the devices in gas-lights far exceeded in splendour anything before or since exhibited; the principal illumination was a Pagoda, erected by order of Government in St. James's Park. This Pagoda was octagonal, composed of wood, eighty feet high, at each angle of which a perforated pipe was fixed; a projecting pipe was also placed at every angle of each story, in the form of a griffin's head, pierced with small holes, through which issued jets of gas. At the lowest orifice of each perpendicular pipe a small oil-lamp was concealed, which, when lighted, ignited the first jet of gas; this communicated the light to the next jet, and so on to the summit. The burners of each angle were thus simultaneously ignited, and the gas-light rose into the air with the majesty of a rocket; and the Pagoda (illuminated by more than ten thousand burners) was fired in a few seconds, the whole appearing like a mass of living light. This device was fortunately exhibited to the Prince Regent and most of the Royal Family at their request on the night previous to the general illumination; their Highnesses walked in Carlton Gardens to witness the effect, and expressed great approbation. The night on which this first grand display of gas-lighting was to have been exhibited to the public, Sir William Congreve, contrary to Mr. Clegg's advice and request, insisted upon letting off fireworks from the Pagoda before the gas should be turned on; the consequence was, that the whole erection was burnt to the ground. The accident was not only mortifying on account of the expense and trouble incurred by the Gas Company in this affair, but still more unfortunate, as gas-lighting had been only lately introduced, and all new schemes (as great improvements are generally called) have many enemies. A report was spread abroad the following day, that the gas had set fire to the Pagoda: the public were never entirely undeceived.

In 1815, Guildhall was lighted with gas; the following paragraph is extracted from one of the papers of the day:—

> "LORD MAYOR'S DAY.—Yesterday, this annual ceremony was celebrated with more than usual display; but the great and striking attraction was the renovated appearance of Guildhall. It would not be easy to conceive a more imposing spectacle than was presented when the whole company sat down to dinner. The profuse delicacies of the table, the waving feathers and sparkling jewels of the ladies, the mild splendour of the gas, shedding a brightness clear as summer's noon, but undazzling and soft as moonlight, altogether formed a magnificent combination worthy the inauguration of the presiding citizen of the great city. Those who have been used only to the brilliancy of oil and

candle-light, can have no adequate idea of the effect of an illumination by gas. It so completely penetrates the whole atmosphere, and at the same time is so genial to the eyesight, that it appears as natural and pure as daylight, and it sheds also a warmth as purifying to the air as cheering to the spirits."

When gas-lighting was first brought into general use, no proper chandeliers, brackets, stop-cocks, etc. for the fitting of shops were to be found; no one was willing to commence their manufacture, considering it as a hopeless scheme: Mr. Dixon was the first to begin. As early as 1807, Mr. Clegg, at a considerable expense, had a chandelier made, with one of the chains hollow, for the conveyance of gas; this plan was many years afterwards patented by a Scotch house.

The Bat's-wing Burner was introduced by a Mr. Stone, an intelligent workman employed by Mr. Winsor.

After the system of lighting with gas had been established, a great drawback was found from workmen commencing the trade of "fitter" without understanding the business, their only aim being to make money; their bad fittings, leaking in all directions, caused various explosions, and the rooms lighted were unbearable from the nauseous smell arising from the leaky joints.

A patent was about this time taken out for the plan of condensing gas into vessels to render it portable; though this was practised at an early period by Sir James Lowther and Dr. Clayton, then by Mr. Murdoch, and afterwards by Mr. Clegg, who, by condensing the gas into a copper globe, conveyed it from his manufactory to Stonyhurst College, where he exhibited the new light previous to receiving the order for lighting the establishment.

A great number of schemes for improvements on gas apparatus have been patented within the last twelve years; but all, except a few for improvements in construction, are of little importance. I have noticed the most valuable in this work.

The Gas Meter and Governor are valuable additions to the manufacturer, and were patented by Mr. Clegg in 1815. His first gas-meter consisted of two large bladders, filled alternately with gas, and contained in tin cans weighted to a certain pressure, the openings between them and the burners being alternately closed with quicksilver. Owing to the action of the various condensed impurities upon the bladders, they soon gave way. Leather and different kinds of membrane, coated with varnish or gold-leaf, were then tried; but they also became stiffened and useless in a very few months. Recourse was then had to two small gasometers, filling and working them alternately, in the same manner as the bladders; but the lights were so unsteady, that the intervention of a gasometer was necessary between them and the meter, which took up much room and was expensive. One of these meters was erected at Mr. Ackerman's, in the Strand, and another at Mr. White's, in Abingdon Street. The next meter was in the form of a concentric cylinder, divided into three chambers, revolving upon an axis in a tank, the water reaching to within a short distance of the axis, the remaining part of the machine being in the open air; the gas entered at one end of the axis, which was hollow, and was discharged at the other end; the entrances to the different chambers were opened and closed by mercury contained in complicated scrolls, far too delicate in their construction to render it a generally useful machine. The third alteration in form was to divide the vessel into two chambers, and to enclose the meter entirely in a case containing water at the bottom, into which the measured gas was discharged; the mercurial scrolls were done away with; the bent siphon tubes, which partly filled with water as the meter revolved and alternately opened and shut off the communication between the hollow axis and the chamber, were alone retained: this axis worked with considerable friction and rendered the meter still very imperfect. The merit of applying a pipe on one side of the axis, to convey the gas into the meter, is due to Mr. Malam, decidedly the most important improvement since its invention; from this time the machine was gradually improved, finally rendered perfect, and brought into general use by Mr. Crosley. The imperfections under which the meters labour, are rapid decay from exposure to the influence of water, the variation of the water-line, freezing, and the pressure required to work them. The former of these have been in some degree remedied by Mr. Hemmings, in what he calls his *Patent Protector* gas-meter,—to what extent, remains yet to be proved; but the last disadvantage can never be removed, owing to mechanical difficulties, which it is impossible in its present form to surmount.

Within the last few years a patent has been taken out for a Dry Gas-meter, upon precisely the same principle of action as that adopted by Mr. Clegg in the first instance, which he was obliged to lay aside, both on account of defects in the material of which the meter was formed, and of the unsteady motion it gave the lamps when immediately connected with them. The Dry

Gas-meter, patented by Mr. Clegg in 1834, is universally adopted in Paris, and is at present undergoing alterations; consequently any description of it would in a short time become useless. As a philosophical instrument, it is one of the most beautiful construction; as a gas-meter, its action is perfectly correct and never-failing; but it has not been adopted in England, and therefore I shall be silent upon its merits.

CHEMISTRY, AS APPLIED TO THE MANUFACTURE OF COAL-GAS.

NOTWITHSTANDING the infinite variety which is presented to us in the contemplation of the materials of which our globe is formed, we are enabled to resolve them, by the aid of science, into a few simple substances or elements. Between fifty and sixty of these elements have been enumerated; but as many are rarely met with, *practically* speaking, they are less numerous.

The force which unites these bodies, and thus forms the various compounds we have observed, so different in their characters and appearances, is called *affinity*; and Chemistry may be defined to be the science which observes and classifies the phænomena produced by this force, and determines the laws by which its action is regulated. To the chemist, then, a thorough knowledge of these laws of affinity is all-important; they furnish him with the means of wresting from Nature her most hidden secrets, and of imitating her in her mysterious operations. To the gas engineer they are not less important, for they enable him to explain the interesting phænomena which are developed in the formation of coal-gas, and supply him with a sure guide in the various processes of his art.

In the following propositions, I think, will be found imbodied all that is essential to the study of these laws.

1. A compound body, so long as it is possessed of the peculiar properties which distinguish it as a species, is always formed of the same elements. By no other than these *can* it be formed. Thus water always consists of two elements, oxygen (O) and hydrogen (H); no other substances are capable of forming it, in whatever way they can be combined.

2. The elements of a body are always united in a determinate proportion; this proportion is fixed and invariable, whether the substance has been formed ages ago by the operations of nature, or but recently in the vessels of the chemist.

The elements of water, O and H, are united in the ratio of 1 of the former to 2 of the latter, if we estimate them by bulk, or of 8 of the former and 1 of the latter, if by weight, oxygen being 16 times heavier than hydrogen.

3. Bodies may unite in several proportions, but for each variation a distinct compound is produced, which frequently bears no resemblance to the others. Thus $O H^2$ (one volume of oxygen to two of hydrogen) forms water, as we have already stated; but $O H$, equal volumes of the same elements, produce a liquid possessing very different properties, being highly corrosive, blistering the skin when applied to it, and exploding violently by mere contact of certain substances.

4. Bodies unite with each other in a very simple ratio; thus in gases, which we can estimate by volume, we find that one volume of one substance unites with one, two, or three of another, or in the proportions of 2 to 3, etc.; as $O H^2$, $O H$, compounds of oxygen and hydrogen, or oxides of hydrogen as they are called; $O C^2$, $O C$, $O^3 C^2$, compounds of oxygen and carbon. By weight the ratio appears less simple, if we compare different substances, O^8 to H^1, O^8 to C^6; but if we compare different compounds of the same elements the proportions are still strikingly simple, as $O^8 H^1$, $O^{16} H^1$, where the proportions of O in the first to that in the second is as 1 to 2, the quantity of hydrogen being the same.

These facts are graphically presented to the mind by the hypothesis propounded by Dr. Dalton, of Manchester, under the name of the *Atomic Theory*. He considers bodies to be formed of certain ultimate particles, or *atoms*. When one body, A, unites with another, B, each atom contained in A seizes upon one of those of B; or one of A may unite with two or three of B, or two with three, etc. These atoms are united by affinity, and the compound molecule or assemblage of atoms (A B, or A B B, or A A B B B) thus produced, becomes possessed of new properties, often bearing no resemblance to those of its constituents. Admitting the size and weight of the atoms of bodies to be constant, we see why the proportions in which they unite are likewise constant. And supposing all these atoms to be of the same size, but of different weights, we can account for the simple ratio in which they unite by bulk and weight; thus, if an atom of oxygen be sixteen times heavier than one of hydrogen, we shall have in the two compounds of these elements the proportions:

By volume.	By weight.
$O H^2$, $O H$.	$O^{16} H^2$, or $O^{16} H^1$.

Affinity is not exerted between the atoms of all bodies; some cannot be made to unite, while others seize upon each other with such energy that their union is accompanied by an explosion, heat and light being generated.

We observe something analogous in mixing some of the common fluids; oil and water cannot be made to unite, while sulphuric acid and water do so readily, with the production of considerable heat.

But what distinguishes chemical combination (the result of the operation of affinity) from mere mixture, is that the latter takes place between substances possessing similar properties, while the former increases in energy with the difference in the properties of the combining substances.

Affinity only acts at insensible distances; in other words, each atom of the combining substances must be in contact before affinity can be exerted between them.

It is obvious, then, that the physical state of a body considerably modifies the action of affinity; between solids, for instance, where the atoms are congregated together into a hard mass, affinity cannot be exerted, since the interior atoms of the one are prevented from being brought into contact with the other. In gases the repulsion which exists between their atoms is equally fatal to combination; we may *mix* two gases, but no *combination* takes place until we have compressed them, or taken other steps to overcome this repulsion and bring the atoms into contact. The liquid state is most favourable to combination; the ultimate particles of a liquid are sufficiently mobile to allow it to mix with the substance with which we wish it to combine, while they are sufficiently approximated to be within the sphere of affinity. The old chemical axiom still obtains, " Corpora non agunt nisi sint soluta."

The physical state of bodies depends on two antagonist forces, *Cohesion* and *Repulsion*. Cohesion acts on the atoms of bodies, tending to bring them into contact. In solids, then, this force preponderates over repulsion. In elastic fluids the contrary is true; since we find such repulsion among their particles, that, were it not for the containing vessels, these particles would be indefinitely separated. In non-elastic fluids, or *liquids*, the forces are about balanced. It is generally admitted that heat, or, more properly speaking, the cause of heat, caloric, is the cause of repulsion. If we consider caloric as a subtle fluid, we may imagine it to produce the effects of repulsion, by insinuating itself between the atoms or molecules of bodies, and thus counteracting the effects of cohesion.

The effects of caloric should be well understood by the chemist: in his hands it is an important power, by which he not only brings bodies into a proper state for combining, as when he converts a solid into a liquid by heat, but also is enabled to destroy previously existing combinations; for caloric not only counteracts the effects of cohesion, but also those of affinity, when the heating process is carried far enough. Thus we form quicklime by heating the natural compound carbonate of lime, or limestone, to redness; the affinity which unites the carbonic acid to the lime becomes neutralized or destroyed by the caloric, and in consequence the gaseous acid escapes, leaving the pure lime in the kiln.

Frequently, however, the action is not so simple; the compound perhaps consists of numerous elements, and these, when freed by the heat from their former union, combine together in new forms. This is the case in the destructive distillation of coal, for the purpose of forming gas. Coal consists of the elementary substances, carbon, hydrogen, oxygen, and nitrogen: by the action of the heat these are separated, but at the same instant they recombine, forming new compounds, which escape. Thus a part of the hydrogen unites with the carbon, and forms gas: another portion unites with oxygen to form water, while a third takes up nitrogen to form ammonia. All these products being volatile at the temperature at which we operate, escape, leaving a large portion of uncombined carbon, in the form of coke, in the retort. But these complicated changes will be best understood when we have entered into a short description of the elements concerned in the production and purification of gas.

OXYGEN was discovered by Priestley in 1774, and termed by him "dephlogisticated air," a name which was changed for "vital air," and subsequently for the name it at present bears.

This gas has resisted all attempts to convert it into a liquid; it is colourless and inodorous, and heavier than atmospheric air, 100 cubic inches weighing 34·193 grains, while 100 cubic inches of the latter only weigh 31·0117. As atmospheric air is considered as unity when comparing the density of gases, the specific gravity of oxygen is 1·1026. It eminently supports combustion, all combustible bodies when introduced into it burning much more vividly than in common air; indeed it is to the presence of this gas that the property of supporting combustion, which common air possesses, is owing.

Various have been the theories to account for the production of heat and light during combustion. All have failed; we can merely express the fact, that combustion is the result of intense chemical action. In ordinary cases of combustion this intense chemical action is produced by the union of oxygen with the combustible substances. Common air consists of one volume of oxygen to four of an element to be described, nitrogen. Now by the act of combustion, the oxygen is absorbed, and this renders the air unfit to carry on the process. If we invert what we improperly call an *empty* glass vessel, but which is in reality filled with air, over water, having previously introduced a lighted taper or jet of gas under the vessel, we shall observe the bulk of air diminish, the flame gradually becoming more dim, until it is at last extinguished. The air no longer possesses its characteristic properties, having been deprived by the combustion of the tallow, of its vital principle, oxygen. We shall examine subsequently the products of combustion, for the oxygen is not annihilated, since matter is indestructible, but by its union with the elements of the tallow has formed a new substance. It has been ascertained that the heat developed by combustion is so nearly proportionate to the quantity of oxygen absorbed by the combustible, that for all practical purposes it may be assumed as true. Berthier has invented a beautiful process for ascertaining the value of a combustible founded on this fact: he mixes the substance to be tested with several times its weight of oxide of lead, and exposes the mixed mass in a crucible to the action of a strong fire. Oxide of lead is formed of oxygen and lead, in the proportion of 8 of the former to 104 of the latter. At a red heat, the combustible matter seizes upon the oxygen, and reduces the lead to a metallic state. This melts, and collects in the form of a button at the bottom of the crucible. As we have shown that the proportions in which bodies unite are always uniform, it is evident that for every portion of oxygen consumed a certain portion of lead will be reduced, so that the quantity of effective combustible matter in the compound examined will be in due proportion to the weight of the button of lead. This process is not entirely free from objections, but sufficiently so for every practical purpose.

HYDROGEN was discovered in the year 1766 by Cavendish. It is gaseous, and the lightest body known, its specific gravity being only 0·06896. This gas is colourless, and, when perfectly pure, inodorous. It is not perceptibly dissolved by water: it has a powerful affinity for oxygen, and is therefore eminently combustible. Intense heat is developed by the combustion of hydrogen in oxygen gas, but little light: the compound thus produced is water.

We have already stated that water is composed of two volumes of H to one of O. Oxygen and hydrogen, although mixed in the proper proportions for combining, do not unite until flame has been applied, or an electric spark passed through them. Oxygen can separate hydrogen from most substances with which it has previously been combined, and in analysis is frequently used for this purpose, as we shall see in the sequel. Yet, under certain circumstances, there are many substances which can separate oxygen from hydrogen. Carbon at a red heat is possessed of this property. If we pass steam over heated coke or charcoal, the oxygen unites with the carbon, forming carbonic oxide, and free hydrogen is evolved. It is on this principle that Mr. Donovan procures his hydrogen, by the impregnation of which with naphtha he proposes to form an illuminating gas. Several of the metals are also possessed of this property, an oxide of the metal being formed, instead of carbonic oxide.

Water is too well known to need description; it is always produced by the decomposition of coal by heat. This arises from two causes, the presence of hygrometric water in the coals, and likewise from its elements forming a part of their composition: the former portion is the first product which passes from the retorts; the second only comes over when the coal has been resolved by the heat into its elements, and the recombination of these elements has been effected. This water is condensed, and carried into the tar-well, where it holds in solution many of the soluble products of the distillation.

CARBON is well known under the form of coke, charcoal, lampblack, etc. It is one of the principal constituents of all varieties of coal. A knowledge of the chemical properties of carbon is of great importance to the gas manufacturer, as it is the basis of the illuminating gases.

Let us examine its compounds. It unites with oxygen in two proportions, $C^2 O$, and $C O$; the first, *Carbonic Oxide*, is formed when carbon is burned with a minimum of oxygen, as when we burn coke or charcoal in a close vessel with a limited draught. It is a colourless and inodorous gas, rather lighter than atmospheric air, having a specific gravity of 0·9727; is sparingly absorbed by water, and does not precipitate lime-water. It is inflammable, burning with a beautiful blue flame; the product of its combustion is *Carbonic Acid.* This gas differs strikingly from the former in its properties, though we have already seen that it only differs in constitution by containing a little more oxygen, carbonic oxide being $C^2 O$ (two volumes of C to one of O), and carbonic acid $C O$ (equal volumes of the same elements). It is pungent and acidulous, soluble in water, to which it communicates the briskness we admire in soda-water. It is considerably heavier than common air, 1·524 being its specific gravity. It renders lime-water turbid, causing a precipitate of carbonate of lime. It is perfectly incombustible, and extinguishes burning bodies when immersed in it. It is produced by many natural operations, such as the fermentation of vegetable juices: it is formed wherever carbon is burned with a full supply of oxygen, and is also formed during the earlier stages of the decomposition of coal; but when a considerable body of coke has been formed in the retort, any carbonic acid which may have been produced unites with a portion of this coke in passing over it, and forms the previously-described compound, $C^2 O$. Carbon unites with hydrogen in many proportions, and many of these compounds are produced during the distillation of coal, but the only two of importance are carburetted hydrogen and olefiant gas.

CARBURETTED HYDROGEN is abundantly formed in nature in stagnant pools, ditches, etc., wherever vegetables are undergoing the process of putrefaction: it also forms the greater part of the gas obtained from coal. Carburetted hydrogen consists of 100 volumes of vapour of carbon and 200 of hydrogen; these during combination are condensed into one volume: we may represent it by $H^2 C$. It is colourless, and almost inodorous; is not dissolved to any extent by water; and is much lighter than atmospheric air, its density being 0·5594. It is very inflammable, burning with a strong yellow flame: the products of its combustion are carbonic acid and water. Mixed with chlorine, no action takes place when quite dry; but if moist (that is, containing the vapour of water) and exposed to sunshine, it is decomposed by this element. The fire-damp of coal-mines consists almost exclusively of carburetted hydrogen gas.

OLEFIANT GAS is thus named from having the property of uniting and forming an oily substance with chlorine. It is a product of the distillation of oil, resin, and also of coal when the process is well conducted. It is colourless, tasteless, and without smell when pure. Water dissolves about one-eighth of its bulk of this gas. It is formed of two volumes of hydrogen, and two of the vapour of carbon, condensed into one volume. It burns with an intense white light, and requires a large portion of oxygen for its combustion; one volume of the gas requiring not less than three volumes of pure oxygen, or fifteen volumes of atmospheric air, for decomposition. The products of the combustion are water and carbonic acid. It is decomposed by being passed over bodies at a red heat, carbon being deposited, and hydrogen set at liberty. This fact is of the greatest importance to the gas engineer; it should teach him the necessity of operating upon the coal in thin layers, and allowing a ready escape for the gas when formed, or the decomposition spoken of will take place; and although the bulk of the gas so formed is increased (each volume of olefiant gas containing two of hydrogen), yet it is possessed of weak illuminating power, and cannot but be designated as bad gas. The more olefiant gas we can form, the richer is the product for the purposes of illumination.

Sulphur exists in coal as an impurity, under the form of the sulphuret of iron, or "martial pyrites," as it is sometimes called. During the distillation it is decomposed, the sulphur combining with a portion of hydrogen, and escaping under the form of sulphuretted hydrogen gas, part of which unites with the ammonia, and is condensed in the aqueous fluid which floats on the surface of the tar; while another portion escapes uncombined, and would mix with and deteriorate the gas, were it not intercepted by the lime purifiers.

Sulphuretted Hydrogen is a colourless gas, with an offensive taste and odour, resembling that of putrefied eggs. It dissolves in its own bulk of water, to which it communicates its taste, odour and characteristic properties. It is combustible, burning with a blue flame, and emitting a suffocating smell similar to that of a burning match. During the combustion its hydrogen unites with oxygen to form water, while its sulphur unites with another portion of oxygen to form sulphurous acid. It is to the presence of the vapour of this substance that the disagreeable property of tarnishing metals which characterizes the combustion of impure gas is owing.

The solution of sulphuretted hydrogen has the properties of an acid. It unites with alkalies and earthy bases, forming compounds denominated hydrosulphurets: on this property is founded the method of purifying gas by lime. It precipitates most of the metallic oxides from their solutions, forming hydrosulphurets of the metal, and liberating the acid with which it was previously combined. The compounds are generally coloured: with salts of lead we have a black precipitate, with those of antimony an orange one. This property is useful, in enabling us to ascertain readily whether the gas we have prepared is sufficiently purified for the purposes of illumination. We have only to pass a portion of it through a solution of a salt of lead, (say the acetate, or sugar of lead) when the smallest quantity of sulphuretted hydrogen, if present, is rendered perceptible ; or we may moisten a piece of white paper with the solution, when, by exposing it to a jet of gas, a blackened surface will be the consequence if the gas be impure.

It is not necessary for the sulphuretted hydrogen to be in solution before combining with the earthy bases: if we merely moisten the lime in the purifiers, the effect is the same, the gas being fully absorbed as it passes through them, provided the surface of lime is great enough.

Sulphuretted hydrogen is constituted of one volume of the vapour of sulphur and one of hydrogen gas. Its specific gravity is generally estimated at 1·178.

Nitrogen is one of the constituents of coal, and its compounds are consequently among the products of the decomposition of that substance. It has the property of extinguishing burning bodies, and is not absorbed by water ; its specific gravity is 0·9760, being lighter than common air, of which it forms a constituent part. Its compounds are of great interest to the gas engineer: ammonia is one of the most important.

Ammonia is formed during the distillation of coal, and of all organic substances containing nitrogen. In such distillation the nitrogen unites with hydrogen in the proportion of one to three, the formula being $N H^3$, and ammonia is the result. It is a colourless gas, very pungent, acting strongly on the eyes and nose when respired. It dissolves in a very small portion of water, one volume taking up about 750 of the gas, forming a liquid possessed of similar properties, and sold in the shops under the name of Spirits of Hartshorn. Ammonia is strongly alkaline, uniting readily with all the acids, and forming salts which sublime at a comparatively low temperature: it also unites with sulphuretted hydrogen, producing a highly offensive volatile substance.

The principal part of the ammonia is found in the liquor which floats on the surface of the bituminous substances in the tar-well, formed during the production of gas; it is collected, and sold to the manufacturers of ammoniacal salts, or otherwise disposed of. In the account I shall give of secondary products will be found a description of the best methods pursued by these manufacturers.

The presence of Cyanogen is frequently detected in coal-gas before purification; it contains its own bulk of nitrogen, and twice its volume of the vapour of carbon. It is, however, a compound of little interest to the gas manufacturer.

Chlorine is one of the elementary substances, supporters of combustion. It is possessed of striking properties, but that which alone is of interest at present is its action on olefiant gas. On mixing chlorine with a gas in which olefiant is contained, a diminution of volume is observed, and drops of oil are seen to fall on the surface of the water over which the operation is conducted. The drops consist of an oily substance, which is produced by the direct union of the two gases. This fact enables us to estimate correctly the bulk of olefiant in any given portion of mixed gases.

COAL.

Geologists agree in admitting coal to be of vegetable origin; impressions of various plants, such as Fern and Calamites, and sometimes trunks of trees, having frequently been found in many kinds: it is classed amongst the Carboniferous group. It is interstratified with sandstone, limestone and shale, in the south-west of England and in South Wales, resting upon Old Red Sandstone. In Yorkshire and the northern counties a slight intermixture of mountain limestone is found with the coal-measures; and after passing through the millstone grit, several hundred feet of complex deposit is found of limestones, coal bearing sandstones, and shale, below which is the great bed of mountain limestone. "Some of the coal-measures are of freshwater origin, and may have been formed in lakes; others seem to have been deposited in estuaries, or at the mouths of rivers, in spaces alternately occupied by fresh and salt water*." There are freshwater strata in the coal-field of Yorkshire, some of which contain shells. The great field from which coal for the purpose of gas-making is obtained, is in the neighbourhood of Newcastle-upon-Tyne. This coal has no regular form or structure; its lustre is resinous, more or less distinct; colour black, passing in earthy varieties into grayish tints, frequently with an iridescent tarnish. When broken it assumes a cubical or rhombo-prismoidal form: it is lamellar in one direction, sometimes in two. Dr. Thomson gives the analysis of Newcastle coal from several varieties.

Carbon - - - - -	75·28
Hydrogen - - - -	4·18
Nitrogen - - - -	15·96
Oxygen - - - - -	4·58

Most varieties of coal contain sulphur and other minerals, together with saline matter; the specific gravity is from 1·271 to 1·352—water being unity. The varieties possessing the most glassy fracture being compact in one direc-

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* Lyell's Elements of Geology, p. 422.

tion, viz. at right angles to the lamellæ, contain the most bitumen, and are the best for the production of gas.

Haidinger, in his translation of Mohs's work on Mineralogy, makes the following observations on coal:

"*Bituminous Mineral Coal.*—No regular form or structure; fracture conchoidal, uneven; lustre resinous, more or less distinct; colour black or brown, passing, in earthy varieties, into grayish tints; streak unchanged, except that it sometimes becomes shining-opake: sectile in different degrees: hardness = 1·0 to 2·5. Sp. gr. = 1·223, moor coal from Teplitz; = 1·270, common brown coal from Eibiswald, in Stiria; = 1·271, black coal from Newcastle; = 1·288, bituminous wood; = 1·329, common brown coal from Leoben, in Stiria; = 1·423, cannel coal from Wigan in Lancashire.

"*Compound Varieties.*—Massive; composition lamellar; faces of composition smooth and even, different gradations; granular texture; often impalpable, and then fracture is uneven, even, or flat conchoidal. Ligniform shapes, the structure of which resembles that of wood, sometimes very distinct, but often obliterated, with the exception of some slight traces: fracture then becomes conchoidal, particularly across the fibres. There are some earthy varieties of a loose friable texture."

In the species of bituminous mineral coal are comprised the *Brown* and *Black Coal* of Werner, excepting the Columnar Coal, which belongs to the new bituminous class (Mohs, vol. iii. p. 62); these two kinds, however, and still more the varieties they contain, are very difficult to be distinguished: colour, structure, and the kind of lustre which depends upon the latter, are almost all that remain to mark their distinction. The colour of *Brown Coal,* as the name imports, is brown; it possesses a ligneous structure, or consists of earthy particles: the colour of *Black Coal* is black, not inclining to brown, and it does not possess the structure of wood. The varieties of brown coal are the following:—*Bituminous Wood,* or Bovey coal, which presents a ligneous texture, and very seldom anything like conchoidal fracture, imperfect and without lustre. *Earthy Coal,* consisting of loose friable particles. *Moor Coal,* or trapezoidal brown coal, distinguished by the absence of ligneous structure, by the property of bursting and splitting into angular fragments when removed from its original repository, and the low degree of lustre upon its imperfect conchoidal fracture. *Common Brown Coal,* which, though it shows traces of ligneous texture, is of a more firm consistency than the rest of the varieties, and possesses higher degrees of lustre upon its more perfect conchoidal fracture. *Slate Coal* possesses a more or less coarse slaty structure, which, however, seems to be rather a kind of lamellar composition than real fracture.

All these varieties are objectionable for the production of gas, owing as well to the extraneous matter contained in them, as to the deficiency of their products in distillation. The following varieties may easily be distinguished by a little practice, and are all œconomical. *Pitch Coal* is of a velvet-black colour, generally inclining to brown, with a strong lustre, and presenting in every direction large and perfect conchoidal fracture. *Foliated* and *Coarse Coal* have both a lustrous fracture, but approach more to a granular appearance. *Cannel Coal* is without visible composition, and has a flat conchoidal fracture in every direction, with but little lustre, by which it is distinguished from pitch coal; it is most like the moor coal, but the difference in their specific gravity is greater than between almost any other two varieties, by which it is the best distinguished. Sp. gr. of cannel coal 1·4; sp. gr. of moor coal 1·10.

The transitions between the varieties of coal are hardly perceptible, and it requires the nicest judgement to detect the good from the bad. They all consist of bitumen and carbon in various proportions, are more or less easily inflammable, and burn with flame and a bituminous smell; several varieties become soft, which is invariably an excellent criterion for valuable coal; others coke when kindled, and leave a more or less earthy residue.

The varieties called slate coal, foliated coal, coarse coal, and pitch coal occur chiefly in the coal formation: some varieties of pitch coal, and also the moor coal, bituminous wood, and common brown coal, are met with in the formations above the chalk; the earthy coal, and some varieties of bituminous wood and common brown coal, are often included in diluvial and alluvial detritus. In the neighbourhood of Garstang and of Lancaster these latter varieties are met with beneath a bed of peat thirty feet deep: trunks of trees, hazel-nuts, and many kinds of bark and ferns are abundant.

The Anthracite is a slaty, glance coal, perfectly free from bitumen, and therefore totally unfit for purposes of gas manufacture. It consists, in some specimens, of 95 per cent. of carbon, the remaining parts being oxide of iron, silica, and alumina, in various proportions.

The Staffordshire bed also furnishes large quantities of coal for the production of gas, and the line between some varieties of these and Newcastle coal can hardly be drawn. They generally require a higher temperature for distillation. The Forest of Dean and Gloucestershire coal generally, are also valuable, and work well, though not so productive as the preceding kinds.

The Cannel coal* from Wigan, in Lancashire, and Scotland, produces gas of better quality and in greater abundance than any other variety.

The following scale, constructed from the results of accurate experiment, will give a good idea of the relative values of the different kinds of coal mentioned above. It must be borne in mind that the quantities of gas are produced by *experiment*, the coal being submitted to distillation in very thin strata: in *practice* (especially as the coal is now generally decomposed) the results will not be so large; still the graduation of the varieties will remain the same.

	NAME OF COAL.	Cu. feet of gas produc'd from 84 pounds.	Sp. gr. of the gas.		NAME OF COAL.	Cu. feet of gas produc'd from 84 pounds.	Sp. gr. of the gas.
1	Wigan Cannel	542	·640	13	Eden Main	390	·400
2	,, ,,	535	·610	14	Heaton Main	390	·410
3	Scotch Cannel	525	·580		STAFFORDSHIRE.		
4	,, ,,	518	·500	15	South's	410	·398
	NEWCASTLE.			16	Second variety	400	·395
5	Berwick & Craister's Wallsend	469	·470	17	Third variety	400	·390
6	Pelaw Main	465	·420	18	Fourth variety	360	·320
7	Russell's Wallsend	450	·418	19	Forest of Dean	380	·350
8	Ellison's Main	420	·416	20	Second variety	380	·360
9	Felling Main	420	·410		WELSH COAL.		
10	Pearith's Wallsend	418	·410	21	First variety	375	·385
11	Dean's Primrose	417	·410	22	Second variety	380	·380
12	Benton Main	412	·400				

The experiments were conducted upon the plan I shall now proceed to explain.

Experiments on the Products from Coal.

I have before observed that it is frequently difficult to detect the good from the bad kinds of coal, and in large operations it would not be prudent to rely solely on the judgement: I have known men of the greatest practice completely deceived. A specimen with a perfect fracture and lustre may produce inferior gas, and that which upon inspection would be rejected may yield gas in abundance and of excellent quality. It is therefore essential to prove the

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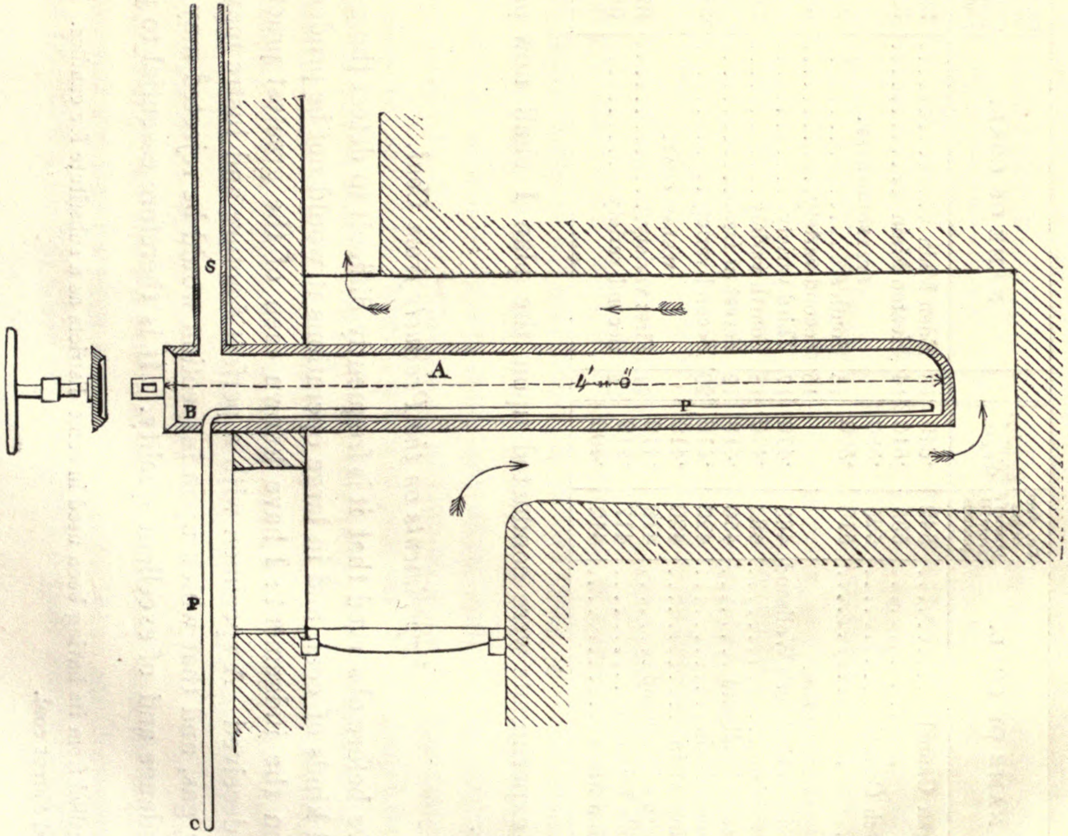
* So called from its having been used in some districts as a substitute for candles. In Scotland it is called Parrot coal.

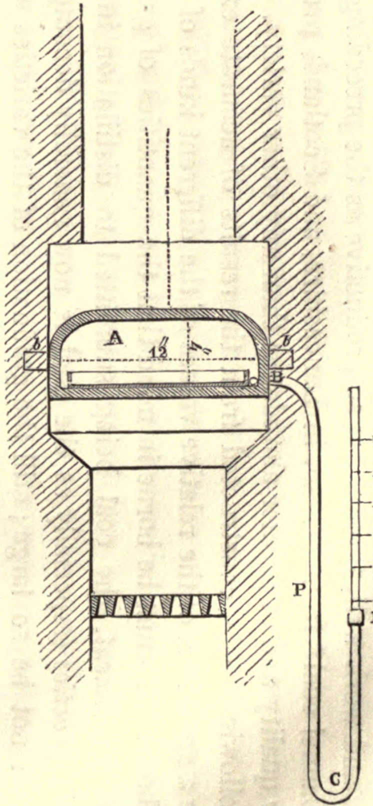
EXPERIMENTAL RETORT.

Fig. 6.



Longitudinal Section.

Fig. 7.



Transverse Section.

coal*, and this may be done in the manner shown in the annexed woodcuts, Figs. 6 and 7.

A is the cast-iron retort, 4 feet long, 12 inches wide, and 4 inches high, set in a furnace exposed directly to the flame, the flue passing beneath and over it, without guard of any kind, and secured into the side walls by the snugs, *b b*. P P is a wrought-iron welded tube, about $\frac{3}{8}$ inside diameter, inserted into the retort at B, and running the entire length from B outwards; it is bent in the form of a gauge, and must not be less than two feet from B to C: at the socket D, one foot from the bottom bend, a glass tube about 14 inches long is firmly fixed by a little plaster of Paris: the whole tube from the retort to the commencement of the glass should be thickly wrapped with flannel or woollen listing (the thicker the better), to ensure an unvarying temperature. Pour mercury into the glass tube until it is just visible at D: heat the retort to a bright red by daylight for a few hours, to decompose all vapour in the gauge; mark the glass gauge as the mercury rises (as at 1, 2, 3, etc.), fixing a point (say for instance at 6) for the heat at which the distillation is to be carried on (say 27° Wedgewood, the degree of heat at which copper melts), and the apparatus is then ready for the reception of the coal†. The coal must be prepared as follows:—sift a quantity through a sieve with meshes about $\frac{3}{8}$ths of an inch apart, and then through another much finer, so that the smallest pieces of coal used will be about the size of coffee-berries. Weigh correctly $3\frac{1}{4}$ pounds, and spread it over a surface of 360 square inches; that is, on a tray of sheet-iron, 10 inches wide and 36 inches long, turned up at the sides. Have the lid of the retort ready luted, and when the gauge marks 6, introduce the coal on the tray and immediately secure the lid.

Before I describe the remaining portion of the apparatus, it will be necessary to make a few remarks upon the necessity of having the barometric-gauge attached to the retort. In the first place, then, if the heat at which the distillation is carried on were not uniform in all the experiments, the results, even from the same piece of coal, would vary from 50 to 60 per cent. both in quantity and quality. If the retort is too cold, nitrogen and hydrogen are libe-

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* Of course the coal supplied from a known main need not be subjected to this test; but that procured from new districts I should certainly advise to be tried by the method described.

† It is always well to have a certain fixed degree of heat, such as the melting-point of tin, marked as 1 on the glass gauge—lead, marked 2, and so on,—both because errors are then less likely to occur, and memoranda, when referred to, more readily understood. The mercury will always indicate the same for the same temperature.

rated and unite, forming ammonia, vapour of bitumen (which afterwards condenses, forming tar, ammoniacal liquor and essential oil), and carbonic oxide. If the retort is too hot, all the dense hydro-carburets are resolved into charcoal and hydrogen; the product is greater, but the specific gravity little more than that of hydrogen, and the illuminating power of the gas decreased in the same ratio. At the heat of 27° of Wedgewood, or that of melting copper, which has been found the best, the bitumen is decomposed, at the same time that the hydrogen is liberated and unites with its carbon, forming olefiant and carburetted hydrogen gases, often of the specific gravity 0·470. The quantity of gas of the above specific gravity produced from 3¼ pounds of the best Newcastle coal, ought to be about 19 cubic feet in one quarter of an hour. The operation must not be carried on too long, for the process in the end would be productive almost exclusively of carbonic oxide and hydrogen.

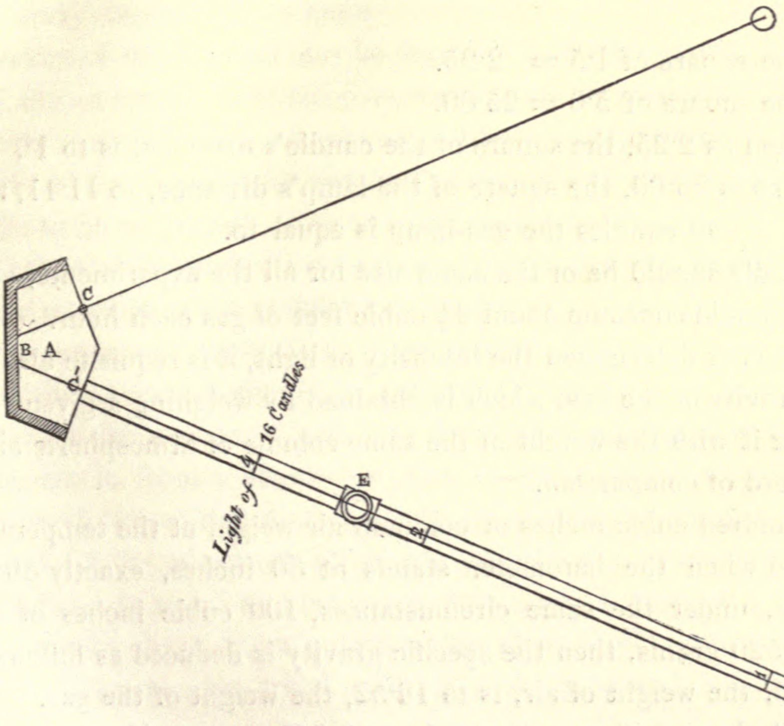
The gas, as it is produced in the experimental retort, escapes by the stand-pipe S, (which ought to be at least seven feet long, to allow some portion of the bituminous vapour to fall back and be converted into gas,) and passes through one or two other vertical pipes, to the gasometer, in order that it may be thoroughly condensed: at the bottom bends of these pipes a siphon must be attached, furnished with a stop-cock to draw off the tar and other condensed vapours that will be deposited. The cup, it will be obvious, is absolutely necessary, otherwise the condensed vapours would seal the pipes and stop the flow of the gas.

The tank of the gasometer should contain as little water as possible, for the reason I shall state hereafter. It is formed of two concentric cylinders, two inches apart, filled with water, between which the rising part works: the whole is fixed in a frame, on which pullies rest, to support the specific-gravity-chain and balance-weights. The chain is best made of stout tape, with pieces of sheet-lead sewn on to it, equal to the difference between the weight of the gasometer when out of the water, and when immersed in it.

The operation being concluded, it only remains to analyse the gas, which should be done as soon as it is produced, by the following simple processes, which are found sufficiently correct for all practical purposes.

The intensity of light is ascertained by an instrument called the Photometer, invented by Count Rumford; it is constructed on the principle that the power of a burning body to illuminate any defined space is directly as the intensity of the light, and inversely as the square of the distance. If two unequal lights shine on the same surface at equal obliquities, and an opake body be interposed between each of them and the illuminated surface, the two shadows must differ in intensity and blackness, for the shadow formed by intercepting the greater light will be illuminated by the lesser light only; and inversely, the other shadow will be illuminated by the greater light, that is, the stronger light will be attended with the deeper shadow: but it is easy, by removing the stronger light to a greater distance, to render the shadow which it produces not deeper than that of the smaller, or of precisely the same intensity; this equalization being effected, the quantity of light emitted by each lamp or candle will be as the square of the distance of the burning body from the illuminated surface. By reference to the diagram (Fig. 8.) the instrument will, I think, be rendered perfectly intelligible.

Fig. 8.



A is a wooden box, painted black inside, except at the back B, which is painted white (or a sheet of fine white paper fastened to it may be preferable); C is the substance intercepting the light of the gas-lamp D, and throwing a shadow on the paper. C is formed of a strip of thin brass, about a quarter of an inch broad, moveable round its axis on a pin at the top and bottom, so that its shadow may be adjusted to correspond in breadth to that cast by the lamp; for the candle being nearer, if its intercepting wire were of the same diameter as that of the lamp, the shadow would of course be much broader, and tend to deceive the operator. D is the lamp placed 5 feet from the wire C; E is the candle-socket sliding upon a rod, which is marked according to the number of candles the gas-lamp is equal to.

If, when the candle is placed at 1, the two shadows are equal, the lamp only gives a light equal to one candle; if at 2, the lamp is equal to 4 candles; and if at 4, the lamp is equal to 16 candles.

A simple rule-of-three statement will give the comparative quantities of light, the candle being at any distance. The burner remaining 5 feet from the interposed wire, supposing the candle to be $1\frac{5}{10}$ths of a foot from its wire,

The square of $1{\cdot}5 = 2{\cdot}25$.
The square of $5{\cdot}0 = 25{\cdot}00$.
Then as 2·25, the square of the candle's distance, is to 1·,
so is 25·00, the square of the lamp's distance, to 11·11, the number of candles the gas-lamp is equal to.

The candle should be of the same size for all the experiments, and of wax: the lamp should consume about 4½ cubic feet of gas each hour.

After having determined the intensity of light, it is requisite also to find the specific gravity of the gas, which is obtained by weighing a given volume, and comparing it with the weight of the same volume of atmospheric air, which is the standard of comparison.

One hundred cubic inches of common air weigh, at the temperature of 60° Fahr., and when the barometer stands at 30 inches, exactly 30·50 grains. Supposing, under the same circumstances, 100 cubic inches of coal-gas to weigh 16·520 grains, then the specific gravity is deduced as follows:—

As 30·5, the weight of air, is to 16·52, the weight of the gas,
so is 1·0, the specific gravity of air, to 0·541, the specific gravity of the gas.

In weighing the gas due regard must be paid to the moisture, which is always present, and which must either be allowed for by calculation, or removed by the methods described in the next section.

The vessel in which gas is usually weighed in the laboratory is a thin glass globe, of known capacity, furnished at one end with a brass stop-cock, by which, after being exhausted by an air-pump, it is attached to the stop-cock of a transfer jar standing upon the shelf of a pneumatic trough, or on to that of the gasometer containing the gas.

As an air-pump, however, is not always at hand, the weighing-vessel may have an aperture at the opposite end from the stop-cock; which, after the gas has been allowed to blow through and expel the atmospheric air, can be closed with a tight cork. Care must be taken to ascertain *exactly* the cubical contents of the weighing-vessel.

It will be found that the illuminating power of the gas is almost directly as the specific gravity; the heavier the gas, the greater the light given. If gas of sp. gr. 0·300 gives the light of six candles, that of sp. gr. 0·500 will give the light of ten candles, or as 3 to 5. This has been doubted; but Mr. Clegg ascertained the fact in 1817, from many experiments, and I have myself frequently proved it beyond all question.

The presence of olefiant gas may be detected, and the quantity ascertained, by passing into a bottle, inverted over water, two measures of coal-gas and one of chlorine; a diminution of volume will take place, the water will rise in the jar, and an oily liquid be formed by the olefiant gas uniting with chlorine, which ought to be in excess. Remove the remaining chlorine by a solution of pure potash, and the diminution in volume which the coal-gas has sustained will give the quantity of the olefiant gas sought.

The most important impurity is sulphuretted hydrogen; the method of ascertaining the amount is simply by inverting a well-stopped bottle containing a solution of the acetate of lead over the shelf of a pneumatic trough, and transferring into it, from a bladder or other vessel, a portion of coal-gas, say about one-fourth the contents of the bottle; re-place the stopper (which has been removed for the admission of the gas), agitate the solution and gas well together, suffer it to stand an hour or so, and a black precipitate of the sulphuret of lead will have fallen: decant the clear liquid, and evaporate the precipitate to dryness; the weight will give the proportion of sulphuretted hydrogen.

The quantity of tar, ammoniacal liquor and oil produced can be measured, when drawn off from the siphons attached to the lower bends of the vertical condensing pipes.

The following letter from Dr. Dalton to Mr. Clegg points out the methods of detecting some impurities :—

"Manchester, Jan. 2nd, 1815.

"Respected Friend,—I should have answered thine inquiries immediately if I had any observations to make of any importance, but I have little of anything to offer more than has been already published in my book ; thou art also acquainted with Dr. Henry's paper in 'Nicholson's Journal,' a few years ago.

"It is remarkable that no olefiant gas* (I believe) is obtained from coals, though they contain all its elements. If it is to be obtained at all, it must be by a minimum of heat, or by using some additional article. Oxymuriatic gas is the best thing for detecting it : when the gases are put together an immediate diminution and the formation of oil ensues. The diminution with carburetted hydrogen is slow and invisible, unless in a strong light. I should put a weak solution of acetate of lead into a given volume of coal-gas, and agitate it, to find the sulphuretted hydrogen ; a black sulphuret of lead would immediately fall down, and from the weight of it, that of the sulphuretted hydrogen might be inferred. I believe arseniuretted hydrogen may sometimes occur in coal-gas ; if the coals contain any arsenic, it must, I apprehend, as this metal and hydrogen unite and are volatile. This gas loses its arsenic by electricity and long standing, it falls as a black powder, or particle, and loses its volume of hydrogen ; it is absorbable by water in the same degree as coal-gas.

"Thine, etc.

"Samuel Clegg." "John Dalton."

The quantity and description of coke yielded by a specimen of coal cannot be ascertained by the apparatus just described, and, if desired, it must be done in one of the working retorts, weighing the coal when it is charged, and re-weighing the coke when drawn ; the quantity ought to be about from 38 lbs. to 44 lbs. per 56 lbs. of coal. It should be granular and compact, the particles shining with somewhat of a silvery lustre, and when exposed to a white heat it should leave no white or brown ashes. The following is an average result of five experiments made after the plan just described :—

August, 1821.—Heat of experimental retort, 27° Wedgewood.—3¼ lbs. of Berwick and Craister's Wall's-end coal yielded—in 10 minutes 16½ cubic feet —in 20 minutes 20 cubic feet. Sp. gr. of first portion 0·471 ; of second portion 0·432 : burnt from an Argand lamp consuming 6·2 cubic feet of gas per hour. The first portion gave a light equal to that of twelve candles called

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* Dr. Dalton at that period was not aware of olefiant gas being evolved during the production of coal-gas. Dr. Henry detected its presence by the test of the action of chlorine.

short sixes; the second portion required nearly seven cubic feet to produce the same effect.

The analysis of 100 cubic inches of the first portion was as follows:—

Olefiant gas - -	8
Carburetted hydrogen -	72
Carbonic oxide and hydrogen	13
Carbonic acid - -	4
Sulphuretted hydrogen -	3
	100

The second portion was not analysed.

In Mr. Nicholson's Philosophical Journal for June 1805, and in the Transactions of the Royal Society for 1808, will be found a communication from Dr. Henry, on the illuminating power of combustible gases obtained from coal admitting of more exact appreciation than the optical method by the comparison of shadows. The method to which he gave the preference was the determination of the quantities of oxygen gas consumed, and of carbonic acid formed by the combustion of equal measures of the different inflammable gases,—that gas having the greatest illuminating power which in a given volume condensed the largest quantity of oxygen gas. He found that 100 measures of pure hydrogen required only 50 of oxygen for its saturation, whereas 100 measures of olefiant gas required 284 of oxygen for its complete combustion: the former produced no carbonic acid, the latter produced 179 measures. The following Tables will show the results he obtained.

One hundred measures of gas from coal of average quality obtained at Clifton, near Manchester,

Consisting of				
Olefiant.	Other inflammable gases.	Nitrogen.	Consume of Oxygen	Give of carbon. acid
10	90	0	164	91
9	91	0	168	93
6	94	0	132	70
5	80	15	120	64
2	89	9	112	60
0	85	15	90	43

One hundred measures of gas from Cannel coal,

Consisting of				
Olefiant.	Other inflammable gases.	Nitrogen.	Consume of Oxygen	Give of carbon. acid
18	77¼	4¾	210	112
16	64	20*	180	94
15	80	5	200	108
13	72	15	176	94

It appears from these experiments that gas from cannel-coal has, with

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* The inferior illuminating power of this gas is owing to the presence of so large a portion of nitrogen. It certainly is a more than average proportion for any gas.

equal volumes, an illuminating power about one-third greater than that from coal of medium quality. The quantity also from the former substance exceeded by about one-seventh that obtained from common coal.

In comparing the value of gases produced from different kinds of coal, or from the same kind of coal differently treated, it is not enough to determine the *quantity* of aëriform products; and no satisfactory conclusion can be drawn respecting the relative fitness of any variety of coal for affording gas, or the advantages of different modes of distillation, unless the *degrees of combustibility* of the gases compared be determined by finding experimentally the proportion of oxygen gas required for their saturation. But, as I have before stated, the specific gravities of the various gases form as correct a method of judging of their illuminating qualities as any other, the lighter gas being the poorest. A gas having the specific gravity of 0·400 I have found, by a great number of experiments on a large practical scale, to be an average standard for comparison. The gas produced from cannel-coal will average much higher. I have not had an opportunity of making such experiments on this gas as I should wish, to be relied on, as those of practical utility require to be made on a working scale. I think, however, the sp. gr. 0·539 is about the standard. Mr. Clegg obtained once, and once only, gas from a specimen of Wigan cannel, having the specific gravity of 0·640. I have not added this in with the rest for the average, because it is not a general result.

Table of the Specific Gravity of Coal-Gas, obtained from different Experiments.

Dr. Henry obtained	·600	Mr. Cooper obtained	·415
——— - -	·431	——— - -	·410
——— - -	·340	Mr. Anderson -	·650
Dr. Dalton - -	·534	Mr. Clegg - -	·640
——— - -	·443	——— - -	·584
——— - -	·410	——— - -	·470
——— - -	·390	——— - -	·410
Dr. Faraday - -	·430	——— - -	·406
Mr. Lowe - -	·425	——— - -	·400
——— - -	·408	——— - -	·390
Professor Leslie -	·600	——— - -	·380
——— - -	·410	——— - -	·380
Mr. Phillips - -	·406	——— - -	·370

The kinds, or rather the different names, of coal used at the London Gas-Works are, South Pelaw, Ellison's Main, Felling Main, or East Garesfield

Main, Dean's Primrose and Pearith's Wall's-end. Most of the Companies have the facilities of water-carriage, and purchase their coals at the pit for about 7*s.* 6*d.* per ton, and charter a vessel from 8*s.* to 11*s.* per ton, according to the time of the year. If the gas-works are far from the water-side, and they purchase their coals at the market, the above would fetch from 17*s.* 6*d.* to 18*s.* 6*d.* per ton; and to a large consumer, for cash, 5*s.* would be charged for cartage, making a total of 22*s.* 6*d.* to 23*s.* 6*d.* If the gas-works are at the water-side, the charges would be as follows:—

	s.	*d.*
Cost of coal at the pit-mouth, say - -	7	6
Freight and loading - - - - -	8	0
Lighterage from ship to wharf - -	0	10
Gang of men carrying from barge to works, per ton, according to distance - - -	1	0
Duty 1*s.* 1*d.*, and weighing 1½*d.* - -	1	2½
Total	*s*18	6½

At Birmingham and in the neighbourhood the price for Staffordshire coal is about 8*s.* 6*d.* per ton, including all expenses.

In Scotland the prices, per ton, paid for the different kinds of Parrot coal at the places where they are shipped, are as follows:—

	s.	*d.*		*s.*	*d.*
Lesmahajo -	17	0	Marquis of Lothian	17	6
Monkland -	16	0	Capledsea -	14	0
Torry Burn -	12	0	Halbeath -	12	0
Wemyss -	13	6	Lochgelly -	10	0

The price of coke in London varies according to the demand: to retailers who fetch the coke it is now about 16*s.* per chaldron, to private persons 18*s.*, and if delivered, from 21*s.*, according to the distance. At West Bromwich coke is considered on an average to be worth 4*d.* per bushel.

Corrections for Moisture in Gas.

Gases expand by heat in the proportion of about $\frac{1}{480}$th of their bulk for every degree of Fahrenheit's thermometer between 32° and 212°; at a temperature of about 1035° Fahr., one volume of gas becomes nearly 2·5*. Dr.

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* Davy, Phil. Trans. 1817, p. 54.

Dalton and Gay-Lussac have proved beyond doubt that all gases expand equally by the same increase of caloric when placed under the same circumstances: it is therefore easy to ascertain the volume any given quantity of gas should occupy under any given temperature. As it may be useful sometimes in experiments to know the volume a portion of gas would occupy at a temperature differing from that in which the experiment is made, the following formulæ will be found correct.

Let V' be the volume of gas at any temperature above 32°, T the number of degrees above that point, and V its volume at 32°: then $V' = \left(1 + \frac{T}{480}\right)$: hence $\frac{V'}{V} = 1 + \frac{T}{480}$; $V'\,480 = V\,(480 + T)$; and $V' = V\,\frac{(480 + T)}{480}$; or if V is unknown, it may be calculated by the formula $V = \frac{V'\,480}{480 + T}$.

It frequently happens, in using Fahrenheit's thermometer, that when V' for the above formula is known, it is not V itself which is wanted, but the volume of gas at some other temperature, as at 60° Fahr.; this value may be obtained without first calculating what V is. Let V', for instance, be any known quantity of gas at a certain temperature, and let V'' be the quantity sought at some other temperature, the degrees of which above 32° may be expressed by T'. Now $V'' = \frac{(480 + T')}{480} \times V$; but as V is unknown, let its value be substituted according to the above formula. Thus $V'' = \left(\frac{480 + T'}{480}\right) \times \left(\frac{V'\,480}{480 + T}\right)$, which gives $V'' = \frac{480^2\,V' + 480\,T'\,V'}{480^2 + 480\,T} = \frac{V'\,480\,(480 + T')}{480\,(480 + T)} = \frac{V'\,(480 + T')}{480 + T}$. Suppose, for example, a portion of gas occupies 100 divisions of a graduated tube at 48° Fahr., how many will it fill at 60° Fahr.? Here $V' = 100$; $T = 48 - 32$ or 16; $T' = 60 - 32$ or 28, the number sought, or the $V'' = \frac{100 \times 508}{496} = 102{\cdot}42$.

This formula was given by the late Dr. Turner, in his Lectures at the University of London, 1830: see also his work on Chemistry.

In estimating the volume of a gas, it is necessary that it be dry, as vapour increases it, and the augmentation will depend upon the temperature. Dr. Dalton has given a formula for the correction of moisture in gases.

Let a = weight of 100 cubic inches of dry common air, at the pressure of 30 inches, and temperature 60° Fahr.; p = any variable pressure of atmospheric air, and f = pressure or tension of vapour in any moist gas; then the following formulæ will be found useful in calculating the volumes, weights, and specific gravities of dry and moist gases, putting M for the volume of moist gas, D for that of dry gas, and V for that of vapour, all of the same pressure and temperature.

$$1.\ \mathrm{M}=\mathrm{D}+\mathrm{V}. \qquad 2.\ \frac{p-f}{p}\,\mathrm{M}=\mathrm{D}.$$

$$3.\ \frac{f}{p}\,\mathrm{M}=\mathrm{V}. \qquad 4.\ \mathrm{M}=\frac{p\,\mathrm{D}}{p-f}=\frac{p\,\mathrm{V}}{f}.$$

If we wish to infer the specific gravity of any dry gas from the observed specific gravity or weight of the same mixed with vapour, it will be convenient to expound p by that particular value which corresponds with a, namely, thirty inches of mercury; and let $s=$ the specific gravity of the dry gas, and $w=$ the observed weight of 100 cubic inches of the moist gas; then we shall have the following:

$$5.\ \frac{30-f}{30}\,.\,s\,a+\frac{f}{p}\times\cdot620\,a=w. \qquad 6.\ s=\frac{30}{30-f\,a}\left(w-\frac{f}{p}\times\cdot620\,a\right).$$

Examples.

1. 98 volumes of dry air + 2 volumes vapour = 100 volumes of moist air.

2. Given $p=30$, $f=\cdot5$ and $\mathrm{M}=100$; then $\frac{p-f}{p}\,.\,\mathrm{M}=\mathrm{D}$, the dry air $=98\frac{1}{3}$.

3. And $\frac{f}{p}\,\mathrm{M}=\mathrm{V}$ the vapour $=1\frac{2}{3}$.

4. Given $\mathrm{D}=100$, $p=30$, $f=\cdot4$; then $\frac{30\times100}{29\cdot6}=101\cdot35$ the moist air. Given $\mathrm{V}=2$, $p=30$, $f=\cdot3$; then $\frac{30\times2}{\cdot3}=200$, the moist air.

5. Let $f=\cdot5$, $s=1\cdot111$, $a=30\cdot5$, $p=29\cdot5$; then $\frac{30-\cdot5}{30}\,1\cdot111\times30\cdot5+\frac{\cdot5}{29\cdot5}\times\cdot62\times30\cdot5=33\cdot64=w$, which gives the specific gravity $1\cdot103$.

6. Let f, a, and p as above, and $w=2\cdot5$ corresponding to specific gravity $0\cdot8197$; then $s=\frac{30}{29\cdot5\times30\cdot5}\left(2\cdot5-\frac{\cdot5}{29\cdot5}\times\cdot62\times30\cdot5\right)=\cdot07266$.

The above formulæ will apply equally well if V be a permanent gas, or any other vapour beside that of water, the specific gravity of the gas or vapour being substituted instead of ·620,—that of steam.

The following is extracted from Professor Faraday's "Chemical Manipulation," p. 381:

Gas, when standing over water, becomes saturated with aqueous vapour, the quantity being proportional to the temperature. In these cases a part of the volume observed, and also a part of the weight, is due to the vapour, which therefore must be ascertained before the true weight of the gas under examination can be determined. The following Table exhibits the proportion by volume of aqueous vapour existing in any gas standing over or in contact with water, at the corresponding temperatures and at mean barometric pressure of 30 inches.

40°—·00933	51°—·01380	61°—·01923	71°—·02653
41 —·00973	52 —·01426	62 —·01980	72 —·02740
42 —·01013	53 —·01480	63 —·02050	73 —·02830
43 —·01053	54 —·01533	64 —·02120	74 —·02923
44 —·01093	55 —·01586	65 —·02190	75 —·03020
45 —·01133	56 —·01640	66 —·02260	76 —·03120
46 —·01173	57 —·01693	67 —·02330	77 —·03220
47 —·01213	58 —·01753	68 —·02406	78 —·03323
48 —·01253	59 —·01810	69 —·02483	79 —·03423
49 —·01293	60 —·01866	70 —·02566	80 —·03533
50 —·01333			

By reference to this Table, which is founded upon the experiments of Dr. Dalton, and includes any temperature at which gases are likely to be weighed, the proportions in bulk of vapour present, and consequently of the dry gas, may easily be ascertained. For this purpose, the observed temperature of the gas should be looked for, and opposite to it will be found the proportion in bulk of aqueous vapour, at a pressure of thirty inches. The volume to which this amounts should be ascertained, and corrected to mean temperature. Then the *whole* volume is to be corrected to mean temperature and pressure, and the corrected volume of vapour subtracted from it: this will leave the corrected volume of dry gas. It has been ascertained in a manner approaching to perfect accuracy, that a cubic inch of permanent aqueous vapour, corrected to the temperature of 60°, and a mean pressure of thirty inches, weighs 0·1929 grains; the weight therefore of the known volume of aqueous vapour is now easily ascertained, and this being subtracted from the weight of the moist gas, will give the weight of the dry gas, the volume of which is also known.

As an illustration, suppose a gas standing over water had been thus weighed, and that 220 cubic inches, (at the temperature of 50° Fahr., and barometer pressure of 29·4 inches,) had entered into the globe, and caused an increase in weight of 101·69 grains. By reference to the Table, it will be found that at the temperature of 50° the proportion of aqueous vapour in gas standing over water is ·01333, which in the 220 cubic inches will amount to 2·933 cubic inches, which, corrected to the temperature of 60°, becomes 2·942 cubic inches. The whole volume corrected to mean temperature and pressure will be found to equal 219·929 cubic inches, from which if the 2·942 cubic inches of aqueous vapour be subtracted, there will remain 216·987 cubic inches as the volume of *dry* gas at mean temperature and pressure; 2,940 cubic inches of aqueous vapour weigh ·5675 grains, for 2·942 × 0·1929 = 0·5675; this subtracted from 101·69, the whole weight, leaves 101·1225 grains, which is the weight of the 216·987 cubic inches of dry gas; and by the simple rule of proportion, therefore, it will be found that 100 cubic inches of such gas, when dried, and at a mean temperature and pressure, will weigh 46·603 grains.

Some experimenters prefer drying the gas before it is weighed, and thus in fact weigh a known volume, not of a mixture, but of a pure gas. Now gases are dried in various ways; one method is to pass them through a glass tube, containing substances having a powerful attraction for water: it is a simple and a useful process, and therefore proper to be described here, though not conveniently applicable to the mode of weighing a gas as above directed, because of the greater difficulty of measuring the quantity of gas which enters. The tube may be about half an inch in diameter, and two feet long, and should have a piece of wire pressed into a loose ball thrust into one end of it, to prevent fragments falling through. 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-gasometer, or other vessel containing or evolving the gas, by caoutchouc connectors, or in any other convenient way; and so much gas should be passed through it, 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 cubic inches having about ten minutes allowed for their passage through such a tube as that described; though if the period be lengthened, no injury is occasioned. If the tube be shorter, or of smaller diameter, more time should be proportionably allowed. Dr. Thomson has published a very useful method of weighing gases in the Annals of Philosophy, vol. xv. p. 352.

ADVANTAGES OF GAS.

All substances, whether animal, vegetable, or mineral, consisting of carbon, hydrogen and oxygen, when exposed to a red heat, as we have already seen, produce various inflammable elastic fluids, capable of furnishing artificial light. We perceive the evolution of this elastic fluid during the combustion of coal in a common fire. The coal, when heated to a certain degree, swells and kindles, and frequently emits remarkably bright streams of flame, and after a certain period these appearances cease, and the coal glows with a red light.

The flame produced from coal, oil, wax, tallow, or other bodies which are composed of carbon and hydrogen, proceeds from the production of carburetted hydrogen gas, evolved from the combustible body when in an ignited state.

If coal, instead of being burnt in the way now stated, is submitted to a temperature of ignition in close vessels, all its immediate constituent parts may be collected. The bituminous part is distilled over, in the form of coal-tar, etc., and a large quantity of an aqueous fluid is disengaged at the same time, mixed with a portion of essential oil and various ammoniacal salts. A large quantity of carburetted hydrogen, carbonic oxide, carbonic acid, and sulphuretted hydrogen, also make their appearance, together with small quantities of cyanogen, nitrogen, and free hydrogen, and the fixed base of the coal alone remains behind in the distillatory apparatus, in the form of a carbonaceous substance called *coke*. An analysis of the coal is thus effected by the process of destructive distillation: the products which the coal furnishes may be separately collected in different vessels.

The carburetted hydrogen, or coal-gas, when freed from the obnoxious foreign gases, may be propelled in streams out of small apertures, which, when lighted, form jets of flame, which are called *gaslights*.

In order to apply this mode of procuring light on a large scale, as now practised with such brilliant success in this country, as well as in many parts of America and continental Europe, the coal is put into vessels called retorts, and furnished with pipes connected with reservoirs, to receive the distillatory products. The retorts are fixed into a furnace, and heated to redness: the heat developes the gaseous and liquid products of the coal: the latter are deposited in receivers or tanks, and the former conducted through lime-water, or thin strata of the hydrate of lime, and purified. The sulphuretted hydrogen and carbonic acid, which are mixed with these, become absorbed by the lime and moisture, and the pure carburetted hydrogen is stored up in a vessel called a gasometer, and is then ready for use. From the reservoir in which the gas has been collected proceed pipes, which branch out into small ramifications, until they terminate at the place where the lights are wanted; and the extremities of the branch pipes are furnished with stop-cocks, to regulate the flow of the gas into the burners or lamps.

The production of gas-lights is therefore analogous to that of flame produced from tallow, wax, or oil. All these substances possess, in common with coal, the elements of certain peculiar matters, which are capable of being converted into inflammable elastic fluids by the application of heat.

The capillary tubes, formed by the wick of a candle or lamp, serve the office of the retorts, placed in the heated furnace in the gas-light process, and in which the inflammable gaseous fluid is developed. The wax, tallow, or oil, is drawn up into these ignited tubes, and is decomposed into carburetted hydrogen gas, and from the combustion of this substance the illumination proceeds. In the lamp, as well as in the candle, the oil or tallow must therefore be decomposed before they can produce a light; but for this purpose the decomposition of a minute quantity of the materials successively is sufficient to give a good light: thus originates the flame of a candle or lamp.

Nothing more therefore is required in the gas-light process which coal affords, when submitted to a temperature of ignition in a close vessel, than to collect these products in separate reservoirs, and to convey one of the products, the inflammable gas, by means of pipes and branching tubes to any required distance, in order to exhibit it there at the orifice of the conducting tube, so that it may be used as a candle or lamp.

The whole difference between the greater process of the gas-light operation and the miniature operation of a candle or lamp, consists in having the distillatory apparatus at the gas-light manufactory, at a distance, instead of being in the wick of the candle or lamp—in having the crude inflammable matter decomposed, previous to the elastic fluid being wanted, and stored up for use, instead of being prepared and consumed as fast as it proceeds from the decomposed oil, wax, or tallow; and lastly, in transmitting the gas to any required distance, and igniting it at the burner or lamp of the conducting tube, instead of burning it at the apex of the wick. The principle of the gas-light manufacture is therefore precisely similar to the general mode in which all light is produced: it is simply conducting on a large and general scale the natural operations of ignition.

Greatly as the number of towns lighted with coal-gas have increased within the last few years, when the brilliancy, œconomy, and convenience of this mode of illumination is considered, it is surprising that there remains a single town, deserving the name, without its gas-works. It has been frequently proved that even a private factory may be lighted œconomically with coal-gas when the cost of artificial light amounts to £40 per annum. Surely, then, a gas-apparatus in the smallest town may be safely erected. The outlay in the first instance, the labour required for the operation, the quantity of coals and material expended, together with the returns, are now so fully understood, and can be calculated to such a nicety, that money sunk in the erection of gas-works returns its interest with the same certainty as that deposited in the funds. It is not a speculation, but a matter of the same kind as the commencement of a factory for the production of any other article of commerce.

While thus speaking of the certainty of success attending the manufacture of coal-gas, it must be understood that the apparatus erected for that purpose be designed and executed with skill. Individuals, from observing the excellent returns given for the capital expended on other establishments, have been induced to erect works of their own, expecting naturally an equal remuneration. From employing ignorant people, their arrangements have in many cases signally failed, and I doubt not that these circumstances alone have tended in a great measure to retard the general diffusion of gas illumination throughout the entire kingdom.

If the number of lamps required is known, the materials necessary for the production of the gas to supply those lamps are known also. The profit and loss of such establishments in actual operation may as surely be relied upon as that given upon paper.

Upon a well-regulated system the cost of producing every 1000 cubic feet of gas with the same coal will not vary one penny the whole year round; the quantity of gas made will be adequate to the demand, and no more. The wear and tear of the machinery will be exactly that which was anticipated, and therefore the annual outlay will be known; the sale of the products of the establishment may be depended upon with equal certainty, and the income known: the profit arising from the difference is thus ascertained. I will give as an example the results of a small gas establishment erected in the country.

	£	s.	d.
Apparatus for the supply of 70 public and 75 private lamps cost	500	0	0
Retort-house and chimney	130	0	0
400 yards of 4-inch pipe	101	13	4
740 Do. 3-inch do.	129	0	0
266 Do. do.	39	13	0
	£900	6	4

OUTLAY IN 1838.

	£	s.	d.
Coal carbonized	204	17	11
Do. as fuel	54	15	0
240 bushels of lime	6	0	0
One man by day and one by night	62	8	0
Lamplighter	31	0	0
Repairs in the streets	15	0	0
Repairs in the works, including wear and tear of retorts, meter and clock	60	0	0
Rent of ground	20	0	0
Taxes	20	0	0
Office expenses	10	0	0
	£484	0	11

INCOME IN 1838.

	£	s.	d.		£	s.	d.
72 Private lamps at	3	0	0	=	216	0	0
64 Public do. at	4	0	0	=	256	0	0
200 Gallons of tar at	0	0	1	=	0	16	8
Coke, 247 chaldrons, at	0	16	0	=	197	12	0
					£670	8	8

Therefore we have	£	s.	d.
Income	670	8	8
Outlay	484	0	11
Leaving a profit of	£186	7	9

OUTLAY IN 1839.

	£	s.	d.
Coal carbonized	204	19	2
Do. as fuel	54	14	0
240 bushels of lime	6	0	0
One man by day and one by night	62	8	0
Lamplighter	31	0	0
Repairs in the streets	16	3	0
Repairs in the works, including wear and tear of retorts, meter and clock	58	16	0
Rent of ground	20	0	0
Taxes	20	0	0
Office expenses	10	0	0
	£484	0	2

INCOME IN 1839.

75 Private lamps at	3	0	0	=	225	0	0
64 Public do. at	4	0	0	=	256	0	0
Coke, 243 chaldrons at	0	16	0	=	194	8	0
					£675	8	0

Income	675	8	0
Outlay	484	0	2
Leaving the profit	£191	7	10

The equal results of these two years is not peculiar to this establishment; there are many of much greater extent that can compare with it. It is only those works, in the erection of which incompetent people have been employed, that fail to answer the expectations of the capitalist. It is at all times unpleasant to find fault; but it cannot be denied that there are many who, from slight or no experience at all, fancy themselves capable of undertaking the superintendence of any gas establishment: the number of failures constantly point out their ignorance. It is no better than imposition for persons thus unqualified to undertake the arrangement of such machinery, upon the correct working of which must depend its success; and those who suffer themselves thus to be imposed upon will only find out their error when it is too late to rectify it.

The manufacture of gas is one of those processes which appear perfectly simple and straight-forward at first sight, and this may in some measure account for the errors of such men as I have just noticed. It is true that the operations do appear exceedingly plain; but there are few that require more scientific judgement, system, and strict care. The retorts, for instance, must be set in such a manner as to be heated sufficiently with the smallest quantity of fuel, and without the liability of being made too hot: they must be carefully watched, lest the incrustation of carbon in the interior accumulate more than is absolutely unavoidable, and lest they burn out before the time calculated. These particulars can only be learned by *practice*; they will vary with every different quality of coal, and be affected by the size and shape of the distillatory vessel itself. It also requires much experience to determine the most œconomical arrangements for the condensers, purifiers, etc., and to regulate the quantity of gas to the demand. But, above all, the proper distribution of the street-mains requires the most skill, which, in the section treating upon this subject, I shall endeavour to point out.

The supplying of light to the street or parish lamps alone, can never be undertaken with œconomy in any district; the most beneficial application being in those situations where a quantity of light is wanted in a small space. Where the light is required to be more diffused, the profit is less, owing to the greater extent of services and fittings.

It is hardly necessary to remark, in the present advanced state of the art, that the use of coal-gas for the purposes of artificial light is more œconomical than that obtained from either wick-lamps or candles. To those, however, unacquainted with the actual saving, I may observe that 6000 cubic feet of coal-gas of the specific gravity ·400, when supplied with a sufficient volume of oxygen for its complete combustion, is equal to the light from 2400 candles, eight in the pound; or 1000 cubic feet will give as much light as 50 lbs. of candles, eight in the pound, for the same length of time.

One thousand cubic feet of gas costs 8*s.*; in some places it is higher, therefore we will say 12*s.*: 50 lbs. of candles at 6½*d.* costs 27*s.* 1*d.*, making a difference in favour of the coal-gas of 15*s.* 1*d.*; and when we consider, in addition to this, its greater convenience, cleanliness and safety, we may wonder how those who have it in their power to obtain these advantages persist in the use of oil and tallow.

There are some disadvantages attending the use of gas-lights in a close room; for unless the apartment be well ventilated, an unpleasant heat will be felt, often producing at the same time the effect of sickness and oppressive headache. The capacity of ventilators adapted to rooms in which coal-gas is burned should greatly exceed that actually capable of carrying off the heated vapours; they should be made of tubes, opening from the top of the room at the angles formed by the meeting of the ceiling and sides, and carried into the open air by pipes several feet high, thus causing sufficient draught to ensure perfect ventilation. One pipe may be taken from the cornice over the chimney-piece and conducted up the flue, and the end of the tube covered by a hood. An adequate supply of fresh air must of course be ensured from the bottom of the room. Dwelling-houses may thus be illuminated with advantage and comfort.

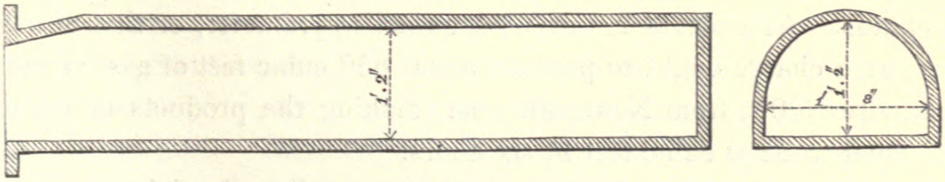
The comparative effect of heat evolved during the combustion of inflammable gases, and other substances capable of burning with flame, will be found in Dalton's System of Chemistry, vol. i. p. 76.

RETORTS.

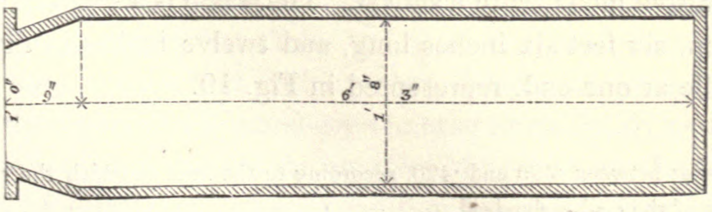
THE proper mode of constructing retorts in which the coal is distilled, and the art of applying them, form objects of primary importance in every gas-light establishment. The quantity of gas which can be obtained in any given time from any given quantity of coal—the consumption of fuel requisite for the production of that quantity of gas—the degree of deterioration to which the distillatory vessel is subjected—the equality, in some measure, of the gas itself—all depend upon the manufacture being conducted with a due regard to physical principles, and, as the ultimate result of all these circumstances, the rate at which the gas-light can be furnished to the consumer.

The forms of the retorts used at the present time are various; I shall, however, confine my observations to those which are considered the best both for the production of gas, and for their durability. The annexed figures represent sections of a retort, commonly known by the name of a York D. The charge is 3 bushels, or 2¼ cwt., which may be drawn at the end of six hours. The dimensions cannot be increased with œconomy beyond those marked on the drawings. Retorts of smaller dimensions are more usually adopted; I have shown them, with the manner in which they are set, in an engraving.

Fig. 9.



Plan.



PLATES I. AND II.

MODE OF SETTING A BENCH OF FIVE D RETORTS.

These Plates represent a front elevation, two sections and plan of a "bench" of five common retorts, such as are in general use.

Plate I. Fig. 1. is a front elevation. Fig. 2. A transverse section, through *a b* in Fig. 3. Fig. 3. A longitudinal section, through *c d* in Fig. 2.

Plate II. Fig. 1. is a plan showing the furnace and side-openings below the fire-tiles, on which the lower retorts rest, and the bedding of the lower retorts. Fig. 2. is a plan over the three lower retorts, the two upper retorts being removed. Fig. 3. is a plan over the oven-arch, showing the flues, etc.

The same letters refer to corresponding parts in the several views.

A. Retorts of the kind called D's. Some engineers prefer those of a cylindrical form, but D's allow of the coal being laid in thinner strata, consequently it is more evenly acted upon by the heat, an advantage under every circumstance. Set in the manner shown in the Plates, the bottoms of those retorts placed immediately over the furnace are well protected. The dimensions are —length 7 feet, diameter 1 foot 2 inches, thickness of metal 1¼ inch. Their weight is about 15 cwt.

The most œconomical charge is two bushels, or 1½ cwt. of coal to each retort, drawn at the end of six hours. This charge will fill the retort to the depth of about five inches; if the coal be moderately small, the layer will be rather less in thickness. At a heat of 27° of Wedgewood's pyrometer, or that of melting copper, each charge ought to produce about 650 cubic feet of gas, of the specific gravity ·400*, from Newcastle coal, making the products of the entire bench equal to 3250 cubic feet in six hours.

To introduce the coal into the retorts, a "scoop" ought to be employed, in preference to the primitive mode, with a shovel. The scoop is a semi-cylinder made of thin plate iron, six feet six inches long, and twelve inches in diameter, with a cross-handle at one end, represented in Fig. 10.

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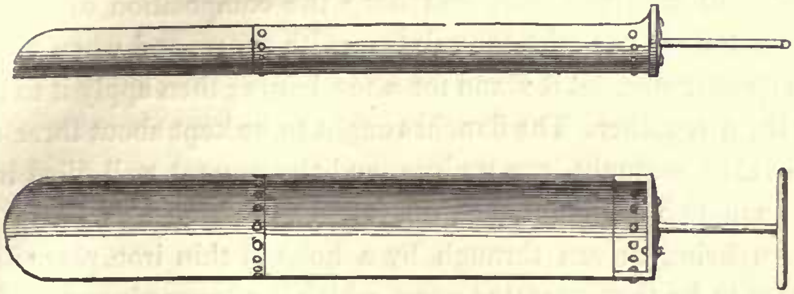
* The specific gravity varies between ·390 and ·420, according to the heat at which the retorts are worked, and the quality of the coal carbonized.

Fig. 10.



The charge for the retort is placed in this; one man takes the cross-handle, and two others at the opposite end lift it with its contents up to the retort; it is then pushed forward, quite to the bottom, turned round, and withdrawn immediately, and the coal left in the retort raked into an even stratum.

The lid, previously luted, is now quickly jointed on to the retort-mouth. It must be obvious that the loss of gas by this simple method is very trifling; indeed I much question whether any is lost, the whole operation not occupying more than forty seconds; whereas, when the shovel is used, the coal is thrown in so much by degrees, that more gas is lost, owing to the greater length of the operation, and the heat producing some effect on each separate shovelfull: in either case the loss is inconsiderable, but I am an advocate for saving in every possible way.

Previous to drawing the charge, loosen the lids of the retorts, and apply a light to the issuing gas, beginning at the upper retorts. This precaution is necessary to prevent explosion, or what the stokers call a "rap."

S is the mouth-piece, ten inches long, with a socket cast on the top to receive the stand-pipe. There ought to be a neck to this socket, as shown in the Plates; because the joint, when close upon the top, from its greater thickness, retains much heat, and decomposes the tar which will accumulate at this place, and eventually choke the pipe with hard carbon. The length of the neck may be from four to five inches. I have mentioned this, from having frequently observed the stand-pipe jointed immediately upon the mouth-piece.

The mouth-piece is three quarters of an inch in thickness, secured to the retort by bolts, and a cement-joint made between their flanches. Iron cement is the most valuable for this purpose, and is used in all places where heat is present. It may be compounded as follows. To one ounce of sal-ammoniac, add one ounce of flowers of sulphur, and thirty-two ounces of clean cast-iron borings: mix all well together, and keep the composition dry. When the cement is wanted for use, wet the mixture with water, and when brought to a convenient consistence, let it stand for a few hours; then apply it to the joints, and screw them together. The flanches ought to be kept about three-eighths of an inch apart, by wrought-iron wedges, and the cement well filled in between them with a square blunt-pointed chisel, called a caulking-chisel; the cement is stopped from being driven through by a hoop of thin iron placed inside the pipe or retort to be thus operated upon, which is afterwards removed. A considerable degree of action and reaction takes place among the ingredients, and between them and the iron surfaces, which causes the whole to unite as one mass; the surfaces of the flanches become joined by a species of pyrites, all the parts of which adhere strongly together. Mr. Watt found that the cement is improved by adding some fine sand from the grindstone trough.

A very œconomical joint for the retort mouth-piece is made of five parts of fine Stourbridge clay, and one part of the mixture just described.

For some purposes it is more convenient to join the parts not exposed to heat, with putty, mixed to a proper consistence, and applied on each side of a piece of thick canvas, flannel, plaited hemp, or a piece of thick pasteboard steeped in linseed oil (previously shaped to fit the parts), and then interposed between the parts before they are screwed together: it makes a close and durable joint, and is generally used for those which have occasionally to be opened, and for those which must be separated repeatedly before a proper adjustment is obtained.

The face of the retort mouth-piece is bevelled inwards, and is chipped and filed, if necessary, to remove any lump that would prevent the lid from fitting close; a clean and true casting, however, seldom requires this to be done.

The lid is shown in Plate III. Figs. 6 and 7. It is jointed on to the face of the mouth-piece, with "luting" made of the spent lime from the dry purifiers, mixed with a little fire-clay, and tightened into its place by a strong, square-threaded screw, and cross-bar of wrought iron, the ends of the cross-bar being passed through projecting ears, against which it bears when the screw is turned.

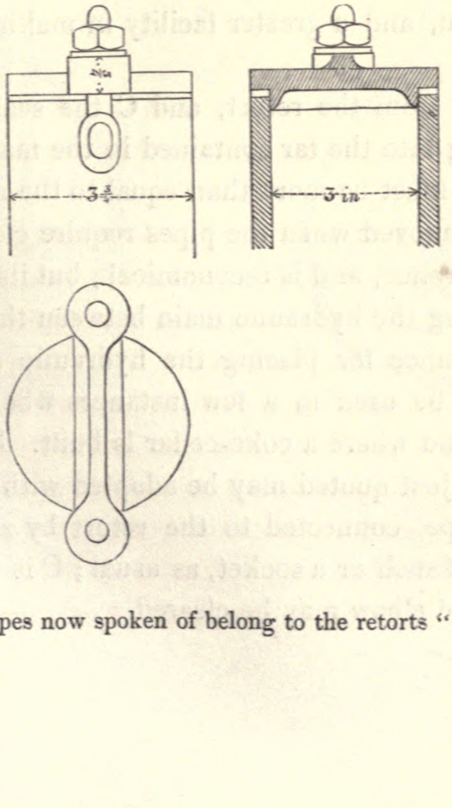
B is the "stand-pipe," through which the gas, as it is generated, passes from the retort; it is three or four inches in diameter at the top, increasing to five inches at the bottom, to prevent the tar which adheres to the lower parts from obstructing the flow of the gas. The lowest joint is made with a socket, instead of a flanch, to allow for some expansion without injury.

B′ is a "bridge-piece," connecting the stand- and dip-pipes.

C is the "dip-pipe," passing through the upper metal of the hydraulic main, upon which it is jointed, and having its lower extremity, which is three inches in diameter, immersed four or five inches into the tar contained therein. The holes in the hydraulic main, through which the dip-pipes pass, are generally drilled and chipped out while the apparatus is in process of erection; because they are at unequal distances from one another, and to have them fixed "out of square" would be an eye-sore. The height of the dip-pipes from the surface of the tar, measured from the lower bend of the bridge-piece, ought to be sufficient to contain the perpendicular head of tar forced up into them by the pressure of the gas from the *working* retorts*. This would probably in no case exceed three feet: I have made it five feet in the engraving, which is perhaps unnecessary.

DD are the bonnets, to be removed when the pipes require clearing, jointed by putty and pasteboard, as just described; they are represented in Fig. 11.

Fig. 11.



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* The dip-pipes now spoken of belong to the retorts "thrown off."

E is the " hydraulic main," running the entire length of the retort-house, over the benches, in a perfectly horizontal direction, and sufficiently high up to allow of head-room, and to be removed from the flame issuing from the retorts while charging. They are sometimes turned the reverse way to that shown in the Plate, and made to rest upon the brickwork of the benches ; but this is inconvenient when the brickwork has to be taken down or repaired.

This main is three-quarters of an inch in thickness, and cast in convenient lengths, contrived to reach over two benches ; in this case they would be equal to 13 feet 6 inches. The joints are made with iron cement. Its use is to cut off the communication between the retorts, when one or more benches are charging or open. Being half full of tar, the gas evolved from the retorts in action remains in the upper part, and the ends of the dip-pipes immersed under the surface are effectually sealed. The pressure of the gas on the surface of the tar will force some up into the dip-pipes connected with the open retorts, the height to which such tar is forced being equal to that pressure.

The diameter of the hydraulic main must be sufficient to form a reservoir capable of supplying the quantity of tar contained in the open dip-pipes without suffering it to fall below their immersed ends, and thus open a communication between the open and working retorts. There are other methods of connecting the retorts with the hydraulic main, as shown in Figs. 12 and 13.

In Fig. 12, A is the main, cast square at the bottom, to allow of more tar being contained therein, and a greater facility in making the bottom joint of the stand-pipe.

B is the stand-pipe from the retort, and C the sealing-pipe covering the stand-pipe and dipping into the tar contained in the main : the annular space between the two pipes must be more than equal to the area of the stand-pipe. D is a bonnet, to be removed when the pipes require clearing. This arrangement has a neat appearance, and is œconomical ; but its great disadvantage is the difficulty of cleaning the hydraulic main between the stand-pipes.

Fig. 13. is a contrivance for placing the hydraulic main under the firing floor. This can only be used in a few instances where the retorts are set singly or in couples, and where a coke-cellar is built. It is very simple, however, and in the cases just quoted may be adopted with advantage. A is the main ; B is the dip-pipe, connected to the retort by an elbow-piece jointed on to the mouth by a flanch or a socket, as usual ; C is the bonnet, by removing which both dip and elbow may be cleared.

Fig. 12.

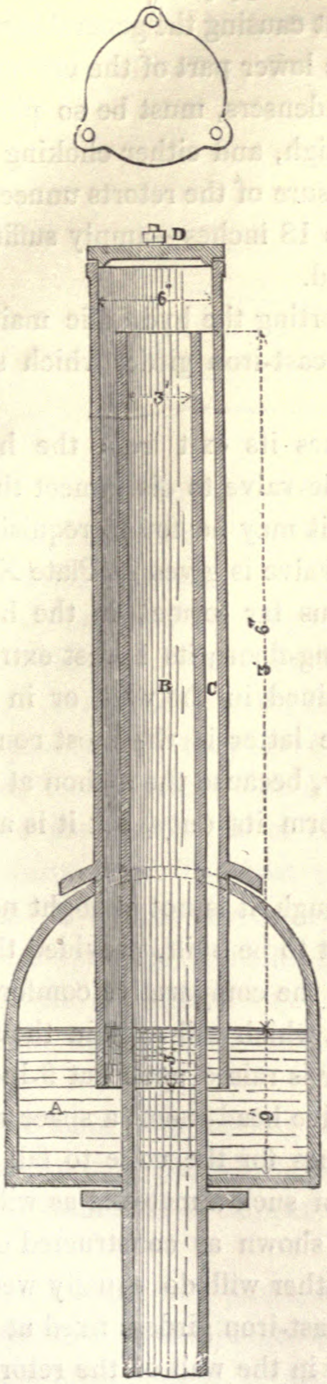
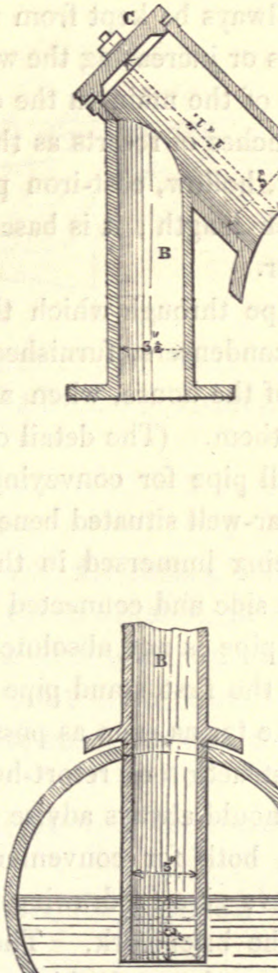


Fig. 13.



In the general arrangement of the hydraulic main two things must be observed. First, the diameter must be sufficient to supply at least 20 inches perpendicular head of tar to each dip-pipe, without causing the general level to fall below their immersed ends; and secondly, the lower part of the circumference of the pipe, which conveys the gas to the condensers, must be so placed that the tar may always be kept from rising too high, and either choking the free exit of the gas or increasing the working pressure of the retorts unnecessarily. The diameter of the main in the engraving is 18 inches—amply sufficient for the fifteen benches of retorts as there arranged.

F is a light, hollow, cast-iron pillar, supporting the hydraulic main in the centre of each length; it is based upon the cast-iron girder which supports the firing floor.

G is the pipe through which the gas makes its exit from the hydraulic main to the condensers, furnished with a slide-valve to disconnect the mains at each side of the house, when at any time it may be found requisite to repair or clear them. (The detail of the slide-valve is given in Plate XIX.)

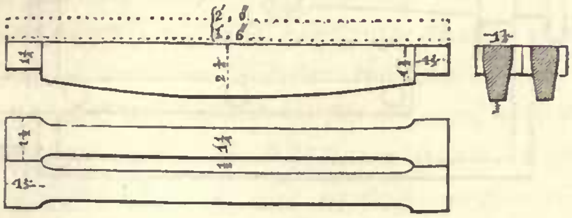
H is a small pipe for conveying the surplus tar formed in the hydraulic main to the tar-well situated beneath the firing-floor; its lowest extremity is sealed, by being immersed in the tar contained in the well, or in a small vessel by the side and connected with it; the latter is the most convenient. This surplus pipe is not absolutely necessary, because the siphon at the bottom bend of the first stand-pipe would perform its duty, but it is advisable to draw off the tar as soon as possible.

In the construction of retort-houses (although it is not thought necessary by many) I should always advise a coke vault to be built, provided the funds are sufficient, both for convenience and for the comparative comfort of the stokers; I have given a drawing in Plate IX. which will explain the arrangement of all the brickwork. The firing-floor is raised upon flat 9-inch brick arches over the coke vault, high enough to give head-room, a space about 24 inches wide being left in front of the benches for the coke to fall through when drawn from the retorts: it should be of such a material as will not be injured by frequent blows. In Plate I. it is shown as constructed of Yorkshire landings; some prefer cast-iron, but either will do equally well. The flat arches supporting the floor spring from cast-iron girders fixed at one end in the brickwork of the benches, at the other in the wall of the retort-house.

The distance between the centre and centre of these girders is six feet nine inches.

L is the furnace for heating the retorts: its breadth is 14 inches, the length of the fire-bars 24 inches: they are represented in Fig. 14.

Fig. 14.



The bars are placed loosely upon the bearers, and must occasionally be "clinkered," or lifted from their seat in the front and cleared from the slag which adheres to them.

M M . . . are side openings, three inches square, left in the brickwork, through which the heat of the furnace passes.

N N . . . are 4½-inch walls, built of Newcastle fire-bricks, one between each of the openings M; they serve to support the fire-tiles T, on which the outside lower retorts rest. The direction of the flues is shown by arrows.

P P are fire-bricks, placed on end, and a fire-lump, upon which the two upper retorts rest. The heat acting on these being somewhat moderated, no guards of fire-tiles are necessary.

O O are openings, 3 inches by 4½, in the crown of the main arch communicating with the branch flue.

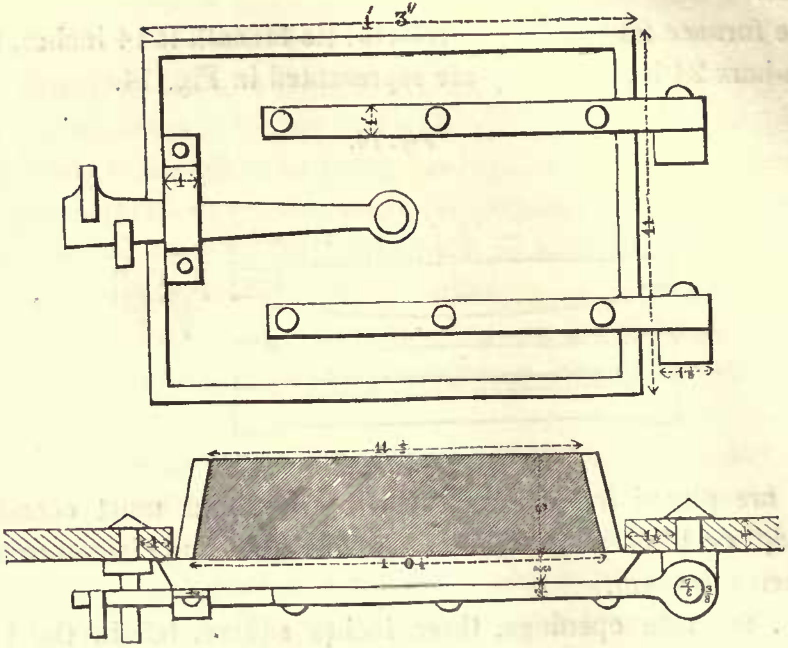
Q is the branch flue, one being built over the centre of each bench of retorts.

R is the main flue, running the entire length of the benches, and connected with the chimney into which all the branches lead. Between this main flue and each branch is a damper, Z, to regulate the draught through the furnaces.

S′S′. . . are cast-iron plugs, covering sight-holes, through which the heat of the retorts is seen and judged of.

V is the furnace-door, protected by a fire-lump inside, as shown in Fig. 15.

Fig. 15,



W is a cast-iron plate, 1½ inch thick, on which the fire-door is hinged, serving also to protect the face of the brickwork which it covers. In the centre, and about six inches above the fire-door, a square opening is cast for the admission of an iron spout, when it is required to burn tar.

X is a pan at the bottom of the ash-pit, for evaporating ammoniacal liquor, and the offensive unsaleable liquid products which cannot be disposed of otherwise.

Y Y are openings left in the walls N, by which the carbon deposited from the furnace is cleared away.

I have stated that everything depends upon the heat at which the retorts are worked. It must be obvious that the durability of the distillatory apparatus greatly depends on the manner in which the heat is applied to effect the decomposition of the coal contained within the retort. If the heat be very intense, the whole vessels are rapidly destroyed; if it be too languid, the distillation is protracted, the gas is of inferior quality, much fuel, time and labour are wasted to no purpose, and the retorts are speedily deteriorated, as the heat acts upon one part more than upon another. The experiments by which the present plan of heating retorts was arrived at, were many and expensive. Originally they were built in brickwork singly, and heated by flues passing beneath and over them, without any guard, except in some instances that of an iron saddle. They were afterwards placed in pairs, then in a greater number; but nevertheless, until the guard of fire-tile was used, the wear and tear was enormous.

The great obstacle to working more than two retorts to one furnace evidently arose from the difficulty of conducting the heat by means of flues around the series of retorts in such a manner that it should act with equal force on all. Different workmen constructed these flues in different ways: in short, the forms varied in every possible manner, and still with the same result. Mr. Rackhouse, in the year 1815, constructed a set of retorts on the oven-plan now generally adopted, and to that gentleman solely are we indebted for the contrivance. The fuel required for heating the retorts, when set without guards on the previous plan, was less by nearly ten per cent. than that required for the same purpose on the oven-plan; but the greater duration of the retorts much more than compensated for the additional fuel. I do not mean to assert that the first construction by Mr. Rackhouse was so perfect as the arrangements adopted in later years; every invention is gradually improved upon, but his *principle* has not been altered; the later improvements are only modifications, pointed out by experience, and rendered necessary by circumstances which the greatest foresight could not anticipate.

The oven represented in Plate I. is one of the latest arrangements. The heat from the furnace passes through the square openings M at each side, and is thus equally divided along the whole length of the retorts; from between the walls N it rises between the fire-tiles at the outer sides of the lower retorts. The flame is not suffered to impinge upon any part, but is equally distributed throughout the oven, and consequently the retorts work and " burn out " evenly. The lower retorts, which would otherwise be exposed to a more direct heat, are carefully guarded by fire-tiles, which at the same time prevent the bottoms from bulging. The openings O at the top of the main arch act more in the manner of safety-valves than flues, serving to regulate the final exit of the heated air, and, being distributed along the outer length, they do not draw the flame to one part.

The whole interior of the oven, as well as those parts in contact with the flame, must be constructed of Newcastle fire-bricks set in Newcastle clay. The main arch, six feet in span and half a brick in thickness, is formed of bricks moulded on purpose to suit the curve, the joint being kept as close as possible. As this arch is permanent, much care should be taken in its formation.

A bench of retorts on this plan, if well and regularly used, ought to last from 12 to 14 or even 15 months, and ought never to be suffered to become cold. The first portion of oxide which forms upon the surface, when allowed to cool, cracks and falls off, leaving a new surface to be acted upon the next time it is heated.

When it becomes necessary to reduce the number of working retorts on the approach of summer, those that are nearly burned out should be selected; or, if there are none in this condition, "let them down" very gradually, by keeping the damper closed after the fire is raked out: it will be a week before they become quite cold. The same precaution should be taken in "getting up" the heat—opening the damper gradually.

When a bench of retorts is newly set, the green work must be suffered to get quite dry before any fire is lighted.

The following is a detailed estimate for taking down and resetting a bench of five D retorts, including the main arch.

	£	*s.*	*d.*
5 D retorts, each weighing 13 cwt. at £7 10*s.* per ton	24	7	6
1 Man, jointing mouth-pieces and pipes, 3½ days at 5*s.*	0	17	6
300 Square Newcastle fire-bricks at 10*s.*	1	10	0
150 Arch ditto.	0	15	0
25 Split ditto.	0	2	6
12 Fire-tiles, at 4*s.* 6*d.*	2	14	0
20 Fire-tiles, at 1*s.* 6*d.*	1	10	0
100 Pavior bricks for front, at 6*s.*	0	6	0
500 Stocks for filling bed, at 5*s.*	1	5	0
8 Bushels of lime and sand, at 7½*d.*	0	5	0
½ Ton of Newcastle clay, at 30*s.*	0	15	0
1 Labourer, taking down old retorts, clearing away, and cleaning bricks, six days, at 3*s.*	0	18	0
1 Bricklayer and 1 labourer, resetting and finishing, six days, at 9*s.*	2	14	0
½ Cwt. of cement for joints, at 7*s.*	0	3	6
	£38	3	0

The results of a chaldron, or 36 bushels of Newcastle coal, weighing 27 cwt.,* distilled in retorts set in the manner just described, and the quantity of fuel used for the distillation, will be as follows.

Dean's Primrose.

Gas of specific gravity ·390	11,700	cubic feet.
Coke of good quality	1¼	chaldron.
Ammoniacal liquor	18	gallons.
Thick tar	16½	ditto.
Fine oil, 19½ oz. or	1½	pint.
Fuel of Wall's-end coal	6	cwt. 1 qr. 15 lbs.

Liddle's Main.

Gas of specific gravity ·400	11,420	cubic feet.
Coke of good quality	43	bushels.
Breeze	3½	ditto.
Ammoniacal liquor	17	gallons.
Thick tar	16	ditto.
Coke used as fuel	18	bushels.
Lime for purifying	2¼	ditto.

Wall's-end.

Gas of specific gravity ·387	12,000	cubic feet.
Coke of good quality	43	bushels.
Breeze	3	ditto.
Ammoniacal liquor	17½	gallons.
Tar	17	ditto.
Fine oil, 16 oz.	1	pint.
Fuel, Wall's-end coal	8	bushels.
Lime for purifying	2¼	ditto.

The following are the products from a ton of coal distilled under the same circumstances as the above examples.

Berwick's Wall's-end.

Gas of specific gravity ·400	8,650	cubic feet.
Coke of good quality	14	cwt.
Ammoniacal liquor	12½	gallons.
Thick tar	12	ditto.
Tar used as fuel	19	ditto.
Lime for purifying	86	lbs.

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* Where I have taken chaldrons as a standard quantity, I wish it to be understood that it is neither the Newcastle nor London chaldron, but a quantity weighing 3024 lbs., consisting of 36 bushels of 84 lbs. each; therefore, if required, the results can be reduced to tons by a rule-of-three statement.

Heaton's Main.

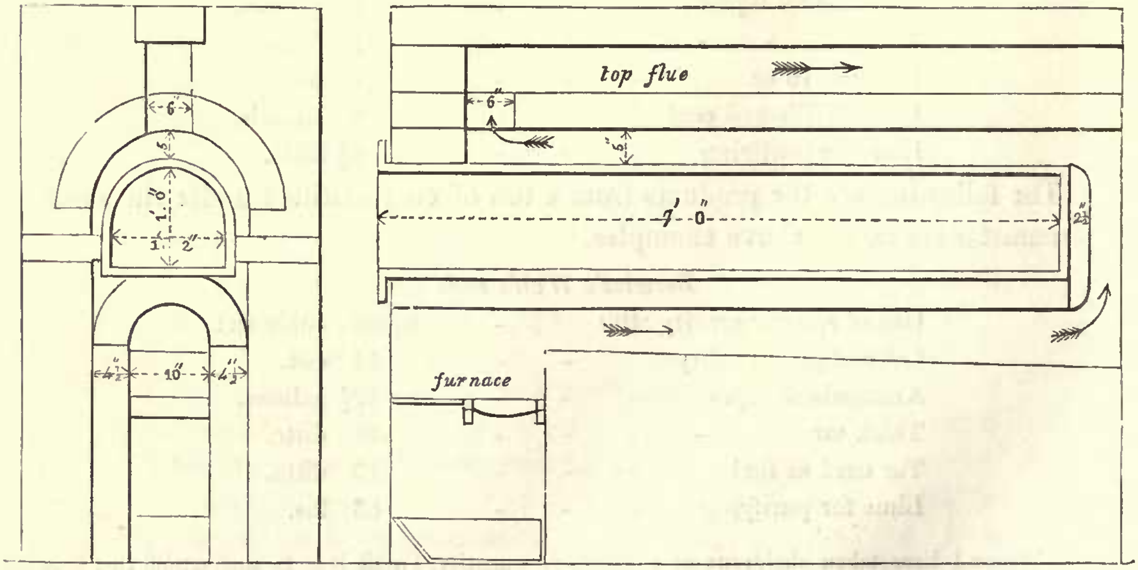
Gas of specific gravity ·390	8,690 cubic feet.
Coke of good quality	31 bushels.
Ammoniacal liquor	12¼ gallons.
Thick tar	12½ ditto.
Coal used as fuel	4 cwt. 18 lbs.
Lime for purifying	1⅓ bushel.

Russell's Wall's-end.

Gas of specific gravity ·400	8,600 cubic feet.
Coke	13 cwt. 3 qrs. 14 lbs.
Ammoniacal liquor	12½ gallons.
Thick tar	11¾ ditto.
Coke used as fuel	6 cwt.
Lime for purifying	84 lbs.

In country towns, where the quantity of gas made during the winter seasons does not exceed 10,000 cubic feet in twenty-four hours, the retorts must be set singly, as represented in Fig. 16., the flue passing beneath and over the retort, which rests upon a half-brick arch, cut flat at the top to receive it; the end is guarded by a thick fire-tile.

Fig. 16.



When the quantity of gas made in twenty four hours does not exceed 30,000 cubic feet, or when the quantity made is decreased 1200 cubic feet at a time, on the approach of summer, the ovens may contain two retorts, as shown in the annexed wood-cut. The flues are arranged in a similar manner to those in a large oven.

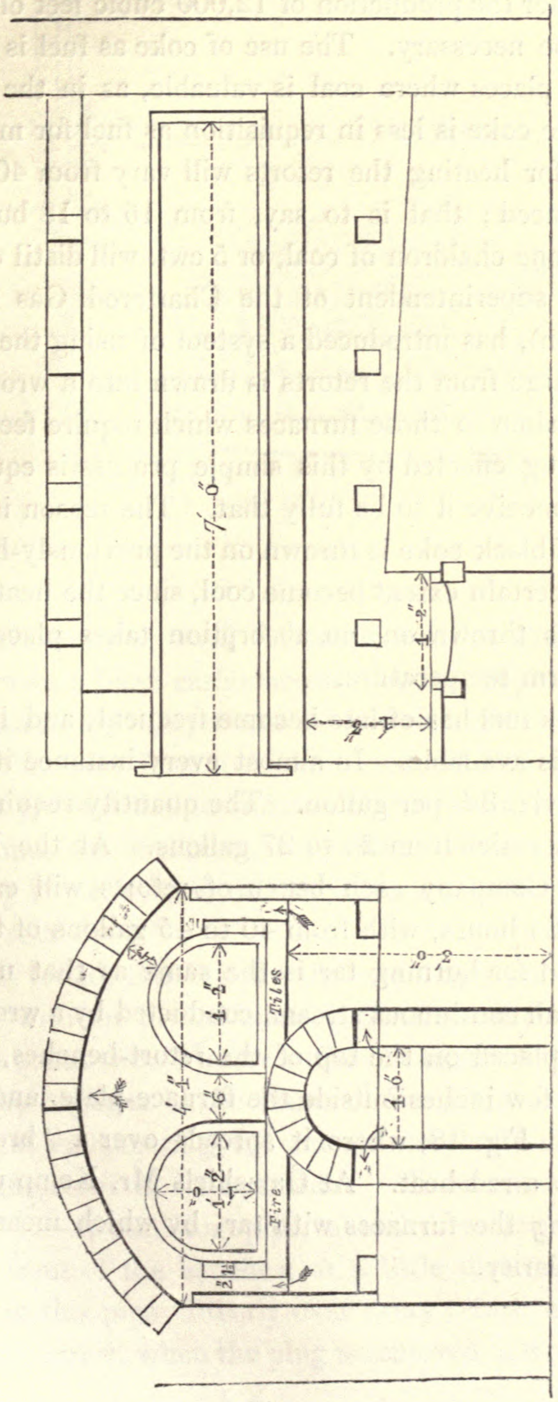


Fig. 17.

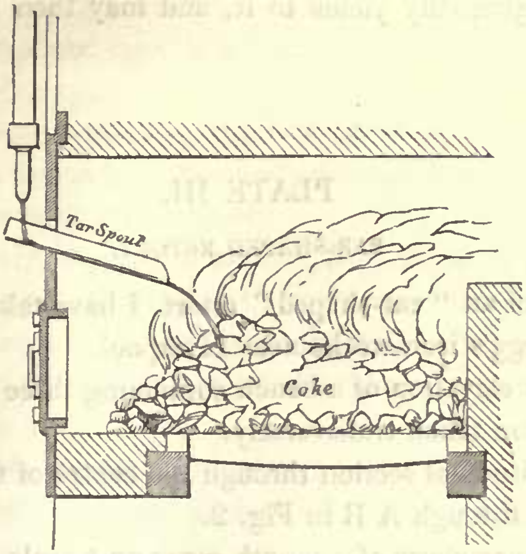
The Fuel used for heating the retorts may be either coal or coke, according to the relative value of each in the district. If coal is used, a well-regulated bench will require about 18 to 20 per cent. of the coal distilled; that is to say, to heat the retorts for the production of 12,000 cubic feet of gas, from 5 to 5½ cwt. of coal will be necessary. The use of coke as fuel is more general, particularly in those places where coal is valuable, as in the neighbourhood of London, and where coke is less in requisition as fuel for manufacturers. The quantity of coke for heating the retorts will vary from 40 to 45 per cent. of the quantity produced; that is to say, from 16 to 18 bushels of coke are requisite to distil one chaldron of coal, or 5 cwt. will distil one ton.

Mr. Croll, the superintendent of the Chartered Gas Company's works (Brick Lane station), has introduced a system of using the coke as fuel while red-hot. The charge from the retorts is drawn into a wrought-iron carriage, and immediately taken to those furnaces which require feeding. He informs me, that the saving effected by this simple process is equal to 10 or 12 per cent.: I should conceive it to be fully that. The reason is evident; because when a quantity of black coke is thrown on the previously-heated mass of fuel, the flues will to a certain extent become cool, since the heated air is absorbed. When hot coke is thrown on, no absorption takes place, and the flues are kept up at a uniform temperature.

The use of tar as fuel has of late become frequent, and is the most œconomical, as far as it is available. In almost every instance it is worth more to burn than to sell, viz. 3*d*. per gallon. The quantity required for carbonizing a chaldron of coal varies from 24 to 27 gallons. At the Pancras station of the Imperial Gas Company each bench of retorts will carbonize about 60 bushels of coal in 24 hours, with from 40 to 45 gallons of tar as fuel.

The furnace used for burning tar is the same as that used for other fuel, and is fed by a small continuous stream, conducted by a wrought-iron service-pipe, from a tank placed on the top of the retort-benches, on to a sheet-iron spout projecting a few inches outside the furnace-plate, and into the furnace itself, as shown in Fig. 18, where it spreads over a "breeze-bottom," previously brought to a red heat. At Galashiels Mr. Kemp uses a small force-pump for supplying the furnaces with tar, by which means the heat is kept up with great regularity.

Fig. 18.



When retorts have been at work for some months, their interior surfaces become incrusted with a hard carbonaceous deposit, approaching, in some of its properties, to plumbago; in process of time carburet of iron and the more infusible parts of the coke form a thicker crust, which it becomes necessary to remove, both to prevent the destruction of the retort, and to allow the fuel to have full effect upon the coal contained within. This was formerly effected with great difficulty by crow-bars, the force required often increasing the evil it was intended to remedy.

It was afterwards found, that leaving the retort open, and allowing cold air to come in contact with the heated interior, the deposit contracted, and could be broken away in about twelve hours without danger to the retort.

Mr. Kirkham, the engineer to the Imperial Gas Company, in order to take off this crust without endangering the retorts, employs an air-blast, which is both speedy and efficacious in its operation. His method of conducting the process is as follows:—A cast-iron pipe, about three inches in diameter, is carried along the front of the benches, at a little distance above the upper retorts; at points in this pipe, directly over every retort, a screw and plug is attached, into which screw, when the plug is removed, a wrought-iron service, about an inch in diameter, can be fixed, and led into any open retort. The main pipe is connected with a blowing cylinder, worked by the steam-engine, so that a strong blast can be made to impinge upon any part of the hard incrustation, which gradually yields to it, and may then be removed without difficulty.

PLATE III.

EAR-SHAPED RETORT.

As an example of an "ear-shaped" retort, I have taken those which were at work at Mr. Clegg's iron-works near Liverpool.

Fig. 1. is a front elevation of a bench containing three retorts.

Fig. 2. is a section taken transversely.

Fig. 3. is a longitudinal section through the centre of the arch.

Fig. 4. is a plan through A B in Fig. 2.

Figs. 5, 6 and 7 are views of a mouth-piece on a scale of an inch to a foot, which will show the method usually adopted for securing the lid in all ordinary retorts; this plan I do not think has been at all improved since Mr. Murdoch first used it in 1805; and as it is simple and effective, I see no reason why it should be altered. There may have been a solitary instance of alteration for the sake of having something new, such as the bar through which the screw passes being made to turn on a hinge at one end, and secured by a latch at the other, or the screw made to act on one side of the retort mouth, etc.—but none of these plans are so cheap or durable as the old one.

The great objection to the ear-shaped retort is, that the bottom bends are liable to become filled up with hard carbon, and when that is the case they are sure to crack. The principle on which they are constructed is good; and if they could be charged properly, viz. with a stratum of coal from 3 to $3\frac{1}{2}$ inches thick, evenly spread over the bottom, they would be found to make more and better gas than York Ds and circular retorts (where the stratum of coal is thicker), simply because it would be more evenly acted upon. In all cases, with the same degree of heat, the thinner the stratum of coal the better the gas.

The mode of setting these retorts may be precisely similar to that explained in Plates I. and II.

PLATE IV.

BRUNTON'S PATENT.

Fig. 1. represents a front view of a bench of four retorts, upon Mr. Brunton's principle.

A A . . are the retort-mouths, the lids of which are fitted with stuffing-boxes, for the reason to be presently described, and permanently jointed in their places with iron cement.

B B . . are hoppers, capable of holding from 20 to 28 lbs. of coal, which, when an air-tight slide-valve C is drawn back, falls into the retort through the neck D: the valve is closed immediately.

E is the furnace, projecting beyond the face of the brickwork in which the retorts are set.

F F . . are handles for working a piston contained in the mouth-piece A.

Fig. 2. is a transverse section of one half of a bench. The retorts G, shown as circular, may be varied in form if thought necessary. I believe the patentee gives the preference to those of a D shape.

E is the furnace; the direction of the flues are shown by arrows.

Fig. 3. is a longitudinal section through the centre of the furnace.

H is a short pipe, open to the interior of the retort, sealed at the lower end by dipping into water, through which, after a charge is thrown into the retort from the hopper B, a portion of coke is expelled, by advancing the piston contained in the mouth-piece.

I is the pipe by which the gas, as it is formed, passes to the hydraulic main.

K is a bonnet, to be taken off at any time when required to examine the interior of the retort.

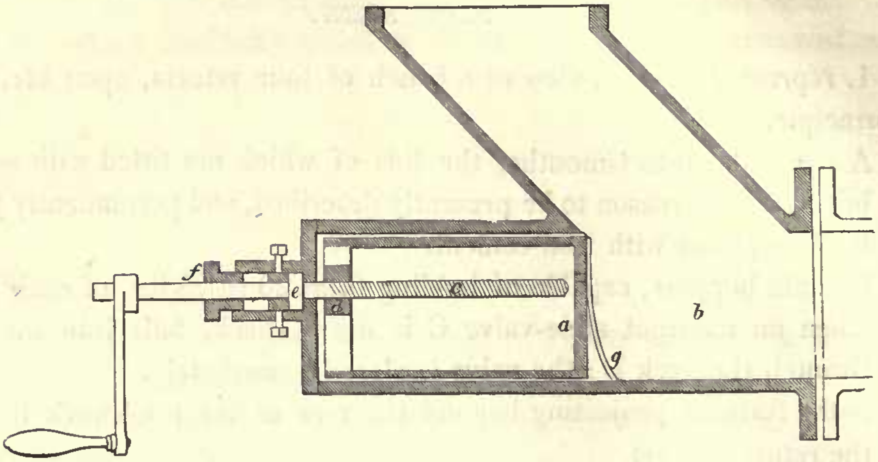
Fig. 4. is a back view of Fig. 1.

Fig. 5. is a plan below the retorts. (The same letters refer to corresponding parts in all the figures.)

The annexed diagram (Fig. 19.) will explain the construction of the piston before alluded to.

a is the piston, drawn back in the proper position to receive a charge, which, when the slide-valve is opened, will fall into the space *b*, and be propelled forwards into the heated part of the retort by turning the screw *c*, which works in a nut *d* on the back of the piston.

Fig. 19.



e is a collar upon the shaft of the screw, working between the bottom of the stuffing-box and a washer held in its place by four pins. The stuffing-box is made tight in the usual way, by screwing the gland *f* against a gasket.

g is a shield loosely attached to the front of the piston, to prevent the accumulation of small coal-dust in the mouth of the retort. When the charge is thrust forward, the piston is turned back directly into the mouth, to preserve it from the action of the heat.

That part of the retort adjacent to the flues only is heated, consequently the only part liable to much wear and tear.

Estimate of a bench of three Retorts fitted complete.

	£	*s.*	*d.*
Three retorts fitted complete, with mouth-piece, feeder, discharging shoot, etc. - - - -	51	0	0
Brickwork and labour - - - -	35	0	0
Hydraulic main, stand-pipe, etc. - - -	5	5	0
Furnace-doors and grate-bars - - -	4	10	0
	£95	15	0

The only part requiring renewal is that of the retort situated between the outer walls of the bench, and weighing about 9 or 10 cwt. The fuel required to carbonize the coal is about 25 per cent. in coal on the quantity distilled.

I subjoin a letter which I have received from Mr. Brunton, fully explaining his views on the subject.

"West Bromwich Gas-Works, 5th Nov. 1840.

"DEAR SIR,—Agreeably to your request I herewith send you a statement of my reasons for adopting the form and principle of my patent retort; in the first place, the particular form and arrangement, and, secondly, wherein I am induced to expect a greater quantity of gas from the coals so introduced, carbonized and discharged.

"It will be seen by reference to the drawings that the arrangements are so widely different from the ordinary form of retort, that scarcely any comparison exists. The external appearance does not present so wide a contrast as in the mode of working them, which by considerable experience has proved satisfactory not to me alone, but to those who have watched and calculated their operation, and found the saving to be 30 per cent. of labour and tools, with 35 per cent. more gas from the same quantity of coals.

"In describing the apparatus and its working, it is necessary to state that to the mouth-piece of my retorts is fixed a slide-valve C, according to the drawing, through which the coal is introduced into the retort, over which, upon a frame, is placed a hopper B, capable of holding one charge of coal, say from 20 to 28 pounds, so that when the valve is withdrawn the charge drops into that part of the mouth-piece in front of the piston; the valve is again closed; this part of the operation never exceeds more than six seconds of time. The object of the piston is to push forward the coal which has fallen into the retort to make room for another charge. The piston is propelled forward by a double-threaded screw, which is worked through a stuffing-box at the end in the middle of the lid to prevent the escape of gas.

"The retort is charged once every hour, or oftener, according to the quality of the coals that are used and the heat of the retort. This is one feature in the improvement of these retorts, that by varying the times of charging, with the other necessary duties requisite, you may increase or decrease the quality of the gas produced to any density or illuminating power, with less labour and more practical correctness than by any other retort in use.

"It will be observed, that in the operation of forcing forward a charge of coal, a quantity of coke will be discharged into the water-cistern at the *wider* end of the retort, to which is attached a close shoot H, through which the coke drops into the cistern, and is taken out of the water by a rake or shovel, or endless chain, with a little contrivance.

"Being in the habit of using South's Staffordshire coals, which swell in a certain ratio during the process of carbonization, and agreeably to the proportion of their enlargement, I have increased the area of my retort, that no obstruction should take place in the passage of the coke.

"I would here observe, that it is necessary to the correct working of these retorts that the quality of coal with respect to its enlargement should be considered in making the retorts, to secure the easy discharge of the coke and prevent breakage, etc.

"Another advantage in this retort is, that its being open at each end and the charge having to pass directly through it, there is no deposit of carbonaceous matter, which is an evil in the ordinary retorts which is attended with much inconvenience and destruction, and which has yet in no case been remedied or rather prevented. The patent retorts, after working twelve months, have been taken down and found quite free from any incrustation.

"I have now gone through the form and arrangement of the patent retort; from its simplicity, and the saving of labour, time and tools—as no rakes or iron barrows are required, and the fuel must be reduced in proportion to the size of the ovens and the retorts, and the conducting principle of the material for heat—it must be obvious that very considerable saving must be realized.

"I shall now proceed to show what I consider to be the chemical advantages that my retort possesses over the ordinary retort; that 35 per cent. more gas can be made by it from the same coal and in the same time. In the first instance, it is well known to all who are acquainted with gas-making in the ordinary way, that when coal is introduced into a retort at a bright red heat (the best for the production of gas), the first products that pass up the exit-pipe are moisture, with a volume of small particles of coal; and the atmospheric air that had gathered in the retort from the interstices between the coal just put in composes the mere undecomposed vapour, which is inflammable for a very considerable time after the retort is closed; this vapour, when the coals begin to ignite, forms the constituent parts of the tar and ammonia, the atmospheric air passing into the gas during forty minutes in an ordinary-sized retort. The greatest part of the product is composed principally of tar, rich with naphtha and ammoniacal liquor, that distils over with the gas, and that of a poor quality, the gas being only produced from that part of the coal which touches the red-hot retort, the body of the coal not yet being sufficiently ignited to decompose the products issuing from their interior; and it is not until the pieces of coal become charred on the exterior surface that the matter which they are disengaging becomes a gas fit for illumination.

"Comparing the above process with that of the patent retort, the advantages cannot but be obvious; the coals being introduced at one end and the gas and carbonized coke discharged at the other, it is very palpable, that all the particles, of whatever kind, disengaged from the newly-introduced coal must pass over the red-hot coke and undergo a more perfect decomposition than it is possible on the ordinary plan, and thus the tar, naphtha and ammoniacal liquor are 50 per cent. less than from the common retort, which I have repeatedly proved by experiment, and am daily confirmed in the truth I have here advanced by the working of not less than fifty retorts in the West Bromwich gas establishment.

"The rationale on which I ground the above process is as follows; viz. the naphtha and tar (carbon and hydrogen), the water (oxygen and hydrogen), and the ammonia (hydrogen and nitrogen), are all evidently decomposed to a certain extent. The oxygen is taken up by the coke, forming carbonic acid, which is again taken up by the lime in the purifying process; the nitrogen, with the carbon of the tar, forming cyanogen, whilst the hydrogen unites with another portion of carbon and forms carburetted hydrogen.

"It will thus be seen that about 50 per cent. of the products of the distillation, which are condensed in the hydraulic main and carried off with the gas to the condenser in the ordinary retorts, are by my patent retorts productive of 35 per cent. more gas, and having it entirely in your power in the course of two hours to change the quantity and quality of the gas with the least possible trouble, which is an advantage that cannot be accomplished by the ordinary process in less than five times that period.

"This I believe to be quite correct, and without dissimulation, or advancing any opinions but what my experience leads me to think are true,

"I remain, &c.
"John Brunton."

"*To Samuel Clegg, Jun., Esq.,*
London."

PLATE V.

RECIPROCATING RETORT.

The arrangement represented in this Plate is the invention of Mr. George Lowe.

It has been stated by Mr. Brunton, that the first portion of vapour produced by coal when undergoing destructive distillation in ordinary retorts will, when converted into gas, form that of the most brilliant quality, and it is to effect this that the following arrangements have been patented. As the opinion of Mr. Lowe on such matters stands amongst the highest in the kingdom, it may be taken in this case without hesitation.

Fig. 1. is a front elevation of two pairs of retorts. A^1, A^2, A^3, A^4 are the retorts; B B . . the stand-pipes; C^1, C^2, C^3, C^4 slide-valves for opening and shutting off the communication between the retorts and hydraulic main; D is the hydraulic main.

Fig. 2. is a back elevation of the same bench of retorts; E E are pipes, by which the interiors of the retorts are connected; F^1 F^2 are slides for closing that connection when required.

Fig. 3. is a plan of the lower pair of retorts; the operation is as follows:—Supposing the entire bench to be at the requisite heat for decomposing the coal, and that they are working six-hours' charges, the lids of the retorts A^1 and A^3 are removed, and by means of scoops (each half the length of the retort) the coal is introduced at both ends, and the lids immediately secured

in their places: the slides F^1 and F^2 are opened, and C^1 and C^3 closed. The bituminous vapours that rise first will pass through the pipes E E, and thence through the entire length of the hot retorts A^2 and A^4, and be converted into gas, which will pass to the hydraulic main by the stand-pipes on which the slide-valves C^2 and C^4 are fixed, and which remain open. When the distillation has gone on for half the duration of the charge—viz. three hours—the valves C^1 and C^3 are opened, F^1 F^2 shut, and the gas evolved from the retorts A^1 and A^3 passes through the stand-pipes attached to them. The retorts A^2 and A^4 are now charged, the mouths closed, the valves F^1 and F^2 again opened, and C^2 and C^4 shut. The operation is now reversed, the first vapours passing through the two first-charged retorts until their charge is expended, when C^2 and C^4 are opened, F^1 and F^2 closed, and the charge drawn. They are then immediately recharged, and the operation of opening and closing the valves repeated.

The working doubtless appears complicated, and I must unquestionably acknowledge this method to be so. None of these valves, however, formed any part of Mr. Lowe's original patent; they are an addition, and certainly not an improvement. Retorts on this construction have been for some months at work at the Pancras station of the Imperial Gas Company, and I believe are found to act well, producing gas of average quality and in greater abundance than by the ordinary method. The reason of the gas being only of an average quality is, that the carburetted hydrogen made after the production of bituminous vapour has ceased, still passes over the red-hot surface of another retort and deposits some portion of its carbon, the rich gas formed by the conversion of the bituminous vapour only serving to make up the deficiency.

If, instead of having only two retorts in a set, the number could be increased to six, and after the first hour the gas be allowed to pass away on the ordinary plan, then, I think, both the quantity would be augmented and the quality improved.

By Mr. Lowe's own arrangement the complication of valves is done away with, and the chance of deposition of carbon from the after gas is decreased, owing to the reduced length of the retort, and consequently the diminished area of heated surface over which the gas has to pass. The annexed woodcut (Fig. 20.) exhibits the plan proposed by him in his specification, from which the following extract is taken.

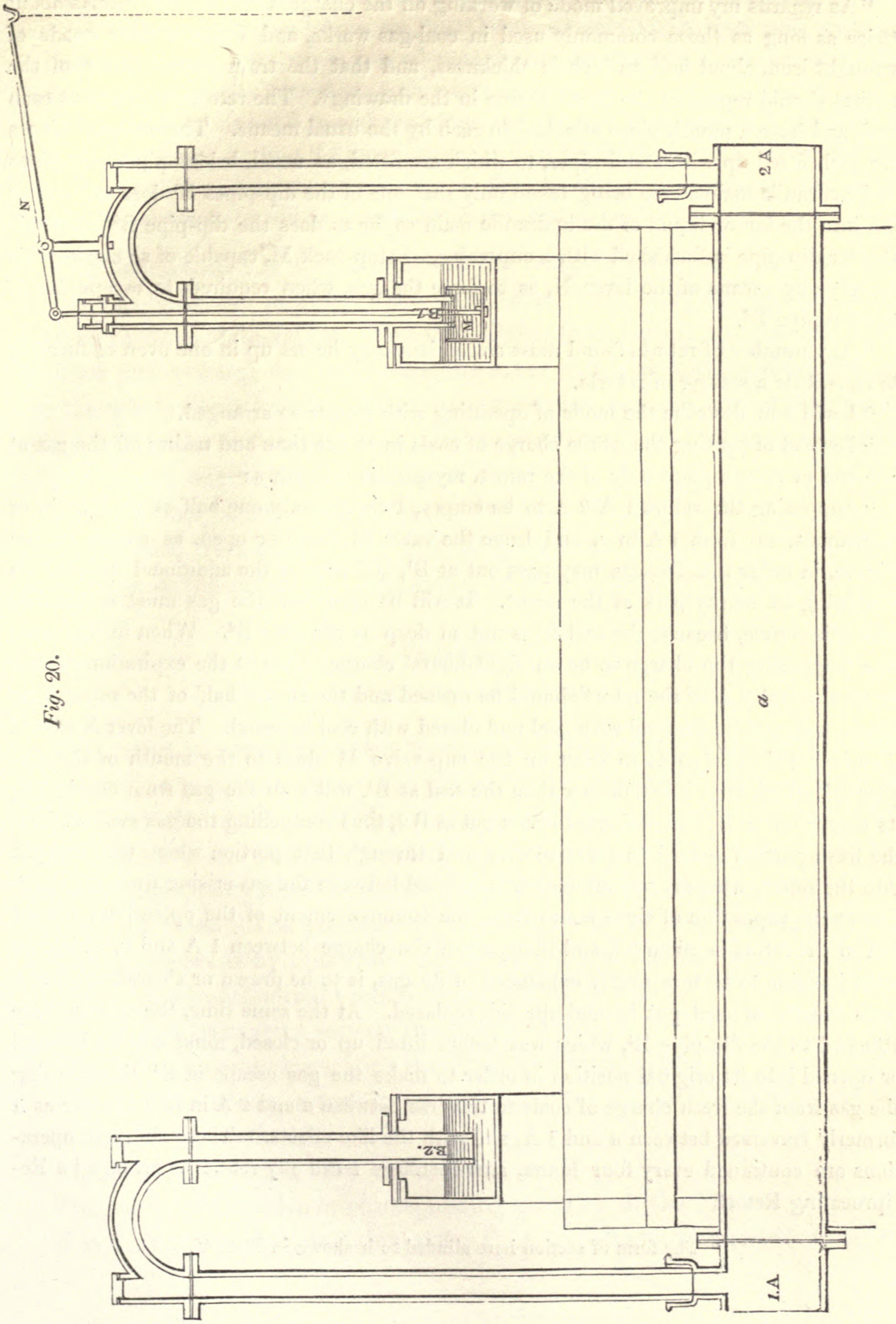


Fig. 20.

"As regards my improved mode of working off the charge, I make use of retorts about twice as long as those commonly used in coal-gas works, and I prefer them made of wrought iron, about half an inch in thickness, and that the transverse sections of the retorts should represent the forms shown in the drawing*. The retorts are open at each end, and have a mouth-piece attached to each by the usual means. These mouth-pieces are each fitted up with stand-pipes, to which are fitted, as usual, bridge-pipes, dip-pipes and hydraulic mains, care being taken only that one of the dip-pipes B^1 does not seal or dip into the tar or liquid of the hydraulic main so far as does the dip-pipe B^2; and this shorter dip-pipe is furnished with a cup-valve, or stop-cock M, capable of so closing this dip-pipe by means of the lever N, as to force the gas, when required, to escape out of the dip-pipe B^2.

"Any number of retorts found most convenient may be set up in one oven or furnace, to constitute a setting of retorts.

"I will now describe the mode of operating with retorts so arranged.

"Instead of putting the whole charge of coals in at one time and taking off the gas at one end or mouth-piece only of the retort, my plan is as follows:—

"Supposing the retort 1 A 2 A to be empty, I charge only one half of its length, or thereabout, say from 1 A to *a*, and leave the valve M down or open, as shown in the Figure, in order that the gas may pass out at B^1, and receive the additional heat of the remaining or empty part of the retort. It will be seen that the gas must necessarily take this course, because the seal B^1 is not so deep as the seal B^2. When in this position (supposing the charge to be an eight-hours' charge), then at the expiration of four hours the end 2 A of the retort should be opened and the empty half of the retort from 2 A to *a* should be charged with coal and closed with coal as usual. The lever N should then be acted upon so as to draw up the cup-valve M close to the mouth of the dip-pipe B^1, which cup, being deeper than the seal at B^2, will stop the gas from continuing its course out at B^1 and oblige it to pass out at B 2, thus compelling the gas evolved from the fresh portion of coal to traverse over and through that portion which was first put into the retort, whereby a combination is effected between the gas arising from each portion at the expiration of eight hours from the commencement of the operation; the lid 1 A of the retort is taken off, and that part of the charge between 1 A and *a*, which we must imagine to be now nearly exhausted of its gas, is to be drawn or cleared out and a fresh charge of coal put in and the lid replaced. At the same time, the cup or valve attached to the dip-pipe B^1, which was before lifted up or closed, must now be lowered or opened into its original position in order to make the gas escape at B^1, thus causing the gas from the fresh charge of coals to traverse between *a* and 2 A in like manner as it formerly traversed between *a* and 1 A, and with the like effects. These alternate operations are continued every four hours, and therefore I call my retort so arranged a Reciprocating Retort.

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* The form of section here alluded to is shown in Plate V.

"By this routine the gas and vapours of the earlier hours of the charge will combine and mix with those produced from the later hours, whereby much more and better gas is produced than by any process now adopted, whilst the quantity of coal-tar and of ammoniacal liquor usually formed are both much reduced.

"If it should be desirable to make gas from coal-tar with these retorts, I introduce an iron pan containing tar into the mouth-piece of each retort at the time of its charging with coal; and it is only necessary further to observe, that if the charge be a six-hours' charge, the alternations will be every three hours, and so on."

This arrangement is unattended with the danger that might arise from neglected valves on the first-described plan, there being only one hydraulic seal instead of three slide-valves. The loss of gas, from having to open the retort to draw and recharge one half whilst the other half is at work, will be trifling; for the whole operation does not occupy a minute, and the coal at that period of its distillation and in that time will not produce more than four cubic feet of gas, which will be the full extent of loss.

The practical benefits that will arise from the adoption of this plan can only be ascertained from experience; but, judging from the talents and chemical knowledge of the inventor, I expect the results to be favourable.

PLATE VI.

REVOLVING WEB RETORT.

This retort is arranged so that the coal is acted upon in a thin stratum and converted into gas at once: the chemical advantages of this method are many;—all the elements of the coal are liberated at nearly the same time, and unite with one another in such proportions as to form gas of the best illuminating quality, and in greater abundance than when the coal is carbonized in mass. The condensed bituminous vapour which forms tar in the ordinary process is by this nearly all converted into olefiant gas.

Fig. 1. is a longitudinal section through A B in Fig. 3.

Fig. 2. is a transverse section through C D in Fig. 1.

Fig. 3. shows end views, with the drum and stand-pipes.

Fig. 4. plans of the retort in section, over the top of the retort, the web and furnace, respectively.

Fig. 5. is an enlarged view of the drum.

The same letters refer to corresponding parts in all the Figures.

E is a hopper containing the coal; F is the discharging-disc; G is the retort; H is a web on to which the coal is discharged by the disc F; I I are the revolving drums carrying the web H; K is the furnace; L L the flues passing under and over the retorts, and finally into the main flue; M the shoot into which the coke falls; the end of which may either dip into water or be furnished with a tight door.

The retort itself, and the chamber in which the drums work, are made of wrought-iron boiler-plates, riveted together so as to be quite gas-tight. The only parts subject to wear and tear are the retort adjoining the flues and the web, both of which are heated; the latter however never becomes so hot that the shape alters. The action of this arrangement is as follows:—

All the coal must be either ground, or beaten small and screened, so that no lumps remain larger than coffee-berries, and a twenty-four hours' charge must be thrown into the hopper, and secured by a luted cover. The discharging-disc, which is nine inches in diameter, with six arms, is made to revolve uniformly with the drum below it, at the rate of four revolutions an hour; for this purpose two shafts run the entire length of the retort-beds, on one of which the drums are fixed; on the other are the discharging-discs, connected at one end by a strap. The diameter of the hexagonal drums is so regulated, that the coal which falls on the web from the discharging-lip will at one revolution have passed the entire length of the retort. Fifteen minutes is quite time enough to convert the coal so distributed into gas. Each link of the web is 14 inches long and 24 inches broad, having a surface of 336 square inches, upon which the contents of one partition of the disc will be discharged, viz. a little more than 124 cubic inches of coal in a stratum less than three-eighths of an inch thick. Each successive link receives the same quantity, so that, in one entire revolution of the disc and drum, 745 cubic inches of coal (equal to 21 lbs.) are distributed over a heated surface of 2016 square inches, and converted into gas.

Eighty-four pounds of Wall's-end coal will by this process make 450 cubic feet of gas of the specific gravity ·490. It therefore follows, that in 24 hours 18 cwt. of coal will be discharged by each retort, making 10,800 cubic feet of gas, equal to 12,000 cubic feet per ton.

These retorts are considerably more expensive in the first instance than those in general use, but in the end they would be found cheaper. Indeed, the entire arrangement is one of great œconomy, and by far the most scientific process yet adopted for making coal-gas: it requires no attendance, except that of keeping up the furnace and charging the hopper once in twenty-four hours. No gas is lost, and no tar made. The coke produced is increased in quantity by about 75 per cent., but its quality is not so well fitted for general purposes (although superior for culinary uses) as that produced by the common process.

The power employed for turning the shafts may be a water-wheel, which would be preferable to a steam-engine, unless in large works, where the latter could be employed for other purposes. The tank from which the water would flow on to the wheel may, in cases where there is no natural fall, be filled by a hand-pump. An overshot wheel, six feet in diameter and nine inches in breadth of float, would drive twelve retorts at the speed required; the water for turning such a wheel for twelve hours may be pumped up by two men in about an hour and a half.

The following is an estimate of the cost of four retorts as shown in the engraving, exclusive of brickwork :—

	£	*s.*	*d.*
Four wrought-iron retorts, each weighing six cwt. at 25*s.* -	30	0	0
Four chambers of No. 9 plate, riveted and made tight - -	35	10	0
Hoppers, four in number, to contain 18 cwt. of coal each, fitted with a water-jointed lid at the top - - - - - -	25	0	0
Eight revolving drums, to drawing, with shafting, turned bearings and stuffing-boxes, complete - - - - - - -	27	15	0
Four webs of plate-iron connected by links of $\frac{5}{8}$ round iron, as shown in the drawing - - - - - - - -	5	5	0
One wrought-iron tank, running the entire length of the bed for receiving the coke - - - - - - - - - -	8	4	0
Eight large doors and fittings - - - - - - -	7	6	6
Fire-door, grate and bearing-bars - - - - - - -	2	5	0
	£141	5	6

This estimate will appear large when compared with the prices given for common retorts; but the debtor and creditor accounts of the two methods, compared together at the end of twelve months, will be found much in favour of the above.

The quantity of gas produced by five D retorts, such as are shown in Plate I., will be about 14,000 cubic feet in twenty-four hours, of specific gravity ·390 or ·400, and the quantity produced by four of the proposed retorts will be 43,200 cubic feet in twenty-four hours, of the specific gravity ·470 or ·490.

At the end of fifteen months, or when a bench of ordinary retorts is worked out, they may be replaced for £38 3*s.*, as stated at page 70. And supposing the wear and tear of the proposed retorts to be the same, at the end of fifteen months they would require to be replaced also, which would be done for about £43 18*s.* All the machinery, except the retorts and webs, will last for years without any repair, except what may arise from contingencies, to which all machinery is subject.

The minor advantages attendant upon this form are, that it occupies less space; the stokers (so called at present) might be spared that name; the heat would not be felt more than in a boiler-house, and the retort-house might be kept perfectly clean, wholesome, and free from suffocating vapour.

The web may be repaired at any time, or even made in the first instance by a labourer. After it has been at work some time, the plates of which it is formed, by their contact with carbon at a red heat, become converted into excellent steel, and might be sold for a sum at which a new web could be constructed.

If I were to become the lessee of any gas-works, I should undoubtedly use this plan, being quite confident that the extra expense of their first erection would be more than returned to me at the end of the first year.

It is well known to every one connected with the manufacture of coal-gas that a thin stratum is desirable. Chemistry will point out the various causes and effects, and I have already shown that the quantity of tar and ammoniacal liquor is much increased when the coal is acted upon slowly, as the centre portion *must* be when decomposed in mass. By the means just described, the conversion of the vapours and rich products of the coal is properly effected, and no deposition of carbon takes place, as the gas passes away immediately on its formation. These advantages, combined with the saving of tools and labour, will fully justify my statement of the advantages attendant upon this form.

EARTHEN RETORTS.

In speaking of clay or earthen retorts, it is necessary to limit my remarks upon them to the *results of practice*; for in many instances, owing to actions not entirely and clearly accounted for, the results given by these vessels differ from those which *theory* in its strict sense would admit as being correct.

What I shall state here I have from unquestionable authority; and although I give my opinions with diffidence, I must acknowledge the advantages of the large earthen retorts, as shown in Plate VII., to be considerable.

One practical point must be observed, that clay retorts of small dimensions are less œconomical than those of larger size, owing to the great per-centage of fuel required to keep them at a proper temperature for decomposing the coal. The advantage of using the latter description of distilling-vessel is simply a question of profit and loss, or whether it is cheaper to *burn iron or coal.* The material of which they are formed is a non-conductor of heat, consequently the absorption of caloric is less rapid; and although they retain their heat when a fresh charge is introduced better than iron retorts, yet not sufficiently to bring down the quantity of fuel as low as that required for metal. Notwithstanding this, even small clay retorts are preferred in many places, particularly in Scotland. Mr. James Reid of the Montrose Gas-works has favoured me with the following description of his earthen retorts:—

> "We have had clay retorts in operation for the last three years, and from the great difference in price, compared with that of iron retorts of the same size, and from the immense superiority over metal in working them, we have entirely given up the use of the latter. I tried the clay retorts in the shape of an ellipsis, in the D and circular form, and find the cylindrical to be the best adapted for carbonizing the coal effectually*. The size I find best adapted to all purposes is eight feet long, fourteen inches diameter, and four inches thick: such a retort costs at Inverkatling or Clakmannan £2 6*s.*; the pillars or columns for supporting them are 6*s.* each, and each retort finished costs £3 4*s.* The mouth-pieces are cast metal, and fastened to the end of the retorts by bolts and flanches, as in the ordinary description, and jointed with fire-clay and iron cement. The retorts are made in two lengths, and are jointed by a body of fire-clay well diluted with water. The most œconomical plan for erecting them is to set them three under one arch, heated by one fire. Their only drawback is, that when the heat is let down they contract unevenly on cooling, and are liable to leak when again required for distillation; they generally last two years."

Clay retorts have been used for some years by Mr. Eunson at Wolverhampton with success, the cost of material for setting an oven being under £2. The retorts are circular and made in joints of 32 inches long. In several places these retorts are made at the works.

Of clay retorts, or ovens on a large scale, I have given two examples.

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* Upon this point I should feel inclined to differ with Mr. Reid, for the reasons stated at p. 60.

The first is that of Mr. Grafton, the second that of Mr. Spinney, which is decidedly inferior in every respect to the former, both from its greater thickness and number of joints, and from its incomplete setting. The quantity of fuel required by each for decomposing the coal will be stated hereafter.

The first idea of adopting fire-clay as a substitute for metal in the construction of retorts occurred to Mr. Grafton in the year 1820, when he took out a patent for the invention; the first of them erected in this kingdom was at the manufactory of Messrs. Butcher, in Wolverhampton. This retort was of the square form, but it was soon afterwards altered to the oven, or D-shape, which form has been adopted ever since, as shown in the engraving; large numbers having been put up under his direction in different parts of this kingdom and in several towns on the Continent.

The reader will fully understand their plan of construction from the elevation and sections in Plate VII., which require no description, except that I may remark that the bottom is exposed directly to the heat of the fire, and is slightly "cambered," or curved upwards, to enable it with more certainty to retain its form. The cement with which the parts of the oven are jointed is a composition which Mr. Grafton has been at much pains to render perfect, but he has not favoured me with the materials of which it is formed. It seems to be an excellent substance, and when the interior is coated with it, becomes vitrified and quite gas-tight under considerable pressure.

During the first seven years after their introduction great prejudice and opposition from interested bodies existed against the plan; and to such an extent did this proceed, that in one of the principal gas-works of the metropolis, where six of the largest ovens of this description were set up at a great cost, a plot was almost simultaneously laid for their destruction, which soon produced the effect desired by the contrivers. The same fate attended two similar retorts erected at Montpelier, where they were wilfully destroyed. It is but justice to add, that the Directors of both Companies afforded Mr. Grafton every advantage and facility for a fair trial, and in the first instance offered a large reward for the discovery of the persons who had designed and occasioned the loss. I mention this as one example out of many, to show that new inventions, however valuable, which profess to make great changes, rarely meet with encouragement in the first instance. As a further proof of this remark, I may notice the long time lost before the immense advantages offered by the Meter to gas companies were acknowledged or appreciated. At

Manchester, one of the most enlightened towns in the kingdom for mechanical and chemical science, this valuable instrument was for a long time expressly forbidden to be used, although five years afterwards the Directors were compelled to acknowledge that the great success of the Manchester works was chiefly attributable to the Meter.

In England and Scotland the fire-clay retort has superseded the use of metal in no less than forty towns; in some instances it has lasted for the extraordinary period of twelve years; while, during this time, at all other works where the invention is not yet used, it may be asserted that iron retorts have been renewed as many times. The oven or D-shaped retorts are found to be the most advantageous, being made with a capacity to carbonize one cwt. of coal every hour. They can be constructed either to be heated by coke ovens, or coke furnaces, or by the burning of tar: with coke ovens they are more durable. It appears that clay retorts, when constructed upon such a scale as that given in the Plate, have great power to *retain* their heat when brought to the proper temperature for decomposing the coal, viz. 27° of Wedgewood, and the introduction of a fresh charge is not nearly so much felt by them as by metal; this is a *practical* point—one which I have been at much pains to ascertain, and which I would not state were I not convinced of its correctness by personal observation. Mr. Grafton afforded me every facility for experiments, and is willing to do so to all who have a desire to test his retorts. This power of retaining heat is proved by constant practice to produce 1000 cubic feet of gas per ton from the same coal more than the average of the London produce, and the consumption of fuel is not more than 22 or 23 lbs. of coke to carbonize 100 lbs. of Newcastle coal, taking the average of six months' working: it is even less with the Staffordshire or Lancashire coal.

When properly constructed, these retorts are not in any degree liable to fracture or to the escape of gas, but are of such strength as to resist the greatest pressure which is likely to be put upon them. The coke also made by them is invariably of better quality, and produces less breeze or waste.

The advantages of the fire-clay retorts, combined with their great durability, will ere long be generally acknowledged, and their use will consequently be more extensive. At the gas-works in Cambridge, where from the beginning this kind of retort has been adopted in every variety of form, no retort has been changed nor any new one erected for four years. The oldest in that establishment, which have been in operation upwards of seven years, remain perfectly sound, and continue as efficient for making gas as on the first day they were at work.

At my request Mr. Grafton has favoured me with the following account of the cause of carbonaceous deposit in retorts :—

"After a series of experiments established in 1839 at the Cambridge Gas-works, and after having in vain offered a large premium for the discovery, I was myself enabled to detect the origin of the great accumulation of the carbonaceous deposit in coal-gas retorts, as well as the means of obviating an evil which has been the source of so much loss to the manufacturers of gas. Previously to that period the most eminent scientific authorities consulted on the subject considered this accumulation as the result of high degrees of heat and too great an extent of heated surface.

"To ascertain how far this opinion was correct, I commenced my experiments with a number of retorts reduced to various lengths, by the ends being filled up with brick-work, the other dimensions remaining unaltered.

"By this difference of length, after repeated trials and at various temperatures, the deposit did not appear to be diminished, although it did not accumulate so rapidly; and finally it formed a coating of the same substance, not less in a short retort than in a long one.

"It was observed in all cases that the substance began to form itself first at the closed end of the retort, whence it gradually advanced and accumulated in bulk; at that end the coal (especially with cylindrical iron retorts) is carbonized first; hence the inference is, that the best constituents, viz. the hydro-carburets, being without the means of escaping, become decomposed, leaving as a result the carbonaceous deposit.

"I then had two retorts constructed with an ascending pipe to carry off the gas at each end, so that its stream might divide itself in equal portions each way, thus reducing its passage over the heated surface from seven feet (the length of the retorts) to three feet six inches, and affording equal means of escape to the gas from all parts of the coal. The deposit after three months of constant working was considerably less at the closed end of the retort; but it formed itself in the same quantities on the roof, and soon covered the whole of the inner surface, gradually, as heretofore, diminishing the capacity of the retorts and increasing the consumption of fuel.

"The resistance offered to the gas during these experiments by the purifiers and the weight of the gas-holders, was equal to a column of water of nine inches by the gauge on the mouth-piece; this pressure having varied by the alteration of the weight of the gas-holders between winter and summer. I remarked that the accumulation was not so rapid in the summer months, when the resistance was less and the gas less compressed. I immediately had the pressure increased to a column of fourteen on the gauge, keeping up the usual heat. The retort for this experiment, like all the rest, was constructed of fire-bricks of the oven form, seven feet nine inches long, five feet wide and sixteen feet deep, capable of holding and carbonizing 130 lbs. of coal every hour, or seven cwt. in six hours. At the end of the first week the deposit appeared about an inch in thickness, and when once formed it accumulated more rapidly till the whole inner surface within a foot of the mouth was covered with it: at the further end it rapidly filled up the retort, preserving an equal thickness, until, at the expiration of two months, it had reached 24 inches in thickness, stopping up the retort quite one-fourth of its length. Under the roof and upon the sides of the remaining portion of the retorts, it formed a coating of not more than two or three inches thick; in four months more it would have filled up the whole.

"We then had the substance cut through into two parts, and taken out; when, after allowing for some of the scattered fragments, it weighed full ten cwt. 24 lbs.

"The coal carbonized during the time of this experiment was 67 tons of Woodside Wall's-end, the same having been used in nearly all the former trials; the deposit, therefore, was in weight about 1$\frac{2}{10}$ths per cent. of the coal carbonized, *and undoubtedly occasioned by the compression of the gas in the retort* immediately after its formation.

"I have applied myself to the means of taking off the whole of the pressure, which I effected, excepting only the resistance offered by the half-inch dip in the fluid of the hydraulic pipe. Under this change of operations, after the same retort was again worked with the Wood-side coals without interruption for four months, I had the satisfaction of observing that scarcely any deposit appeared at the expiration of that time.

"If I mistake not, this will prove a welcome discovery to all Gas Companies, more especially to those where the Newcastle coal is used."

PLATE VIII.

SPINNEY'S BRICK RETORT.

Fig. 1. represents a front elevation of the brick retort and hydraulic valve of Mr. Thomas Spinney, of the Cheltenham Gas-works.

Fig. 2. is a transverse section through the furnace.

Fig. 3. is a longitudinal section through the centre of the oven and flue.

A is the retort or oven. The bottom and sides are formed of Newcastle fire-tiles; the crown of fire-bricks is composed of Stourbridge clay, mixed with about 10 per cent. of sharp river-sand and pipe-clay, which addition prevents the bricks from cracking and improves them in other respects. The interior dimensions of the oven are three feet two inches wide, eight inches to the springing-line of the arch, and from thence to the crown six inches.

The fire-bricks just spoken of, which compose the crown of the oven, and also the fire-tiles which form the bottom and sides, are made with a groove round the jointed edge, into which the fire-clay with which they are set is compressed, this serving effectually to keep the ovens gas-tight.

B is a cast-iron plate secured against the front of the oven by wrought-iron bolts, built into the general brickwork at *a a* . . and jointed with a channel running round the mouth of the retort, as shown at *b b*, Fig. 3. When heated, this joint is slightly compressed by the expansion of the oven against the plate; for the rods by which it is secured, being comparatively cold, will retain their original length, and consequently prevent the advance of the plate.

C is the mouth-piece, bolted on to the cast-iron plate B, and jointed with iron-cement in the usual manner. The lid, being considerably larger than those used on ordinary retorts, is secured by two screw-bars, S S, Figs. 4. and 5, and when removed is supported by a small crane T turning in a socket cast on to the side of the mouth-piece.

D is the furnace communicating with the flues F F through the openings E E . . The arrangement will be sufficiently explained by the engraving.

G is the stand-pipe, furnished at its upper end with an hydraulic valve. When the retort is in action, the lever H (Fig. 6.) is acted upon, and the cup I raised above the surface of the fluid contained in the larger cylinder, so that the gas passes away by the outlet-pipe K without being obstructed in the least degree. When the charge has to be drawn, the cup is let down into the position shown in the figure, sealing the stand-pipe by a head of ten inches.

The reason assigned by Mr. Spinney for the use of this kind of valve, instead of the ordinary hydraulic main, is that the retort may not be exposed to any pressure; and as the charge is only drawn once in twelve hours, the inconvenience of having to *attend* this valve is not felt as formerly when used with iron retorts.

L L . . are plugs covering sight-holes, through which the heat of the flues and oven is examined.

The first cost of the erection of one of these ovens, complete, is £90,—the annual wear and tear is about £5.

The usual charge for these retorts is five cwt. of Welsh coal, from which, Mr. Spinney informs me, he can produce 2400 cubic feet of good gas in twelve hours. The quantity of coke obtained from a ton of coal is from fourteen to fifteen cwt.

The fuel required for heating the retort is 50 per cent. of coal on the quantity distilled. If coke is used as fuel, three-fourths of the quantity made is necessary. This large quantity is owing to the incomplete setting and the unnecessary thickness of the retort itself; and if we allow that an increase of 1000 cubic feet of gas may be obtained from a ton of coal by distilling it in a brick oven instead of an iron retort, we shall arrive at the following costs by each process.

One bench of five large York Ds will carbonize two tons of coal in twenty-four hours; each ton will yield, say 8000 cubic feet of gas, with ten cwt. of coal as fuel—

	£	*s.*	*d.*
Two tons of coal, at 20*s.* per ton - - -	2	0	0
Fuel 25 per cent. - - - - - - -	0	10	0
Wear and tear of retorts for 24 hours - -	0	2	6
Cost for 16,000 cubic feet - -	£2	12	6

which is equal to nearly 3*s.* 3½*d.* per thousand.

Two brick ovens will carbonize the same quantity, viz. two tons in twenty-four hours, and produce, say 9000 cubic feet of gas from each ton, with one ton as fuel—

	£	*s.*	*d.*
Two tons of coal, at 20*s.* per ton - - -	2	0	0
Fuel 50 per cent. - - - - - - -	1	0	0
Wear and tear of ovens - - - - - -	0	0	6
Cost of 18,000 cubic feet - -	£3	0	6

which is equal to nearly 3*s.* 4¼*d.* per thousand; giving three farthings per meter in favour of iron retorts.

I have taken neither labour, purifying, leakage, nor interest on capital into consideration, supposing them to be the same in both cases.

BRICKWORK.

In Plate IX. are represented sections and a plan of a large retort-house, to a scale of a quarter of an inch to the foot, containing thirty benches of retorts, and capable of producing 300,000 cubic feet of gas in twenty-four hours.

The interior dimensions are—length, 116 feet seven inches—width, 44 feet eight inches—height from the ground-line to the firing-floor, eight feet $5\frac{1}{2}$ inches, and from thence to the wall-plate fourteen feet, making the total height 22 feet $5\frac{1}{2}$ inches. The thickness of the outer walls will vary according to the foundation; in the example before us the basement is eighteen inches, and from the firing-floor to the roof fourteen inches. If I were not confined to a certain expenditure, I think in another case I should be inclined to increase the thickness of the basement and upper portion, as high as the roof of the coal-stores, by half a brick. The outer walls are so well tied together and supported throughout, that a moderate thickness only is requisite; $4\frac{1}{2}$ inches added, however, would perhaps not be superfluous.

In the basement, semicircular arches of five feet three inches span run the entire length of the building, except the two at the ends, which are left blank, to give additional strength to the angles. By means of these arches a free current of air is allowed entirely through the coke cellar; and if the coke is well spread abroad immediately it is drawn from the retorts, no inconvenient heat is suffered.

The space occupied by the arches in which the retort-benches are built is 102 feet ten inches long by fifteen feet eleven inches* broad, with one arch of five feet three inches span at each end.

The piers are eighteen inches thick by fifteen feet eleven inches wide, built from nine-inch inverts, and carried up three feet $4\frac{1}{2}$ inches, at which height the

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* When worked out, these dimensions most probably will be exceeded; but I never lose an opportunity, in cases like the present, of giving the workmen odd inches in their dimensions: they may not always work to them, but it increases the probability of correctness.

semicircular arches spring. The spandrils of these are faced with nine-inch work, and the centre space filled in with concrete or brick rubbish.

Plumb with the centre of each pier, level with the crown of the arches, and having a bearing, at one end upon the face of the spandril, and at the other in the outer wall, are placed the cast-iron girders G G, from which the flat segments spring that support the flags of the firing-floor. The rise of these arches is about twelve inches, formed of well-burned cut stocks, and carried from the outer wall of the house to within two feet of the face of the retort-benches. These flat arches are likewise carried across the coal-stores and supported in a similar manner, as represented in the cross section. The backings are filled in with concrete.

The ovens for the reception of the retorts are separated by a 14-inch wall running the entire length of the beds. In the immediate vicinity of the furnace it must be constructed with fire-bricks laid Flemish bond.

The walls on each side of the furnaces must be of Stourbridge fire-bricks, and nine inches thick, as high as the springing of the arch, which is 4½ inches thick, turned with moulded bricks of the same description. The space between the furnace-walls is fourteen inches. All the solid parts may be filled in with brick rubbish.

In turning the arches of the ovens, great care must be taken that the joints are close, and for that purpose the clay used for setting the bricks must be rendered fine with continued working. The bricks must be the best Newcastle, moulded to fit the curve. The flues must be faced with nine-inch work, the intermediate spaces between the ovens filled in with concrete or brick rubbish.

H H is the hydraulic main.

P P is the position for the cast-iron columns which support the main.

Q is the pipe which conveys the gas to the separators or condensing pipes SS.

The roof is of wrought-iron, constructed in the form shown in the engraving: the principals are twenty-two in number, eleven on each side, supported in the centre of the house by a cast-iron pillar resting on the wall which separates the retort-ovens. The dimensions of the iron-work are,—the principal rafters three inches by five-eighths of an inch; tie and brace-rods 1¼ inch round iron. The ventilator on each division is also of wrought-iron, with the exception of the wind-boards, which are of three-quarter yellow deal. The covering of the roof is of Countess slate.

The cost of a retort-house, of the dimensions before given from the ground-line, will be as follows:

	£	s.	d.
Outside walls and centre portion as high as the firing-floor, including cast-iron girders, York landings for firing-floor, coal-stores, etc. - - - - - -	1975	0	0
Wrought-iron roof - - - - - -	320	0	0
Brickwork for ovens, including the setting of 150 retorts, etc.	600	0	0
Chimney, 120 feet high - - - - -	180	0	0
	£3075	0	0

In the design for a retort-house, many things must be taken into consideration. The principal circumstances that will guide the builder in the construction are, first, the nature of the soil, upon which will depend the depth of the foundations, the number of footings, etc.: in made earth and marshy ground it is necessary to build upon a bed of concrete, composed of five parts of river ballast, or gravel, free from argillaceous matter, and one part of ground lime mixed intimately together with water, and thrown into the trench from a height of some feet. Secondly, the builder must consider the extent of the funds upon which he has to draw. This, of course, is an important point, and it is a merit if he gives the "*most for the money*" without exceeding the estimate: upon this latter consideration will depend the arrangement of the ovens, coke-cellar, and coal-stores.

The capacity of a coal-store should be accurately ascertained, and made fully equal to hold eight weeks' consumption of coal in the winter season, especially in those situations where it is carried by water; because, during severe frosts, canals are often rendered impassable for that period. I do not refer to the neighbourhoods where coal abounds—where sometimes the pit-mouth is not a mile from the works; but to those districts where coal is valuable, and difficult to be obtained except through the regular channels.

A ton of coal will occupy a space of 42 cubic feet: therefore in an establishment, such as that at page 101, which produces 117,000 cubic feet of gas in twenty-four hours, the stores should be capable of holding 756 tons of coal, or have a cubical content of 31,752 feet between the entrances. This, however, is seldom if ever attended to; stores are generally made to contain about three weeks' consumption, the excess being stacked outside the house and covered with tarpaulins, which quantity should be used first. A space, twelve feet by ten feet, and three feet six inches deep, will hold ten tons of coal.

In the example just referred to, the spaces were divided into three, by passages five feet wide, the entire length of the store being seventy feet; the spaces for the coal were fifteen feet by twelve at each end, and one thirty feet by twelve in the centre: 200 tons could be stored with convenience. When full, the stacks must be retained by three-inch planks, placed vertically and strutted, spaces being left to work the coal.

As a check upon the delivery and use of the coal, the walls of the stores should be marked at certain heights corresponding to five or ten tons.

The adjoining cut (Fig. 21.) represents a retort-house built of brick, upon the most simple construction, and well adapted for a town requiring 70,000 cubic feet of gas for the supply of each night in the winter season. Being without coke-cellar, the charges must be drawn into wrought-iron barrows, the contents wheeled into the open air, and spread abroad to cool.

The outside walls are calculated to give the greatest security with the least possible material. The piers *a a*, are eighteen inches thick at the base, projecting 4½ inches (on the outside) from the brickwork filling the space between them. Half-way up the walls there is a 4½-inch offset, which leaves the thickness of the panels fourteen inches below, and nine inches above the offset.

The roof is of wrought-iron, covered with common pantiles. The ventilator is of wood.

The estimate for this house, including a chimney seventy feet high from the ground-line, was £550. The cost of the ovens for the reception of the retorts, eight in number, was £57, and the setting of the retorts cost £103.

The retorts were set five in one oven, making forty retorts; which will allow two extra benches for repairs.

In twenty-four hours, thirty working retorts will carbonize 240 bushels, or 180 cwt. of coal, and produce 78,000 cubic feet of gas. In some places where little gas is required in the summer season, one half or even the entire number of retorts may be set three to one oven with œconomy.

Fig. 21.

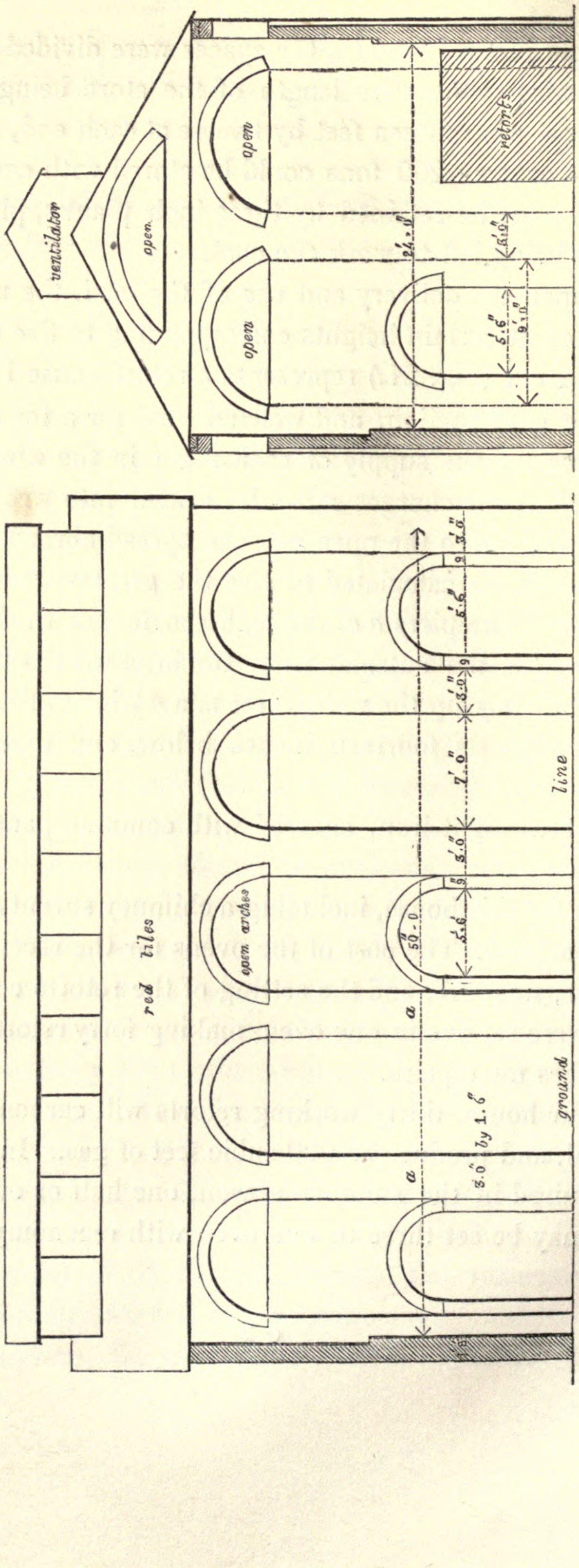
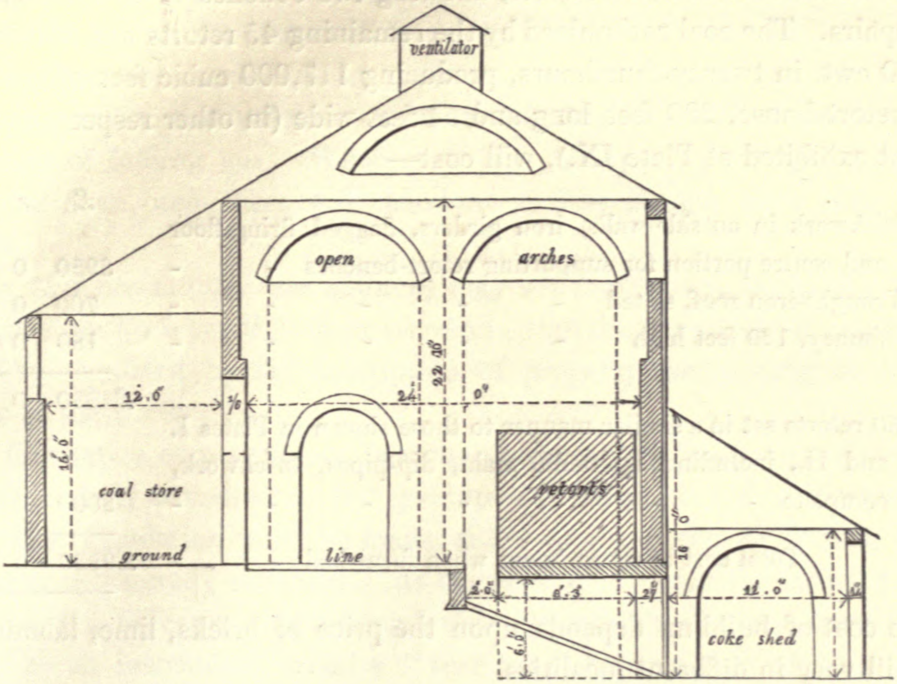

ventilator
open
open
open
retorts
24.0
6.0
5.6
9.0
red tiles
open arches
a
a
50.0
3.6
5.6
9
3.0
7.0
5.0
3.0 by 1.6
ground
line

Fig. 22.



In this example (Fig. 22.) advantage was taken of sloping ground to form a coke-shed, which saved a considerable quantity of brickwork. The charge, as it was drawn, fell through the space in front of the retorts, and was carried by an inclined plane into the shed behind.

This house is considerably larger than that described in the last example, and is furnished with a coal-store. It may, perhaps, be as well to state here, that coal from which gas has to be distilled should if possible be always kept under cover, because, when moisture is present, the hydrogen arising from the decomposition of water will deteriorate the quality of the gas. It is therefore a matter of œconomy to construct a sufficient shed to preserve the coal in a dry state.

	£	s.	d.
The contract for this building, which is 70 feet long, including a chimney 90 feet high, independent of the foundations, was	1200	0	0
A wrought-iron roof, slated - - - - - -	190	0	0
Ventilator, of wood, and slated - - - - -	43	0	0
	£1433	0	0

Eleven benches of retorts set complete = £220; cost of retorts = £268 2*s.* 6*d.*

The house contained 55 retorts, allowing two benches of five retorts each for repairs. The coal carbonized by the remaining 45 retorts was 360 bushels, or 270 cwt. in twenty-four hours, producing 117,000 cubic feet of gas.

A retort-house, 200 feet long and 54 feet wide (in other respects the same as that exhibited at Plate IX.), will cost—

	£	s.	d.
Brickwork in outside walls, iron girders, flagged firing-floor and centre portion for supporting retort-benches - -	3950	0	0
Wrought-iron roof, slated - - - - -	700	0	0
Chimney, 120 feet high - - - - -	180	0	0
	£4830	0	0
250 retorts set in a similar manner to those shown in Plates I. and II., including hydraulic main, dip-pipes, brickwork, complete - - - - - - -	5000	0	0
Total cost of retort-house when furnished - -	£9830	0	0

The cost of building depends upon the price of bricks, lime, labour, etc., and will vary in different localities.

CONSTRUCTION OF CHIMNEYS.

Previous to entering upon the particulars of the construction of chimneys, I would remark, that it may afterwards be found convenient, from an increase in the number of retorts, to have a chimney built considerably larger than is necessary for the actual number for which it is erected; while the expense bears a small ratio to the increase of size.

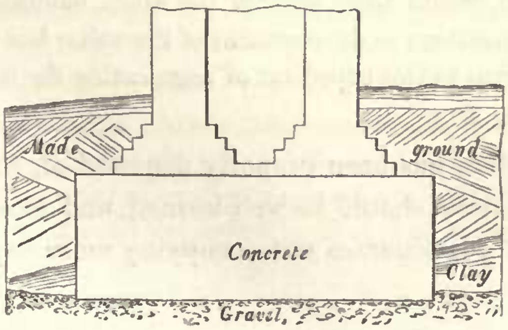
The draught absolutely required for the proper combustion of the fuel beneath the retorts is little; indeed, that usually given to a common coke-oven would be sufficient. It is necessary to build a high chimney, however, to carry off the smoke, which, if not allowed to spread, would become a nuisance to the neighbourhood. The height of a chimney does not decrease the *quantity* of smoke, but distributes it over a larger surface and causes less inconvenience.

To obviate the excess of draught, it is advisable to make an opening into the shaft communicating with the external air. The dampers of the retort-flues might be used to adjust the draught; but this would be relying too much upon the workmen. It often happens, if there is no check, that during the night the heat of the ovens will be neglected, and suffered to fall below the proper temperature; and then, to make up, the dampers are opened and the furnaces forced, to the deterioration of the retorts, the waste of fuel, and the production of inferior gas. When there is an air-opening into the shaft this cannot be done, and there will therefore be less danger from such carelessness.

With this precaution, the chimney may with advantage be built seventy feet high even for a small number of retorts; but the height of the shaft must always be regulated by the description of property surrounding or in the vicinity of the works.

The foundation of a structure bearing a great weight upon a small surface must be carefully attended to. If a good natural bottom is not to be obtained, an artificial foundation must be made, either by concreting or driving piles; the former is generally sufficient. At the spot upon which the structure is to be raised, the different strata immediately beneath the surface must be examined by an instrument called a "searcher," being a kind of auger, with which the earth may be bored, until some definite stratum is reached: by a reference to the depth of this bed, some idea of the extent of excavation is arrived at. In all cases the "made earth" must be removed. If the stratum immediately beneath is of clay, gravel, chalk, or other firm bed, and found to be sufficiently thick for a solid bearing, the excavation may be finished and the foundation laid in. In the neighbourhood of London the substratum is generally made earth, beneath which, at variable depths, not often exceeding twelve feet, a good bottom is usually met with; when, to save brickwork, concrete may be thrown in, until only enough depth is left from the surface to cover the footings of the chimney, as shown in Fig. 23.

Fig. 23.



I cannot give a better example of the value of concrete than by referring to a chimney that was built by Mr. Clegg at Fulham, in 1829. The foundation was a quicksand. After the excavation was got out to the depth of fifteen feet, an iron rod sunk, with little more than its own weight, fifteen feet more; it was, in fact, as bad a foundation as could possibly occur. In Plate X. I have given a representation of this chimney, which will explain the construction. In about twelve days after it was built, it had settled bodily down 16½ inches, without a crack, or deviating in the least from the plumb. It therefore follows, that the only disadvantage attending a bad natural foundation is the expense of making an artificial one. It perhaps will not be out of place to insert here the following extract from Mr. Farey's Treatise on the Steam-Engine, which relates to the erection of an extensive building upon bad ground.

> "The building for the Albion Mills was erected upon a very soft soil, consisting of the 'made ground,' at the abutment of Blackfriars Bridge: to avoid the danger of settlement in the walls, or the necessity of going to a very unusual depth with the foundations, Mr. Rennie adopted the plan of forming inverted arches upon the ground over the whole space upon which the building was to stand, and for the bottom of the dock. For this purpose the ground upon which all the several walls were to be erected was rendered as solid as is usual for building by driving piles where necessary, and then several courses of large flat stones were laid to form the foundations of the several walls; but to prevent any chance of these foundations being pressed down in case of the soft earth yielding to the incumbent weight, strong inverted arches were built upon the ground between the foundation courses of all the walls, so as to cover the whole surface included between the walls; and the abutments or springings of the inverted arches being built solid into the lower courses of the foundations, they could not sink unless all the ground beneath the arches had yielded to compression, as well as the ground immediately beneath the foundation of the walls. By this method the foundations of all the walls were joined together so as to form one immense base, which would have been very capable of bearing the required weight, even if the ground had been of the consistency of mud; for the whole building would have floated upon it as a ship floats in water; and whatever sinking might have taken place, would have affected the whole building equally, so as to have avoided any partial depressions or derangement of the walls; but the ground being made tolerably hard, in addition to this expedient of augmenting the bases by inverted arches, the building stood quite firm."

When the foundation has been properly disposed of, the brickwork may be commenced. The bricks should be well burned, and sound stocks or paviors, set with a thin joint, four courses not occupying more depth than 11¾ inches.

The mortar will be regulated in some degree by the quality of the lime, but as a general rule, one part of the best Dorking lime, used fresh from the kiln, to three parts of clean sharp river-sand are good proportions. At the distance of about every fifteen feet, a wrought-iron hoop, 2½ inches deep and half an inch thick, well pitched and sanded, must be built into the brickwork as the chimney rises; this is necessary to avoid cracks from settlement. At the top of the chimney, where the thickness of the work will only be 4½ inches, the hoop must be laid *flat.* The interior of the flue must be "parged" with fire-clay and chopped straw, laid on as plaster.

The cost of a chimney will depend upon the foundation and the extent of finish and ornament given to the shaft. In the neighbourhood of London, a plain shaft from the ground-line, independent of the foundation, will average £1 5*s.* for every foot in height. The cost of the foundation to the Fulham chimney was as follows:—

	£	*s.*	*d.*
287 cubic yards of excavation and retaining, at 1*s.* 6*d.*	21	10	6
143½ cubic yards of concrete, at 7*s.* 6*d.* - -	53	16	3
400 super feet of Yorkshire flagging, six inches thick, at 2*s.* 1*d.* - - - - - -	41	13	4
26½ cubic yards of brickwork in mortar, at 21*s.* -	27	16	6
287 cubic yards of filling-in, ramming and spreading, at 3*d.* - - - - - - -	3	11	9
	£148	8	4

The contract for the remaining part of the chimney above the ground-line was taken at £117. The situation for the chimney of a retort-house may be at the end, at the side, or removed to some distance from the building*; the first position is the most convenient. If the house is of considerable extent, it is usual to erect the chimney in the centre, dividing the retort-benches into four sections. Structures of this size being generally in large towns, the shaft of the chimney may be ornamented and made to produce a good effect.

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* At Dolphinholme in Lancashire, where a large worsted-mill was lighted with gas, it was requisite to remove the chimney to some distance, the dwelling-house of the owner being close by. For this purpose the flue was carried along a field rising about 1 in 20 for a quarter of a mile, and on the summit of this rise the chimney was erected in the form of an obelisk.

FIRE-BRICKS, ETC.

The parts of furnaces exposed to heat are built of bricks made of a description of clay which is to different extents infusible, the qualities chosen for use being regulated by the degree of heat to which they are to be exposed. They are known in commerce by the names of Bristol, Stourbridge, Newcastle, Welsh, and Windsor bricks. The first of these are composed almost entirely of silex, and are infusible at the greatest heat of the blast-furnace; but they are very costly, and seldom used. The second quality are made from clay found in the neighbourhood of Stourbridge, lying in a stratum of considerable thickness between the upper soil and the coal-formations; they are used in the construction of furnaces required to resist great heat, such as those for smelting iron-ores, glass-making, etc., and sometimes for the linings of retort-ovens: for this latter purpose I consider them too expensive, except for the arch immediately over the furnace, as the heat is not intense. The third variety are composed of the clay lying above the coal-measures in Northumberland, and for the construction of retort-furnaces and ovens are the most desirable. This will not be generally admitted, perhaps, but I am well convinced of the fact; it is useless to employ a brick which costs nearly double the price, when these will serve equally well; Stourbridge bricks are 150*s.* per thousand, and Newcastle bricks are 95*s.* per thousand. All parts of the ovens may be built of Newcastle brick except the arch above-mentioned. Welsh bricks were until lately used for the parts less exposed to heat, because they were the cheapest; now, however, Newcastle bricks are less by 10*s.* per thousand. Welsh bricks are liable to "honeycomb" when heated, owing to the admixture of inferior clay and extraneous matter. The Windsor bricks made at the village of Hedgesley are good, and bear the same price as Newcastle. Fire-lumps are made in various shapes and of different sizes, and may be obtained to suit any purpose of oven-work if ordered; those kept on stock vary from 4 to 6 inches thick, and from 12 to 36 inches long. Fire-tiles are made from 1½ to 3 inches thick, and from 9 to 24 inches long: their application has already been explained.

In setting these bricks, etc., care must be taken to use the same clay as that of which the brick is composed, and to have the joint close; for this purpose the clay must be well "tempered" with little water, and the brick or lump well bedded. If the lump is of large dimensions, a "maul" should be used. The work must be suffered to dry before heat is applied, and even then by slow degrees. The following are the London prices, furnished by Mr. Newton, of Bankside:—

	s.
Stourbridge bricks, per 1000	150
Newcastle „ „	93
Welsh „ „	110
Windsor P P „ „	95

Newcastle and Welsh Lumps and Tiles.

	s.	d.		s.	d.
12-inch lumps, each	0	8	24-inch lumps, each	2	11
14 ———	0	10	26 ———	3	3
16 ———	1	0	28 ———	3	6
18 ———	1	2	30 ———	4	3
20 ———	1	6	33 ———	4	9
22 ———	2	3	36 ———	5	3

	s.	d.		s.	d.
9-inch tiles, each	0	5	18-inch tiles, each	2	0
12 ———	0	9	20 ———	2	9
14 ———	1	3	22 ———	3	9
16 ———	1	6	24 ———	4	9

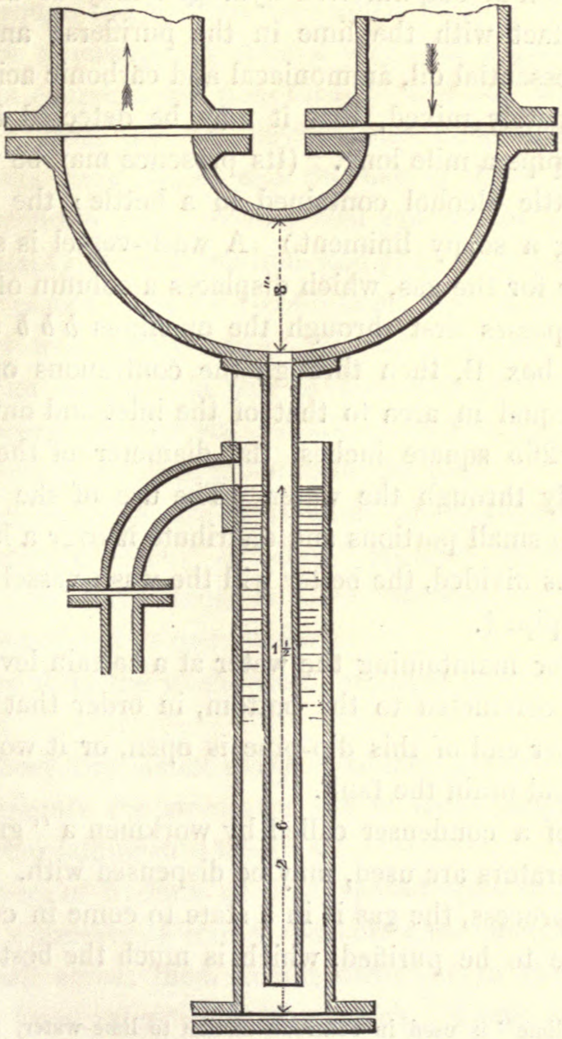
Split bricks, 90*s.* per 1000.
Splaid bricks, ditto.
Closing bricks, ditto.
18 × 20 in. R. tiles, 2*s.* 9*d.* each.
8 × 10 ——— 1*s.* 3*d.* ———
Stourbridge clay, 50*s.* per ton.
Newcastle ——— 30*s.*

PURIFIERS.

THE gas, when it leaves the retorts, retains its impurities, and in this state is quite unfit for the illumination of private houses, or even public thoroughfares. The impurities are bituminous vapour, ammoniacal gas, essential oil, and sulphuretted hydrogen; the processes adopted for removing these are partly mechanical and partly chemical. The first operation is the condensation of the volatile portions, which is effected at different places in different ways. The condensers generally adopted either consist of a series of pipes arranged in the manner of a distiller's worm, or of a number of chambers contained in a tank and surrounded by cold water; at the lowest points of these vessels siphons are attached, sealed by dipping them into tar to a sufficient depth to prevent the gas from escaping, and through them the condensed bituminous and ammoniacal vapours pass away to the cistern constructed to receive them in the forms of tar and ammoniacal liquor.

The same tank serves to contain both, the difference of their specific gravities keeping them separate; the ammoniacal liquor, being the lightest, swims on the surface of the tar. The tank is generally sunk below the surface of the ground; the respective heights of the two fluids are registered by floats and gauges, and, when found necessary, are pumped out. If there be no sale for the tar, it is burned beneath the retorts, and the ammoniacal liquor is either evaporated in the cast-iron pans placed under the furnaces for that purpose, manufactured into the carbonate and muriate of ammonia, or used as manure. The simplest and best condenser is formed of a few upright pipes, as shown in Plate IX. at S S. Their number and length being regulated by the quantity of gas required to pass through them, ten feet run of pipe for every 10,000 feet of gas is ample; in height they may be equal to that of the wall of the retort-house, for the convenience of placing a tank on the roof to supply them with water. In this instance the tank was placed against the chimney, thus allowing a greater *length* of pipe; at the bottom of each bend is a siphon, similar to that represented in the annexed woodcut, by which the condensed vapours before mentioned are conveyed to separate vessels, the fluids passing away being of different values (that from the last siphon is the most valuable).

Fig. 24.



These pipes must be kept wet in warm and dry weather by small streams of water running on to them from a tank placed at the top of the retort-house. The quick evaporation of this moisture will keep the pipes much colder than if they were completely immersed in water; because, as a large quantity of caloric passes from a sensible to an insensible state during the formation of vapour, it follows that cold should be generated by evaporation. If the sun shines upon the pipes, they will be colder than when it does not (always supposing the quantity of water supplied is greater than the evaporation), owing simply to the quicker generation of vapour. If after condensation "dry lime*" is used for purifying, the gas must pass through a wash-vessel, that a portion of sulphuretted hydrogen may be absorbed before the gas comes in contact with the lime in the purifiers; and to effect a final separation of the essential oil, ammoniacal and carbonic acid gases, the essential oil is so intimately mixed, that it may be detected in gas after it has passed through a pipe a mile long. (Its presence may be proved by shaking the gas with a little alcohol contained in a bottle; the oil will unite with the latter, forming a soapy liniment.) A wash-vessel is shown in Plate XI. A is the inlet pipe for the gas, which displaces a column of water about three inches high, and passes first through the openings *b b b* and at the sides of the wrought-iron box B, then through the continuous opening or slit C C (which must be equal in area to that of the inlet and outlet pipes,—viz. in this example, 50·265 square inches, the diameter of the pipes being eight inches), and finally through the water. The use of the opening C C is to divide the gas into small portions and distribute it over a large surface. The more minutely it is divided, the better will the wash-vessel effect its object.

D is the outlet-pipe†.

E is a siphon, for maintaining the water at a certain level; the part which enters the tank is conducted to the bottom, in order that the sediment may run off. The upper end of this dip-pipe is open, or it would otherwise form an actual *siphon* and drain the tank.

F is a portion of a condenser called by workmen a "gridiron condenser," which, when separators are used, may be dispensed with.

After this last process, the gas is in a state to come in contact with the dry or hydrate of lime to be purified, which is much the best for that purpose‡,

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* The term "dry-lime" is used in contradistinction to lime-water, the first being simply a hydrate, the latter holding lime in suspension with a large quantity of fluid.

† A better situation for the outlet-pipe is represented by the dotted lines on the top of the vessel, since all liability of its filling with water is avoided.

‡ It has been stated that the use of hydrate of lime, for the purposes of purification, is more expensive than lime-water; but I do not think it is so, if properly managed.

as it is attended with less nuisance, less pressure (which is also of importance), and the sulphur which has united with the lime may be sublimed from it by putting the *spent* lime from the machine into burnt-out retorts kept at a heat just red by daylight, with the refuse coke dust and cinders, for which there is no sale. The sulphur thus produced is a marketable commodity. The larger the surface of dry lime to which the gas is exposed the better; for if it be allowed to pass through the stratum with much velocity and in an undivided stream, it will work a passage in such a way that a great bulk will not be purified at all, for of course it will pass through that part where it meets with the least resistance: from this not having been understood or attended to, many superintendents have abandoned the use of dry-lime purifiers. The quantity of lime required for purifying coal-gas by the above process will depend upon the quality of both the lime and gas. One bushel of quicklime will suffice in some places to purify 10,000 cubic feet of gas, while in others twice that quantity will hardly serve. By being slacked and reduced to a proper consistency for use, its bulk will be more than doubled; two bushels of this hydrate will spread over a surface of 25 square feet, 2½ inches deep, which is about the thickness found in practice to be the best.

In Plate XII. Figs. 1 and 2, are represented an elevation and plan in section of one of a series of three "dry-lime" purifiers, through which the gas passes successively; in other words, they are "worked together," and, though separate, may be considered as one machine.

A is the inlet-pipe from the wash-vessel, entering at the bottom of the first purifier.

B is a plate of sheet-iron, about two feet square, placed over the mouth of the inlet-pipe, to separate the stream of gas in some degree, as well as to prevent any lime from falling into the pipe.

C C C are the layers of hydrate of lime, spread upon screens formed of an outside frame, and a number of round rods or wires about $\frac{5}{16}$ths of an inch in diameter, stretched across them in one direction, to afford greater facility for clearing, with a small interstice between each. These screens are placed one over another, in three tiers, from six to eight inches asunder; each tier may consist of four screens, for the convenience of lifting them out and replacing them.

D is the outlet-pipe leading to the second purifier. This arch-pipe is made of thin plate-iron, sealed at each end by a water-joint; because, when the lid has to be lifted, this arch-pipe must be removed, and any other kind of joint would be troublesome.

E is the lid of the purifier, also sealed by a water-joint; *e e* are round $\frac{5}{8}$ rods, keyed at one end into the keep-ring *k*, and riveted to each corner of the lid at the other; a chain is hooked on to the ring *k*, and passed over a pulley to a balance-weight, by which, and the rods just mentioned, the lid is lifted.

F F are blank flanches or bonnets, through which, when removed, the pipes are cleared from any deposited impurity.

G G are clamps, to keep the lid of the purifier in its place. The general arrangement of the purifiers will be more fully explained by reference to Plate XIII., where the two sets are shown with their several pipes and valves.

A is the pipe leading from the wash-vessel into one partition of the hydraulic valve, which I shall describe immediately.

B is the pipe leading to the three purifiers C D E in action, and rising into the same partition of the valve as B.

F is the pipe leading the purified gas back to another partition of the valve.

G is the pipe conveying this gas to the meter and gasometers; the connexion between the two last-named pipes is formed in the same way as that between the pipes A and B. It will be evident that the lime contained in the first purifier will be spent or saturated before the other two, and that contained in the third will be comparatively untouched. At the expiration of twenty-four hours C D and E must be shut off, by changing the divisions of the hydraulic valve to the situation shown by the dotted lines in the figure representing that valve, and turning the gas through H I K, having previously been put in readiness; at the instant of turning the valve the gas will pass through both sets of purifiers, all the communications being open.

When the covers of C D and E are taken off, remove the screens from C, and place those from E in their stead. The lime from C is quite expended, and must be either heated to sublime the sulphur, or laid aside until it can meet with a sale as manure, or be otherwise disposed of. That from D may be spread for a time in the open air (if there be room in the works), and in a week or two it will be fit to use in the first purifier. After renewing the lime in the second and third purifiers, replace the covers, and they are again ready for action. The same operation is repeated when H I and K are spent.

The annexed woodcut represents the hydraulic valve just mentioned.

A is a cast- or sheet-iron tank, three feet diameter and two feet six inches deep, generally filled with tar to within six inches of the top.

B is a light sheet-iron or tin gasometer-shaped vessel of less diameter, divided into three partitions by the plates C D and E, of less depth than the rim.

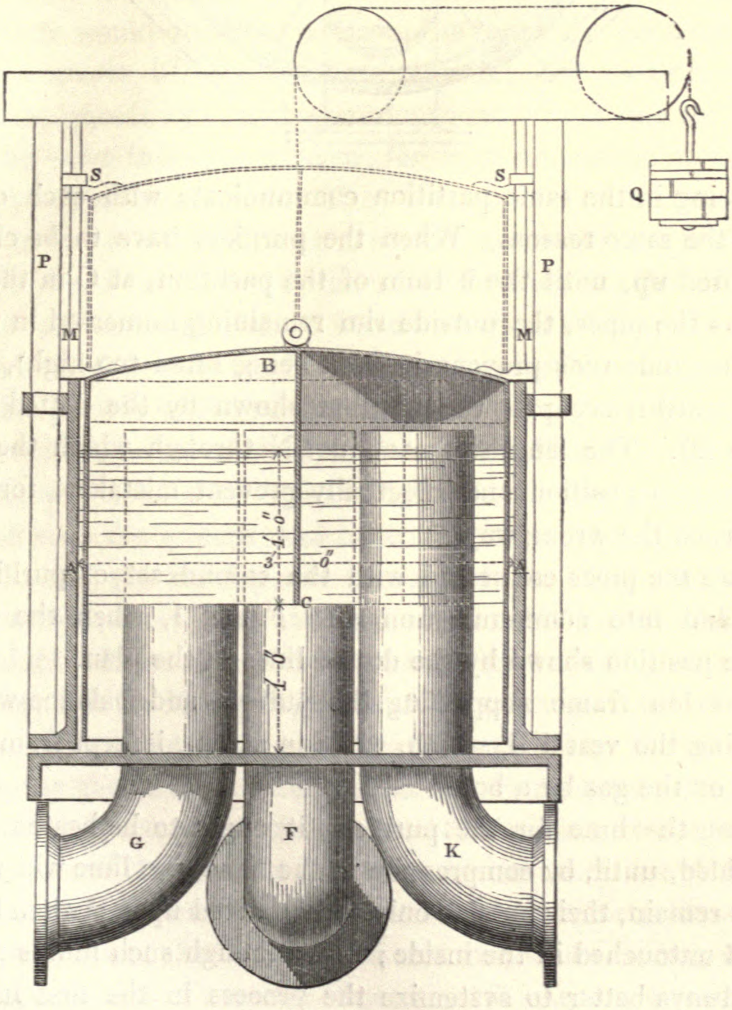
F is the pipe from the wash-vessel or condenser.

G is the pipe leading to the first set of purifiers.

H is the outlet or return pipe from them.

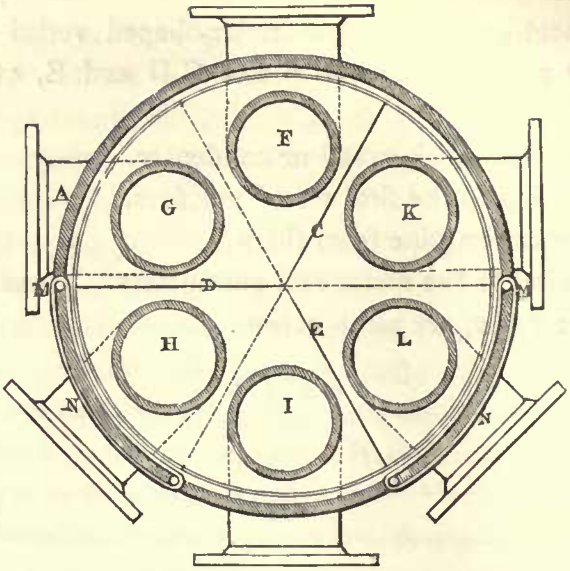
I is the pipe leading to the meter and gasometers. These pipes, in the present position of the valve, are all in action.

Fig 25 (1).



Q

Fig. 25 (2).



F and G being in the same partition communicate with each other, as do H and I, for the same reason. When the purifiers have to be changed, the vessel B is lifted up, until the bottom of the partition, at C in the elevation, Fig. 25, clears the pipes, the outside rim remaining immersed in the tar (the stops S on the guide-rods prevent it from being lifted too high), and turned partly round until it occupies the position shown by the dotted lines in the plan, Fig. 25 (2). The length of each dot N through which the guide-rods M pass, mark this position and effectually prevent mistakes, for the vessel cannot be turned the wrong way.

K and L are the pipes connected with the second set of purifiers thrown into action and into communication with F and I, when the vessel B is shifted to the position shown by the dotted lines in the plan.

P is a wooden frame supporting the pulleys and balance-weight Q to assist in lifting the vessel B, which, while in action, is kept from rising with the pressure of the gas by a bolt.

In preparing the lime for the purifiers, it ought to be beaten, well sifted, and water added, until, by compression in the hand, the lime will just adhere; if any lumps remain, their outside only will be acted upon; when broken they will be found untouched in the inside; and although such lumps may be used again, it is always better to systemize the process in the first instance, and prevent even the smallest waste. This care, to some, may appear frivolous and unimportant; but if œconomy is to exist in a gas establishment, there is no better method of preserving it than by order, and attention to detail. Almost all gas-works are more or less slovenly, and it will be found on examination that want of system is the cause; some degree of dirt, if I may use the expression, is quite unavoidable, but order will always prevent that dirt becoming a nuisance.

The arrangement of valves connected with this part of the apparatus is of consequence. I decidedly prefer one hydraulic valve to four or more slide-valves, for the reason that if the man whose duty it is to attend to them were to shut those leading to the spent purifiers before he opened the others, the consequences would be serious; the sudden check given to the exit of the gas from the retorts would drive the tar from the hydraulic main up the dip-pipes into the open retorts, if there happened to be any, and most probably do much injury. I have myself witnessed several accidents from this cause. With the one hydraulic valve this cannot occur, for it is impossible to close one partition without opening another. They are much cheaper, less liable, or not liable at all to be out of order, and altogether more advantageous. As a substitute for the wash-vessel already described for *cleansing* the impure gas from essential oils and ammonia, the "breeze condenser" is preferred by some; the action of which is quite mechanical, but answers the purpose of removing a considerable portion of the tar and fatty oils. Its construction is similar to a dry-lime purifier, layers of "breeze," or coke-dust and cinders being laid upon the screens instead of hydrate of lime; the layers may nearly fill up the space between the screens, and have a surface of one square foot for every 5000 cubic feet of gas which passes through them. The reason of the preference given to these is, that the olefiant gas and heavy carburets are not absorbed, which will be the case in some considerable degree when it passes through water, that fluid being capable of taking up one-eighth of its volume of olefiant gas. It is a matter of practical opinion whether the essential oil still contained in the gas, after having passed the "breeze condenser," is more injurious than the presence of olefiant gas is beneficial. It has been proposed to use a solution of the muriate of potash in the wash-vessel to absorb the carbonic oxide, which pure water will not effect; but the portion of this gas generally contained in that from coal is not worth the expense that would be attendant upon the use of muriate of potash. The arrangement of the vessels just mentioned may be varied if there be not a plentiful supply of water. The gas, as it leaves the condensers, may pass first through the " breeze separators," then through the dry-lime purifiers, and finally through the wash-vessel.

PLATE XIV.

LIME-WATER PURIFIER.

I will now proceed to the subject of purification by lime-water.

Fig. 1 is an elevational section of a lime-machine, and Fig. 2 a plan through *a b* in Fig. 1.

A is the inlet pipe through which the gas passes into the chamber B, which is four feet diameter, jointed to the lid of the purifier, and supported upon two cast-iron beams C. On to the bottom flanch of this chamber a circular ring of thin wrought-iron plate is riveted, of such a diameter that its outside rim will be within five inches of the tank of the purifier.

D is a hoop supported from the tank by bolts *d d*, etc., having its upper edge level with the before-named plate, and its lower edge four or five inches below it. The space left between this hoop and the ring is three-eighths of an inch, through which the gas (after having overcome the pressure of the column of water contained in the tank, plus the pressure in the gasometers) will pass, and bubble up through the lime-water.

E is an arm made to revolve on the spindle S: the parts *e e* of this arm continue through the aperture and over the ring, serving to keep the lime from settling or obstructing the passage of the gas.

F is the outlet for the purified gas.

G is a stuffing-box, through which the spindle S passes.

H a miter-wheel, connected to a water-wheel or steam-engine for turning the spindle.

I is a pipe, through which the lime-water is drawn off when it has become saturated with the impurities of the gas. It will be observed, that by this contrivance the water can be completely drained off, by opening a slide-valve bolted to the flanch of the pipe K, without suffering the gas to escape along with it, because a column of water will remain in the tube I equal to the height of the bottom of the tank, measured from the inner radius of the curve of the tube, viz. twelve inches, which is always more than sufficient to overcome the pressure of the gas in the purifier when the valve on the inlet-pipe A is closed, which should be done before that at K is opened.

L is a cylindrical vessel, open at the top, for filling the purifier; it also serves to show the quantity of water required; when the machine is at work the column contained in the vessel will be as much higher than that in the tank, by the pressure of gas in the gasometers, usually about three inches.

The explosion at Peter Street, mentioned at page 18, was occasioned by the gas escaping with the lime-water, no sealing-tube being attached.

The lime-water may be mixed in a cistern (having its bottom *above* the level of the water in the purifier when filled, and furnished with an agitator worked by hand), and drawn off by a hose into any of the machines, care being taken to keep the mixture well agitated while passing. The proportions are one measure of paste-lime to three of water; that is, to every five bushels of paste-lime about 120 gallons of water must be added. The size of the lime-machines ought to be so regulated that they will contain sufficient lime-water to purify the quantity of gas made in twenty-four hours, without having occasion to fill them higher than the water-line shown in the engraving.

Four lime-machines are necessary, two being in action and two out, alternately. When that machine is spent through which the gas first passes, shut it off, and open a third, leaving the second to perform the duties of the first, and so on. The following extract from Mr. Clegg's Journal will give his opinion on the construction and use of lime-machines:—

> "The grand principle of the construction of a lime-water purifier is to divide the gas as minutely as possible, at the same time avoiding unnecessary pressure. If the machine is well constructed, seven or eight inches pressure in each machine is quite sufficient. Two sets are necessary, in order to have a pair clean and ready for immediate use. The practice of working the contents of the vessel over again, by passing them from one to another, is mistaken œconomy."

I have before stated that the quantity of lime required for the complete purification of coal-gas varies very much with the quality of the lime and the gas; that coal which produces the greatest volume of sulphuretted hydrogen from the presence of iron pyrites will require the most lime. As the best means for arriving at a proper practical conclusion, I annex the quantities used at different gas-works in various parts of the kingdom.

At the Imperial Gas-Works, London, one bushel of quicklime purifies on an average 10,000 cubic feet of gas, the price of lime being 7*d*. per bushel.

The lime is used both as a hydrate and in the fluid state, in the following proportions:—For the purification of 1,000,000 cubic feet, the produce in the winter season of twenty-four hours, eighty bushels mixed as "dry lime," and twenty bushels mixed into a fluid: this quantity performs its part thoroughly.

At Cheltenham $1\frac{1}{2}$ bushel of quicklime, reduced to the state of a hydrate, will purify 10,000 cubic feet of gas perfectly: cost per bushel from 5*d.* to 6*d.*

At Birmingham the purification of 1000 feet costs, in lime and labour, from $1\frac{1}{4}$*d.* to $1\frac{1}{2}$*d.*, but in reality not nearly so much, as the refuse is sold for two-thirds the original cost of the lime. Lias lime is used, and "dry purifiers."

With the dry-lime purifiers at Chester 1 cwt. 2 qrs. is required to purify 10,000 cubic feet of gas. The Welsh lime is used, its price being 13*s.* 4*d.* per ton; therefore the purification of 10,000 feet will cost 12*d.* without labour, which is about the average cost.

In conclusion, I may observe, that in making the dry lime-purifiers, that they may present a sufficient surface to the gas which passes through them, an excess, rather than a smaller area, should be given. A bushel of lime, when reduced to the state of a hydrate, contains very nearly 4500 cubic inches: allowing that this quantity will purify 5000 cubic feet, it follows that 12·5 square feet of screen surface is required, the depth of the lime being 2·5 inches.

From the retorts contained in the building represented in Plate IX., 300,000 cubic feet of gas may be produced in twenty-four hours. The purifiers should present a surface of at least 750 square feet. If three machines are worked together, each containing five screens, their dimensions may be 8 feet 6 by 6 feet, and 3 feet deep, four bushels of hydrate of lime being spread on each screen. The surface presented by the three machines in Plate XIII. is 324 square feet: they were erected for an establishment producing 130,000 cubic feet of gas in twenty-four hours.

The work performed by a lime-water purifier is generally computed by its contents in gallons, and the head of water or pressure opposed to the passage of the gas through it. Taking the latter at a constant quantity of eight inches, the computation is easy. 4500 cubic inches of hydrate of lime, (which has been before stated is the quantity produced by reducing one bushel or 2150 cubic inches of quicklime) mixed with forty-eight gallons of water, will purify 10,000 cubic feet of gas, if properly applied. In the example at Plate XIV. the lime-machine contains 316 gallons, which will hold in solution thirteen bushels of hydrate of lime, and purify 65,000 cubic feet of gas. Two of these machines will therefore do the same work as the three dry-lime purifiers before mentioned, viz. 130,000 cubic feet.

To reduce the operation of one of these machines to theory, the gas should be so divided that each atom of sulphuretted hydrogen should be brought into close contact with its equivalent atom of lime; the chemical change would then be effected instantly, a hydrosulphuret of lime being formed, and the depth of water holding the lime in solution need not exceed that of a single atom. It is impossible practically to effect this perfect contact, but we can approach in some considerable degree towards it, by allowing the gas to pass through the liquid only in small bubbles, which is effected by the ring and plate touching each other within half an inch, the gas being made to pass through this annulus. In some machines the gas is allowed to pass through the lime-water in masses, as it would escape from under the plate if no ring confined the space: *then* the purification would not be effected by double the pressure, for the chemical reason that the atoms of sulphuretted hydrogen would not be brought into contact with their equivalent atoms of lime; a quantity would therefore escape through the machine unchanged, and remain as an obnoxious impurity. The most essential thing then to be attended to in the construction of both dry and lime-water purifiers is *surface.*

Notwithstanding, however, that the quantity of lime required may be well known, it is necessary to *test* the gas in its progress through the various purifiers. In some cases it is advisable to use the test every twelve hours, or oftener, in districts, for instance, where coal is of inferior and various qualities. Every morning, as soon as the superintendent arrives at the works, he ought to test the action of his purifiers, more especially if he has received a fresh supply of coal or lime. A saturated solution of the acetate of lead in distilled water is an excellent test, detecting the presence of the minutest quantity of sulphuretted hydrogen, and more convenient than the carbonate, from its complete solubility. Test-papers may be printed in the following form:—

Station and Date.

Crude Gas.	1st Purifier.	2nd Purifier.	3rd Purifier.

Lime-machine having been charged hours with bushels of lime.

Let the superintendent go (not send) and fill a bladder, furnished with a stop-cock, full of gas from the main, before it enters the purifiers, and also one from each separate purifier, and let the bladders be labelled; with a camel-hair pencil paint the square marked crude gas with the test solution, and force the gas from the proper bladder upon it while wet; the paper will immediately be turned black: then paint the square marked 1st purifier, and force the gas into it, and proceed in like manner with the two others: the paper in the fourth square ought not to be discoloured. The squares must not be moistened at once, because the first impure gas would in that case blacken them all.

Were I to mention all the various contrivances for purifying gas, they alone would fill a volume; in many instances the simple alteration of the machine an inch or two either in height or length, or the position in which it was placed, has served to found a claim of improvement, the machine so constructed being called by the name of its *inventor*. Cream-lime, or a solution between the hydrate and the completely fluid, has been tried several times; the gas was found to be acted upon efficiently, and completely purified, but the vessels so soon became clogged that they were laid aside. If, however, some simple means were devised to keep the lime in a proper state, they would be found more œconomical than any other plan. Again, the purification has been attempted by passing the gas through heated iron tubes; the sulphuretted hydrogen, it is true, is got rid of by this means, but the carburetted hydrogen is also resolved into its elements, and the gas rendered perfectly unfit for the purposes of illumination. If charcoal is introduced into these tubes the sulphuretted hydrogen is converted into carburetted and hydrogen gases. The carburetted hydrogen of the coal-gas is partly, though not entirely decomposed, and cyanogen, carbonic acid, and carbonic oxide, are formed abundantly. It is a better process than the former, but still very imperfect, and attended with expense, uncertainty, and trouble.

The following observations of Mr. Brande will be found in the Transactions of the Royal Society, vol. cx. p. 19:—

> "The readiness with which carburetted hydrogen is decomposed when passed through red-hot tubes, appears to me to offer a solid objection to a mode of purifying gas which has been proposed by Mr. G. H. Palmer, since it would deposit carbon, and consequently sustain great loss in illuminating power: the object in view was probably to get rid of the sulphuretted hydrogen, but neither is this to be attained."

Mr. Alexander Croll, the superintendent of the Chartered Gas Company's works at Brick Lane, has lately taken out a patent for freeing gas from its ammonia, and a part of the sulphuretted hydrogen, producing at the same time muriate of ammonia. He introduces a solution of the muriate of zinc into a vessel, upon the same construction as a wet-lime purifier; on admitting the gas double decomposition ensues; an insoluble sulphuret of zinc and a solution of muriate of ammonia are produced. The gas must be further purified with lime, in the usual way.

Lime for the purpose of purifying coal-gas should be free from foreign matter. That which slackens the quickest, and produces the greatest heat during the operation, is the best. When dissolved in diluted muriatic acid it should not effervesce, and should, when perfectly pure, leave no insoluble residue.

The purest lime is obtained from lias-limestone, and the lower oolite. The former contains 90 per cent. of carbonate of lime, has a brownish tinge, is perfectly non-effervescent when properly burnt, and slackens readily. The latter is white, with the same properties, but when dissolved in acid leaves a larger residue. Dorking and Mersham lime, obtained from chalk, are also esteemed, particularly in the neighbourhood of London. Magnesian limestone is inferior.

GAS-METER.

BEFORE passing the purified gas to the gasometers, it is necessary that it should be measured and its quantity registered, which operations are effected by the *Meter*. Of this valuable machine there are two kinds,—the *Station-Meter*, for measuring the total products of the coal at the works before it is supplied to the mains; and the *Consumer's Meter*, for measuring small quantities as supplied to individuals.

It is of the former I now propose to speak. Its advantages are so well known and so generally appreciated, that it would be superfluous to enter into any lengthened enumeration of them; I shall therefore confine myself to a more practical consideration of it.

In Plate XV. Fig. 1 is a front elevation in section; Fig. 2 is a side elevation, also in section, of a station meter of the capacity of 200 cubic feet, by which 300,000 cubic feet of gas may be measured and registered in twenty-four hours.

The principal part of the machine consists of a hollow drum of thin sheet-iron A A, revolving upon an axis *a*, and divided into compartments, so arranged, that, as the gas enters, it shall in revolving successively fill all the chambers, pass through them, and be discharged measured.

The part of the drum which contains the gas is in the form of a concentric ring, one foot six inches broad, and six feet deep, and seven feet six inches in extreme diameter, which will be understood by reference to the engraving. The plates which form the sides are of the same outer diameter as the drum, viz. seven feet six inches, but are two feet nine inches broad; they will therefore project within the smaller diameter, leaving the centre circle (through which the inlet-pipe K passes) two feet in diameter. The surface of the water contained in the drum and outside tank of the meter, is four inches above the upper circumference of this centre circle, when the drum is in its place; so that the communication between the outside and inside of the drum is cut off by a head of water of that height, and continues to be so in every part of the revolution. It is evident, therefore, that the gas must enter any chamber having its inner hood above the surface of the water.

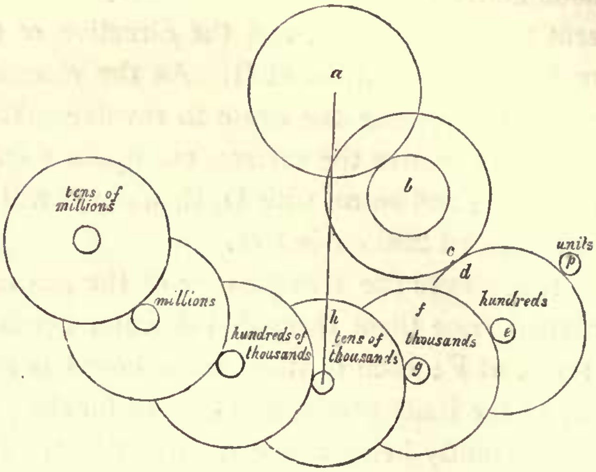
B C D E represent the inner hoods, and the direction of the gas from the inlet-pipe is shown by the small arrow at B. As the chamber fills with gas, it displaces the water, and causes the drum to revolve. Before B dips into the water, the hood C rises above the surface, and opens a communication for the gas into its chamber; and so on with D, E, when it will have completed one revolution and measured 200 cubic feet.

The same action that allows the free passage of the gas *into* the chambers causes it to be expelled *from* them through the outer hoods F G H I, in the direction of the arrow at F: each of these outer hoods is sealed alternately in the same manner as the inner hoods, and opened for the passage of the gas from them, by one constantly being above the water-line. In setting out the hoods care must be taken to have them of a proper length. The direction in which the drum revolves is marked by the arrow over the top of the case.

The bevels of the division-plates *d d* are arranged so that they will enter the water without effort; and, for the convenience of workmen, they are generally made to slope towards the points where lines drawn at right angles through the centre of the axis would intersect the inner circumference of the drum, as *d m*, *d n*. The axis *a a* on which the drum revolves is supported on friction-rollers; on the front end of this axis a spur-wheel S is fixed, working into another wheel T, having half the number of teeth; at every half revolution of the drum it will therefore make an entire revolution; its spindle passes through a stuffing-box, and is furnished at the opposite end with another wheel V, which marks 100 feet on the index. From a pinion on the spindle of this last wheel another wheel is worked, having ten times the number of teeth on the pinion, which will therefore mark thousands. This last wheel is again furnished with a pinion and works into a third wheel, which will mark tens of thousands, and so on; the quantities marked on the dials increasing in a tenfold ratio up to hundreds of millions, or higher if thought necessary.

The entire train of wheel-work is shown in Fig. 26, where *a* is the first spur-wheel, working upon the main axis; *b* the second wheel, both being inside the meter-case; *c* is the wheel on the opposite end of the shaft of *b*, which projects through a stuffing-box on the case, in order to communicate motion to the train of wheel-work, which must of course be on the outside of the meter-case; *d* is the wheel driving the hand which marks hundreds on the index,

Fig. 26.



and having 100 teeth (*c* has likewise the same number of teeth); *e* is the pinion on the wheel *d*, having ten teeth; *f* is the wheel driving the hand which marks thousands on the index, having 100 teeth, and driven by the pinion *e*; *g* is the pinion of the wheel *f* driving *h*, which marks tens of thousands on the index: in this manner any quantity may be registered. If it be required to register units (and in smaller meters it is useful), the first wheel *d* is made to drive a pinion, *p*, having ten teeth, to the spindle of which the hand marking units is attached.

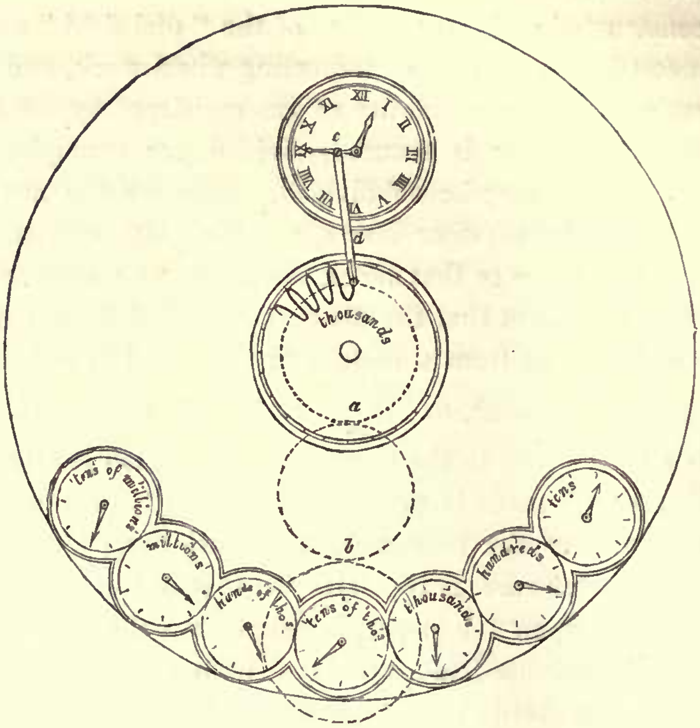
The old contrivance of the "Tell-tale," when attached to the station-meter, becomes a valuable instrument, as it serves the purpose of effectually pointing out every irregularity that occurs in the production of the gas during any hour of the twenty-four. Suppose, for example, the superintendent desires to know whether his workmen have at any time during the day or night made the proper quantity of gas from the given quantity of coal: he may upon examination find all the retorts in an excellent working state; but whether they have been so at all hours, or whether the requisite quantity of gas has been really produced during the time that the pipes which convey it into the mains have been open, is to him a matter of uncertainty: the "tell-tale" will show him by inspection if any irregularities have occurred, and, if any, at what hour: this appendage may, then, be considered as a check on the conduct of the workmen. It may also be known what man or set of men have been negligent; for the retorts having their proper hours of work, will, if neglected, speak for themselves, and the men whose duty it is to look after them will be to blame.

It is thus constructed :—in the centre of the " dial-field " a circular plate is fixed, connected to the train of indicating wheel-work, and made to revolve in a certain ratio to the quantity of gas registered by the meter. Upon this plate a sheet of paper is secured, divided, for example, into twenty-four parts, which parts may be subdivided. Suppose the meter to register 300,000 cubic feet in twenty-four hours, and the plate connected by wheels in the ratio of three to one to that index which marks a hundred thousand in one revolution, it is evident that the distance travelled by one of the twenty-four divisions of the plate from a certain fixed point will indicate the quantity of gas made in one hour, or $\frac{300{,}000}{24} = 12{,}500$ cubic feet. Above this divided disc is a time-piece, to the minute-hand of which is attached a detend, furnished with a pencil made to press gently upon the disc by a light spring. As the minute-hand of the time-piece revolves, the pencil, by means of a guide fixed to the meter-case, is regulated, so that in the first half-hour it will make a vertical line upon the paper, in length equal to the diameter of the circle formed by the minute-hand, measured from the centre to the point on to which the detend is fixed; in the second half-hour the line will be retraced by the hand rising again. This is supposing the divided disc to be stationary; but as it revolves in the manner previously described, the pencil will make a series of curved lines, meeting the divided circle of the disc every hour, and the distance travelled from point to point will mark the number of cubic feet of gas made during every hour of the twenty-four. If the production of gas is regular, the figures formed by the pencil will be regular also: if, on the contrary, any negligence has occurred, the irregularity of the figure will detect it, pointing out the hour and the amount of difference; because, if the speed of the revolving disc be decreased, the figure formed will approach nearer to the straight line; if increased, the points of intersection upon the divided circle will be further apart.

By reference to the diagram (Fig. 27.) I think the " tell-tale " will be understood.

a is the divided disc upon which the curved line formed by the pencil is shown.
b is the train of the wheel-work connected with the index marking 100,000.
c is the time-piece and point at which the detend is attached to the minute-hand.
d is the detend, to the lower extremity of which the pencil is attached.

Fig. 27,



Mr. Lowe used this instrument at the Chartered Gas-works in 1823; it has since been adopted by many, but not so generally as it ought to be.

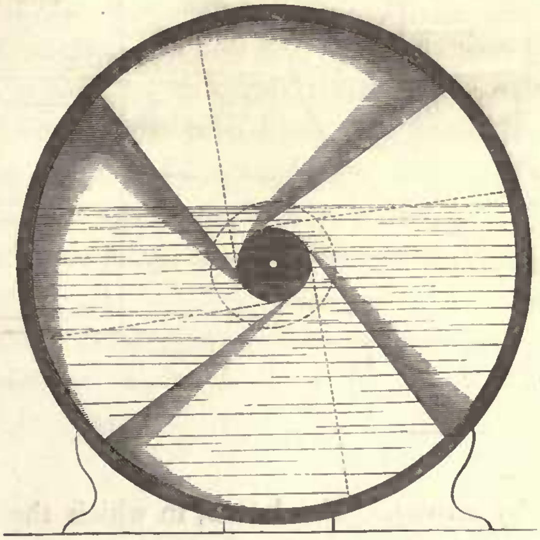
The case of a station-meter is generally ornamented, sometimes tastefully enough, but very often in an elaborate and unmeaning manner, covered with small insignificant scrolls and Latin inscriptions; the cost in some instances exceeding that of the machinery. I much prefer a simple Tuscan pedestal, relieved by a base and cornice, having perhaps upon the dado a panel, or four pilasters in the front.

The consumer's meter is constructed upon precisely the same principle as that shown in Plate XV.; but the partitions of the drum are differently arranged, and placed in such a manner, that, as they reach the water, the surface presented shall be as small as possible, or the resistance offered shall be so gradual that the stream of gas flowing through the machine is uniform and constant. This is necessary in a meter from which any number of lamps are immediately supplied; because the most minute diminution or increase of the volume of gas flowing to them would cause a variation in the light, and produce an oscillation or "jump." In a station-meter the intervention of the gasometer will remedy this defect. A variation in the arrangement of the drum, therefore, is a matter of necessity. The station-meter is formed for strength and durability, the way in which its drum is put together being more *mechanical* than that of the consumer's meter.

I have stated that the construction of the drum of the consumer's meter differs of necessity from that of the station-meter: it is so when the drum of the latter is made in the forms given in Plate XV. Station-meters are, however, sometimes made with drums like the smaller kind, but the *measure* will vary with every change in the water-line. If it is too high, the quantity marked will be too little; if too low, the quantity marked will be too great; these are circumstances to which the station-meter ought not to be liable, and which the form shown in the Plate completely obviates.

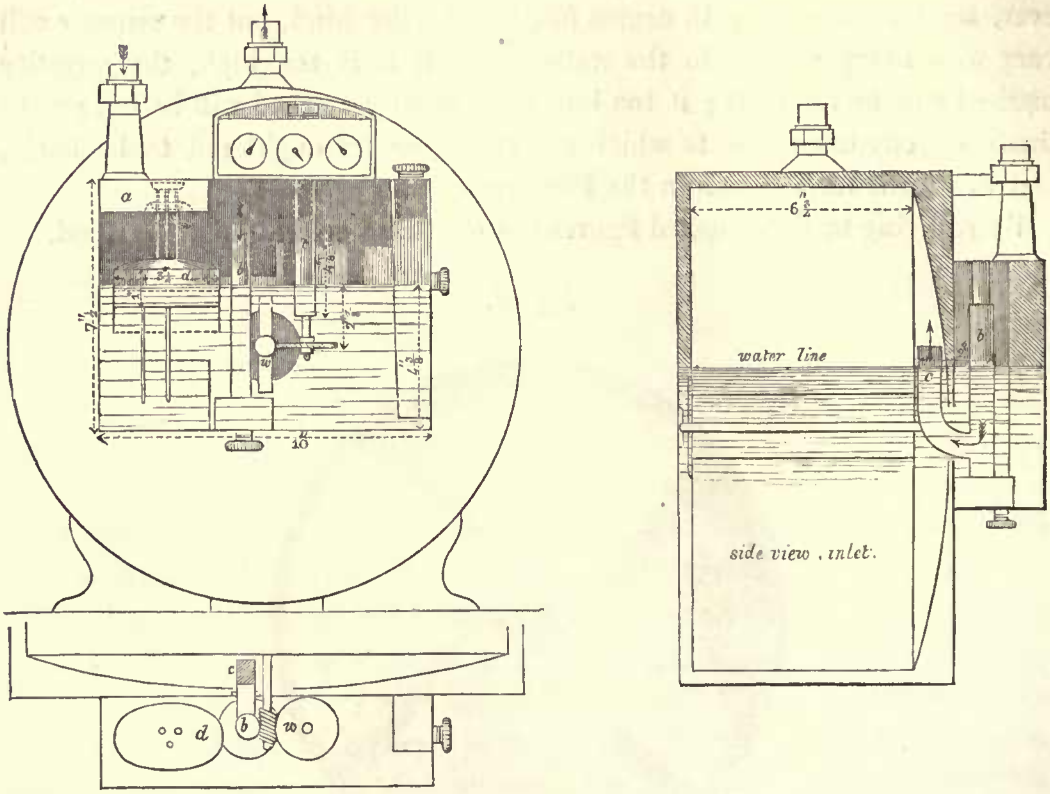
By referring to the annexed figures the construction will be understood.

Fig. 28.



As in the former case, the outer circumference or rim of the drum is divided into four partitions, separated from each other by partition-plates, not running across directly at right angles with the face, but beveling from the plane of the water, meeting the wrap of the opposite hood. The sides of these partitions are also beveled; the space left between each plate forming, on one side of the drum, the inlet, and on the other side the outlet for the gas; the area of the latter being greater than the inlet, to ensure perfect freedom of action. The dotted lines show the wrap of the hoods. The woodcut represents a view of the front or inlet side of the drum, with the convex cover removed. The outlets will present the same appearance, but of course reversed. By referring to Fig. 29. the remaining parts will be understood. The direction of

Fig. 29.



the gas is marked by arrows. The box *a*, in which the inlet-valve is contained, is soldered tight, having no communication with the rest of the case, except through the valve, the position of which is shown by the arrows; *b* is the inlet-pipe projecting above the water-line, conveying the gas into the meter by the bent arm *c*, rising above the water between the convex cover and the inlet-hoods; *d* is a float attached to the inlet-valve, adjusted so, that when the water falls below the centre opening, the valve will close and the gas cease to enter the meter.

Motion is communicated to the train of wheel-work behind the index from a spiral worm *w* fixed on to the axis of the drum, working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

The following are the principal dimensions of consumer's-meters :—

Number of lights	5	10	20	30	50	80	100	150	200	400	800
Diameter of drums ..(inches.)	12¼	14¾	17½	19½	21½	25	27¾	33	33	44	60
Depth ,, ,, ... ,,	5	6¾	9⅛	10⅞	11¾	12¾	13¾	20¼	24¾	30¾	40¼
Diameter of water circle ,,	3½	3¾	4½	5	5	6½	7½	9	10	15	21
Centre opening ...... ,,	1¾	2	2¾	3	3¼	4	5	6	7	10	15
Hollow cover projects.. ,,	¾	1	1⅛	1¼	1⅜	1½	1¾	2¼	3¼	3¾	4¾
Depth of inner hoods .. ,,	½	⅝	⅝	⅝	¾	1	1	1½	2	3	5
,, ,, outlet ,, .. ,,	¾	1	1⅛	1⅛	1¼	1½	1½	2	2½	4	5½
Capacity in cubic feet...	·25	·50	1 00	1·50	2·00	3·00	4·00	8·00	10·00	20·00	50·00

The inlet-hoods are those under the convex cover, or the inlet openings for the gas, and the dimensions given are extreme depths at the circumference of the drum. The outlet hoods are for the escape of the gas into the meter-case. Dimensions given for the same part.

In setting out the wrap of the hoods over the division-plates, care must be taken to have them of the proper length, which will be, when the water is just touching the outer end of the inlet-hood, the outlet-hood of that division must be clearing the water. If the hoods are too long it will prevent the gas from escaping from that division which is entering the water ; and if the hoods are too short in the wrap, the gas will blow through, and the meter stand still.

The following are the London prices for meters :—

Consumer's-Meters.	£	*s.*	*d.*
3 lights	2	2	0
5 ——	2	10	0
10 ——	3	5	0
20 ——	4	7	0
30 ——	5	17	0
50 ——	8	10	0
100 ——	18	10	0

Station-Meters. To measure	£	*s.*	*d.*
50,000 cubic feet in 24 hours	50	0	0
100,000 —— ——	100	0	0
200,000 —— ——	150	0	0
300,000 —— ——	190	0	0
500,000 —— ——	300	0	0
1,000,000 —— ——	500	0	0

GASOMETERS.

THE simplest and most general kind, consist of an iron vessel, open at the bottom, and inverted into a tank of water below the surface of the ground, having perfect freedom to rise and fall, and guided by upright rods fixed at several points in the circumference. The diameters and numbers of the vessels will vary according to the magnitude of the works to which they are attached, and the space to be occupied by them. If the works are situated in a town, where ground is too valuable to allow an increased extent, "Telescope Gasometers" are used.

The constructions and management of gasometers I now propose to explain.

Plate XVI. represents the section of a gasometer, capable of containing 150,000 cubic feet, the diameter being eighty-seven feet six inches, and height twenty-five feet. The sides A A are made of No. 16 iron-plate (Birmingham wire-gauge), weighing 2½ pounds to the square foot, riveted together; the top B, of plate weighing about three pounds to the square foot, or No. 14 gauge.

C C, etc. are rings of three-inch T iron, placed five feet asunder, and riveted strongly to the sides; the rivets ought not to be more than three inches apart. The top and sides are secured together by three-inch angle-iron, rolled to fit the curve, as shown in the cut.

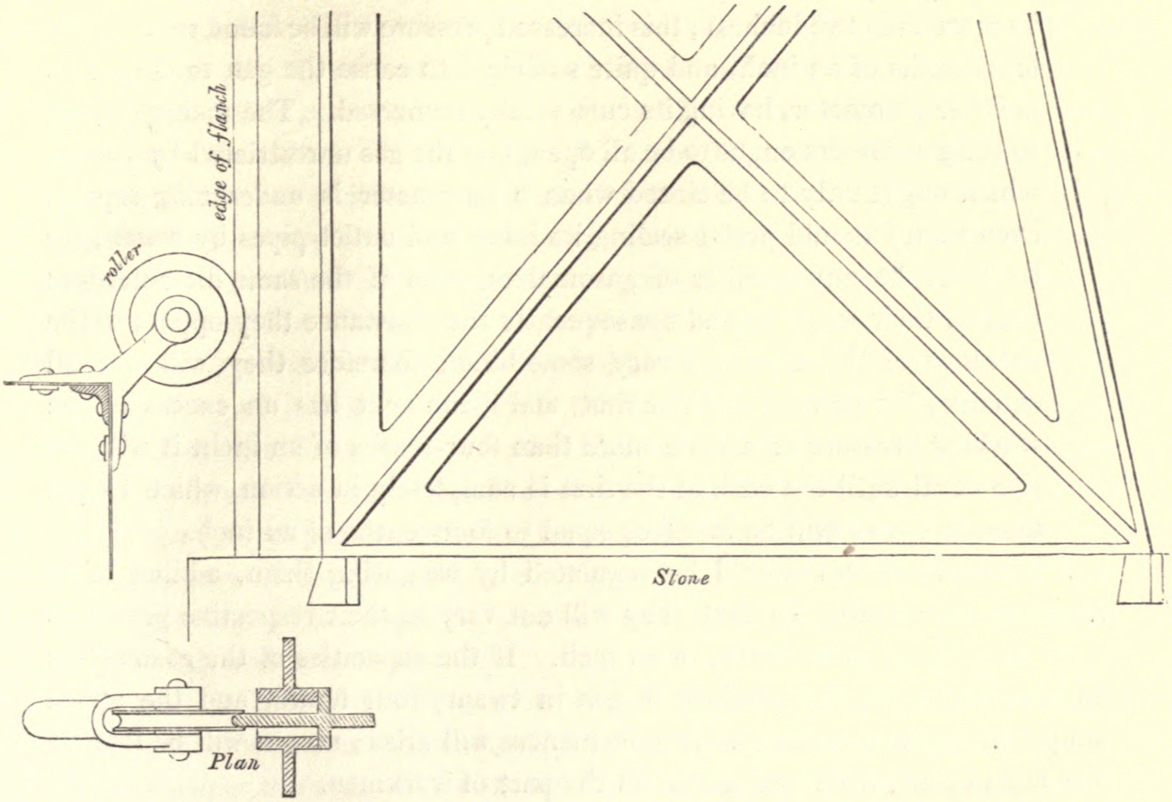
d d are rings of bar-iron, about half an inch thick and three inches deep, fastened to the top by clips, which are riveted; these rings are placed about six feet apart, and strengthened further by diagonal bars, from one to another, breaking-joint.

E are stays formed of wrought-iron pipe, about 1½ inch diameter fixed in the situations represented in the Plate, their ends being bolted to the T iron at the sides, and the rings on the top.

G are vertical rods, fixed at their upper and lower ends to the brickwork of the tank, and being passed through eyes fast to the bottom of the side of the gasometer, serve to guide the vessel in its rise: their positions are between the standards S, on which are also guide-rods acting in like manner. The eyes serve as stops to prevent the vessel rising out of the water.

The standards S, eight in number, are each formed of three cast-iron frames, six feet broad at their bases, of the same height as the gasometer, and jointed together in the form of a T on the plan; they are secured to the stone (marked in the engraving) by dovetailed lock-nuts, keyed and leaded, as represented in the figure.

Fig. 30.



Preference is often given to rollers, instead of rings, for guiding the rise of the gasometer, and perhaps as there is less friction they may be more advantageous; their only inconvenience is the liability of their coming out of the guides. I have shown a roller in the cut which works against the flanch of the centre standard, widened for that purpose.

H is the wooden curb, which ought always to be attached to a gasometer; its use is to regulate the flow of gas from one gasometer to another. While immersed in the water of the tank it acts as a float, and, to some extent, buoys up the vessel; when the gasometer has risen to its full height, it acts as a weight, being partly *out* of the water, thus causing the gas to flow into another gasometer not yet full, and which, having its curb completely immersed, is under less pressure. For example, suppose the weight of the gasometer to be thirty-three tons, and its working pressure to be $2\frac{4}{10}$ths inches; suppose also the weight of the curb in water to be $2\frac{1}{2}$ tons, then, when it partly rises out of the water, the working pressure will be increased by the weight of so much of curb in air plus $2\frac{1}{2}$ tons, minus the buoyancy of so much as yet remains in the water (which ought not to be more than two inches); this increased pressure will be found to be nearly four-tenths of an inch, and quite sufficient to cause the gas to flow into another gasometer, having its curb totally immersed. The mains leading to the gasometers ought to be all open, and the gas unrestricted by valves, which ought only to be closed when a gasometer is undergoing repair; even then I should prefer sealing its inlet- and outlet-pipes by water; for let there be any number of gasometers, even of the same diameter and height, their weights, and consequently the resistance they oppose to the entrance of the gas, will vary something; therefore they will not fill equally; the lightest will rise first, and if the next has an excess in the working pressure of a little more than four-tenths of an inch, it will not rise at all until the curb of the first is completely in action, which I have already shown will be in effect equal to four-tenths of an inch.

All the gasometers should be regulated by weighting them, adding to or reducing their curbs, so that they will not vary in their respective pressures more than about three-tenths of an inch. If the capacities of the gasometers be made equal to the produce of gas in twenty-four hours, and the above simple precautions taken, no inconveniences will arise; no gas will be lost, or accidents occur, from negligence on the part of workmen.

The dimensions of the curb H will be 12 × 12 inches, formed of Memel timber, scarfed and fastened together in segments by trennels, and secured to the sides of the gasometer within three inches of the bottom, so that when it is out of the water ten inches, the sides may be sealed by a head of water five inches, more than is actually necessary, but completely to guard against accident, not more than advisable.

I is the inlet-pipe, of the same diameter as that leading from the retorts, viz. eight inches. Its *mouth* above the water-line should be rather higher than the edge of the tank.

K is the outlet-pipe, twelve inches diameter, entering the gasometer, under the same circumstances as the inlet-pipe.

L are receivers, in which the tar or water collects from the mains, being pumped out by a small hand-pump, of which *a* and *b* represent the suction-pipes.

The well, down which these pipes are conducted, may be about seven feet diameter, built of brickwork in mortar, and well puddled, and as much lower than the tank of the gasometer as to allow the top of the receiver to be below the bottom of the tank. The tank of the gasometer may also be built of brickwork in mortar; in good ground the dimensions marked in the engraving, with a counterfort every ten feet, projecting eighteen inches, will be strong enough. Care must be taken, however, to have good, sound, and well-burned stock-bricks. The outside of the tank, to the thickness of two feet, must be well puddled. In getting out the ground the method pursued will vary so much under every different circumstance that little can be said about it here. In very bad marshy ground, abounding in land-springs, and otherwise disadvantageous, it will often be found less expensive to construct an iron tank.

At Chester, Mr. Clegg found so firm a bed of red rock that no brickwork was necessary, the tank being simply fashioned with the pick, and a few land-springs stopped. The earth-work in the centre of the excavation may be left, with a sufficient slope, and a "berm" half-way down; to guard against slips; and may in some cases be hurdled, or staked and osiered, whichever may be found the least expensive; the angles of these slopes will also vary according to the nature of the ground; a good gravel will stand at the slope shown in the engraving. The slopes of porous earth, such as the last-named, must be puddled, and made water-tight.

In tanks, whose diameter does not exceed fifty-five or sixty feet, the earth, if requiring puddle or other finishing, may be got out entirely, as it will be found cheaper to do so. In rock, stiff clay or chalk, the centre portion may be left in for much smaller diameters.

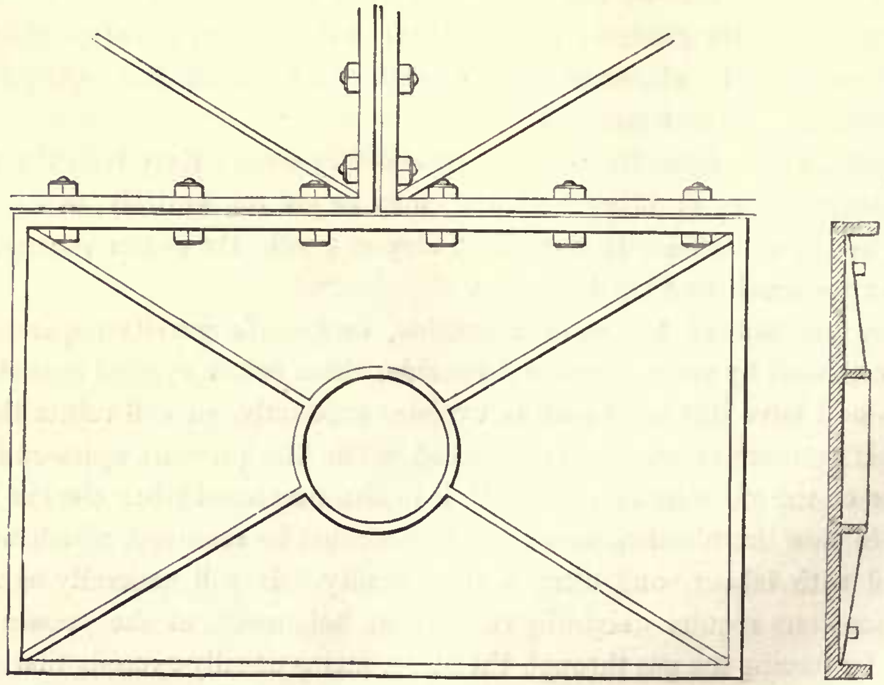
I have not noticed the counter-weights, or specific gravity-apparatus, as they are termed by some, because I consider them (when applied to such gasometers as I have just attempted to explain) productive of evil rather than of good. If gasometers are counterbalanced, while the pressure opposed to the entrance of the gas may be decreased, it is also decreased when the gas is required to flow from them, and the weights must be removed, which will be attended with labour, and often with difficulty. It will generally be found that gasometers require weighting rather than balancing, as the pressure necessary for forcing the gas through the street-mains usually exceeds that given by the vessel itself. In a well-constructed apparatus both pressures ought to be equal, but I only know of one or two instances where the adjustment is so correct.

TELESCOPE GASOMETER.

I now have to speak of the "Telescope Gasometer," so called from being something similar in its action to the lengthening slides of that instrument. They are only used in cases of necessity, arising from confined space or very bad ground.

The diameters of these vessels will be from thirty to fifty feet, but not more; their tanks are usually formed of cast iron, which constitutes the principal part of their expense, when compared to those of the simple form. By reference to Plate XVII. the action will be more clearly understood. A A is a cast-iron tank, fifty-one feet diameter and twenty-five feet high, constructed of plates about three feet one inch deep, by five feet wide, strengthened by ribs, and jointed together with flanches and cement in the usual way, as shown in the annexed cut, which is drawn to a scale of three quarters of an inch to the foot.

Fig. 31.



The figures at the side of the tank in the engraving refer to the thickness of metal at that part opposite to which they are placed.

In any vessel containing a heavy fluid, the parts that are deepest below the surface sustain a proportionably greater pressure; in the construction of the tank, therefore, we should run into superfluous expense by making the sides equally thick in every part; for if the substance be uniformly thick, and the lower parts are sufficiently strong, the upper parts are consequently much more so than necessary. The method suggested by theory is, while we give to the whole tank the same interior diameter, to give a safe and sufficient thickness at the lower part, and let it gradually diminish to the top, in the same ratio nearly as the diminution in the depth of the fluid. But in practice we must vary the construction; for although the plates of which the tank is composed, taken separately, may be sufficiently strong to resist the pressure of the water, yet, taken collectively, their thicknesses must depend in a great measure upon the strength required at the joints; therefore iron hoops are added to the two lower tiers of plates, to make up the difference in strength between the upper and lower tiers, instead of increasing the thickness of metal at these parts, and adding to the expense.

It may be as well also to say, that in bolting the plates together they must "break joint," as represented in the figure.

The plates forming the bottom are three quarters of an inch thick, and joined in the same way as those at the sides.

B B is the lower division or slide of the gasometer, furnished at the upper part with a returned rim, *b*, about twelve inches deep, and three inches wide from the side.

C C is the upper division, having at its lower edge a corresponding rim at *b*, but reversed; so that when in action it has risen to its full height, the returned rim of the lower division will dip into the water contained in that of the lower one, and form an hydraulic joint.

In the action of this gasometer it is evident that the upper portion must rise first, and having attained the proper altitude, will, as it were, unite itself with the lower portion, when they will both rise together: the whole vessel is guided by rollers, similar to those used in ordinary gasometers; but in addition to these, it is found necessary, for the greater security of the upper portion, to use standards and balance-weights, because the perpendicular height being great, the vessel would otherwise have a tendency to work sideways, or bind;

and likewise, the weight bearing a large proportion to the surface, unless some portion of it was removed by a counterbalance, the opposition to the flow of the gas into the vessel would be inconveniently great.

Fig. 32.

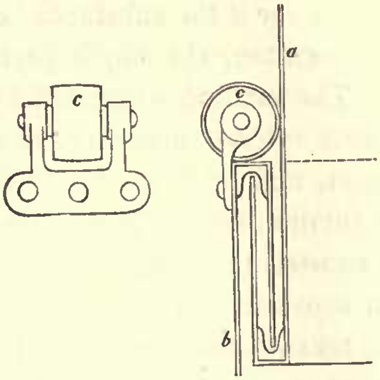


Figure 32 will explain the water-joint: *a* is the upper, and *b* the lower portion of the gasometer, dipping into the water twelve inches; *c* is a roller, guiding the upper portion as it rises. These rollers may be placed about six feet apart, entirely round the vessel.

D D are the standards, cast in several lengths, bolted to the tank, and braced at the top by the girders E.

F are the balance-weights, regulated according to circumstances; that is to say, if the gasometer, when brought into action, is found to oppose too much resistance to the entrance of the gas, weights must be added, until the pressure corresponds with that of the other gasometers in the works or is equal to about three inches perpendicular head of water. It is often necessary to balance both the upper and lower vessels.

The braces and ties for strengthening the sides and top of these gasometers are precisely similar in arrangement to those in ordinary use, and need not be again described. A well for the reception of the outlet- and inlet-pipes is not of course necessary, as the tank is above the level of the ground. The receivers and valves are the same.

There is not the slightest drawback to the practical adoption of these Telescope Gasometers; they rise and fall with the same precision, and can be adjusted with the same nicety, as the single gasometer. The wear and tear is about the same, and are repaired with the same ease, but their first cost is greater, and therefore they are not generally used, except in cases before mentioned. They are in use at the Chartered, Phœnix, and other companies' works in London, and are worked with the same confidence as the more simple vessels.

I insert the following extract from Mr. Clegg's Journal, because the observations contained therein are founded upon a practice of forty years, and are therefore valuable:—

" All the gasometers at the works must be connected together, as if they were one vessel, and each one must regulate its own pressure, by a wooden curb, assisted by weights where found necessary, when the gasometers are put into action. The flow of gas from one to another must not, on any account, be guided by a workman, nor must he be allowed to close any valve connected with them, unless expressly ordered to do so. Indeed it would not be amiss to remove all the valves, and seal the outlet- and inlet-pipes by water, when the gasometer they belong to requires repair.

" I would warn all young engineers, upon the necessity of making pneumatic, hydraulic, and other machinery, as much as possible *self-acting*. In the first place it is the perfection of mechanism; in the second place it prevents danger from neglect; and in the third place it is universally found cheaper, and tends much towards the œconomy of machinery in general.

" When the steam-engine was first invented, a boy was employed to open and shut the valves connected with the steam-ways, above and below the piston, when the engine was at the top and bottom stroke. A man was also employed to regulate the quantity of steam according to the power required. The engine now regulates itself. The damper which regulates the draft of the furnace rises and falls, as the steam is high or low, by the same contrivance as that by which the water in the boiler is kept at one uniform level.

" The water-wheel, if it does not regulate its own supply of water, according to the quantity of work it has to perform, is a very imperfect machine. The same may be said of windmills, blowing-engines, and even of switches on railways, which ought also to be self-acting; and in gas-works where it can be, and is not done, it is the cause of many serious accidents.

" In all the parts that are self-acting, such as the hydraulic main, no accident ever arises from a neglected valve, which was constantly the case when there was a valve to each retort requiring attendance. The engineer of the Glasgow gas-works, when they were first erected (and before Mr. Liddle had the management of them), would not use the hydraulic main. Had he been as ready to embrace new improvements, as he was to find fault with what he would not be at the trouble to understand, we should have had a more correct account of the subject of 'Gas-Lights' in the Supplement to the Encyclopædia Britannica. In speaking of the Telescope Gasometer, he says:

"'Other contrivances have been proposed for saving of room, on somewhat similar plans, but, like the above, they are not deserving of much attention, and only proper to be resorted to in cases of necessity.'

"They probably will not be resorted to but in cases of necessity, because they are more expensive; but they certainly *are* deserving of attention, and gas-companies are much indebted to the inventor. No engineer who uses them will find any practical difficulty in their operation.

"Again, he says, when speaking of a gasometer without counterpoise:

"'Fig. 5 is another variety of gasometer which appears lately to have got into use, though it is very imperfect, or rather totally deficient in the essential property of giving an uniform pressure to the gas contained within. Having no counterpoise, it requires to be elevated by the forcing in of gas under a considerable and varying pressure, and the addition of a regulator or governor is necessary to equalize that pressure where the gas is emitted for the purposes of combustion.'

"Now the above is given with an opinion so decided, that it might lead to great inconvenience, as it is totally wrong; for no one now would think of counterbalancing a gasometer to the nicety he seems to think necessary; and I should never think of using counterweights at all, except in telescope gasometers, having invariably found that they require an additional weight rather than a decrease; and as to the governor, it certainly is a much more scientific and correct machine for regulating the flow of gas into the street-mains, than an immense framing to support wheels and balance, with a chain sufficiently heavy to regulate the specific gravity of the iron of the gasometer: the former would cost about £20, and be perfectly correct without friction; the latter would cost £200, and the friction be very great.

"Engineers are not always to be blamed for the imperfections of their establishment, as they are in many cases tied down by directors, who, wishing to increase the dividend of the Company, often go to extremes.

"It is certainly praiseworthy in them to do their best for the Company which they represent; but if they employ an engineer, and place confidence in him, they ought to be guided, in matters involving essentially engineering questions, by his opinion. It is not to be supposed that a man, simply because he *is* a director, should know better than those who by education and constant practice are qualified to judge of the arrangements essential to the œconomy of a gas establishment.

"There are many parts of the apparatus objected to because they are in the first instance expensive, and because it is possible to carry on the works without them. The directors, not being gifted with foresight, see only the present outlay, and do not consider the *constant* saving, because those savings are small. System, order and proper attention to these small savings are the groundworks of œconomy, and consequently the best means by which their dividend may be increased."

WEIGHT AND ESTIMATES OF GASOMETERS.

The weight of a gasometer of 87 feet 6 inches diameter, and 25 feet high, the sides made of No. 16 wire gauge, and top of No. 14, will be as follows:—

	Tons.	Cwt.	Qrs.	℔s.
Sides, No. 16 wire-gauge	8	13	1	23
Top, No. 14 ditto	9	1	0	7
T iron at the sides	6	19	2	0
Angle iron	2	10	1	24
Iron rings, clips, &c.	2	3	1	23
Cross-braces, pipe, stays, eyes, bolts, etc.	3	14	3	8
Rivets	0	7	2	5
Curb at bottom	5	0	0	0
Tons	38	10	1	6
8 sets of tripods, each £5 2*s.* 1*d.*	40	18	0	0
Bolts, brackets, etc.	0	9	3	8
Tons	41	7	3	8

	£	*s.*	*d.*
Estimate for gasometer, including the erection	1292	0	0
Tripods, etc.	317	10	0
	£1609	10	0

Estimate for Excavation and Brickwork of Tank.

	£	s.	d.
2625 Cubic yards of excavation, in stiff marl, at 1*s.* 8*d.*	218	15	0
35½ Rods of stock brickwork, in mortar, at £13 -	479	5	0
590 Cubic yards of puddling, to stop land-springs, and filling in, at 1*s.* 9*d.* - - - - - -	51	12	6
	£749	12	6

The large gasometer at the Pancras Station of the Imperial Company is 100 feet diameter and 39 feet high at the sides, containing 300,000 cubic feet. Its weight is as follows:—

	Tons.	Cwt.	Qrs.	℔s.
30 Pieces of bottom curb - - - - -	6	16	1	2
8 Bags of rivets - - - - - - -	0	9	3	10
60 Plates and rivets for bottom curb - -	0	1	1	4
24 Bottom eyes - - - - - - -	0	8	0	24
100 Small sheets, 2 plates each, for side plates -	2	8	0	17
300 Large ditto, 6 plates each, ditto - - - -	19	6	0	7
30 Short pieces of angle-iron bottom curb -	0	3	0	0
24 Vertical stays - - - - - - -	10	16	2	0
60 Pieces of angle-iron top curb - - -	2	13	1	26
350 Short bracket irons, for crown framing -	1	9	1	17
4 Bags of rivets - - - - - - -	0	5	0	0
1 Centre crown plate - - - - - -	0	9	3	17
1 Cast-iron cup and ring - - - - -	0	18	2	6
1 Centre pipe - - - - - - -	0	10	0	23
6 Bags of rivets - - - - - - -	0	9	3	2
1 Ditto ¾-bolts - - - - - - -	0	3	3	6
150 1-inch bolts for top curb - - - - -	0	5	0	1
50 Upright rods - - - - - - -	2	11	3	19
50 Ditto ditto, 6 feet long - - - - -	1	2	2	0
50 Ditto ditto, 3 feet 6 inches long - - - -	0	9	0	7
150 Long braces - - - - - - -	3	4	1	9
196 Crown plates - - - - - - -	17	5	2	15
8 Diagonal stays, at centre pipe - - -	0	2	2	8
48 Small plates, at bottom and top curb - -	0	4	0	4
1 Man-hole, cover, ring, and bolts - -	0	0	1	24
130 Small plates for joints and bolts - - -	0	3	0	15
Carried forward - -	72	19	0	11

	Tons.	Cwt.	Qrs.	lbs.
Brought forward	72	19	0	11
100, 1-inch bolts, and 100, $\frac{3}{4}$ ditto	0	3	2	8
100, $\frac{5}{8}$-bolts	0	0	2	4
50 Principal bars for roof	11	17	1	23
50 Secondary bars	3	16	2	2
50 Tie-rods for principal	4	17	3	2
1 Bag of bolts	0	1	0	17
200 Diagonal stays for roof	1	11	3	26
72 Cast-iron brackets for vertical stays	0	15	2	16
24 Timbers for middle, curb, and king-post	1	0	2	8
48 Tie-rods and bolts for ditto	0	12	0	24
12 Cast-iron carriages, rollers and bolts, complete	2	6	2	0
4 Pigs of lead for ditto	0	3	0	0
2 Extra man-holes, plates and rings, over 18-inch pipes	0	0	3	16
Tons	100	6	3	17
24 Brackets for guide-rods	2	2	0	16
24 Lock-nuts for bottom of guide-rods	0	5	0	16
24 Guide-rods, each 6, 3, 20	9	3	0	8
12 Sets of tripods, each 8, 13, 3, 1	104	5	0	12
528, 1-inch bolts for ditto	0	18	3	12
Tons	116	14	1	8

The following is the weight of a gasometer 50 feet diameter and 18 feet deep, containing 35,300 cubic feet. Top, No. 14 wire-gauge; sides, No. 15 ditto:

	Tons.	Cwt.	Qrs.	lbs.
Ironwork of gasometer	10	14	2	27
Wood-curb and diagonal stays, bolts, etc.	1	19	0	0
Sundry bolts, man-hole, etc.	0	5	0	0
Tons	12	18	2	27
5 Sets of tripods	10	6	1	17
5 Guide-rods	1	0	1	12
Tons	11	6	3	1

Estimate.

	£	s.	d.
Gasometer work, including erection - - - - -	456	2	0
Cast-iron work, at £7 10*s.* per ton - - - - -	85	0	0
	£541	2	0

Tank for the above.

	£	s.	d.
1890 Cubic yards of excavation, at 10*d.* - - - -	78	15	0
176 Cubic yards of puddling at bottom, at 1*s.* 6*d.* -	13	4	0
334 Superficial feet of York landing at bottom of wall, at 1*s.* 9*d.* - - - - - - - -	29	4	6
12½ Rods of stock brickwork in mortar, at £13 -	162	10	0
238 Cubic yards of puddling, and filling in behind wall of tank, at 1*s* 6*d.* - - - - - -	17	17	0
70 Cubic feet of Bramley Fall stone for tripods, at 4*s.* 3*d.* - - - - - - - -	14	17	6
	£316	8	0

A gasometer 36 feet diameter and 12 feet deep contains 12,200 cubic feet, and weighs as follows:—

	Tons.	Cwt.	Qrs.	℔s.
Ironwork of gasometer, sides of No. 18 and top of of No. 17 wire-gauge - - - - - -	2	17	2	1
Wood-curb and diagonals - - - -	1	0	3	13
Stays and bolts - - - - - - - -	2	5	0	7
Sundry bolts, man-hole, etc. - - - - -	0	2	1	0
Tons - -	6	5	2	21
3 Sets of tripods - - - - - - -	4	19	1	0
3 Guide-rods - - - - - - - - -	0	3	0	21
Tons - -	5	2	1	21

Estimate.

	£	s.	d.
Gasometer-work, including erection - - - - -	210	0	0
Cast-iron work at £7 10*s.* ditto - - - -	37	10	0
	£247	10	0

Tank for the above.

	£	s.	d.
752$\frac{2}{3}$ Cubic yards of excavation, at 1*s.*	37	12	8
107 Cubic yards of puddling at the bottom of tank, at 1*s.* 6*d.*	8	0	6
246 Superficial feet of York flagging under wall, at 1*s.* 9*d.*	21	10	6
5½ Rods of brickwork in mortar, at £12 10*s.*	68	15	0
119 Cubic yards of puddling, and filling in behind wall, at 1*s.* 6*d.*	8	18	6
30 Cubic feet of Bramley Fall stone for base of tripods, at 4*s.* 3*d.*	6	7	6
347 Cubic yards of earth carted away, at 2*s.* 2*d.*	37	1	10
	£188	6	6

I have given the above estimates of gasometers that have been executed, to serve as some guide to the knowledge of the cost of that part of the apparatus. The prices of the ironwork will vary considerably at different places, and also from different manufacturers. A few months ago I received estimates from two houses for a gasometer fifty feet diameter and eighteen feet deep, to be delivered in London in convenient sheets for shipment; one price was £250, the other £176. It is requisite, therefore, before deciding, to examine into the merits of the contractors as workmen, and also to determine the precise *meaning* of their tenders.

It is hardly necessary to observe, that the cost of brick-tanks will never be twice alike. If the ground in which the tank of the gasometer represented in the engraving was built, had been less favourable, the thickness of the retaining wall must have been greatly increased, and other expenses incurred, perhaps amounting to one half more than the estimate given here.

The estimates for the tanks of the two last gasometers will seldom be exceeded, as they were built in ground requiring strong rivetments.

If the ground in which the tank has to be built is examined by a *practical* man, the cost can be estimated to within almost a few shillings.

The "working pressure" of a gasometer will depend upon the area of water-surface, and the weight of the vessel itself. For example, in the gasometer quoted as 100 feet diameter, the area of water-surface is 7854 feet, a stratum of which 5$\frac{5}{10}$ths deep, will be equal in weight to the gasometer, viz. 100 tons

5 cwts. Its working-pressure will therefore be equal to a column of water $5\frac{5}{10}$ths of an inch high.

The working pressure of the gasometer 87 feet 6 inches diameter, weighing 38 tons 10 cwt., will be found equal to a column of water $2\frac{7}{10}$ths high, the area of water-surface being 6013·2 feet.

A gasometer 50 feet diameter, weighing 12 tons 18 cwt., will rise with a pressure of $2\frac{8}{10}$ths perpendicular head of water, and a gasometer 36 feet diameter, weighing 6 tons 5 cwt., will work with a pressure equal to a head of water $2\frac{7}{10}$ths of an inch high.

The weight of a cubic foot of river water is 62·5 pounds.

THE GOVERNOR.

The Governor is a machine for regulating and equalizing the flow of gas from the gasometers to the street-mains, and is much more perfect in its action than any slide-valve applied for that purpose requiring attendance. Its use is nowhere sufficiently appreciated. Had it been a complicated piece of machinery, or expensive in its first cost and after application, objections to its adoption would not have been surprising; but it is perfectly simple: its action is certain and unvarying, and its first cost inconsiderable.

The velocity of gas in the mains and pipes of supply is, in the first instance, as various as there are differences in their altitudes and extent. A main at one place will furnish, with a certain pressure of gas, a flame one inch high, while at a different altitude it will furnish a flame double that height. If, again, in the direction of the main, there are many bends, angles, or contractions in its diameter, the velocity of the gas through it will vary considerably more than if it were direct and uniform. If the pipe be of any great length and of an uniform bore, but unequally furnished with branches, the burners will be unequally supplied with gas; those which are near its head will be supplied with a fuller stream of gas than those which are situated towards its termination.

Independently of these differences, arising from diversity of local positions, there will always be one great variation in the velocity of the gas, occasioned by the variety of periods during which lights are required by different consumers supplied from the same main or system of pipes: for example, when a certain number of burners are to be supplied, and it happens that one half are shut off sooner than the rest, the velocity of the gas in the mains will be materially increased, and the remaining lamps must be turned down; but many would not be reduced, and the Company would lose much gas.

The inequality thus occasioned may be seen particularly exemplified in the case of houses situated in the vicinity of any large manufactories, and supplied with gas from the same mains. While the establishments are open, the lights in the adjacent houses are low and feeble, often too much so for the necessary purposes of the consumer; but the moment the manufactories are closed, the great quantity of gas which they previously carried off being transferred to such of the shops or private houses as continue to be lighted, their flames are raised to an extragavant height, and burn with the formation of large quantities of smoke, from the imperfect combustion of the gas. The remedy for all these evils, resulting from the various degrees of velocity of gas through the mains, is to be found in the Governor.

It is true, that at a certain time during the evening, when a number of lights ought to have been turned off, the slide-valve at the entrance of the main on the works may be partially closed by the attendant, but this never effects the object properly; whereas the Governor, besides being self-acting, regulates the supply exactly according to the demand. This is especially valuable where meters are used.

For the purpose of lighting all ordinary districts, one leading main from the works is sufficient, and therefore one governor. If it be necessary to have more than one leading main, a separate governor must be used to each.

Lisbon is an example of a town that would require not less than three separate pipes of supply, because its elevations are great, and rise suddenly in terraces, one above the other; but there are few towns that would present such difficult sections; still, without considering the number of leading mains, I should use governors to them all.

In Plate XVIII. will be found an elevation, in section, and a plan of a governor capable of equalizing the flow of 300,000 cubic feet of gas in twenty-four hours.

A A is a cast-iron tank containing water, five feet four inches diameter, and four feet six inches deep, in which the regulating vessel B B floats.

C is a cone of cast iron, turned true in the lathe, and suspended by an eye-bolt to the top of the floating vessel.

D is the inlet-pipe, having a plate *d* on the top, furnished with an aperture, bored out to fit the diameter of the cone at the base, and which, if raised to that height, will completely shut off the gas from entering the vessel.

E is the outlet-pipe, its diameter being regulated by the distance to which it has to convey the gas to the equilibrium-cylinder of the street-mains.

The floating vessel B, when immersed in water, of course loses a portion of its weight, equal to that of the water which it displaces; and the density of gas contained in it will vary as the immersion. By making the chain F of a proper weight, it may be made to answer the purpose of a regulator of the pressure. Let it be supposed, for example, that the vessel weighs 1000 lbs., and loses 100 lbs. of that weight when immersed in the water, and that a portion of the chain, equal in length to the height which the vessel rises, shall weigh 50 lbs., and the counterbalance weigh 950 lbs.,

	lbs.
Then, when the vessel is immersed, its effective weight is	900
To which must be added the portion of chain now acting, as increasing the weight of the vessel	50
The sum corresponds with the actual weight of the counterbalance	950
Again, let the vessel be elevated out of the water, its actual and effective weight then is	1000
To balance which is opposed the counterpoise	950
And the portion of the chain now removed to the other side of the pulley to counterpoise, and acting with it	50
The sum corresponds with the actual weight of the vessel	1000

The effects of the vessel and counterpoise being thus opposed to each other, the pressure of the gas contained therein is equalized.

By adding or removing the weight of the counterbalance, an increase or decrease of pressure may be effected.

The action of the Governor is as follows. The outlet-pipe is connected with the mains, and the inlet-pipe with the gasometer supplying gas into the machine: it will be evident, that if the density of the gas in the inlet-pipe becomes by any means increased, a greater quantity of gas must pass between the sides of the adjusting cone and the aperture in the plate *d*, the consequence of which will be that the floating vessel will rise, and therefore contract the area of the opening in *d*; and if, on the contrary, the gas in the inlet-pipe decreases in density, the vessel will descend; so that whatever density the gas may at any time assume in the gasometers or mains, its pressure in the floating vessel will remain uniform, and consequently the velocity of the gas passing into the mains will be regular: for when the aperture of the plate *d* would admit more gas than necessary for the supply to the mains, the floating vessel rises and diminishes the area of the inlet-pipe; and when, on the contrary, the inlet does not allow a sufficient quantity of gas to come from the gasometers, the gas passes out of the governor into the mains, and in so doing the vessel descends, and increases the area of the inlet-pipe, to admit the requisite gas into the mains.

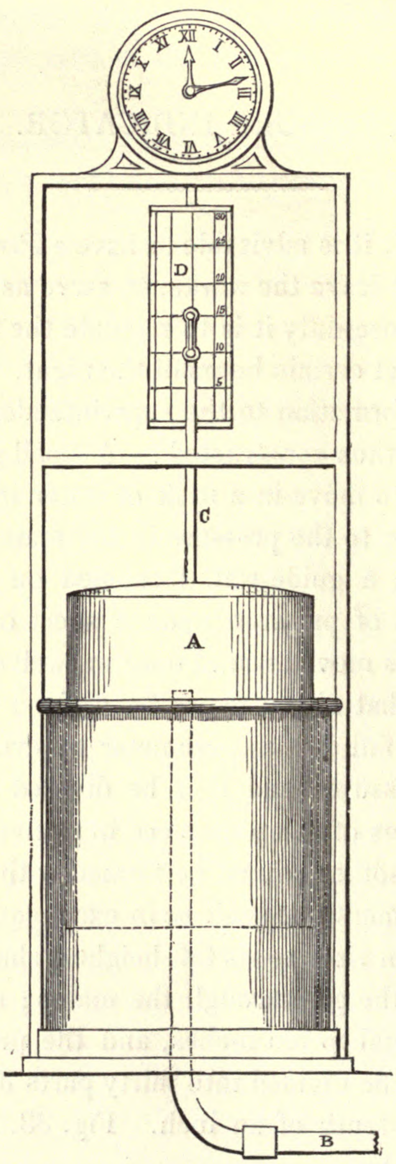
This action is not influenced by any circumstances connected with pressure or velocity, but is constant and uniform, ensuring at all times a proper and sufficient discharge.

PRESSURE INDICATOR.

If a governor be not used, it is advisable to have a *Pressure Indicator* attached to the main or mains that leave the works, to serve as a check upon the conduct of the workmen, whose duty it is to regulate the pressure of gas in them according to the demand at certain hours of the night. It is, in fact, an instrument giving the same information to the superintendent as the "tell-tale" of the station-meter. It is thus constructed:—A small gasometer about twelve inches diameter is made to move in a tank of water in such a manner that it shall rise or fall according to the pressure in the mains, with which it is connected by a small pipe; a guide-rod, furnished on the top with a pencil, marks the exact amount of pressure upon a sheet of paper coiled round a cylinder. This cylinder is moved round once in twelve hours by a time-piece. It is evident, therefore, that if the paper be divided by horizontal lines corresponding to the rise or fall of the gasometer by every tenth of an inch increase or decrease of pressure; and if it be divided by vertical lines corresponding to the revolutions of the time-piece in twelve hours, it will effect the object required. The gasometer must be formed with an air-vessel inside, so that when it is totally immersed it shall be in exact equilibrium with the external atmosphere; and when risen to its full height it shall have a pressure equal to that required to force the gas through the mains; say the height to which the gasometer rises is equal to ten inches, and the pressure required is three inches; then if the paper be divided into thirty parts by horizontal lines, each division will indicate one-tenth of an inch. Fig. 33. represents an elevation of one of these instruments.

A is the gasometer, having double sides, as shown by the dotted lines, which serves as an air-vessel to render the gasometer exactly in equilibrium with the external air when totally immersed in the water. No specific gravity apparatus being attached, it is evident that every different point of immersion will require a different pressure to cause it to rise, and these being known, a correct register is obtained.

Fig. 33.



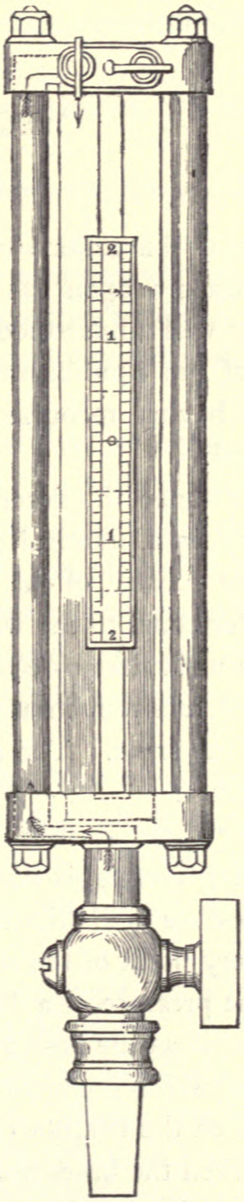
B is the pipe forming the communication between the floating vessel and the main on the *outside* of the valve, by which the opening is regulated.

C is the rod, on the top of which the pencil is fixed.

D is the revolving cylinder, divided into horizontal lines corresponding to five-tenths of an inch, and into vertical lines corresponding to the revolutions of the time-piece.

This instrument was invented by Mr. S. Crosby in 1824, and first applied by Mr. G. Lowe at the works of the Chartered Gas Company.

Fig. 34.



Pressure-gauges, as the name implies, are instruments by which the velocity with which the gas flows into the mains is ascertained. They are made of glass tubes partially filled with coloured water, and furnished with graduated scales divided into inches and tenths from a point in the centre of the scale marked zero.

When no gas is passing into the main to which one of these instruments is attached, the columns of water contained in the tubes are in equilibrium with the external air, and stand at 0. When the gas is admitted, the equilibrium is destroyed; the gas depresses one column and raises the other, the total variation being the amount of pressure. In Fig. 34. I have given a form of gauge which has a very neat appearance; the glass tubes can be taken out and cleaned, which it is difficult to do when the two tubes are connected by a simple bend. The pressure marked in the drawing is thirty tenths or three inches; each column varying fifteen tenths from the zero point.

The length of the tubes and the graduated scale will of course depend upon the quantity of pressure desired to be indicated.

EQUILIBRIUM OF FLUIDS.

Although the actions of various machines already spoken of depend in a great measure upon the laws of hydrostatics and pneumatics, they may be perfectly well understood, without particular reference being made to the theory of the equilibrium and motion of elastic and non-elastic fluids, and without having recourse to the various formulæ by which their effects are calculated.

For instance, in describing the action of a gasometer, it would be only necessary, in a practical point of view, to know that the pressure of the gas upon the surface of the water contained in the tank displaces a column of that water equal to the weight or gravity of the vessel, and causes it to float upwards until the gas ceases to enter, and which, if both ingress and exit are prevented, will remain at the height it has attained as long as the temperature remains the same. The action of all such vessels will depend upon the following laws :—

1. The upper surface of any fluid in any vessel, or in a number of communicating vessels, is horizontal.

2. Pressure is distributed equally in all directions, and acts perpendicularly upon every point of the surface of the vessel which contains that fluid.

3. The pressure of a fluid on the horizontal base of a vessel in which it is contained is as the base and perpendicular altitude, whatever be the shape of the vessel which contains it.

4. When the heights of the same fluid are equal, the pressures are as the bases ; when the bases are equal, the pressures are as the heights ; when both heights and bases are equal, the pressures on the horizontal bottoms are equal in all, however irregular the shape and capacities of the vessels may be.

5. In different vessels containing different fluids, the pressures are as the areas of the bottoms multiplied by their depths, multiplied by their specific gravities.

6. If two fluids (not capable of mixing) are contained in a bent tube, and balance each other, their perpendicular altitudes, measured from the same horizontal plane, will be reciprocally as their specific gravities.

7.—(1.) The specific gravities of bodies are in the same proportion as their weights, when their sizes are equal.

(2.) When the weights are equal, the specific gravities are *inversely* as their sizes.

(3.) When the specific gravities are equal, their weights are *directly* as their sizes.

(4.) When neither the sizes nor the specific gravities are equal, the weights of bodies are as their sizes and specific gravities together.

8. A solid immersed in a fluid, will sink if its specific gravity be greater than that of the fluid; if less, it will float on the surface.

9. The entire weight of a body which will float in a fluid, is equal to the weight of as much of the fluid as the immersed part of the body displaces.

Therefore, as the size of the whole body, is to the size of the part immersed, so is the specific gravity of the fluid, to the specific gravity of the body.

I have previously described the operation of computing the specific gravity of a gas; I shall now point out the methods to be pursued in finding the specific gravities of liquid and solid bodies, which it may frequently be useful to know.

When the body is heavier than water (which is taken here as the standard of comparison, as air in the case of a gaseous fluid), weigh it both in water, and out of water, and the difference of these weights will express the weight lost in water. Then, if its weight is five out of the water, and when immersed three, the weight lost will be two. The rule will be,—

As 2, the weight lost in water, is to 5, the absolute weight, so is 1·0, the specific gravity of water, to 2·5, the specific gravity of the body.

When the body is lighter than water, attach to it a piece of another body heavier than water, so that they may sink together. Weigh the heavier body and the compound body separately, both out of the water and in it, and find how much each loses in water, but subtracting its weight in water from its weight in air, and subtract the less of these remainders from the greater. Then use this proportion:—

As the last remainder, is to the weight of the light body in air, so is the specific gravity of water, to the specific gravity of the body.

Suppose the heavy body to weigh seven out of water and three in water, its loss will be four; and suppose the light body weighs ·65 out, and ·27 in the water, its loss will be ·38; by subtracting ·38 from 3·00, we have 2·62.

Therefore, as 2·62, the last remainder, is to ·65, the weight of light body in air, so is 1·00, the specific gravity of water, to ·24, the specific gravity of the body.

When the specific gravity of a fluid is required, take a piece of some substance of known specific gravity, weigh it both in and out of the fluid, and find the loss of weight by taking the difference of these two; then say,

As the whole or absolute weight, is to the loss of weight, so is the specific gravity of the solid, to the specific gravity of the fluid.

Take 2·31 as the specific gravity of the known substance, suppose its weight out of the fluid to be five, and in the fluid 3·2, the loss will be 1·8.

Therefore, as 5, the whole weight, is to 1·8, the loss, so is 2·31, the known specific gravity, to ·83, the required specific gravity of the fluid.

VALVES.

At page 113 I have already given a description of one hydraulic valve: two different valves are represented in the adjoining figures. The advantages of water-valves are cheapness, durability and certainty of action.

Fig. 35.

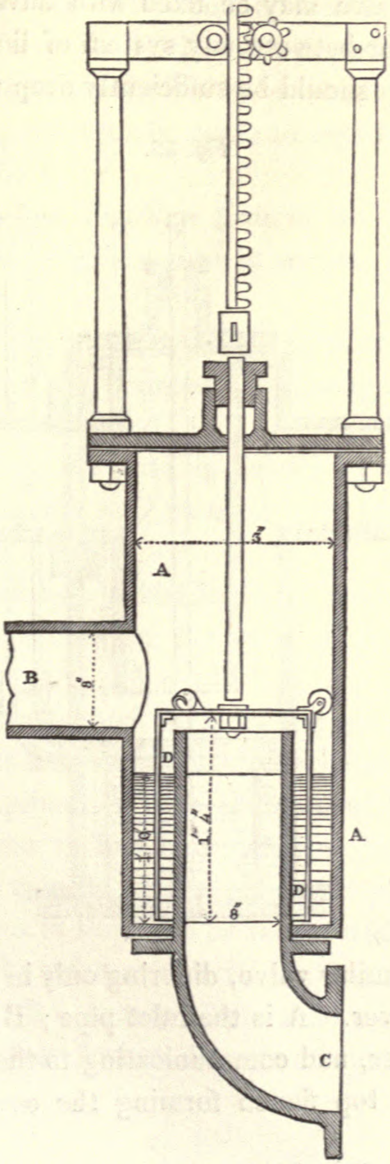


Fig. 35. shows a section of one of these valves: it is formed of an air-tight cylinder A A, containing a portion of tar or water. B is the inlet-pipe, which communicates with the gasometer; C is the outlet-pipe, which conveys the gas to the mains; D D is an inverted cup, ten inches deep, furnished with a rod passing through a stuffing-box, by which it is raised or lowered. When the cup is in the situation shown in the figure, it is evident that the communication between the outlet- and inlet-pipes is shut off by the pressure of a column of water ten inches high. When the cup is raised above the mouth of the outlet-pipe by the rack and pinion, a free passage is left for the gas.

This description of valve may be fixed with advantage between the gas-holders and the mains, or between any system of lime-water purifiers. Care is necessary that the cup should be sufficiently deep for the required pressure.

Fig. 36.

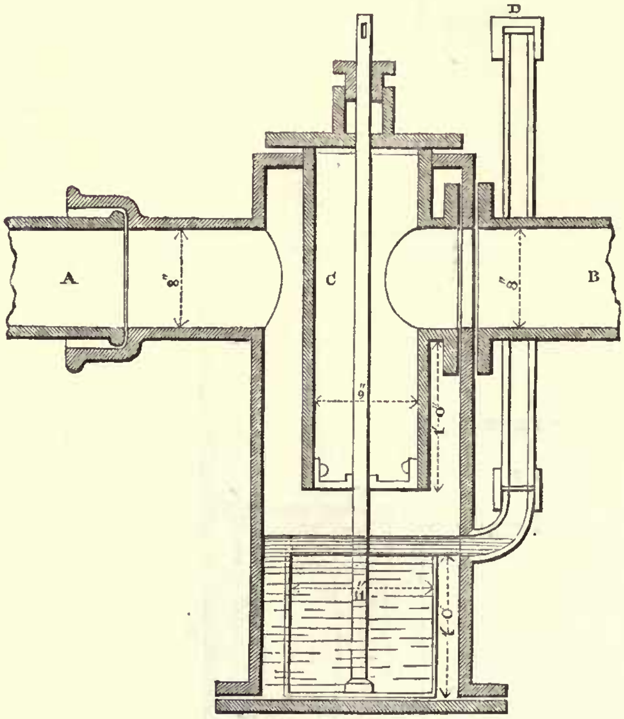


Fig. 36. exhibits a similar valve, differing only in its construction, the outer case serving for a receiver. A is the inlet-pipe; B the outlet, jointed to the side of the outer cylinder, and communicating to the interior pipe C, which is open at the bottom, its top flanch forming the cover to the outer cylinder.

The cup is brought into action by being lifted and immersing the open end of the pipe C into the tar which it contains. It will be observed, that when it is lowered, the tar contained in the receiver, being higher than the edge of the cup, will run into it and fill up the quantity displaced by C. D is a small service-pipe, through which, by a hand-pump, the superfluous tar may be drawn off.

This last form of hydraulic valve may be used in the streets, and the cup raised by a screw on the rod, working through a nut at the bottom of the cup, which, being secured from turning round, would follow the thread of the screw. As receivers must be attached at certain distances along the lengths of the main pipe to drain them of water (and a certain portion of tar and oil which still may remain in the gas even after it has travelled miles), they may be easily formed into valves, and thus be made to answer two purposes. A slide-valve is shown in Plate XIX.

Fig. 1. is an elevation, and Fig. 2. a plan at the top of the stuffing-box. Fig. 3. is a vertical section; Fig. 4. a plan in section, and Fig. 5. a back elevation of a valve.

A is a faced cast-iron disc, which by being raised or depressed opens or shuts off the passage for the gas; it is pressed by the spring B against the part C of the valve-box, which is also faced.

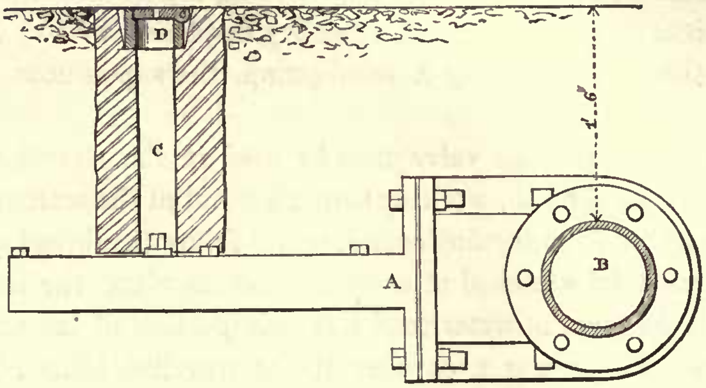
By the rack and pinion, the disc is drawn up into the position shown by the dotted lines, the spring still causing it to work *fair* upon the faced part C.

D is a rod passing through a stuffing-box, and secured by a screw-bolt between the cross feathers cast on the back of the disc A: the same bolt fastens the spring.

The pillars and cross-head which support the pinion are only used in the works. The arrangement for use in the street-mains is represented by Figs. 6 and 7. The rack and pinion is here enclosed within a cast-iron box, the cover being secured by four or five half-inch pins, taped into the sides, and having a hole left for the spindle of the pinion to project through; by this contrivance no dirt can get to the teeth or to the stuffing-box. The position of the valve is explained by reference to the woodcut, Fig. 37.

A is the valve laid flat; B a section of the main; C a bored wooden block, through which the key is passed when the valve requires to be shut or opened;

Fig. 37.



D is a cast-iron plug, closed at the top by a hinged lid, and driven firmly into the wooden block.

The price of these valves is usually about 20*s.* for every inch in the diameter up to twelve inches, beyond which size they increase 10*s.* for every inch. Thus a twelve-inch valve costs £12, and a sixteen-inch valve £14.

If no valve happens to be contiguous to the spot where a main should require repairing, a simple and efficacious contrivance of Mr. G. Lowe may be had recourse to as a substitute. For example, supposing that a fractured pipe had to be taken out from the middle of a long run of main, or a junction had to be made with another; drill a hole about 1½ inch in diameter upon the top of the pipe, on each side of the space to be taken up; through these holes insert empty bladders furnished with small tubes and stop-cocks; when these bladders are inflated, by blowing into them through the tubes, they will fill up the mains and stop the exit of the gas almost perfectly, and form an excellent temporary valve. When the repair is finished, withdraw the bladder, and stop up the drilled hole either by screwing a pin, or driving a wooden plug into it.

STREET-MAINS.

The term main is applied to all cast-iron conduit-pipes that serve to convey gas from the works to the place or district to be lighted, and especially applied to those pipes from which smaller ramifications branch. The diameters of the mains vary from 1½ to 15 or 18 inches, according to the quantity of gas required to be supplied, and the distance it has to flow.

The 1½-inch mains are cast four feet six inches long, the two and three-inch mains about six feet long, and all the other sizes nine feet, with a socket at one end, and a plain bead at the other.

When they arrive at the works, before they are suffered to be laid, every length must be *proved*; that is, water should be forced into them until the internal pressure is equal to a column of water 250 or 300 feet high, and if any moisture appears on the outside having a certain direction or shape, the length must be rejected; for although so minute a fissure may at first be gas-tight, yet after being exposed under the ground to wet and frost, it would soon increase and become leaky.

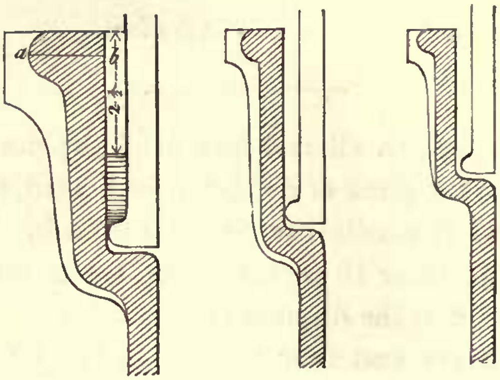
In warm weather, if the pipe is proved by cold water, a dew-point will be formed, which, by condensing the vapour in the atmosphere upon the outside of the pipe, will often deceive the workmen, and lead to the rejection of those that are sound. It is therefore necessary during the summer months to prove pipes with water of the same temperature as the atmosphere.

An experienced workman in the habit of proving pipes will distinguish a perfect pipe from a faulty one with considerable correctness, by the difference in sound produced by blows of a hammer. A perfect pipe will ring when struck, while that having a crack will jar; by this means also a difference in the thickness of metal may be detected.

Sockets.

Nos. 1, 2 and 3, in the adjoining figures, represent the sections of sockets of different-sized pipes to a scale of three inches to one foot. No. 1. is that

Fig. 38.



of mains from nine to fifteen and eighteen inches diameter. The usual thickness of metal is shown by the hatched lines, and is proved to be sufficient; the pipes are occasionally made the thickness marked by the outside line; the reason given being that "thinner metal cracks in making the joints." This is an erroneous idea, since the extra strength must depend on the width of the bead from *a* tó *b*. The *depth* of these sockets is 4½ inches.

No. 2. is a section of the sockets of mains from four to eight inches diameter; their depth four inches.

No. 3. is the thickness of those of a smaller diameter, three inches deep.

The thickness of the main pipes ought to be as follows:—

1½ inches diameter	¼ inch thick.	9 inches diameter	½ inch thick.
2 ———	¼ ——	10 ———	½ — full.
3 ———	¼ — full.	12 ———	⅝ ——
4 ———	⅜ ——	13 ———	⅝ ——
5 ———	⅜ ——	14 ———	¾ ——
6 ———	⅜ — full.	15 ———	¾ ——
8 ———	½ ——	18 ———	⅞ ——

The throat of the socket a little stronger, as shown in Fig. 38.

The annular space left between the bead end of one, and socket of the next pipe, should be about half an inch in the large mains, and not less than three-eighths in the small. The diameters of the sockets must therefore be guided by this.

Joints.

To make the joints, spun yarn is driven between the pipes to within 2½ inches of the lip of the socket, and a good fitting of the two pipes being effected, melted lead is poured into the remaining cavity, which, when set, is caulked or hammered in with a blunt square-pointed chisel. There is no necessity for driving the lead in very hard, as the joint will not be at all the tighter in consequence ; it is very probable that the ordinary sockets before alluded to were split by downright hard-wedging ; no metal will stand against such force. A strict watch must be kept over the men while jointing ; they are very apt to stint the quantity of lead if the work be done by contract.

After a certain length of main-pipe has been laid, it *ought* to be proved, in order to be certain that all the junctures are gas-tight. The most convenient manner of doing this is by means of a portable gas-holder (from two feet six inches to three feet diameter, running upon a truck) filled with common air, and connected, by means of a small service, with the length of mains to be tried. This gasometer should be made to act with a pressure at least four times greater than the pressure of gas they will afterwards have to sustain. If the mains are tight, the vessel will remain stationary ; if not, it will descend in proportion to the extent of the leak.

This is very seldom done, because it is attended with a little additional expense and trouble ; but if an engineer wishes to increase the œconomy of his establishment, he will do well to insist upon every quarter of a mile being proved whilst the mains are in progress of laying. From the careless manner in which the mains are generally laid, more gas is lost than all the œconomy in the works can make up.

The prices commonly given to the foreman pipe-layer for laying mains of the following sizes, by contract, are,—

			s.	*d.*
For 2- and 3-inch mains	4*d.* per yard.	For 10-inch mains	1	0 per yard.
4-inch ditto	4½ ”	12-inch ditto	1	1 ”
5-inch ditto	6 ”	14-inch ditto	1	2 ”
6-inch ditto	6½ ”	18-inch ditto	1	8 ”
8-inch ditto	8 ”			

The foreman will find his own picks and small tools, watchings, coals and candles. The Company is at the expense of repair of lead pipes and roads, carting the mains to the spot, and removing rubbish. The above prices are for laying pipes, the Company finding lead; but it is generally managed so that the contractor finds all material for jointing, and the work is done under the inspection of a Company's servant.

The following is an estimate in detail for laying fifty yards of eighteen-inch pipe:—

	£	*s.*	*d.*
Two joint-makers, at 5*s.*	0	10	0
Eight excavators, at 3*s.* 6*d.*	1	8	0
One potman	0	3	6
Steeling and sharpening tools	0	5	0
Candles and watching	0	3	6
Repair of lead pipes (casual)	0	5	0
„ roads, at 9*d.* per yard	1	17	6
40 lbs. of spun yarn in 16 joints, at 3*d.*	0	10	0
480 lbs. of lead in 16 joints, at 2*d.* per lb.	4	0	0
Carting surplus earth (casual)	1	0	0
	£10	2	6

This brings the cost of laying eighteen-inch pipes to about four shillings per yard, to which must be added the expense of carting the pipes to the work.

The details of the expense of laying sixty yards of twelve-inch pipe will be,—

	£	*s.*	*d.*
Two joint-makers, at 5*s.*	0	10	0
Eight excavators, at 3*s.* 6*d.*	1	8	0
One potman	0	3	6
Steeling and sharpening tools	0	5	0
Candles and watching	0	3	6
Repair of lead pipes (casual)	0	5	0
40 lbs. of spun yarn in 20 joints, at 3*d.*	0	10	0
380 lbs. of lead in 20 joints, at 2*d.*	3	3	4
Carting surplus earth (casual)	0	10	0
	£8	18	4

This brings the cost of laying twelve-inch pipes to about three shillings per yard, to which must be added the item of carting the pipes to the work.

The price of 1*s*. 8*d*. given to the foreman pipe-layer for laying a yard of eighteen-inch pipe, may be divided :—

Digging the trench - - -	8*d*. per yard.
Putting in pipes and making the joints -	4 " "
Filling in the ground and ramming down	5 " "
Watching, coals and candles, tolls -	3 " "
	1*s*. 8*d*. per yard.

Also the 1*s*. 1*d*. for a twelve-inch pipe :—

Digging the trench - - -	6*d*. per yard.
Putting in the pipes and making joint -	2 " "
Filling in the ground and ramming -	2 " "
Watching, coals and candles - -	3 " "
	1*s*. 1*d*. per yard.

The average weight and prices of socket-pipes will be found as in the following Table :—

Diameter.	Thick.	Length.		Weight.			Price per yd.	
in.	in.	ft.	in.	cwt.	qrs.	lbs.	s.	d.
1½	¼	4	6	0	0	25	1	6
2	"	6	0	0	1	9	1	8
3	¼ full.	6	0	0	3	4	2	7
4	⅜	9	0	1	1	11	3	8
5	"	"	"	1	2	23	5	3
6	"	"	"	2	0	2	7	0
8	½	"	"	3	2	4	10	8
9	"	"	"	4	0	5	12	3
10	½ full.	"	"	4	2	20	14	4
12	⅝	"	"	6	2	10	17	6
14	¾	"	"	9	1	6	21	0
15	"	"	"	9	3	18	23	6
16	"	"	"	10	2	0	26	0

1-6 — 12—0—
2" — 16—0—
3 — 22—0—

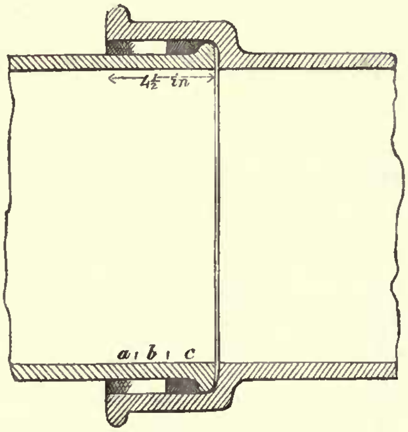
Elastic Joint.

I will now describe a new method of making joints for gas-pipes, which cannot fail to be tight, which is very much cheaper than the use of lead, and possesses other advantages.

Let the pipes be placed in the socket in precisely the same way as for a lead joint; caulk into the bottom of the socket, to the depth of about two inches, white rope-yarn well covered with putty; then at the lip of the socket caulk in tarred gaskets of such a thickness that it will just fit into the annular space left between the pipe and the socket, and to such a depth, that a space of about 1½ inch will be left between the two yarns all round the pipe. At the top of the socket, where the ends of the tar-gaskets meet, draw up a portion to form a "gate," exactly in the same way as for running a lead-joint. Take two parts of melted Russian tallow and one part of common vegetable oil, and pour the mixture, while it is warm, into the "gate;" it will run into and fill up the space between the two yarns. As the mixture does not contract on cooling, and is quite impervious to the air, it must form an air-tight joint.

a is the tarred rope-yarn; *b* the tallow and oil; and *c* the puttied white yarn.

Fig 39.



Mr. Clegg adopted this plan when laying down his atmospheric railway, knowing, from long experience, that lead-joints were not to be depended upon; but jointed upon the above plan, half a mile of nine-inch pipe was found by the barometer to be perfectly air-tight, when exhausted, equal to a pressure of twenty-four inches of mercury.

When mains require to be taken up to be replaced by others, which is frequently the case, the pipes may be drawn out of the socket without trouble; whereas, when the joints are made with lead, the pipes are obliged to be broken before they can be removed, which causes a great sacrifice both of labour and metal.

The depth of mains below the surface of the street ought to be about one foot six, not less. Their course should be as nearly as possible in straight lines, inclining at the rate of 1 in 100.

In order to guard against the danger of water remaining that enters from the external surface into the pipes, and the deposition of other condensed matter, a reservoir should always be placed at the lowest point, where two or more descending mains meet and form an angle, to receive the water, etc. that may happen to collect at this angular point, an accumulation of which would obstruct the passage of the gas through the mains. These receivers ought to be at least twice the diameter of the mains between which they are interposed, and four times that diameter in depth. These receivers afford the best indication of the sound or leaky state of the system of mains. In all instances where the pipes are perfectly sound, observation has shown that half a mile of gas-mains three inches in diameter, does not deposit more than a quart of condensed vapour or water in the year; on the other hand, when the mains are leaky, the water of the reservoir requires to be pumped out, particularly in wet weather, as frequently as once a fortnight. The loss of gas by such leakage is much greater than is generally imagined. In order to keep the common air out of the faulty mains, a constant influx of gas is often necessary; this is of course so much gas lost to the œconomy of the establishment.

In all wide streets, where there are a number of houses to be supplied on both sides, it is more œconomical to employ a separate gas-main for each side of such street than one large main, because much smaller pipes may then be laid down, and the collateral branch-pipes leading to the houses are shorter, which circumstance more than compensates for the additional small main.

DISTRIBUTION OF GAS THROUGH MAINS.

There is no branch of science connected with the subject of gas engineering so highly important as that which relates to its conveyance and distribution through pipes; there is none in which theory affords more assistance, and there is hardly any branch to which so little attention has been paid. The interests of the Company are not best served simply by increasing the quantity of gas from the same quantity of coal, or improving the lime-machine, etc. The laying of street-mains forms the most considerable item in the outlay, and, by a judicious arrangement in the first instance, much may be saved both at first and last.

It is to render this branch of the science and that of the passage of gas through pipes perfectly plain, that the following pages are written. I hope even those previously unacquainted with the subject will find rules and data contained therein by which their practice may be regulated under every probable variation of circumstance. These data are not founded upon theory alone, nor are they advanced with any wish to change existing systems (if there be any); they have been proved to be correct by many years of uninterrupted practice, and I therefore invite my readers to follow the reasonings and examine the principles upon which they are based.

When it is proposed to light any town or district of a town, with gas, the first step to be taken is to ascertain the number of lights, both public and private, that will be required, with as much accuracy as circumstances will permit; the length of time such lights will have to burn, and the quantity of gas consumed by them per hour, making allowances for the increase of lamps that will probably be required by the extension of the town. The size of the works themselves may be easily ascertained from this calculation; it will then remain to fix upon a proper situation in which to erect them. The best local position is upon the banks of a navigable river or canal, and at the lowest available level. It is not possible to give a decided rule for the choice of situation, because the value of ground, and difficulties in many cases connected with purchase, title, etc., will throw obstacles in the way, but the nearest approach to such a situation is advisable for obvious reasons. The erection of the works upon a marshy ground will be attended with more expense, but this is of minor importance to the attainment of a good situation with respect to the level. A map of the town must be obtained, or a survey made of the different streets and thoroughfares; running levels must be taken through them at several points, and their respective heights marked with reference to the level of the works as a datum; upon this map all the mains must be drawn, also their branches, valves, and governors. Their arrangement must be such as to allow of a perfect circulation of the gas, and a nearly uniform pressure at the highest and lowest point. All the pipes upon the same level should be joined into one another, and no valves used but such as are necessary to shut off the gas for repair of mains. To supply a higher level a governor should be placed at the summit of the lower level, with the lower main leading into it. The pipe or pipes for supplying the higher parts should proceed from the regulating vessel. A cellar may be appropriated for the reception of this vessel. One leading main should be taken direct from the works to an equilibrium cylinder situated at some point from which several streets diverge, and no supply taken from this main until it reaches the cylinder. Branches suitable to the supply of each division of the district should lead from this cylinder. The supply of gas to the cylinder should be so regulated as to cause the gas to flow along the branches at an even pressure of about five-tenths of an inch. If the cylinder be at any considerable distance from the works, a smaller main with *increased* pressure may lead *to* it, its size being sufficient to equalize the discharge.

Supposing a district were to be lighted requiring 1000 public or street lamps, and 7000 private burners; it is considered that each lamp on an average will consume five cubic feet of gas every hour, therefore 40,000 cubic feet will be required to light the district for an hour, and the leading main must be capable of delivering that quantity into the equilibrium cylinder in that time. We will suppose that the cylinder is situated at the distance of 440 yards from the gasometers in the works. By referring to the Tables, it will be seen that a twelve-inch main, with a pressure of three inches, will serve. But in determining the size of this main the probable increase of lamps must be taken into consideration; and as that will depend so much upon circumstances in every instance, the judgment of the engineer alone can serve to regulate the additional area. If the increase should be beyond that which was expected, the gas must be forced through the leading main at a greater pressure.

In this example, if the diameter of the main for the *present* consumption be twelve inches, but if to secure an adequate supply at any future period its diameter should be increased to fifteen inches, the *present* working pressure may be reduced to $1\frac{5}{10}$ths of an inch instead of three inches; and as the leakage will also be decreased, the extra-sized main will not be found disadvantageous even in the first instance.

We will suppose again that the level of the district to be lighted varies in no place more than thirty feet from the datum line; in which case the whole district may be supplied direct from the equilibrium cylinder, without the interposition of a governor. The quantity of gas required for each separate street must now be ascertained, and the proper-sized pipes (which will be found in the Tables) be taken from the cylinder down each main street, the pressure being considered equal to five-tenths of an inch. The cross streets will be supplied from the main streets, and the sum of all the quantities and the several distances from one another will give the various diameters of the pipes.

The direction in which the town will be improved or extended is generally pretty well known, therefore there can be no difficulty in arranging the discharge mains so as to meet the extra supply in that quarter. Every main and cross pipe, whatever may be their diameters, must be connected together in every available place, and thus form a *system* of mains. On no other plan can a certain and regular pressure be ensured; deficiencies in the quantity of gas in one place will be made up by a supply from another point, in which there may be an excess, and thus cause a constant circulation. The pressure in the mains will vary directly as the rise above or the fall below the datum line, at the constant rate of one-tenth of an inch for every ten feet. Thus, at those points which rise ten feet *above* the datum the pressure will be increased one-tenth, and will be decreased one-tenth at a point ten feet *below* the datum. If, therefore, these points are connected together, the discharges will be equalized; and so at every intermediate elevation.

The various inconveniences arising from the scarcity of gas in some divisions, and an excess in others, are often severely felt, sometimes to such an extent that the atmospheric air will take the place of the gas, and cause what is termed a " blow." An excess of pressure causes a wasteful expenditure of gas, increases the loss by leakage, and is otherwise injurious. None of these evils will arise if the circulation through the system of mains be perfect. If the general level of any division of the town or district rise more than thirty feet above the datum line, it must be supplied from the lower level, but the pressure equalized by a small governor, similar in construction to that at Plate XVIII., but of smaller dimensions: the principle of its action is the same in both cases. This governor need only be applied where the high level is uniform, and where there are no means of equalizing the pressure by uniting its mains with those of a sufficiently low division. Should there be two distinct portions of the town rising one above the other, like a terrace, each maintaining a general level, they will be more conveniently lighted from different leading mains, the entire arrangements being kept separate.

By these few examples I have endeavoured to convey my ideas of the most œconomical arrangements for street-mains. Though practical knowledge is necessary, theory will lend us considerable assistance in determining the diameters of the various mains necessary to supply the requisite quantities of gas for any length and under any pressure. The following data will furnish every facility for the calculations.

All gases are elastic, or capable in a greater or less degree of compression and expansion. The elastic force is exactly equal to the force of compression. Heat increases and cold diminishes the elasticity of gases; in other words, heat expands and cold contracts. The effect of pressure upon gas is the same as upon any *non*-elastic fluid; and the velocity with which it is discharged through an orifice or tube will depend upon the pressure, and will be as the *square root* of the perpendicular height or head of the water giving that pressure. For example, carburetted hydrogen gas of the specific gravity ·420 will flow through a circular orifice one-fourth of an inch diameter, with a pressure equal to five-tenths of an inch head of water at the rate of eighty cubic feet per hour, and under different pressures, as follows:—

Pressure.	Quantity of Gas in cubic feet by experiment.	Quantity of Gas in cubic feet by calculation.
1 inch.	113·0	111·7
2 —	160·5	160·0
3 —	195·0	193·1
4 —	226·0	226·2
5 —	253·0	253·0

In this last instance the square root of 5 being 2·236,

$$\text{As } \sqrt{50} = {\cdot}707 : 80 :: 2{\cdot}236 : 253{\cdot}0\,;$$

and so for any other pressure, the specific gravity and aperture being the same.

The velocities of different gases under the same pressure will be to one another, inversely, as the square roots of their specific gravities; therefore a heavy gas will be discharged through the same opening with a less velocity than that due to a lighter gas. For example, if coal-gas of the specific gravity ·420, and with a pressure of five-tenths of an inch, flows through a circular orifice one-fourth of an inch in diameter at the rate of eighty cubic feet per hour, gas having the specific gravity ·400 will flow through the same opening at the rate of 81·9 per hour, pressure remaining the same. For by inverse proportion.

As $\sqrt{400} = 20{\cdot}000$

Is to 80, the quantity discharged of the heavy gas,

So is $\sqrt{420} = 20{\cdot}493$

To 81·9, the quantity of lighter gas discharged.

The discharges of the same gas through different openings and under the same pressure, are proportional to the areas of the orifices in circular inches, or to the squares of their diameters. Allowing an excess in the larger openings for the difference of the friction, the results of the following experiments will agree very nearly with this law* :—

Diameter of orifice in inches and parts.	Quantities of Gas discharged in cubic feet per hour. Pressure = $\frac{5}{10}$ths.	
	By experiment.	By calculation.
·25	80	
·50	321	320
·75	723	720
1·00	1287	1280
1·125	1625	1620
1·25	2010	2000
1·50	2885	2880
6·00	46150	46080

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* Allowance must also be made for slight and unavoidable errors, always attendant upon experiments conducted even with the nicest care.

To obtain the velocities of the same gas from any other opening, say,

As the square of given opening,
Is to the given quantity discharged,
So is the required opening
To the required quantity discharged.

It therefore follows, from the preceding corollaries in general, that the discharges of the same gas during the same time, from different openings and under different pressures, are to one another nearly, in the compound ratio, of the squares of the diameters of the openings, and the square roots of the pressures.

By the preceding rules the *initial velocity* of a gas through any opening and under any pressure may be calculated, and it remains to show what effect the *length* of a pipe will produce on the discharge. The quantity of gas of the specific gravity ·420 discharged in one hour through a circular orifice (on the top of a gasometer) six inches diameter, with a pressure equal to five-tenths of an inch head of water, is 46,150 cubic feet.

In order to determine the diminution of velocity sustained by the same gas in passing through similar pipes of different lengths, the following experiments were made by Mr. Clegg and myself. To the outlet-main of a gasometer (which main was sixteen inches diameter) a cast-iron pipe six inches in diameter, and exactly 3·46 yards long, was jointed in a horizontal position, the gas discharged from the open end being allowed to escape. At the end of an hour 44,280 cubic feet was found to have been discharged. For the second experiment an additional piece was jointed on to the first pipe by a thimble, making the length equal to 4·50 yards; at the end of the hour 38,838 cubic feet was discharged. The length was again increased to 7·50 yards, and at the end of an hour the quantity discharged was exactly 30,000 cubic feet. The variation in this last, from the quantity given by calculation, although small, was greater than that in the preceding experiments; we were therefore induced to carry them out considerably further. Three lengths of six-inch pipe were jointed on to the existing length, making altogether 16·50 yards; and the quantity found to be discharged at the end of an hour was 20,270 cubic feet. Three pipes were again added, making an entire length of twenty-five yards; and the quantity of gas discharged at the end of the hour was 16,460 cubic feet. Lastly, three additional pipes were jointed on, making the total length equal to 34·20 yards; and the discharge was 14,080 in the hour. The pressure in all the experiments was equal to a head of water of five-tenths of an inch.

The following Table will show how nearly the results of the experiments agree with those found by calculation:—

Length of pipe.	Quantities of Gas discharged.	
	By experiment.	By calculation.
3·46 yards.	44,280	
4·50 —	38,838	38831·1
7·50 —	30,000	30080·6
16·50 —	20,270	20275·9
25·00 —	16,460	16472·1
34·20 —	14,080	14083·5

It therefore follows that the quantities of the same gas discharged in equal times by a horizontal pipe under the same pressure and for different lengths, are to one another in the inverse ratio of the square roots of the lengths. Hence, when we know the quantity of gas discharged from a given length of pipe, we may find the quantity discharged by any other length with any pressure, and of gas of any specific gravity.

Example of the foregoing rule:—It is required to find the number of cubic feet that will be discharged from a horizontal pipe six inches diameter and 1760 yards long, the specific gravity of the gas being ·420, and the pressure equal to five-tenths of an inch perpendicular head of water. We know that 44,280 cubic feet will be discharged by a six-inch pipe 3·46 yards long; therefore, by inverse proportion, say,

As $\sqrt{1760} = 41{\cdot}952$, the required length,
Is to 44,280, the known quantity discharged,
So is $\sqrt{3{\cdot}46} = 1{\cdot}860$, the known length,
To 1963·2, the required quantity discharged.

We therefore find that the loss by friction in a pipe a mile long is 44,116·8, the initial velocity being equal to 46,080 by calculation.

A horizontal main sixteen inches diameter and 1760 yards long, is laid from the works to the equilibrium cylinder: it is required to know how many cubic feet of gas of the specific gravity ·390 will be discharged with a pressure equal to a head of water of six-tenths of an inch.

We have already found by the last example, that a six-inch pipe one mile long, with a pressure of five-tenths of an inch, will deliver 1963 cubic feet of gas having the specific gravity ·420 in one hour. And to find how much a sixteen-inch main will deliver, same specific gravity and pressure, say, as 36, the square of the diameter of the six-inch pipe, is to 1963, the quantity of gas delivered, so is 256, the square of the diameter of the sixteen-inch pipe, to 13959, the required quantity delivered by a sixteen-inch one mile long. For the difference of specific gravity, say,

As $\sqrt{\cdot 390} = \cdot 197$, the specific gravity of the lighter gas,
Is to 13,959, the quantity delivered of the specific gravity ·420,
So is $\sqrt{\cdot 420} = \cdot 204$, the specific gravity of the heavy gas,
To 14,455 = the quantity delivered of the specific gravity ·390.

And for the difference of pressure, say,

As $\sqrt{\cdot 50} = \cdot 707$, the first pressure,
Is to 14,455, the quantity discharged through a sixteen-inch pipe by that pressure,
So is $\sqrt{\cdot 60} = \cdot 774$, the required pressure,
To 15,824, the required quantity, of specific gravity ·390 discharged from a sixteen-inch pipe, with a pressure equal to six-tenths of an inch head of water.

The actual quantity discharged is about 16,500 cubic feet *.

An accurate experiment was made by Mr. Clegg in the spring of 1831, at the Pancras Station of the Imperial Gas Company, on the quantity of gas discharged through a four-inch main, six miles in length, with a pressure of three inches perpendicular head of water. The specific gravity of the gas was not taken until some hours after the experiment, when it was found to be ·398.

As this experiment exactly bears out the previous rules, I will describe the manner in which it was conducted. A new four-inch main had to be laid for the purpose of supplying parts of the parish of St. Marylebone with gas; after completing a circle of nearly six miles in circumference, it terminated within the distance of a short street from the point at which it left the works. By completing this distance, the two ends of the pipe were brought together

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* This difference of 676 cubic feet from the quantity given by calculation is owing to the decrease of friction in the sixteen-inch pipe, the *rubbing surface* bearing a smaller proportion to the area than in a six-inch pipe. The exact amount of this difference has never been satisfactorily determined; I have therefore omitted the consideration of it in my calculations. At present, practice must give the amount.

on exactly the same level. There were no short bends, and all the services and branches were closed. The pipe measured exactly six miles in length. The leakage was ascertained in the first place by shutting the valve adapted to the returned end, and observing the gasometer; it was found to be thirty-three cubic feet at the end of one hour, and was allowed for. At the commencement of *another* hour the valve was opened and free passage given to the gas, which was allowed to escape: by observing the gasometer at the end of this hour, it was found that 885 cubic feet had been expended; deducting thirty-three cubic feet from this for the leakage, 852 will remain for the actual quantity discharged at the end of six miles. This experiment is valuable to the practical man, both for the unquestionable data it supplies, and for its close approximation to the rules here laid down.

The quantity discharged by calculation is - - - 873 cubic feet.
By experiment - - - - - - - - 852 „
Difference - - 21 „

Tables of the different quantities of Coal-Gas of the Specific Gravity ·420, delivered in one hour, from horizontal pipes of different diameters and lengths, and under different pressures.

Quantities delivered by a two-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
10	2896	3558	4135	4923	5792	6950
15	2364	2904	3331	4089	4728	5768
20	2047	2507	2886	3541	4094	4994
25	1830	2241	2580	3165	3660	4465
30	1673	2049	2368	2894	3346	4082
40	1445	1770	2037	2490	2890	3525
50	1294	1585	1824	2238	2588	3157
100	915	1121	1290	1582	1830	2232
150	748	916	1054	1304	1496	1825
200	647	792	912	1119	1294	1578
250	579	709	816	1010	1158	1412
300	522	639	736	903	1044	1273
400	457	559	644	790	914	1115
500	409	500	576	707	818	997

Quantities delivered by a three-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
10	6516	7981	9187	11272	13032	15899
20	4606	5642	6494	7964	9212	11238
30	3764	4610	5307	6511	7528	9184
40	3258	3990	4593	5635	6516	7949
50	2911	3565	4104	5036	5822	7102
100	2059	2522	3303	3562	4118	5023
150	1682	2060	2371	2909	3364	4004
200	1456	1783	2052	2518	2912	3552
250	1302	1594	1835	2252	2604	3176
300	1188	1455	1675	2055	2376	2898
400	1029	1260	1450	1780	2058	2510
500	920	1126	1297	1591	1840	2244
600	840	1027	1184	1453	1680	2049
700	778	953	1096	1345	1556	1898
800	728	892	1026	1259	1456	1776
900	686	840	967	1186	1372	1673
1000	651	797	917	1126	1302	1588
1760	490	600	690	847	980	1195

Quantities delivered by a four-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
50	5177	6341	7299	8956	10354	11263
100	3660	4483	5160	6331	7320	8930
150	2990	3662	4215	5172	5980	7295
200	2589	3169	3670	4478	5178	6317
300	2113	2588	2979	3655	4226	5155
440	1755	2149	2474	3036	3510	4282
500	1637	2005	2308	2832	3274	3994
600	1495	1831	2007	2686	2990	3647
700	1384	1695	1951	2394	2768	3376
880	1234	1511	1739	2134	2468	3012
900	1220	1494	1720	2110	2440	2976
1000	1157	1417	1631	2001	2314	2823
1760	872	1068	1229	1508	1744	2127
2640	712	869	1003	1231	1424	1737
3520	617	755	869	1067	1234	1505
5280	504	617	710	871	1008	1229
7040	431	528	607	745	862	1051
8800	390	477	549	674	780	951

Quantities delivered by a five-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	5724	7010	8095	9914	11448	14021
150	4673	5724	6609	8095	9347	11898
200	4047	4987	5724	7010	8095	9914
300	3305	4047	4673	5724	6609	8095
440	2729	3342	3959	4726	5457	6684
500	2560	3135	3620	4434	5119	6270
600	2337	2862	3305	4047	4673	5724
700	2163	2650	3060	3747	4327	5299
880	1979	2363	2729	3342	3959	4726
900	1908	2337	2698	3305	3816	4673
1000	1810	2217	2560	3135	3620	4434
1760	1364	1671	1979	2363	2729	3342
2640	1114	1364	1575	1979	2228	2728
3520	965	1181	1364	1671	1929	2363
5280	788	965	1114	1364	1575	1929
7040	682	835	965	1931	1364	1671
8800	610	747	863	1056	1220	1494
10000	572	701	809	991	1145	1402

Quantities delivered by a six-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	8242	10095	11657	14276	16484	20190
150	6730	8242	9517	11657	13460	16484
200	5828	7138	8242	10095	11657	14276
300	4759	5828	6730	8242	9517	11657
440	3929	4813	5557	6806	7858	9626
500	3686	4515	5213	6384	7372	9030
600	3365	4121	4759	5828	6730	8242
700	3115	3816	4406	5396	6230	7632
880	2778	3403	3929	4813	5557	6807
900	2747	3365	3886	4759	5494	6730
1000	2606	3192	3686	4515	5213	6384
1760	1965	2406	2778	3403	3929	4813
2640	1604	1965	2269	2778	3208	3929
3520	1389	1702	1965	2406	2778	3403
5280	1134	1389	1604	1965	2269	2778
7040	982	1149	1389	1702	1965	2298
8800	879	1076	1287	1521	1758	2152
10000	824	1010	1166	1428	1648	2019

Quantities delivered by a seven-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	10876	13219	15380	18837	21752	26438
150	8879	10876	12557	15380	17758	21751
200	7689	9475	10876	13219	15378	18951
300	6279	7689	8879	10876	12559	15378
440	5185	6350	7520	8979	10370	12700
500	4864	5956	6878	8425	9728	11913
600	4439	5438	6279	7689	8879	10876
700	4110	5035	5814	7120	8220	10070
880	3760	4490	5183	6350	7520	8979
900	3625	4439	5126	6279	7250	8879
1000	3439	4212	4864	5956	6878	8425
1760	2592	3175	3760	4490	5183	6350
2640	2117	2592	2994	3760	4233	5183
3520	1880	2244	2592	3175	3760	4488
5280	1497	1880	2117	2592	2994	3760
7040	1296	1586	1880	2244	2592	3173
8800	1159	1419	1640	2006	2318	2839
10000	1088	1322	1538	1884	2175	2644

Quantities delivered by an eight-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	14653	17946	20723	25380	29306	35892
150	11964	14653	16920	20273	23928	29306
200	10361	12690	14653	17946	20723	25380
300	8460	10361	11964	14653	16920	20723
440	6986	8556	9879	12100	13972	17112
500	6553	8026	9268	11350	13106	16052
600	5982	7327	8460	10361	11964	14653
700	5538	6783	7833	9592	11076	13566
880	4940	6050	6986	8556	9879	12100
900	4884	5982	6908	8460	9768	11964
1000	4634	5675	6553	8026	9268	11350
1760	3493	4278	4940	6050	6986	8556
2640	2852	3493	4033	4940	5704	6986
3520	2470	3025	3493	4278	4940	6050
5280	2017	2470	2852	3493	4034	4940
7040	1746	2139	2470	3025	3493	4278
8800	1562	1918	2209	2702	3122	3836
10000	1465	1795	2072	2538	2931	3589

Quantities delivered by a nine-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	18544	22714	26227	32121	37089	45427
150	15142	18544	21414	26227	30285	37089
200	13113	16060	18544	22714	26227	32121
300	10708	13113	15142	18544	21414	26227
440	8840	10829	12502	15313	17680	21658
500	8293	10159	11727	14364	16587	20317
600	7571	9272	10708	13113	15142	18544
700	7009	8586	9913	12141	14017	17172
880	6251	7657	8840	10829	12502	15313
900	6181	7571	8743	10708	12363	15142
1000	5863	7182	8293	10159	11727	14364
1760	4420	5413	6250	7657	8840	10827
2640	3609	4420	5094	6250	7218	8840
3520	3125	3828	4420	5170	6250	7657
5280	2547	3125	3609	4420	5094	6250
7040	2210	2585	3125	3828	4420	5170
8800	1978	2421	2896	3422	3955	4842
10000	1854	2271	2622	3212	3709	4543

Quantities delivered by a ten-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	22896	28042	32380	39656	45792	56084
150	18694	22896	26438	32380	37388	47592
200	16190	19828	22896	28042	32380	39656
300	13219	16190	18694	22896	26438	32380
440	10915	13368	15436	18905	21830	26736
500	10239	12540	14480	17736	20478	25080
600	9347	11448	13219	16190	18694	22896
700	8654	10599	12242	14989	17308	21198
880	7718	9453	10915	13368	15436	18905
900	7632	9347	10793	13219	15264	18694
1000	7240	8868	10239	12540	14480	17736
1760	5458	6684	7718	9453	10915	13368
2640	4456	5458	6302	7718	8912	10915
3520	3859	4726	5458	6684	7718	9453
5280	3151	3859	4456	5458	6302	7718
7040	2729	3342	3859	4726	5458	6684
8800	2441	2989	3452	4227	4882	5978
10000	2290	2804	3238	3966	4579	5608

Quantities delivered by an eleven-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	27704	34640	39180	47984	55408	69280
150	22620	27704	31990	39180	45240	55408
200	19590	23992	27704	34640	39180	47984
300	15995	19590	22620	27704	31990	39180
440	13207	16180	18678	22876	26414	32360
500	12390	15174	17522	21460	24780	30348
600	11310	13852	15995	19590	22620	27704
700	10471	12824	14810	18137	20982	25648
880	9339	11438	13207	16180	18678	22876
900	9235	11310	13060	15995	18469	22620
1000	8761	10730	12390	15174	17522	21460
1760	6604	8090	9339	11438	13207	16180
2640	5392	6604	7626	9339	10784	13207
3520	4670	5719	6604	8090	9339	11438
5280	3813	4670	5392	6604	7626	9339
7040	3302	4045	4669	5719	6604	8090
8800	3164	3876	4475	5481	6328	7751
10000	2770	3464	3918	4798	5541	6928

Quantities delivered by a twelve-inch Main in cubic feet.

Length of pipe. in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	32968	40380	46628	57104	65936	80760
150	26920	32968	38068	46628	53840	65936
200	23312	28552	32968	40380	46628	57104
300	19036	23312	26920	32968	38068	46628
440	15716	19252	22228	27224	31432	38504
500	14744	18060	20848	25536	29488	36120
600	13460	16484	19036	23312	26920	32968
700	12460	15264	17624	21584	24920	30528
880	11112	13612	15716	19252	22228	27224
900	10908	13460	15544	19036	21816	26920
1000	10424	12768	14744	18060	20848	25536
1760	7860	9624	11112	13612	15716	19252
2640	6416	7860	9076	11112	12832	15716
3520	5556	6808	7860	9624	11112	13612
5280	4536	5556	6416	7860	9076	11112
7040	3928	4596	5556	6808	7860	9624
8800	3516	4304	5148	6084	7032	8608
10000	3297	4038	4663	5710	6594	8076

Quantities delivered by a thirteen-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	38694	47390	54722	67020	77388	94780
150	31593	38694	44680	54722	63186	77388
200	27361	33510	38694	47390	54722	67020
300	22340	27361	31593	38694	44680	54722
440	18447	22592	26082	31950	36894	45184
500	17304	21194	24472	29972	34609	42388
600	15796	19347	22340	27361	31593	38694
700	14625	17912	20683	25331	29250	35824
880	13044	15975	18447	22592	26082	31950
900	12898	15796	18241	22340	25796	31593
1000	12236	14986	17304	21194	24472	29972
1760	9223	11296	13044	15975	18447	22592
2640	7531	9223	10650	13044	15062	18447
3520	6522	7987	9223	11296	13044	15975
5280	5325	6522	7531	9223	10650	13044
7040	4611	5648	6520	7987	9223	11296
8800	4125	5052	5833	7143	8250	10104
10000	3869	4739	5472	6702	7739	9478

Quantities delivered by a fourteen-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	44876	54961	63464	77727	89752	109923
150	36641	44876	51818	63464	73282	89752
200	31732	38864	44876	54961	63464	77727
300	25909	31732	36641	44876	51818	63464
440	21394	26202	30256	37056	42788	52404
500	20069	24580	28382	34760	40138	49159
600	18320	22438	25909	31732	36641	44876
700	16961	20774	23987	29378	33923	41548
880	15128	18528	21394	26202	30256	37056
900	14959	18320	21155	25909	29917	36641
1000	14191	17380	20069	24580	28382	34760
1760	10697	13101	15128	18528	21394	26202
2640	8734	10697	12352	15128	17468	21394
3520	7564	9264	10697	13101	15128	18528
5280	6176	7564	8734	10697	12352	15128
7040	5348	6550	7564	9264	10697	13101
8800	4784	5859	6765	8286	9568	11718
10000	4488	5496	6346	7773	8975	10992

Quantities delivered by a fifteen-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	51516	63094	72855	89226	103032	126188
150	42061	51516	59485	72855	84122	103032
200	36427	44613	51516	63094	72855	89226
300	29743	36427	42061	51516	59485	72855
440	24558	30078	34745	42538	49116	60156
500	23037	28215	32580	39886	46074	56430
600	21031	25758	29743	36427	42061	51516
700	19471	23848	27544	33725	38942	47696
880	17365	21269	24588	30078	34730	42538
900	17138	21031	24285	29743	34276	42061
1000	16290	19943	23037	28215	32580	39886
1760	12280	15039	17365	21269	24588	30078
2640	10026	12880	14179	17365	20052	24588
3520	8683	10633	12280	15039	17365	21269
5280	7092	8683	10026	12280	14179	17365
7040	6140	7519	8683	10633	12280	15039
8800	5492	6725	7767	9511	10984	13450
10000	5151	6309	7285	8923	10303	12618

Quantities delivered by a sixteen-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	58612	71784	82892	101520	117224	143568
150	47856	58612	67640	82888	95712	117224
200	41444	50760	58612	71784	82888	101520
300	33840	41444	47856	58612	67640	82888
440	27944	34224	39520	48400	55688	68448
500	26212	30104	37072	45400	52424	60208
600	23928	29306	33840	41444	47856	58612
700	22112	27132	31332	38368	44224	54264
880	19760	24200	27944	34224	39520	48400
900	19536	23928	27630	33840	39072	47856
1000	18536	22700	26212	30104	37072	45400
1760	13972	17112	19760	24200	27944	34224
2640	11408	13972	16136	19760	22816	27944
3520	9880	12100	13972	17112	19760	24200
5280	8068	9880	11408	13972	16136	19760
7040	6981	8556	9880	12100	13972	17112
8800	6248	7672	8836	10808	12496	15444
10000	5861	7178	8289	10152	11722	14356

Quantities delivered by an eighteen-inch Main in cubic feet.

Length of pipe in yards.	Pressure in inches and parts. Perpendicular head of water.					
	0·50	0·75	1·00	1·50	2·00	3·00
100	74178	90855	104904	128484	148356	181710
150	60570	74178	85662	104904	121140	148356
200	52452	64242	74178	90855	104904	128484
300	42831	52452	60570	74178	85662	104904
440	35361	43317	50004	61254	70722	86634
500	32174	40635	46908	57456	64348	81270
600	30285	37089	42831	52452	60570	74178
700	28035	34344	39654	48564	56070	68688
880	25002	30627	35361	43317	50004	61254
900	24726	30285	34974	42831	49452	60570
1000	23454	28728	32174	40635	46908	57456
1760	17685	21658	25002	30627	35361	43317
2640	13436	17685	20412	25002	26872	35361
3520	12500	15313	17685	21658	25002	30627
5280	10206	12500	13436	17685	20412	25002
7040	8842	10830	12500	15313	17685	21658
8800	7911	9684	11583	13689	15822	19368
10000	7418	9086	10490	12848	14836	18170

In the foregoing Tables I have considered the mains as *horizontal.* The quantities of gas noted as passing through them are in many instances checked by experiment, and may be safely relied on in practice. Inequalities of interior surface will affect the passage of the gas through the pipes; but as those inequalities constantly vary, no rules can be given by which to ascertain the amount. The quantities given for the discharge through pipes above six inches in diameter are too small, according to the French mathematicians, and strictly they are so. The question is yet to be answered, What influence does the diminution of surface in a large pipe exert over the discharge? Some years ago I calculated the size of a pipe according to the data given by them, and I found it necessary to increase the pressure three-tenths of an inch beyond the calculated pressure, to produce the desired effect. A four-inch pipe six miles long will discharge 852 cubic feet of gas with a pressure of three inches; an eight-inch pipe will certainly discharge more than four times that quantity under the same circumstances, but there is no correct data from which the extra discharge can be calculated. This being the case, the prudence of constructing the tables for pipes beyond the diameter of six inches will be questioned; but to this charge I plead " not guilty," since the expense of laying down a pipe of half an inch more than the exact diameter will be scarcely felt, and for which the decrease of leakage will amply compensate. For the discharge of the quantity of gas through a sixteen-inch pipe given in the Tables, probably a pipe of fifteen inches diameter would serve, and this would be the extent of the variation.

In mains rising *above* the horizontal line the quantity of gas delivered by them will be greater, and in mains falling *below* that line it will be less. In the first instance, the resistance offered to the flow of gas by the atmospheric pressure will be lessened, and in the latter it will be increased, and will cause a difference in the necessary pressure for the discharge of the gas of one-tenth of an inch head of water for every ten feet rise or fall. For example, if a six-inch main one mile long laid horizontally, supply 1963 cubic feet of gas in an hour, with a pressure of five-tenths of an inch head of water, it would supply the same quantity with a pressure of four-tenths of an inch at an elevation of ten feet above the level of the curb of the gas-holder; and likewise, if the point to be supplied were ten feet below the works, the pressure given must be equal to six-tenths of an inch. From this it is obvious, that sections of the town to be lighted are necessary, as well as a map. The quantity of elevation or depression of the main must be measured from a horizontal line drawn at the level of the governor to the *end* of that main, because the differences of altitude at any intermediate parts of the length will counteract one another.

The effect of bends and angles in the main, upon the quantity of gas delivered, is essentially a matter of experiment: they may be considered as so many mechanical obstructions. The results of the following experiments will show, in some measure, what allowance to make for quadrant, semicircular, and right-angle bends. A two-inch pipe thirty feet long, perfectly horizontal and free from obstructions, delivered 2898 cubic feet of gas in one hour, with a pressure of five-tenths of an inch head of water. The same pipe, disconnected in the middle of its length, and returned by a semicircular bend to the point at which it left the gasometer, delivered 2754 cubic feet in the same time, being a difference of nearly one-twentieth in the whole quantity. The semicircular bend was removed and a quadrant bend substituted, making the two fifteen-foot lengths of pipe form a right angle with one another; the quantity delivered was 2834 cubic feet in the hour, a difference of about $\frac{1}{45}$th of the first discharge. Again, the pipes were disconnected, and a right-angle bend substituted for the quadrant; the quantity delivered in the hour was 2824, a difference of $\frac{1}{39}$th of the first discharge.

In Mr. Clegg's Journal I have the results of some experiments on the same subject; they serve to show that the obstruction to the flow of the gas is very nearly as the number of bends, two semicircular bends making twice the difference, three bends three times, and so on. One semicircular and one right-angle bend forms an obstruction equal to the sum of the two, or $\frac{1}{20} + \frac{1}{39}$; and this seems to be the same under all variation of circumstances.

These results may be explained by the tendency of fluids to flow in right lines and the obstructions formed, by the bends causing a reaction in the contrary direction to the flow; thus friction is increased, and the velocity decreased in the same ratio. In pipes of large diameter the effects of bends will not be so much felt, because the *surface* will bear a less proportion to the area than in those of smaller diameter, and consequently the friction is not so considerable.

I have been favoured with the following, by Mr. G. A. Jermyn, whose abilities in the surveying of towns for the purposes of distributing mains, have tended in many instances greatly to facilitate the operations in the first instance, and the regulation of the works afterwards:—

> " In lighting towns with coal-gas, there is no branch more worthy consideration than the arrangement of the mains, their ramifications, and the apparatus connected immediately with them, in order that every part may be in perfect keeping with the size of the magazine from which they draw their supply. To effect this a plan of the town should be obtained; and not only is a plan giving the lengths and widths of streets necessary, but their respective levels are indispensable, for upon this latter point many circumstances will depend. Having ascertained the number of lights required in each particular street, the main must be in accordance not only as to the value of 'diameter,' but as to the density of supply likely to be obtained from its peculiar level, taking the gas-holder curb always as a datum. Errors entailing a permanent expense and inconvenience have been the result of the operations of most of the great companies, from this simple point having been neglected, and many irregularities have come under my own observation; for instance, in a street of half a mile in length, where one, or at the most two receivers, would have sufficed to drain the pipes, not less than twelve have been discovered when taking up the main, and this was undoubtedly in consequence of not having a proper map of reference as to where receivers had been laid down; the extra ten vessels would have covered the expense of making a map.
>
> " Experience has made manifest how necessary it is to have a perfect record of every

feature in this branch of gas-lighting, and a good plan *drawn to a large scale* is the only available method that can be adopted; no *written* description will answer.

“In commencing operations for the survey, take several running levels from the works with your first ‘back sight’ on the curb of any of the gasometer tanks, and fix upon some spot commanding the entrance into several streets, for the position of the equilibrium cylinder or chamber into which the *leading main* empties itself: this point should be as nearly as possible on the same level as the works: if it should be a little lower no matter, but carefully avoid having its altitude much greater, as its discharge will not be so readily appreciated. Still there are circumstances which will determine the position of this ‘starting-point’ even of greater consequence than the level, and those are the localities of the principal streets; and that point where several meet must be fixed upon as the place for the equilibrium cylinder. In the margin of the map the level and distance of this point from the works must be marked, the level in red, either above or below a line, as $\overline{5{\cdot}75}$ would signify a fall, $\underline{5{\cdot}75}$ a rise of 5·75 above the datum; the length should be marked opposite in black ink. If there is room upon the map, the level may be marked as above, within a circle on the spot.

“As the mains are laid from this point, let them be carefully plotted from the measurement-book, so that their exact position will be apparent at one view; the valves, receivers, and branches distinctly marked, and the relative positions of water-pipes, sewers, &c. occurring in the same street, that may be met with on opening the ground, or otherwise known.

“Draw the line indicating the mains with a permanent colour; ultra-marine is the best, as it never fades, and is capable of being washed out in case of alterations; the plan is thus preserved distinct by avoiding erasures, which must be made if the line is marked with any but a body-colour. Show the valves by a blue cross, and receivers by a small circle at every point at which they may occur, and let the directions of their drainage be marked by arrows. If the map be to a small scale, write the name of each street within the line of buildings, and suffer no interference with the spaces, by any description but what distinctly belongs to the mains and apparatus. If any remarks are necessary, they must be written in the margin of the map, and referred to by a corresponding symbol. Show the connections; and where mains cross one another, note if under or over. It was a custom to indicate the different sizes of mains by different colours: this is a very bad method, for reasons which must be obvious; for the positive colours are few in number and are liable to fade, and even under some influences to change their colour completely. Draw the lines with ultra-marine of comparative thickness, and mark the diameter with a red figure, dotting to crosses at the termination of the lengths of the respective sizes. It is also advisable that the position of the public lights should be shown, as also the district and parish boundaries. A small book should accompany each map, in which the names of the streets should be set down alphabetically, and the levels of the different points with respect to one another, and with the datum, should be distinctly noted, together with remarks on the work, impediments met with, price given for laying, etc., and all dates.

"If the town to be lighted is of two distinct levels, or has one part so much above or so much below the datum as to require to be supplied by a street-governor, such districts must be indicated in the map by a coloured boundary-line (yellow, for example), and the levels of the upper or lower district, taken from their respective governors as well as from the original datum-line, and marked as before directed in the margin, distinguishing the two by letters, as D original datum, G governor, thus: $\frac{35{\cdot}27}{D}\ \frac{2{\cdot}25}{G}$, or $\frac{D}{35{\cdot}27} \mid \frac{G}{2{\cdot}25}$. The first will signify that the point is 35·27 above the original datum, and 2·25 above the street-governor; the last as much below.

"I have frequently been employed to construct maps, after the mains have been laid, companies having found them to be indispensable, if a correct and systematic code for the supply and repairs is to be framed. The time occupied and the expense incurred in the construction of such maps will be evident, besides their necessary imperfections. Of so much importance do I consider correct maps, that I would as soon think of making a steam-engine without a drawing as lighting a town without a map."

SERVICES.

Services are wrought-iron or pewter tubes, for the purpose of supplying the interior of houses with gas from the mains; every small tube on to which a burner is fixed, whether for public or private use, is called a *Service*. The arrangement of these tubes, and their adaptation to the interior of private dwellings, shops, &c., is a separate branch of business, and "fitters" are almost universally employed, who work quite independently of the Gas Company. Public lights are generally fitted by the Company.

The few precautions necessary to the proper arrangement of services will be found in the following remarks. It must be obvious that the art of arranging the pipes and adapting them, is one of that class of operations in which it is a real saving to employ the best materials and good workmen, to avoid repairs and subsequent alterations of the work. The supply and distribution of the services, or the *fitting up*, as it is termed by the workmen, may be done almost at any price with regard to workmanship and materials. The price is usually estimated by the number of burners, or by the yard run of service, adding so much for union joints and burners.

In order that the pipes for conveying the gas from the mains and distributing it through the houses or other buildings to be lighted, may in the first place be neither unnecessarily large or too small, the following rule is given:

One gas-lamp consuming four cubic feet in an hour, if situated forty feet from the main, requires a service not less than a quarter of an inch in the bore.

Two lamps, 40 feet from the main, require a three-eighth service.

Three lamps, 30 feet from the main, require a three-eighth tube.

Four lamps, 40 feet from the main, require a half-inch surface.

Six lamps, 50 feet from the main, require a five-eighth service.

Ten lamps, 100 feet from the main, require a three-quarter service.

Fifteen lamps, 130 feet from the main, require an inch service.

Twenty lamps, 150 feet from the main, require a service 1¼ in diameter.

Twenty-five lamps, 180 feet from the main, require a 1⅜ service.

Thirty lamps, 200 feet from the main, require a service 1½ in diameter.

It is desirable that all bends should be circular, but it is impossible to make them so in many instances, as they would have an unsightly appearance. No branch ought to proceed from a service of a quarter of an inch in the bore, and no more than two from a three-eighth service. All pipes, before they are fixed, must be proved by condensing air into them by means of a hand-syringe while under water; the leak will be easily detected by the air-bubbles which rise through the water. For conducting the gas from the street-mains into the interior of a house, or any building to be lighted, a wrought-iron pipe of sufficient diameter is tapped into the main, and carried in a straight line to the nearest wall of that building, through which it must pass; and on the inside be furnished with a good stop-cock. If all the fittings rise from the main no siphon is necessary, but if any part of them fall below the main a small receiver must be attached to the lowest point, fitted with a screw-plug at the bottom, so that any moisture may be drawn off. The pipes which convey the gas to the burners must be in as direct a line as possible, to avoid unnecessary expense and obstructions. The union joints used to connect two services together must be of the same diameter as the pipes, and soldered firmly on to them. It is customary with workmen when they prove their pipes to coil them up, place their thumb over one end and suck the air out from the other; if the tongue adheres, it is a proof of a vacuum existing in the pipe, which is therefore faultless.

A useful little book has lately been published by Mr. J. W. Parker, West Strand, entitled "Hints to Gas Consumers," from which I have taken the following extracts:—

"The excessive cost and defective construction of fittings have in numerous instances tended more than anything besides to engender prejudices against gas, and more particularly in private houses. No greater annoyance can well be imagined than, after expending a considerable sum in fitting up one's premises, to have the odour of gas diffused throughout the most frequented apartments. This can only happen through defects in the fittings, or from ignorance, or culpable neglect on the part of those whose duty it is to open and close the cocks by which gas is admitted to the burners.

"Gas-fittings ought to be made of the best materials; they should be judiciously arranged, and fixed by sober and skilful workmen. The choice of a situation for the main cock is of importance; it should be placed as near as possible to the inside of the wall through which the gas is admitted from the street-main, and where it will at all times be accessible to the inmates of the house. The key or *spanner* by which it is turned should always be attached, and the nick which indicates whether it is open or shut should be distinctly marked. The cock should be literally a *stop*-cock, a caution applicable to all gas-cocks; for it has of late become so much the fashion, in studying the *ornamental* to neglect the *useful*, that even a practised hand is sometimes at fault. Whatever be the style of fittings, however massive or rich in embellishment, the stop-cocks should be made on one uniform principle, and the more simple they are the better.

* * * * * *

"Throughout their various ramifications the pipes should have a slight inclination towards the point where the main-cock is fixed, and thence to the street-main; this is to allow the water, which is occasionally deposited in them, to drain off without interrupting the passage of the gas. In fittings which are not thus arranged the water accumulates in some curvature of the pipes, and occasions an oscillation, or, as it is very commonly called, *jumping* of the lights. When this happens, the first thing to be ascertained is, whether the cause be *general* or *partial*; that is, if it exist in the street-mains, or in the consumer's fittings. If the lights in the immediate neighbourhood, and which are supplied from the same main, burn steadily, it is a proof that the obstruction is in the fittings, but if *they* oscillate, it is in the main, of which immediate notice should be sent to the office of the Company. * * * *

"Under particular circumstances, it is impossible to fix the pipes in the way we have mentioned, so that they may all incline towards the street-main. In that case the lowest point must be fitted up with what is usually, but very improperly, called a *siphon*, and which consists of a short piece of tubing with a stop-cock near its extremity. Hither the condensable products will flow, and may be drawn off periodically.

* * * * * *

"Where it can be done without inconvenience, it is a good plan to turn off the main-cock at night, thereby excluding gas from the premises."

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Mr. Parker's work is full of useful instruction, and I cannot do better than refer my readers to it for further information on the subject of fittings and consumers' meters.

BURNERS.

While the engineer labours at the works to procure the most perfect gas from his coal, and relies upon the truth of his calculations for the quantity required by the consumers' lamps, he must not forget that the effect his operations will produce depends much upon the manner in which the gas is burnt. It is a simple theory, involving only one question, but the results would make it appear to be both perplexing and difficult. Coal-gas has now been used for the purposes of artificial illumination thirty-eight years, and the burners sanctioned by the Companies at the present day are of the same shape, size, and uneconomical construction as those used in 1805. Unless some steps be taken by the gas companies themselves to improve the system of burning, it may in all probability continue as defective as it now is for generations. The generality of consumers have other things to think of than the construction of burners; and manufacturers, although they may induce some few to adopt burners made upon correct principles, have not influence enough to introduce them universally. The engineers of gas companies are those with whom this must rest; and if they studied their own reputation, and the proper interests of their establishments, the present description of burner would soon be abandoned, and those calculated for the complete combustion of the gas substituted in their stead.

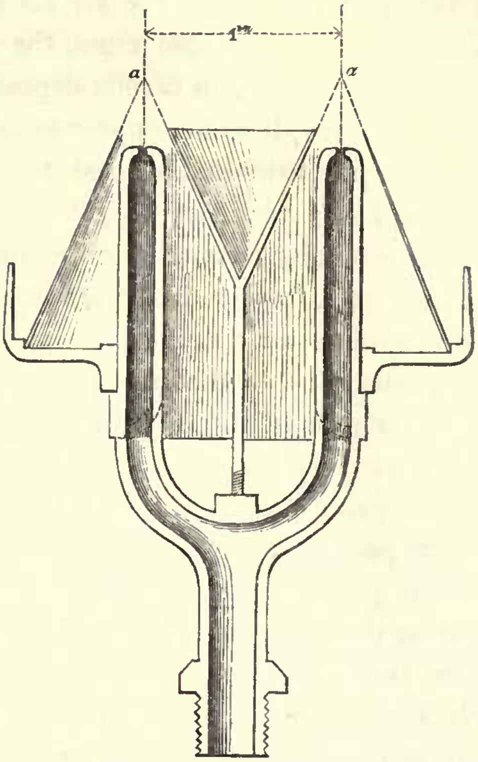
Carburetted hydrogen of the specific gravity ·390 (which is about the density of gas when arrived at the point where it has to be burnt), requires two volumes of pure oxygen for its complete combustion and conversion into carbonic acid and water. Atmospheric air contains, in its pure state, twenty per cent. of oxygen; in populous towns less; but twenty per cent. is near enough for the present purpose. One cubic foot of carburetted hydrogen then requires for its proper combustion ten cubic feet of air; if less be admitted on to the flame a quantity of free carbon will escape (from its not finding a proper volume of oxygen for conversion into carbonic acid), and be deposited in the form of dense black smoke. When the flame from an Argand burner is turned up high, the air which rushes through the interior ring becomes decomposed before it can reach the air on the top of the flame, which consequently burns in one undivided mass, the gas being in part unconsumed, the products unconverted, and carbon deposited abundantly.

If an excess of air is admitted, it would appear at first to be of no consequence, but we shall find upon examination that the quantity of nitrogen accompanying this excess has a tendency to *extinguish* the flame, while it takes no part in the elective affinity constantly going on between the several elementary gases, viz. hydrogen, oxygen, and the vapour of carbon ; and also that the quantity of atmospheric air passing through the flame unchanged, tends to reduce the temperature below that necessary for ignition, and therefore to diminish the quantity of light. For the proper combustion of the gas, neither more nor less air than the exact quantity required for the formation of carbonic acid and water can be admitted through the flame without being injurious. It is not possible practically to regulate the supply of air to such a nicety, we therefore prefer to diminish the quantity of light by having a slight excess of air rather than to produce smoke by a deficiency, the former being unquestionably the least evil.

In the year 1815, Mr. Clegg and Mr. Grafton commenced a series of experiments upon the best form of burner, the principal object in view being to regulate the supply of air to the flame. They found that the pressure given to the upward rush of air through a glass chimney eight inches high, when the interior air was highly rarefied, was equal to a head of water about three-twentieths of an inch, and that a concentric ring having an area of one-fourth of an inch admitted thirty cubic feet of air in one hour with the above pressure. This served as some data upon which to construct a burner ; for, by knowing the quantity of gas it consumed, the exact quantity of air requisite for its entire combustion could be allowed to pass through the flame.

The woodcut Fig. 40 represents the kind of burner finally determined upon as the best. The burner itself was an Argand one inch in diameter within the drilled ring of jets, which, with a flame three inches high, consumed five cubic feet of gas in an hour. For the complete combustion of that gas, fifty cubic feet of air are required. To regulate the admission of the air to the flame, an exterior cone was supported upon the gallery bearing the glass chimney, the space at the top being $\frac{1}{26}$th of an inch from the edge of the burner ; this annulus admits thirty feet of air. The interior of the flame was supplied with

Fig. 40.



air through the space left between the upper rim of an inverted cone and the interior edge of the lamp. This annular ring was $\frac{1}{20}$th of an inch wide, and supplied twenty feet of air, so that the quantity was regulated to fifty cubic feet exactly. The combustion of the gas was further improved by the air being made to rush towards a point *a*, which it is evident would be its direction, and thus each atom of the elements of the carburetted hydrogen meets its equivalent of oxygen, and becomes entirely decomposed. The interior cone was made to adjust upon its supporting wire, and its annulus increased or diminished at pleasure.

This burner has lately been *patented* under the name of the double-cone burner: certainly no contrivance would better deserve an exclusive privilege had it been original, for this description of burner is by far the best Argand, and should be universally adopted. An Argand burner three quarters of an inch in diameter within the drilled ring, with a flame $2\frac{1}{2}$ inches high, consumes $3\frac{1}{2}$ cubic feet per hour, and will require thirty-five cubic feet of air for the proper combustion of the gas. A burner half an inch diameter will consume $1\frac{3}{4}$ cubic feet of gas per hour with a flame $1\frac{3}{4}$ inch high, and require $17\frac{1}{2}$ cubic feet of air for its combustion. The distance between the holes in the drilled ring should be so much, that the jet of gas issuing from each, shall, when ignited, just unite with its neighbour; beyond this, the number of holes is of no consequence, the *size* of the burner being computed from its diameter. The diameter of the holes should be about $\frac{1}{32}$nd of an inch.

Another kind of burner, which produces a very intense light, is the double Argand, similar in make to two common Argands placed one within another, the admission of air to the flames being regulated in the same manner as described above; the space between the concentric flames should be so small as to require no adjustment, and yet large enough completely to separate them*. A glass chimney must of course form an essential appendage to every Argand lamp, its use being to create a draught and direct the current of air through the flame; the pressure will be as the height of the chimney, one eight inches high, giving a current equal in pressure to a head of water $\frac{3}{20}$ths of an inch.

The second series of experiments were made upon a burner represented in Fig. 41, formed of two parallel plates inclining towards each other, so that the gas may be directed towards a point P, about three quarters of an inch above the orifices from which it issues. The space between the plates was just sufficient to admit the proper quantity of atmospheric air; the supply to the exterior of the flame was regulated by plates having the same effect as the larger cone in the Argand lamp, and adjusted for the proper supply of air in the same manner. The ignited jets of gas proceeding from the drilled parallel plates were separated by the rush of the air between them. The holes in each plate were drilled so that the hole in one plate was opposite the space between two in the other. The light produced was intense, more so than could be attributed to the mere regulation of the air; nor can I assign any cause why it should be so. Several explanations have been given, but none of them sufficiently correct to form the foundation of a theory. Increasing the temperature of the atmospheric air supplying the flame I am convinced does not improve the *light*, provided the regulation is attended to, therefore I cannot agree with those who assign this as the cause. The same brilliancy is produced if two candles are inclined towards each other, so that

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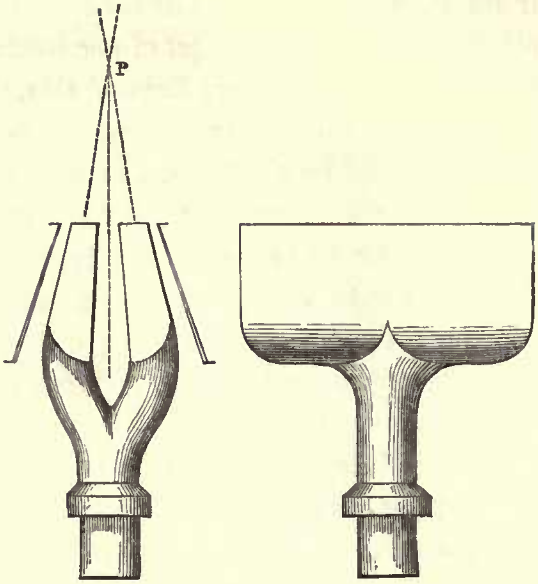
* A burner of this description was fixed on the staircase to the House of Commons in 1815, where it remained until the fire in 1834.

Fig. 41.



their flames will just touch ; both will immediately burn with a white light, and the quantity be increased more than a third, which can easily be proved by the test of relative shadows with the photometer. A greater quantity of light can therefore be produced from the same quantity of gas by using this description of burner.

Fig. 42. represents a burner that was contrived by Mr. Clegg in 1813, to silence some objections that were raised by the Insurance Companies against the use of gas, and mentioned at page 17. It is too expensive for general use, but may be applied in vaults and confined places, where the escape of gas from an open lamp might cause an explosion.

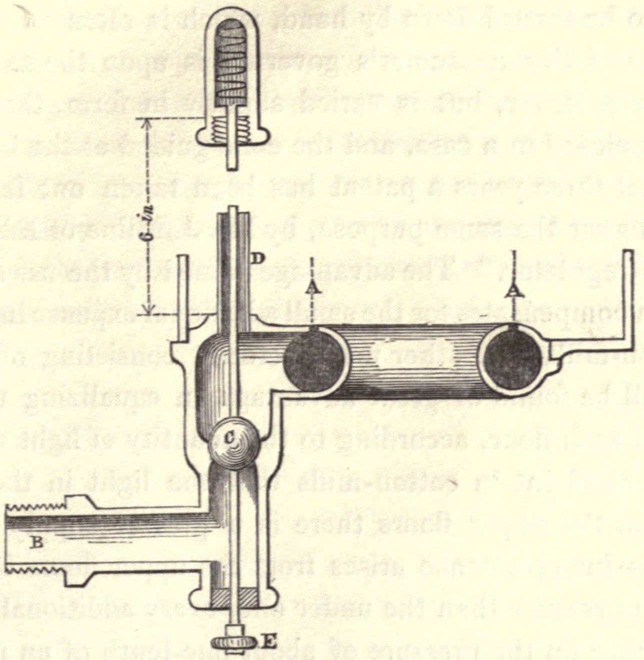
A A is the drilled ring, from which the gas is burnt.

B is the inlet for the gas.

C is a valve which closes when the brass tube D cools, and prevents the escape of the gas.

When the lamp is to be lighted the valve is lifted by pressing the button E upwards with the thumb ; the expansion of the rod D, by the heat of the flame, retains it in this position, and when the flame is extinguished the valve is suffered to fall on to its seat by the contraction of the rod D. The form of the burner itself may be varied in any way. The woodcut represents that in which the experimental lamp was constructed.

Fig. 42.



The burners calculated for lamps exposed to wind, such as those in the public streets, etc., and used without a chimney, are various in shape and size; they are known by the names of the bat's-wing, fish-tail, single jet, or cock's-spur, double and treble jet, star, fan, and Scotch burners. The first of these are usually employed in street lamps; for the quantity of gas consumed they give the least light of any, but seem to be very well adapted to their purpose. The "cut," or narrow opening from which the gas issues, can readily be cleared by a piece of watch-spring, an advantage, when a number must necessarily be attended to by one man during a short space of time. The quantity of gas they consume varies from five to six feet per hour. It has been proposed to case-harden the nipples after they are finished, in order to prevent the cut from opening.

The other burners mentioned are of little importance, and need not be more particularly described.

To regulate the altitude of the flame from the burners, Messrs. Clegg and Crosley, in 1817, applied a small governor to the outlet-pipe of the gas-meter. It is useful in many cases, where the number of lights vary; for if the opening of the supply-pipe remain the same under the different circumstances, either a waste of gas is occasioned by the flames being unnecessarily high, or each lamp has to be turned down by hand, which is often very inconvenient. The construction of this consumer's governor is upon the same principle as the large station governor, but is varied slightly in form, the floating vessel being entirely enclosed in a case, and the cone guided at the bottom.

Within the last three years a patent has been taken out for an ingenious instrument to answer the same purpose, by Mr. J. Milne of Edinburgh, which he calls a " gas-regulator." The advantage gained by the use of these instruments more than compensates for the small additional expense incurred in fixing them. In cotton-mills, and other manufactories consisting of several floors, the regulator will be found of great advantage in equalizing the pressure or supply of gas to each floor, according to the quantity of light required. It is a very general complaint in cotton-mills that the light in the under floor is deficient, while at the upper floors there is a greater supply of gas than is necessary. This inconvenience arises from the upper floors being subject to less atmospheric pressure than the under one, every additional rise of ten feet making a difference on the pressure of about one-tenth of an inch. Suppose a mill of six floors is supplied from the gas-mains at a pressure of six-tenths, and that the difference of altitude between the highest and lowest lights is equal to fifty feet, the gas in the highest or sixth floor will issue from the burners at a pressure of eleven-tenths, the fifth floor at ten-tenths, the fourth at nine-tenths, and so on. In order to gain full advantage from the regulator, one should be placed in each floor; and in this manner one placed at the top or sixth floor, and adjusted to six-tenths of an inch pressure, will send the surplus pressure of five-tenths to the floor below; another placed on the fifth floor, also set to six-tenths, will send the surplus of four-tenths down to the fourth floor; a regulator on the fourth floor will send the surplus three-tenths to the third floor, from which the surplus two-tenths will be sent to the second floor; between that floor and the ground, the fall being ten feet, the remaining surplus of one-tenth is lost, and thus an uniform pressure of six-tenths will be established over the whole building; and to prevent any inequality from outward pressure, a regulator ought to be placed on the ground-floor also. Very frequently the gas companies are obliged to supply mills at a much greater pressure than is above stated as necessary, in order that the ground-floor may have sufficient light; and it is in such cases that the advantage in point of œconomy to be derived from using these instruments will be most decidedly experienced.

Many cotton-mills are provided with a check-cock on each floor to reduce the pressure in the pipes of supply; this, if strictly attended to, will prevent an improvident waste of gas as long as the pressure remains the same; but whenever any other mills or consumers supplied from the same street-main light up *after* the mills in question, or stop *sooner*, the pressure will be respectively lessened or increased; and unless the cocks are altered at each change, either a deficiency of light or an excess of pressure, and consequently an extra consumption of gas, will invariably follow.

SECONDARY PRODUCTS.

COKE.

The most valuable of the secondary products of a gas establishment is coke. The best kind is obtained from coal when carbonized in large masses, in ovens constructed on purpose. In a gas manufactory, the production of coke being of minor importance to the formation of good gas, it is generally of an inferior quality to that made in coke ovens, where it is the primary, and indeed sole object for which the coal is carbonized. But gas-coke is excellent for many purposes in the arts and manufactures, producing as clear a fire as that of the first quality, though it is neither so lasting or so free from slag: for domestic use, however, it is unobjectionable, and may be burnt both in the drawing-room and kitchen with œconomy and comfort.

The distinguishing characters of good coke are, first, a clean, granular fracture in any direction, with a pearly lustre, inclining to that exhibited by cast iron. Secondly, density, or close proximity of its particles, which adhere together in masses, and specific gravity of 1·10, or rather higher. Thirdly, when exposed to a white heat it consumes entirely away, without leaving either slag or ashes.

It is invariably the case that the quality of the coke is inversely as that of the gas. The manufacturer must not expect to produce *both* of the best quality. The process by which the best gas is made generally leaves the coke light, spongy and friable, although an increase of quantity is gained ; for the simple reason, that the degree of heat and other circumstances required to form perfect coke must be entirely changed when gas of a high specific gravity is to be obtained. Thus large masses of coal exposed to a red heat in close vessels are acted upon by slow degrees, the external portions preventing heat from penetrating into the interior until most of the bituminous portions are given off in condensable vapour, or as charcoal and free hydrogen; the after products being light carburetted hydrogen, carbonic oxide and carbonic acid gases. The residue is a carbon of a dense granular composition.

If coal is *immediately* decomposed, the coke formed is spongy and friable, owing to the quick distillation of the expelled gases; the bulk is increased and the density destroyed, but the volatile products are rich in gas of a high illuminating power; and it is to effect this latter object the gas manufacturer must more particularly confine his operations. In other words, he must be a gas, and not a coke manufacturer.

The average quantities of coke obtained from 27 cwt. of Newcastle coal distilled in cylindrical and D-retorts, set on the plan shown in Plates I. and II., are as follow:—

	bushels.		cwts.	qrs.	lbs.
Berwick's Wall's-end - -	47¼	=	18	2	8
Heaton Main - - -	45½	=	18	1	4
Primrose Main - - -	46	=	18	1	25
Felling Main - - -	44¼	=	18	3	24
Pearith's Wall's-end - -	46½	=	18	2	0
Eden Main - - - -	45½	=	18	1	14
Russell's Wall's-end - -	45	=	18	1	0

We may take the average production of coke from a ton of Newcastle coal to be 33 bushels, or 13½ cwt. The quantity of coke required to heat the retorts for the distillation of a ton of coal I have already stated to be about 12½ bushels; consequently, if the fuel used was entirely coke, we should have 33 — 12½ = 20½ bushels for sale; but when tar is substituted, the quantity for sale will be proportionably increased.

COAL-TAR.

When the manufacture of gas from coal was in its infancy, great advantages were expected to be derived from the coal-tar which distilled over with the inflammable gas. It was considered to be a substance possessing even superior properties to the vegetable tar for the preservation of timber, and other perishable materials exposed to the influences of the weather.

In the year 1665, a German chemist proposed to distil coal for the sole purpose of obtaining this tar, and in 1781 the Earl of Dundonald took out a patent for collecting the tar which appeared during the formation of coke. Neither scheme answered. After a few years' trial, coal-tar as a substitute for vegetable tar fell into disuse. It was tried, I believe, in the navy, and was found to give the timber a considerable degree of hardness, but not of durability. Its smell is extremely offensive, and at the present time is used only in places where that is of no consequence. The exposed part of the machinery of a gas establishment may be protected by being coated with coal-tar.

Another product obtained by the distillation of coal-tar was a peculiar oily naphtha, which burned with a very bright flame. It was used as a substitute for whale-oil in the lamps on Waterloo Bridge and its neighbourhood in 1819; but unless copiously supplied with atmospheric air, and kept with a small flame, the quantity of carbon it deposited was excessive; the gas supplying the flame being almost entirely bi-carburetted hydrogen, which requires at least three times its bulk of pure oxygen for its complete combustion, and consequently fifteen times its volume of atmospheric air.

If coal-gas is conducted through this naphtha before being burned, the light is increased in brilliancy more than fifty per cent. I witnessed an experiment of this at Mr. Lowe's house a few weeks ago, and certainly the effect was dazzling. The naphtha was contained in a sponge placed in an air-tight cup or vase below the burner. Mr. Lowe has also obtained this increase of illuminating power by filling the meter with naphtha, and thus describes his method:—

> "As regards the first part of the same in increasing the illuminating power of such coal-gas as is usually produced in gas-works, by impregnating such gas with naphtha, commonly called spirit of coal-tar, or with any other volatile hydro-carbonaceous liquid: the method I adopt for so impregnating the said gas is by merely filling the case of the common gas-meter to the usual height with any of the said liquids instead of water, by which means the said gas discharged by the meter to the burners, is, during the operation of measuring, sufficiently impregnated with the said liquid in the meter-case.
>
> It is important to maintain a proper and uniform supply of such liquids in the meter-case, and this may be effected by means of any self-acting apparatus, such as the bird-fountain."

To ensure the separation of the richer naphtha during the condensation of coal-gas, Mr. Lowe, in another part of his specification, proposes to turn steam into the upper portion of a long inclined pipe, through which the gas passes on its way to the purifiers. The vapours of the water and bitumen have a mechanical affinity for each other, and will fall together at several points in the condensing-pipe: for the purpose of conducting them away, syphons are attached at the proper places. The contents of the last or lowest siphon are the most valuable, and are those which Mr. Lowe more especially refers to when speaking of the spirit of coal-tar.

Although the cost of the above spirit is very trifling, I much prefer the use of native naphtha for the purpose of impregnating the coal-gas, since it has a less offensive odour. This last substance oozes out of several rocks, as sandstone, slaty clay, etc., or is found on the surface of springs and other waters, in various districts of Italy; in Sicily, Zante, the Caspian Sea; in Persia and other countries in Asia; also in Westphalia and Alsace: it is an article of commerce, and is used by varnish manufacturers, of whom it may be purchased.

Coal-tar yields inflammable gas in great abundance*, of a high specific gravity: on one occasion I procured it as high as ·710. It is seldom lower than ·650. From this circumstance engineers have been induced to submit the tar obtained in their first process of forming coal-gas to a second distillation, with an intention of improving the quality of the first products. The form of apparatus used is similar in construction to that for procuring gas from oil. If it could be stored and burnt, separately from the coal gas, in lamps made on purpose, it might be found to answer; but the expense and trouble attending its formation renders the use of it, independent of other circumstances, objectionable.

Experiments have been tried by pouring tar upon the charge of coal before being introduced into the retort. If the gases formed by these substances would unite chemically, and the combustion of them be equally effected, the process doubtless would be œconomical; but they do not unite: they are two distinct compounds, possessing different properties, and having no affinity for one another under ordinary circumstances; therefore this operation has always failed to produce the desired end.

I decidedly think that the most œconomical use to which coal-tar can be applied, is to burn it beneath the retorts, as directed in another part of this volume.

AMMONIACAL LIQUOR.

If the properties of manure, and its agency upon the growth of the vegetable world, can be explained by chemistry, we shall find the ammoniacal liquor

---

* 112 lbs. of coal-tar yield upon an average 1000 cubic feet of gas of the specific gravity ·650.

produced in gas-works to be a valuable substitute for those manures, by the application of which it is intended to supply the soil with nitrogen.

It would be out of place to make any remarks upon the elements absorbed from the earth by different plants, even if I had studied the subject sufficiently to give my opinions to the world: we all know, however, that carbonic acid, water and ammonia contain the elements which support both animal and vegetable life, and that it is the object of the agriculturist, when he manures his land, to supply the deficiency of any of these elements, from the want of which his crops would fail.

One of the most valuable manures is urine, and its excellence depends almost entirely upon the ammoniacal salts which it holds in solution, and the quantity of nitrogen it affords for the development of the seeds or roots of those plants to which it is applied. The relative value of urine as manure depends upon the quantity of nitrogen the different kinds yield. Thus human urine is the most esteemed, and that of horned animals the least.

According to Professor Liebig, 547 pounds of human excrement contain 16·41 pounds of nitrogen; a quantity sufficient to yield the nitrogen of 800 pounds of wheat, rye, oats, or of 900 pounds of barley. How much more, then, will be supplied from an equal weight of ammoniacal liquor!

Mr. J. Watson, the manager of the Gas-works at Kirriemuir, has favoured me with the following facts:—

> "The ammoniacal liquor on the surface of the tar-well has been found a very great improvement as a manure for the raising crops of grass in this quarter, by being sprinkled on the field in the same way as water is put on public streets in large towns, to keep down dust in dry weather. I have myself seen an experiment of this tried, and can say that part of a field of grass sprinkled in this way (after first cutting) was far superior to any other part of the field receiving manure of any other kind, and that the part so sprinkled or showered over was ready to be cut down a second time in the course of between fourteen days and three weeks; whereas the other part of the field cut at the same time, was only beginning to spring or rise from the roots in that time: it has to be mixed up before use with four parts of common water. In particular, the said experiment of the gas-water has been used by David Nairn, Esq., Doumkilba, near Meigle, in this neighbourhood, with success; and I am informed that he has purchased and taken a lease of the ammoniacal liquor from different gas companies in this country."

The statement of this fact will be more acceptable than the mere notice of theoretical writers upon this subject, although much weight may be given to their propositions by the knowledge of the chemical changes that take place during the process of vegetable generation.

This liquor is applicable probably only to certain soils; but those which require the aid of sulphate of lime may certainly be further aided by uniting with the gypsum a portion of the ammoniacal liquor, since it would fix the alkali forming sulphate of ammonia, and render it more easily absorbable by the ground on which it is laid.

In many parts of Flanders, Belgium, and France, but particularly in China, human urine is collected with great care for the purpose of manuring meadow land and corn-fields. The barren soils on the coasts of South America are manured with the excrement of a sea-bird very numerous in those parts, and which consists of urate of ammonia and other ammoniacal salts; and good crops are produced. There are numerous instances of the same results being produced all over the world, upon soil of almost every different variety; and ammoniacal liquor would have the same effect (if chemistry is to be believed) as those substances just mentioned.

I am convinced much good might be derived from different qualities of the refuse products of gas-works as manure. An inquiry into this subject would remunerate the engineer or agriculturist to the full, would besides confer a considerable benefit upon his fellows, and give that practical proof of the correctness of a theory so welcome to the man of science.

The above is comparatively a new application of the ammoniacal liquor; it has generally been used for the manufacture of the carbonate and muriate of ammonia, and is the great source in this country from which the manufacturers of the salts of ammonia obtain their supply; so fruitful is it, that since the manufacture of gas has become general, the price of muriate of ammonia, one of the most useful of these salts, has been reduced to one-fifth of that at which it was previously sold.

The process usually adopted is the following:—The salts contained in the liquor are the sesquicarbonate and hydrosulphate of ammonia: the first object is to reduce both to a sulphate, or by some, to a bisulphate, and then, by sublimation with chalk or common salt, to procure the carbonate or muriate of ammonia.

The ammoniacal liquor is allowed to stand at rest for a few days, either in cisterns or casks, in which it has been transported from the gas-works. The heavy tarry matters subside, and the lighter collect on the surface, and are skimmed off. The quantities of these will constantly vary, and will depend upon the care with which the liquor has been taken from the well.

The water holding ammonia in solution is now decanted, by means of a siphon, from the tarry deposit into leaden evaporating pans; sulphuric acid is then added, so as to convert the sesquicarbonate and hydrosulphate into the sulphate of ammonia.

During this operation a large quantity of sulphuretted hydrogen is given off, and is conducted to the ash-pit of one of the furnaces, under the evaporating pans, to be consumed, and prevented from extending an injurious influence on the health of the workmen. The saturated liquor is evaporated until a strong pellicle is formed on the surface; then decanted into shallow vessels, and allowed to cool and deposit its crystals.

If it be considered necessary further to purify this salt, it may be accomplished by heating it, to drive off the remaining portion of bituminous matter; but then it is essential that the salts contained in the liquor be converted into the bisulphate, otherwise one equivalent of ammonia would be lost by sublimation.

In some manufactories the liquor is rectified previous to the addition of the acid; for this purpose it is run into a boiler (such as those used for steam-engines), connected by a long iron pipe, with a closed receiver; on applying heat, the ammoniacal products are evolved, and condensed in the receiver and connecting-pipe. To the distilled liquor, containing a large quantity of ammonia, the acid is now added, and the subsequent operations proceeded with. This, however, is a process not generally recommended, since the sesquicarbonate of ammonia is not volatile at the temperature of boiling water, but is decomposed, free ammonia escaping, while the neutral carbonate remains dissolved.

The sulphate of ammonia, prepared by the above process, is tolerably pure, and may be used for the purpose of obtaining the carbonate and muriate, the salts most used in the arts. If for the former, a portion of carbonate of lime (common limestone or chalk) is added to the sulphate, well triturated with it, and the mixed mass sublimed in earthenware vessels. If the muriate is required to be formed, common salt is substituted for the carbonate of lime, and the mixture similarly treated.

INDEX.

THE END.

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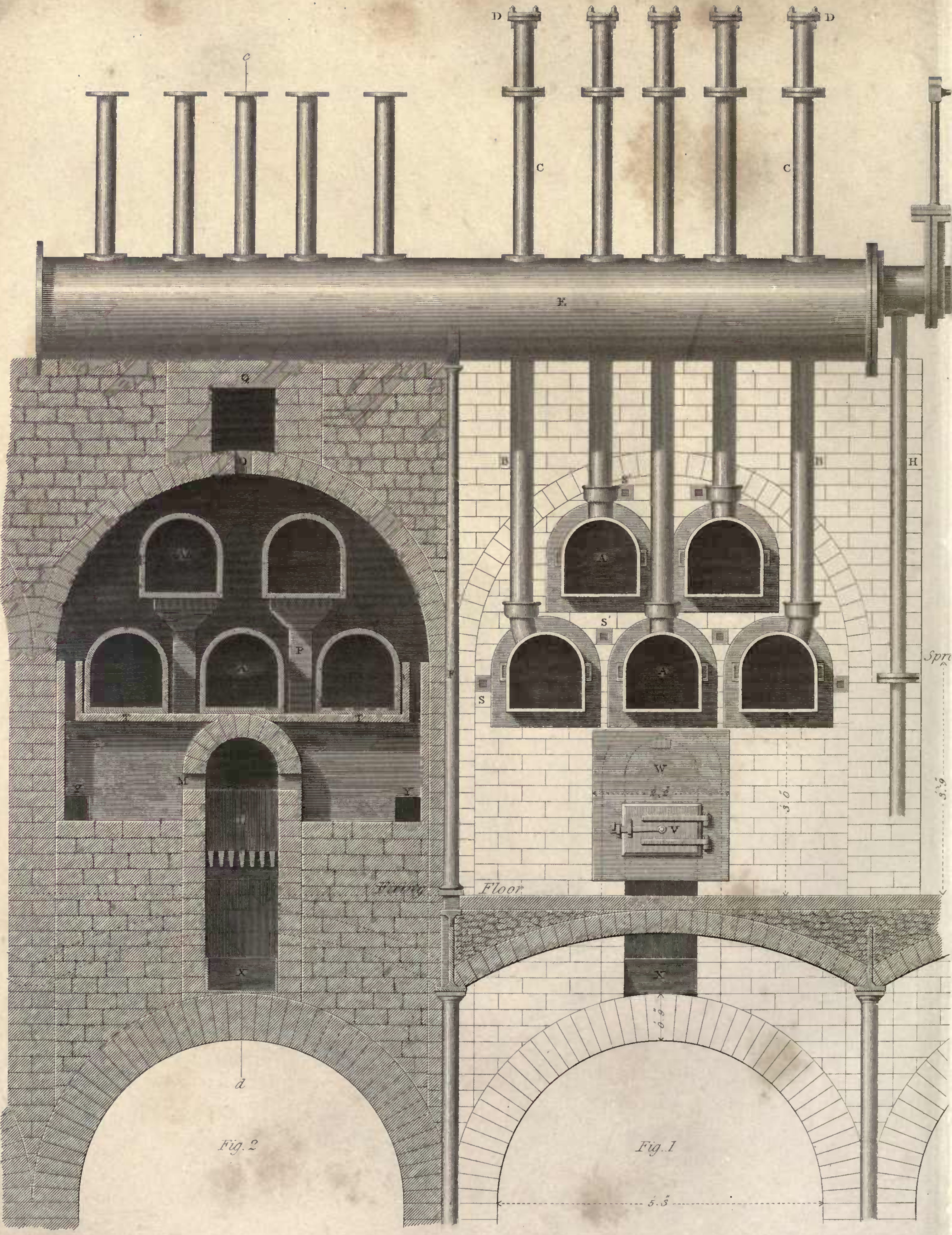
COLLEGE BLACKB



Saml. Clegg Junr. del.

John Weale, Architectural

Plate I.

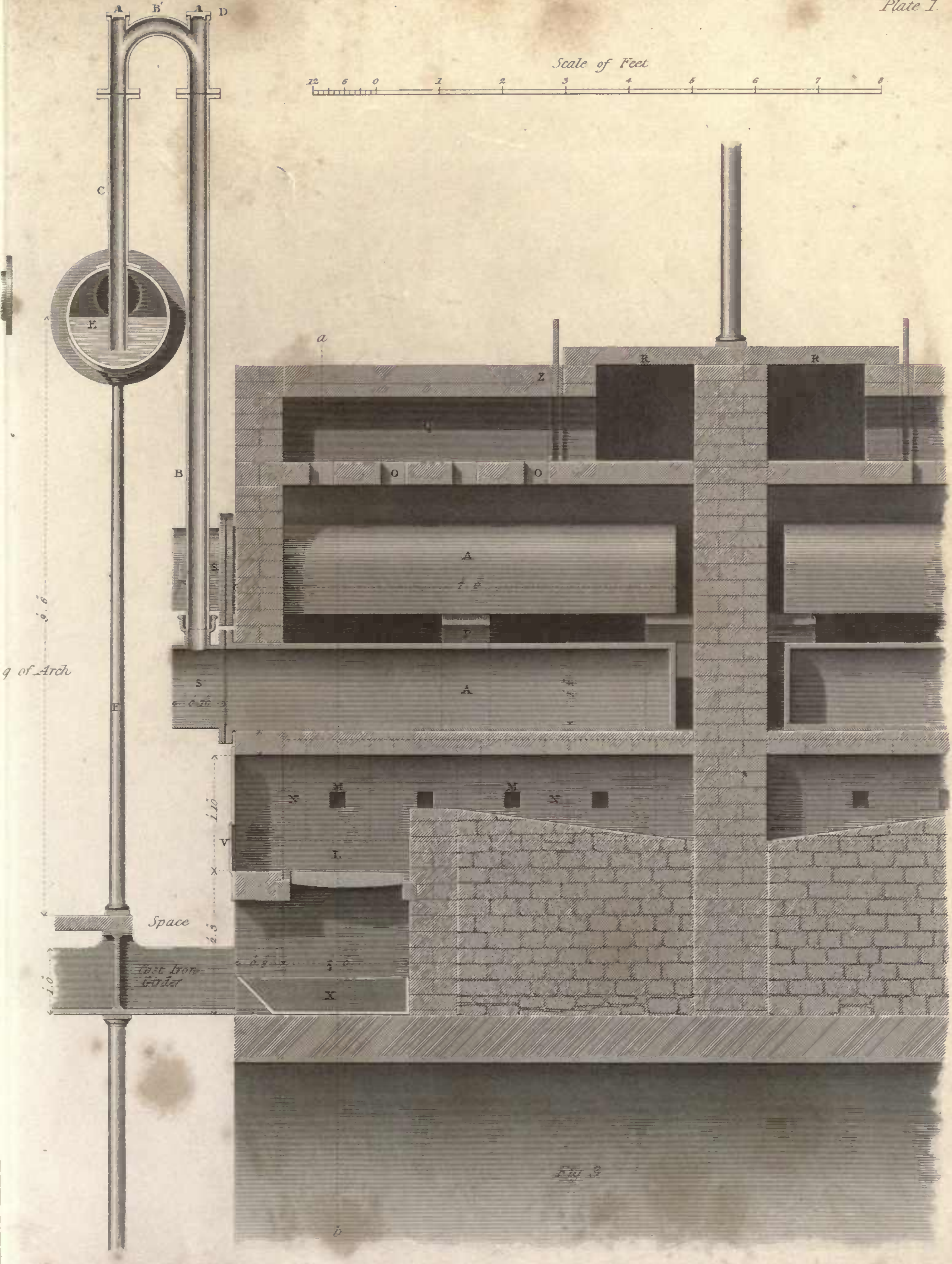


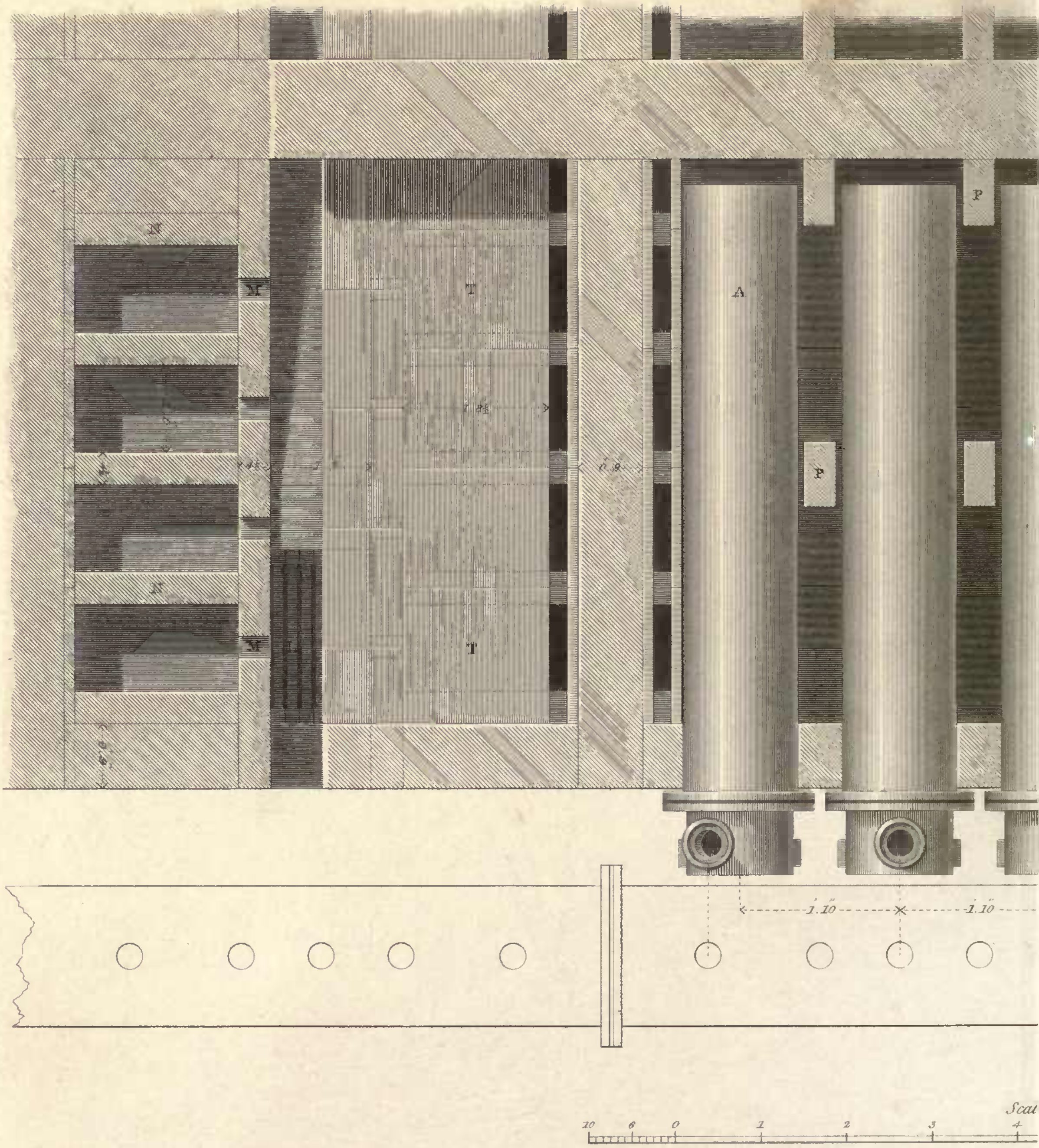
Fig 3.

ary 59 High Holborn

G. Gladwin sculp.

COLLEGE BLACKHEATH

Fig. 1 *Fig. 2*

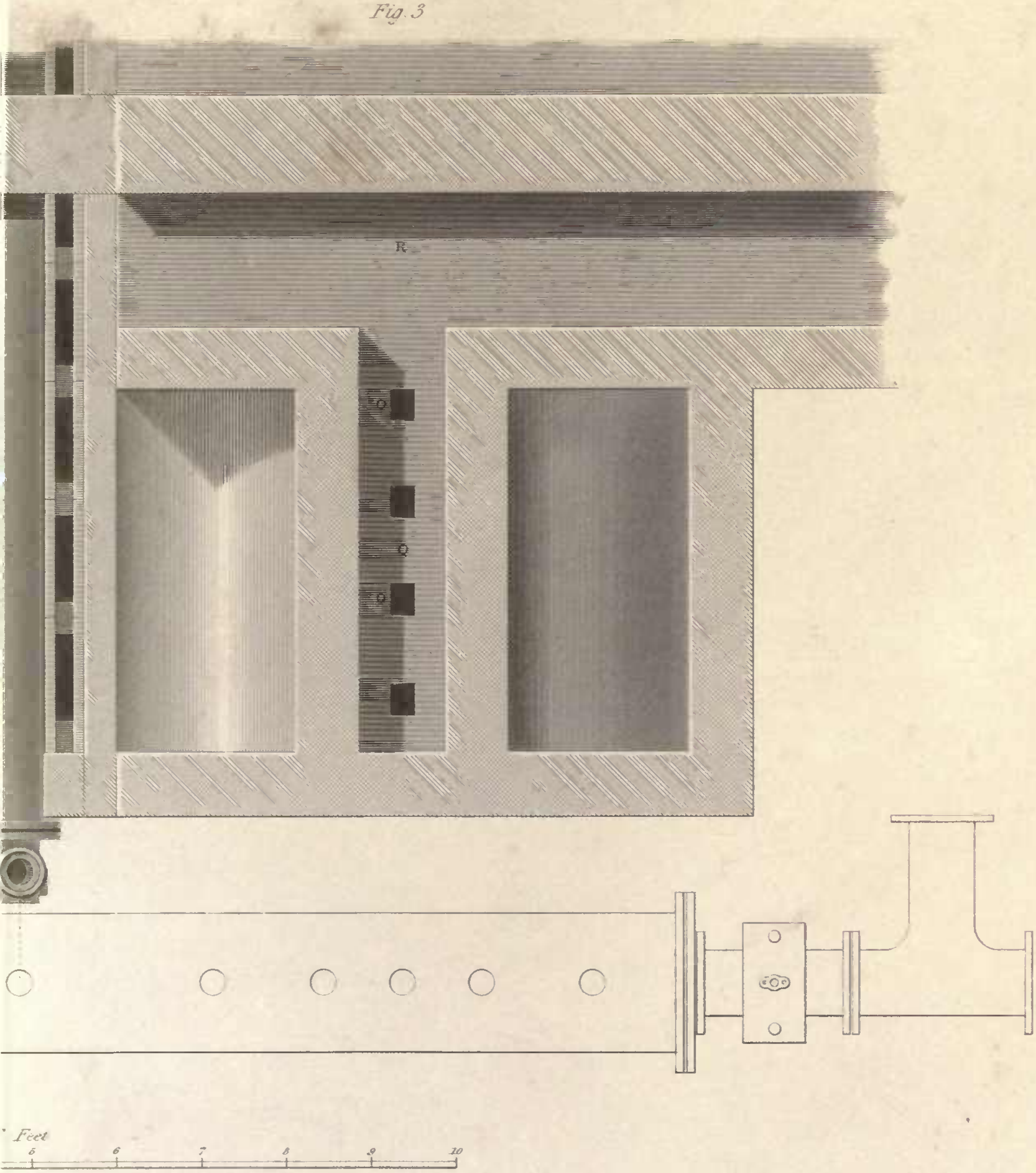


Saml. Clegg Junr. del.

John Weale, Architectura

Plate II.

Fig. 3



G. Gladwin sculp.

brary, 59. High Holborn.

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Fig. 2

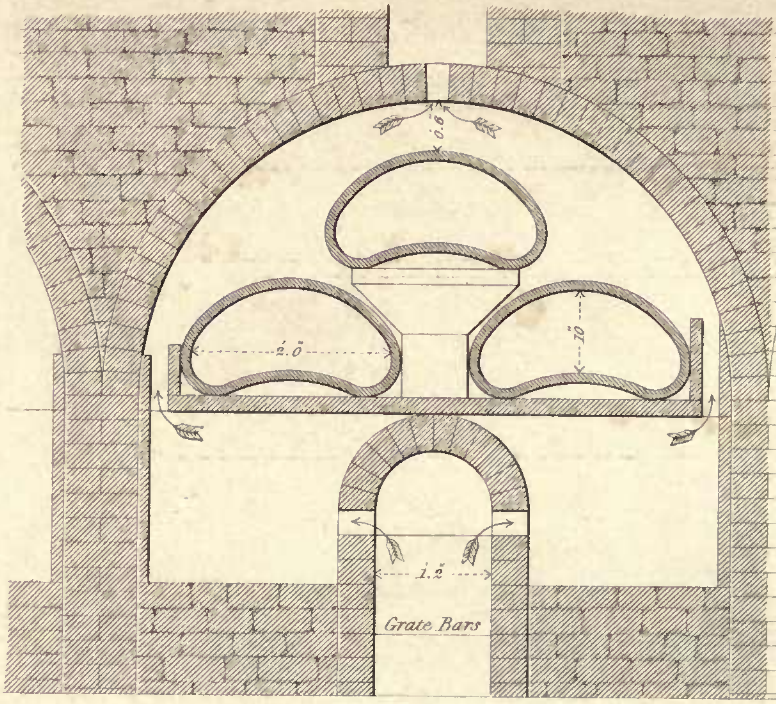


Fig. 1

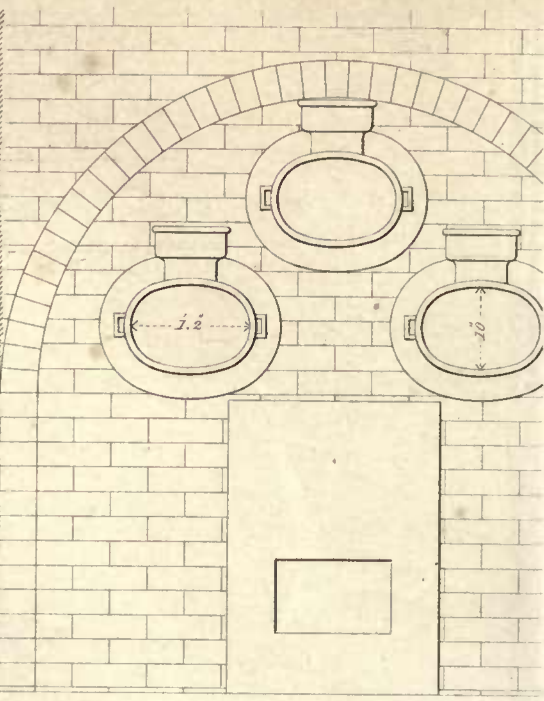
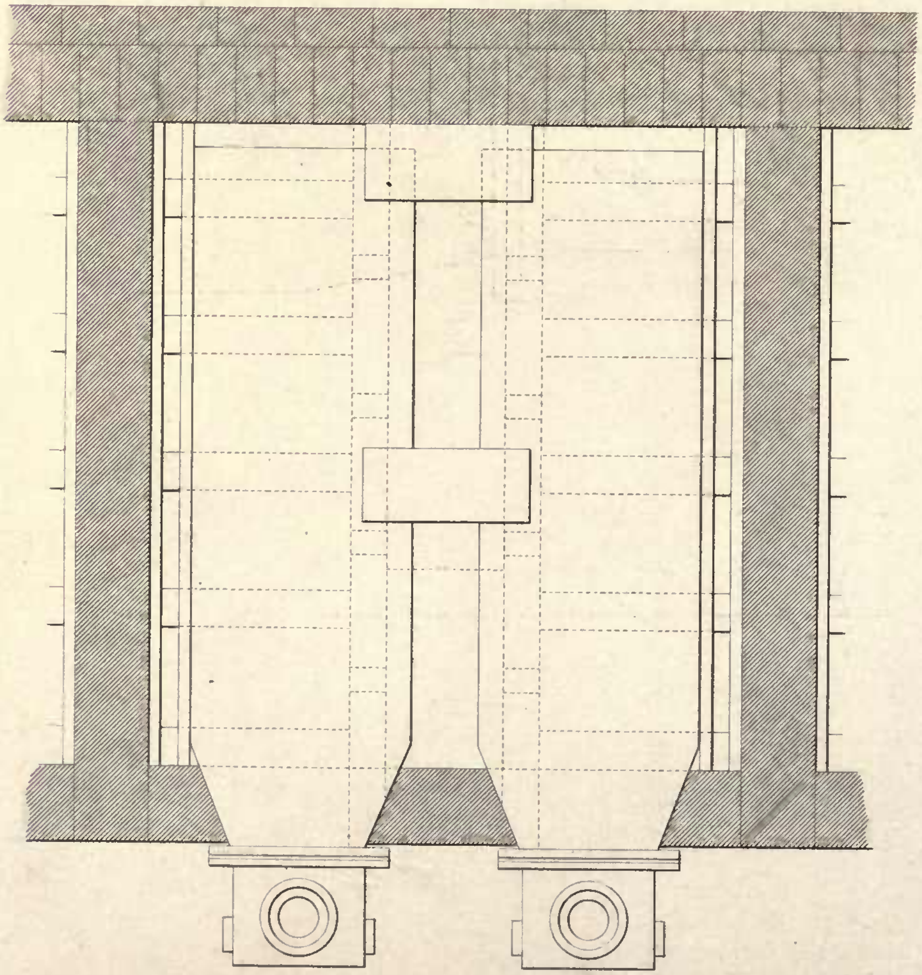
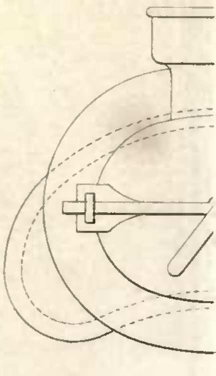
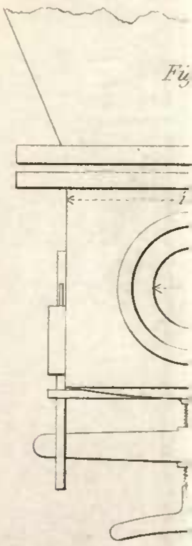


Fig. 4







Sam^l. Clegg Jun^r. del.

John Weale, Architectural

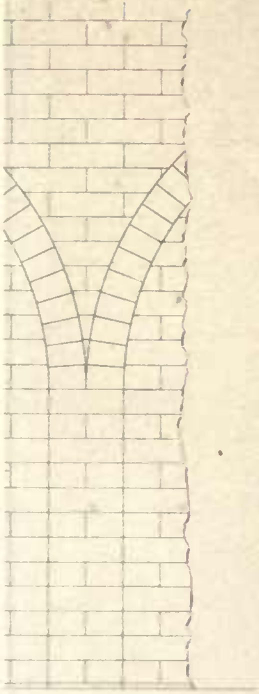
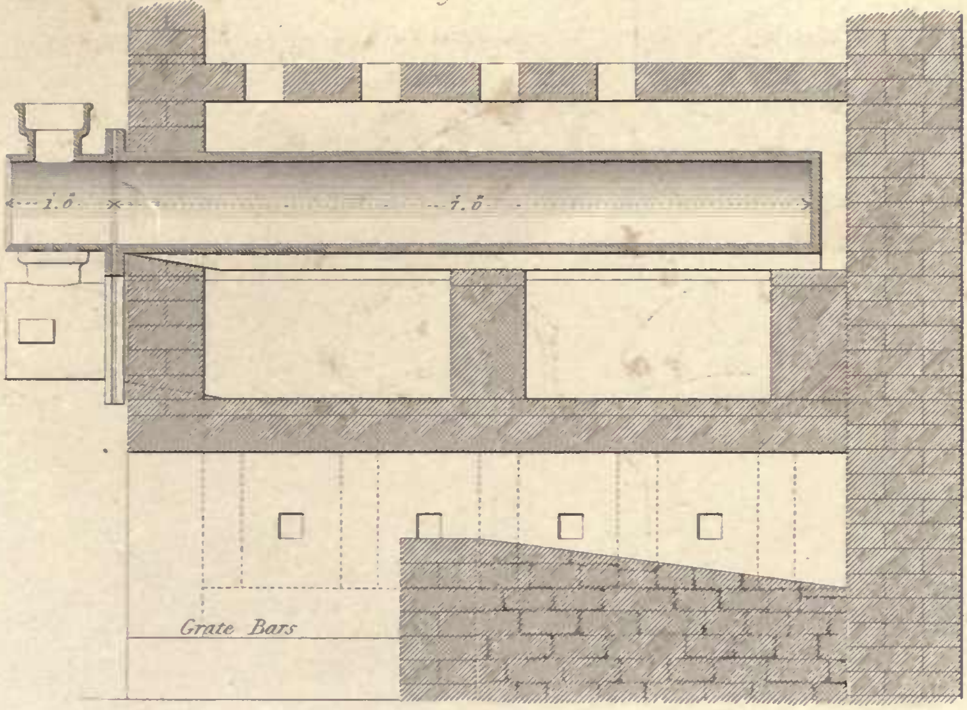


Fig. 3



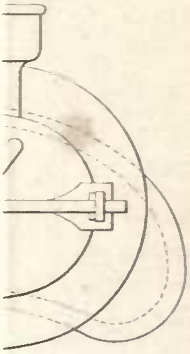
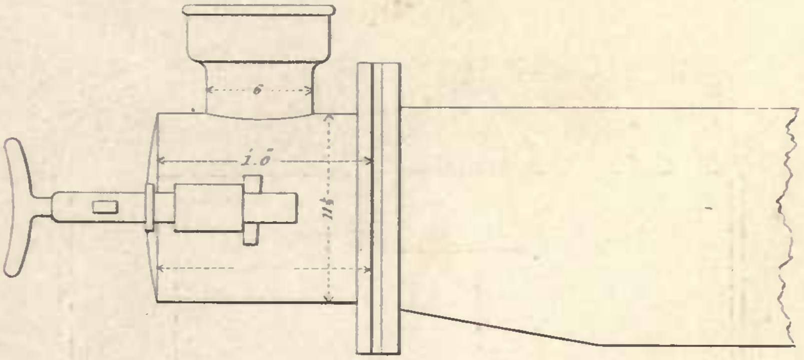
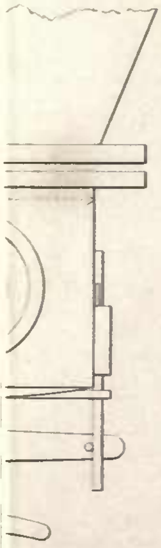


Fig. 6





Scale to Figs. 5.6.7.

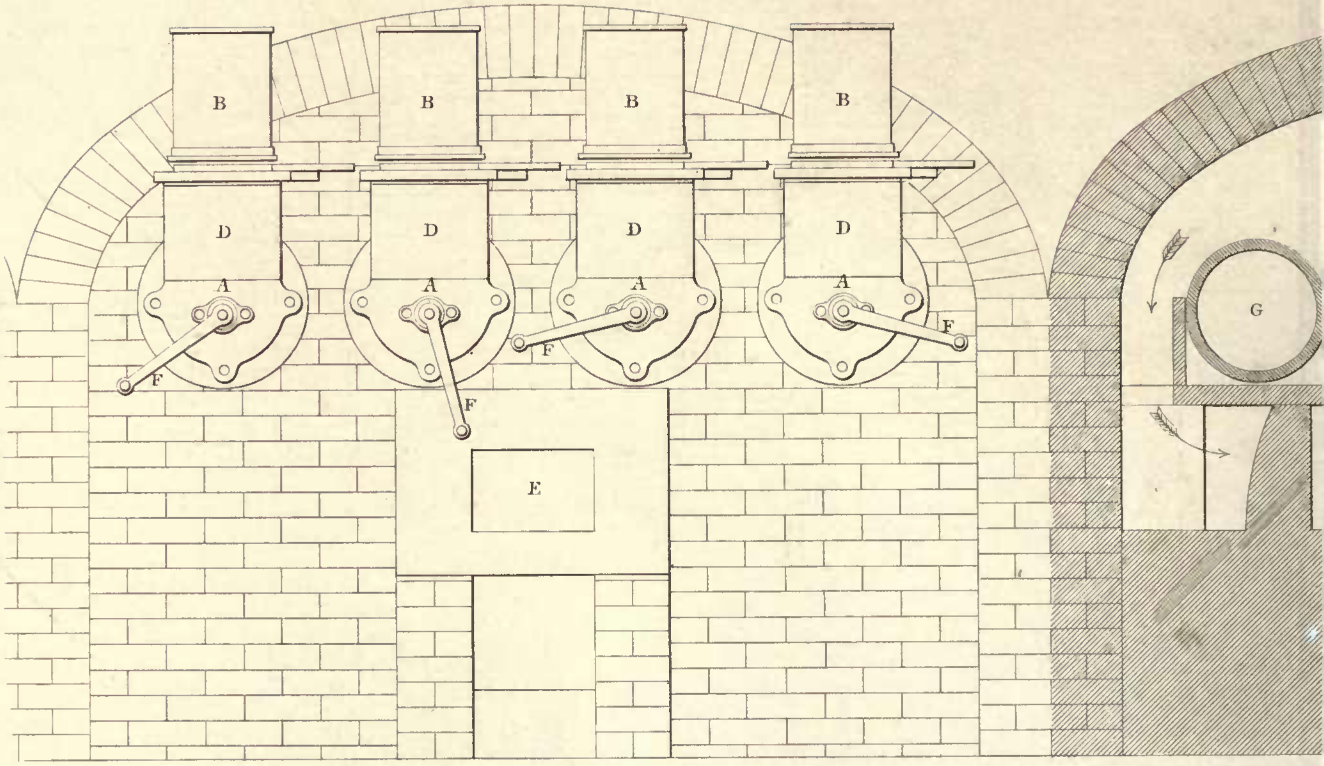
Scale of Feet

rary, 59 High Holborn

G. Gladwin sculp.

MORDEN COLLEGE BLACKHEATH

Fig. 1.



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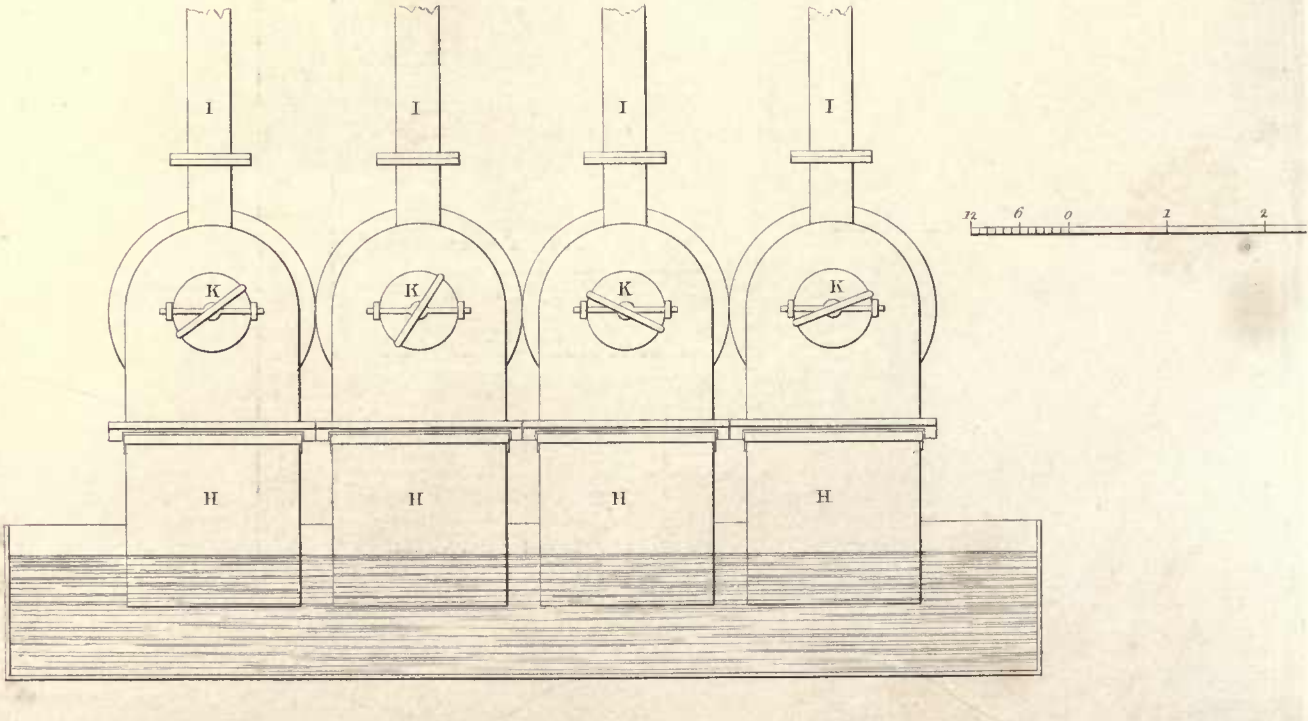


Saml. Clegg. Junr. del.

John Weale, Architectu

Fig. 2.

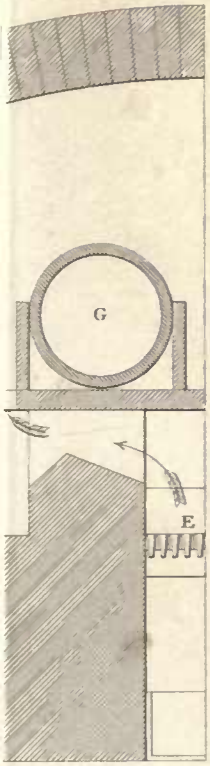


Fig. 3.

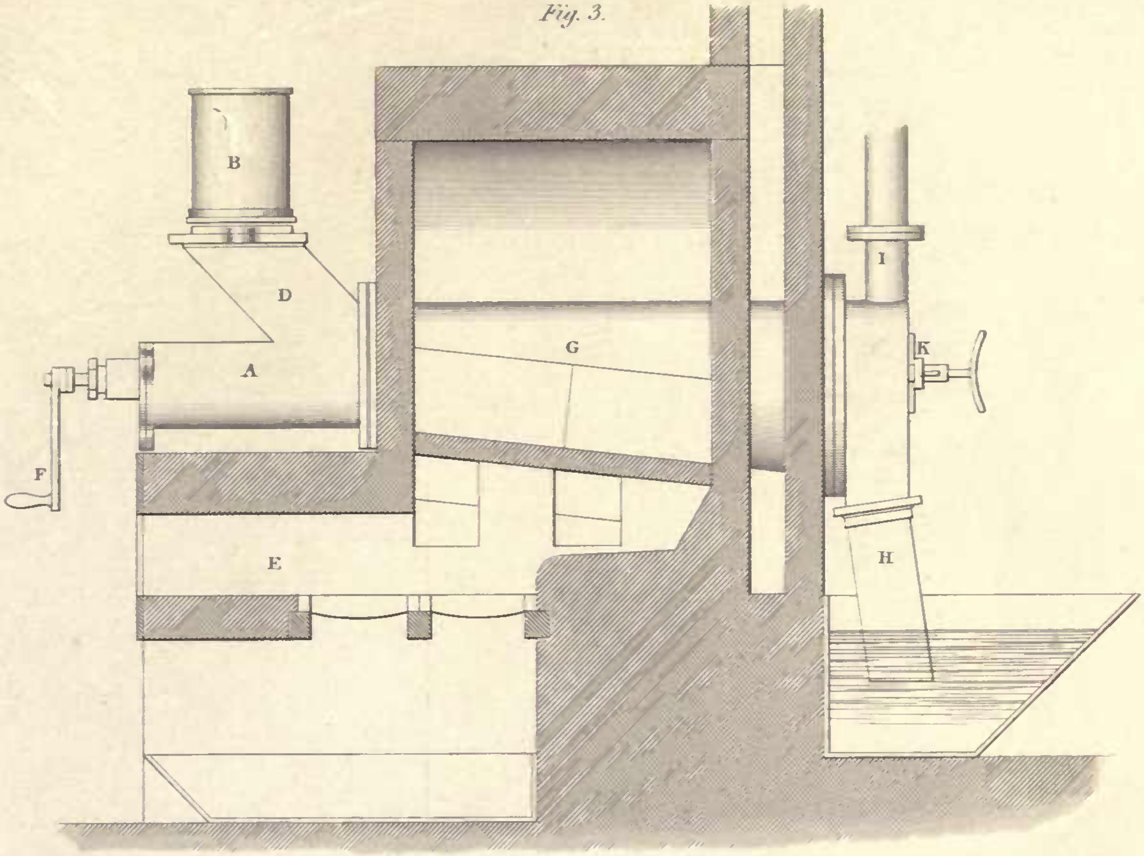
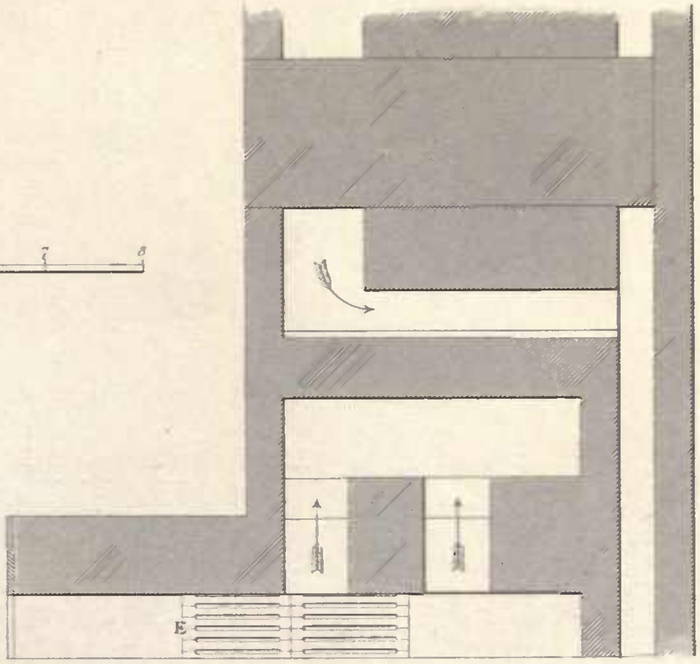


Fig 5.

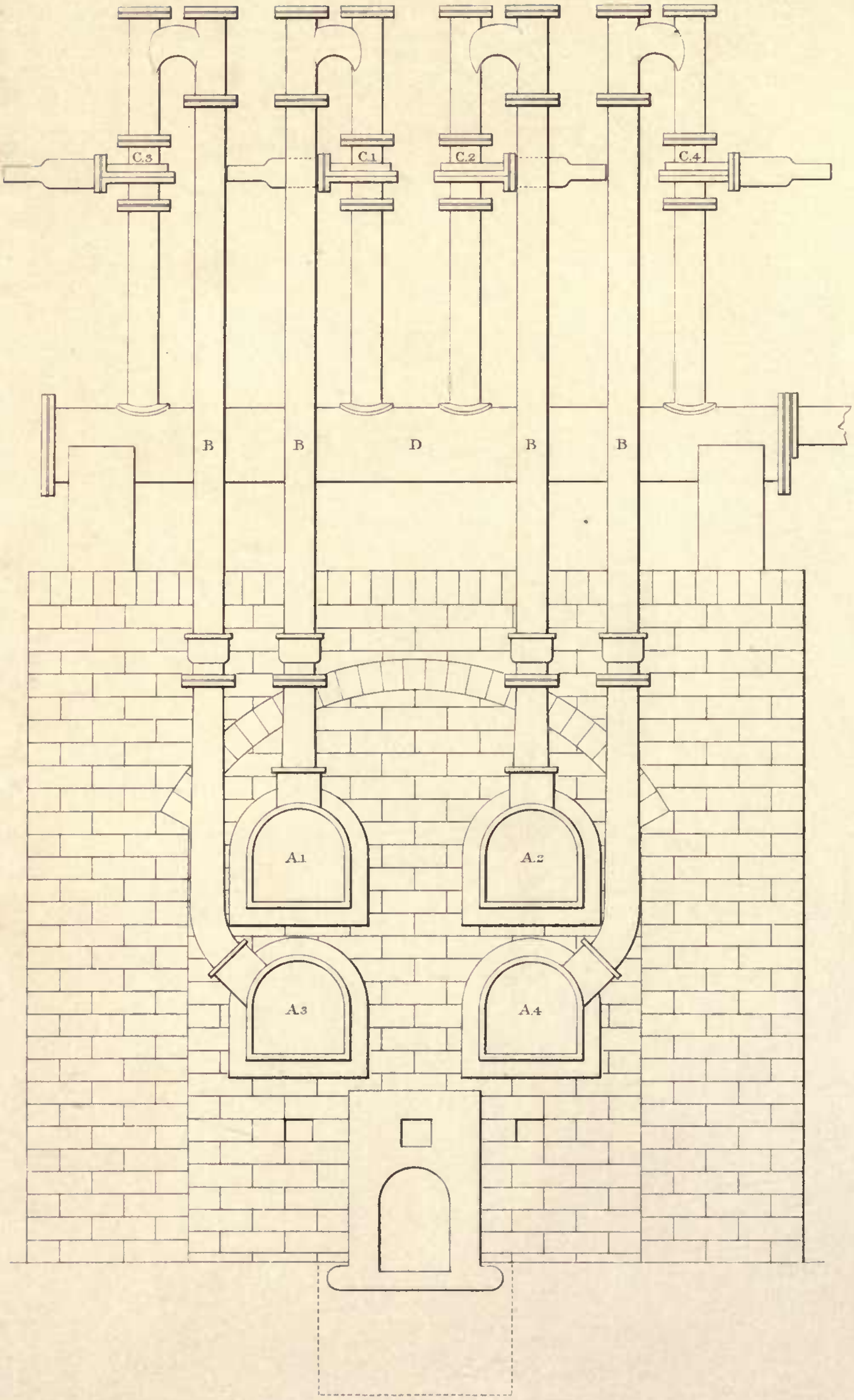


cale of Feet

G. Gladwin sculp.

ibrary, 59 High Holborn

Fig. 1



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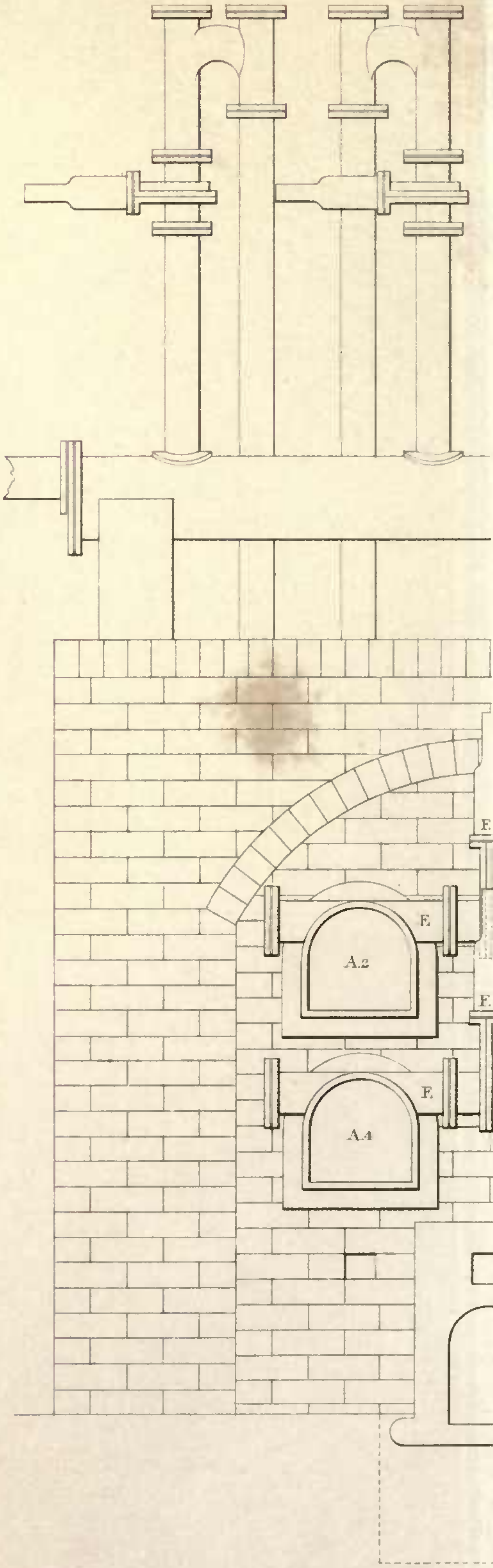


G. A. Jermyn del.

John Weale, Architectura

Plate V.

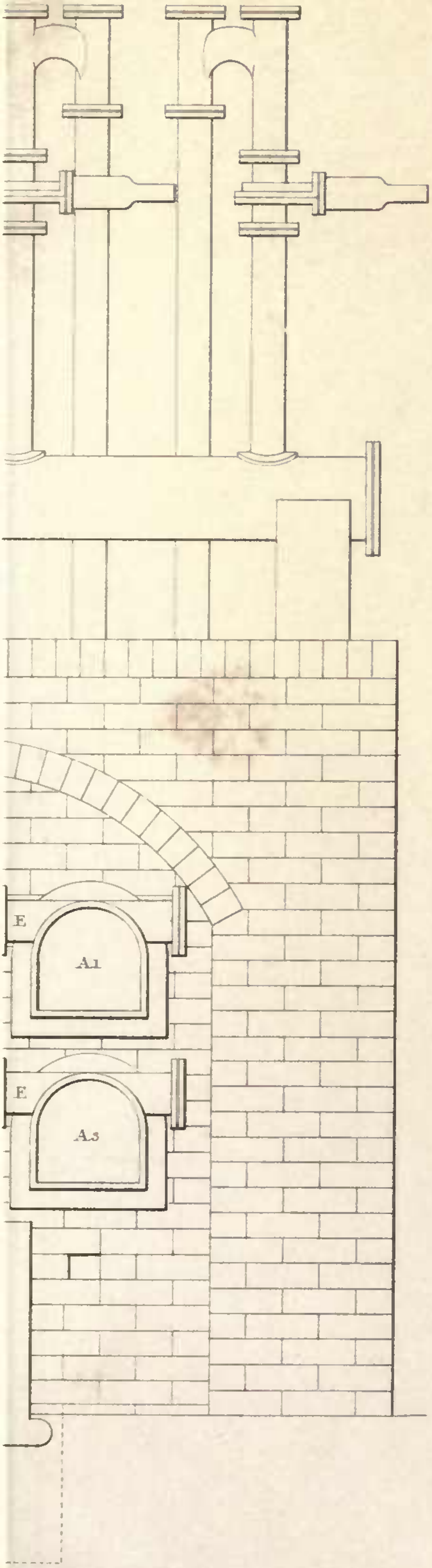
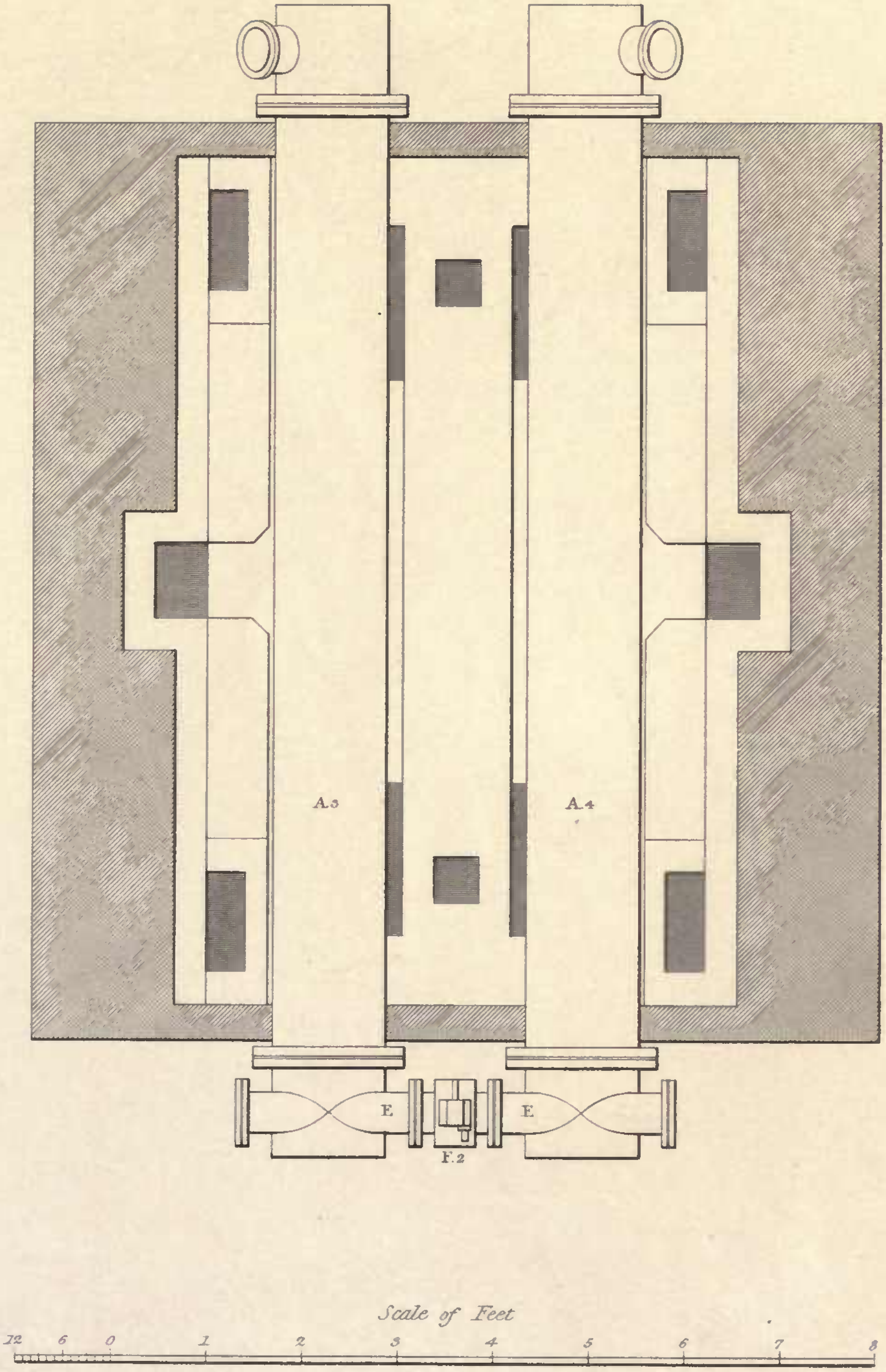


Fig. 3



brary, 59, High Holborn.

G. Gladwin sculp.

Fig. 1

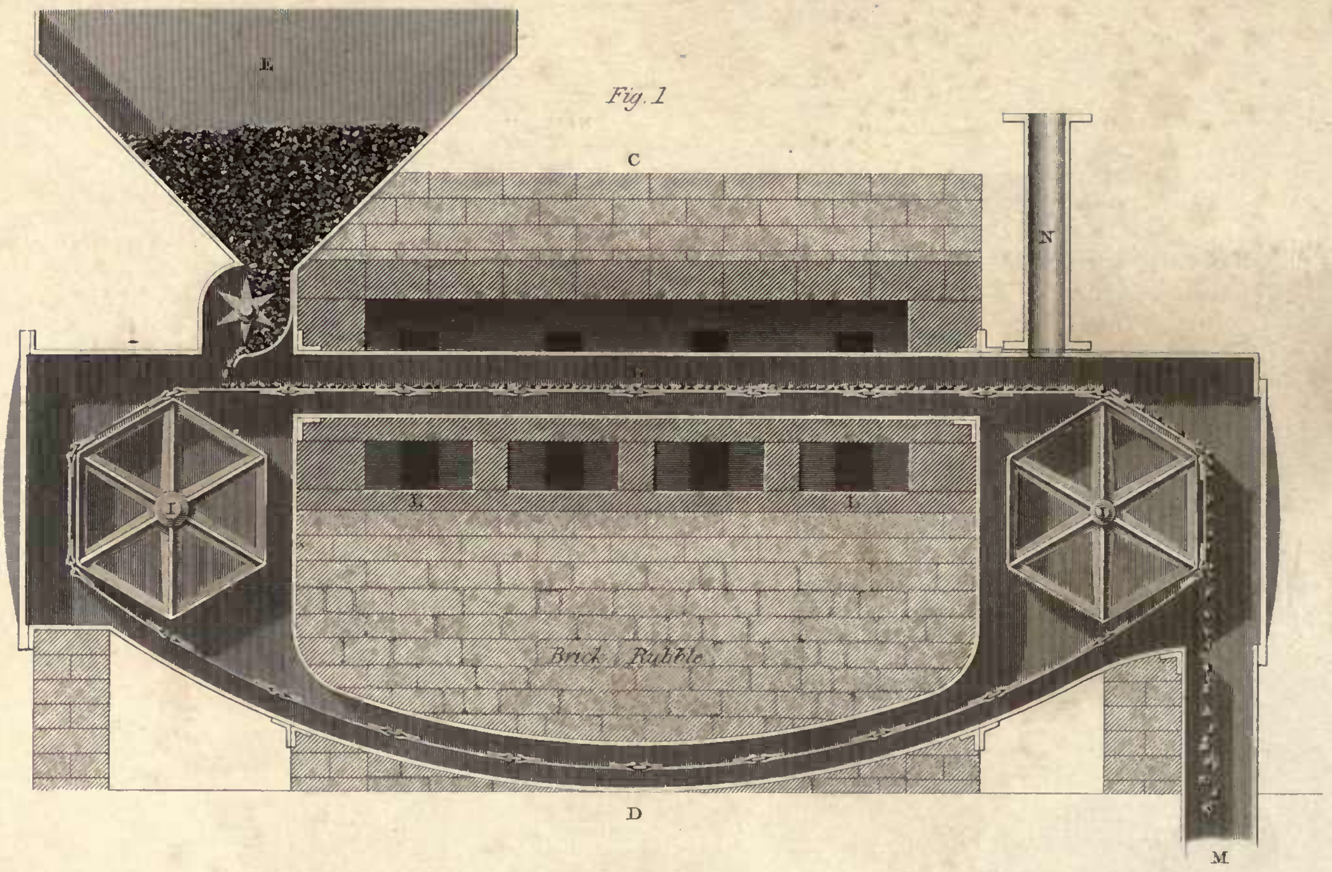
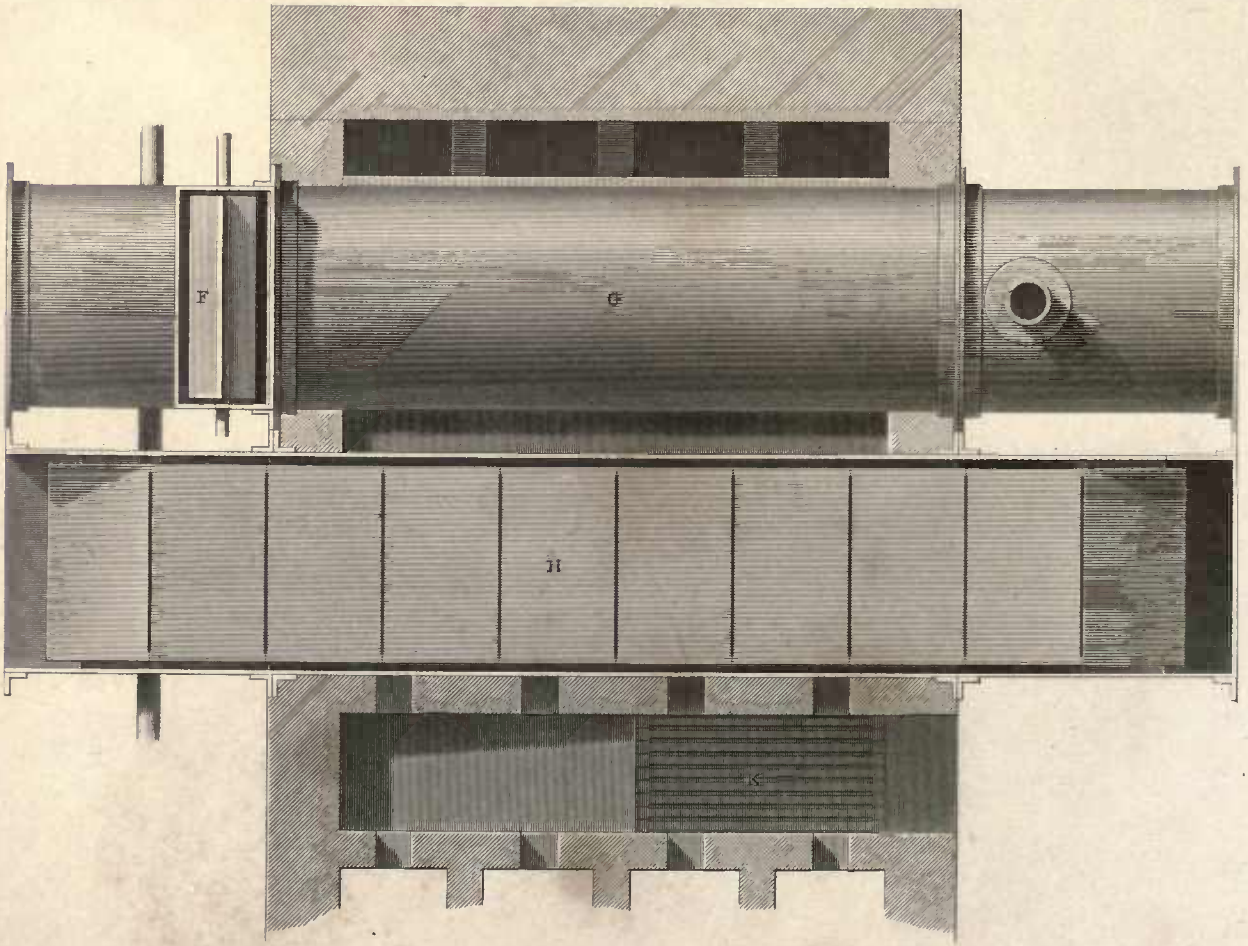


Fig. 4



Saml Clegg Junr del.

John Weale, Architectural

Fig. 2

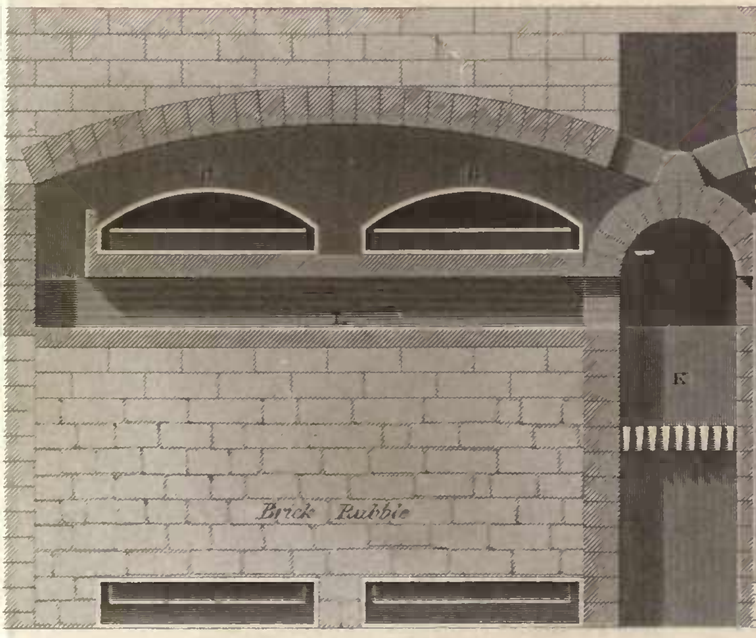


Fig. 3

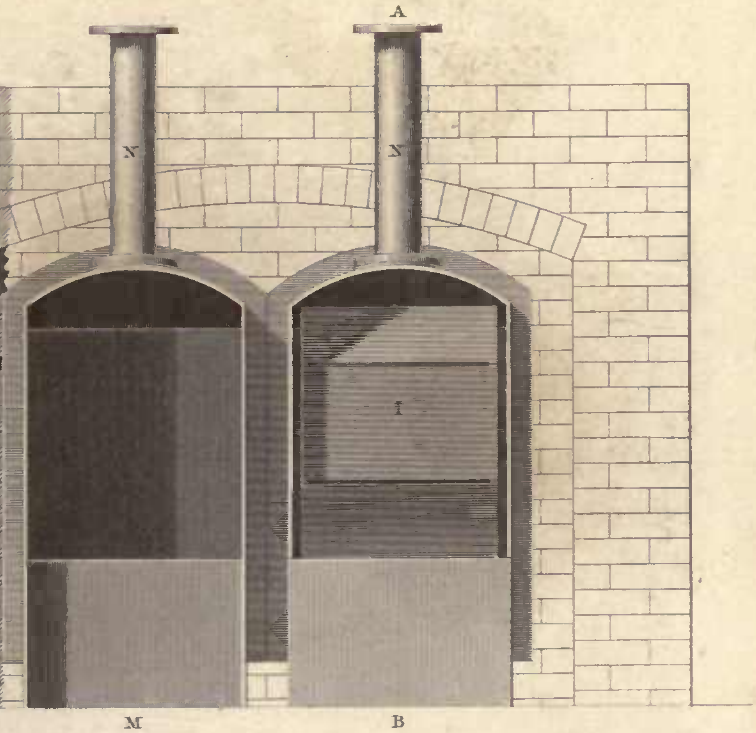
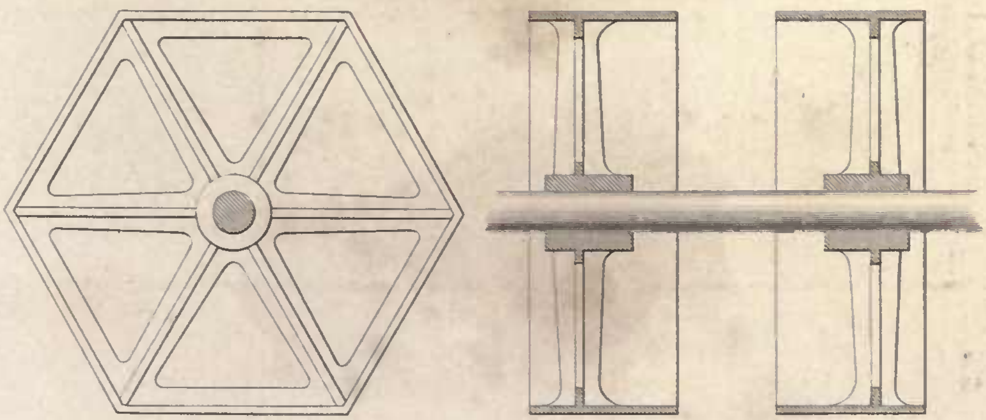


Fig. 5

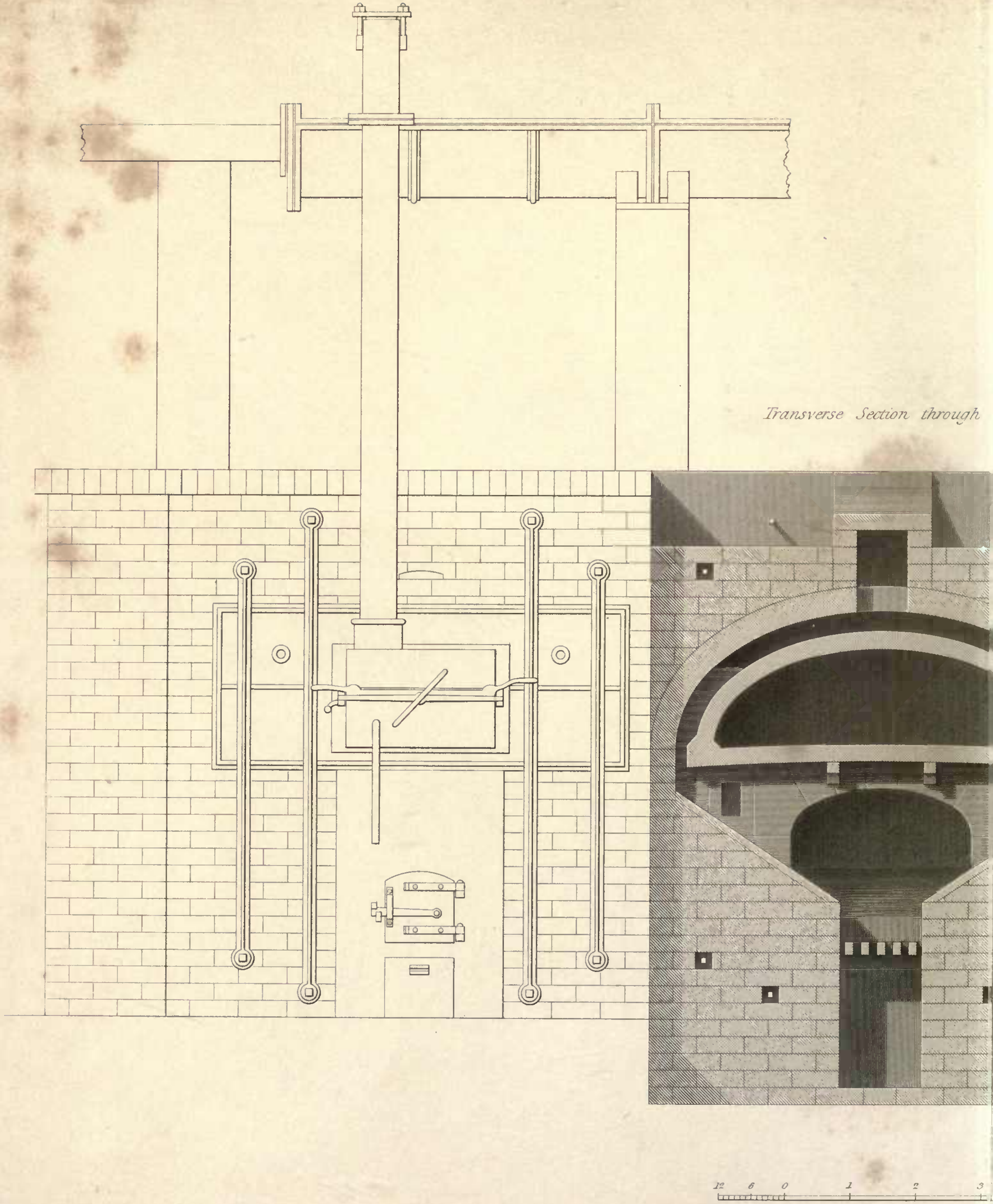


Scale of Feet

rary, 59, High Holborn

G. Gladwin sculp.

COLLEGE [illegible]

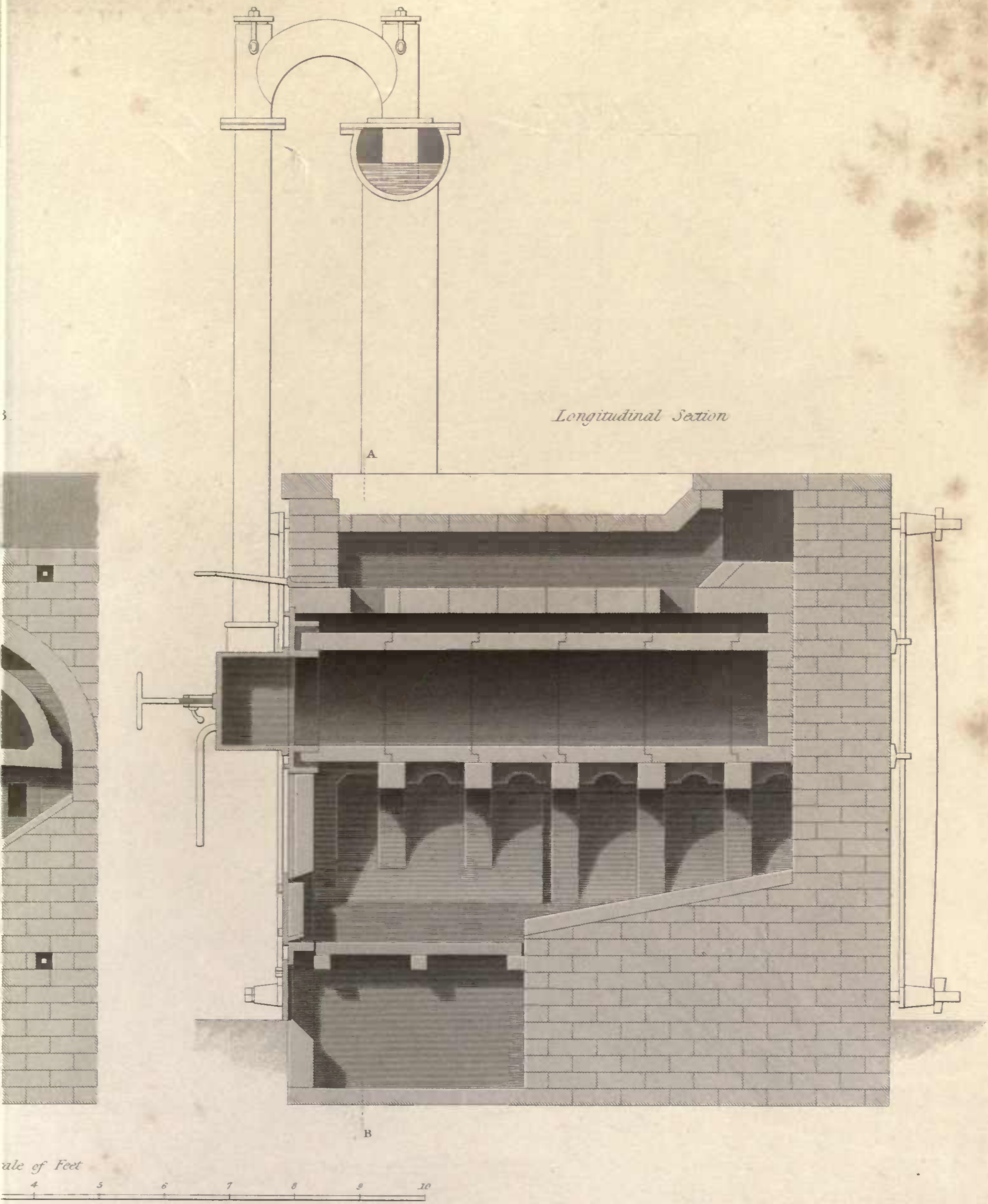


Transverse Section through

A Burn Jun^{r} del

John Weale. Architectura

Plate VII.

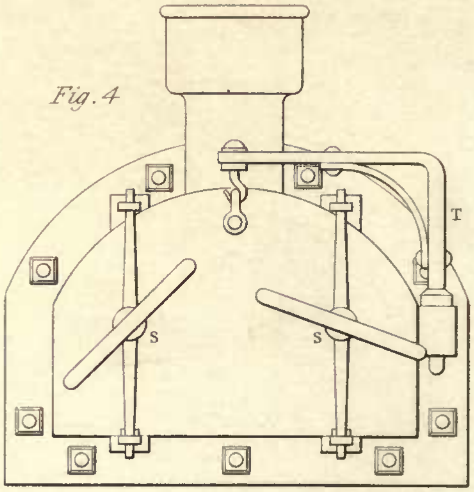


ibrary, 59 High Holborn.

G. Gladwin sculp

[illegible] COLLEGE BL [illegible]

Fig. 4



Scale of Feet

Fig. 1

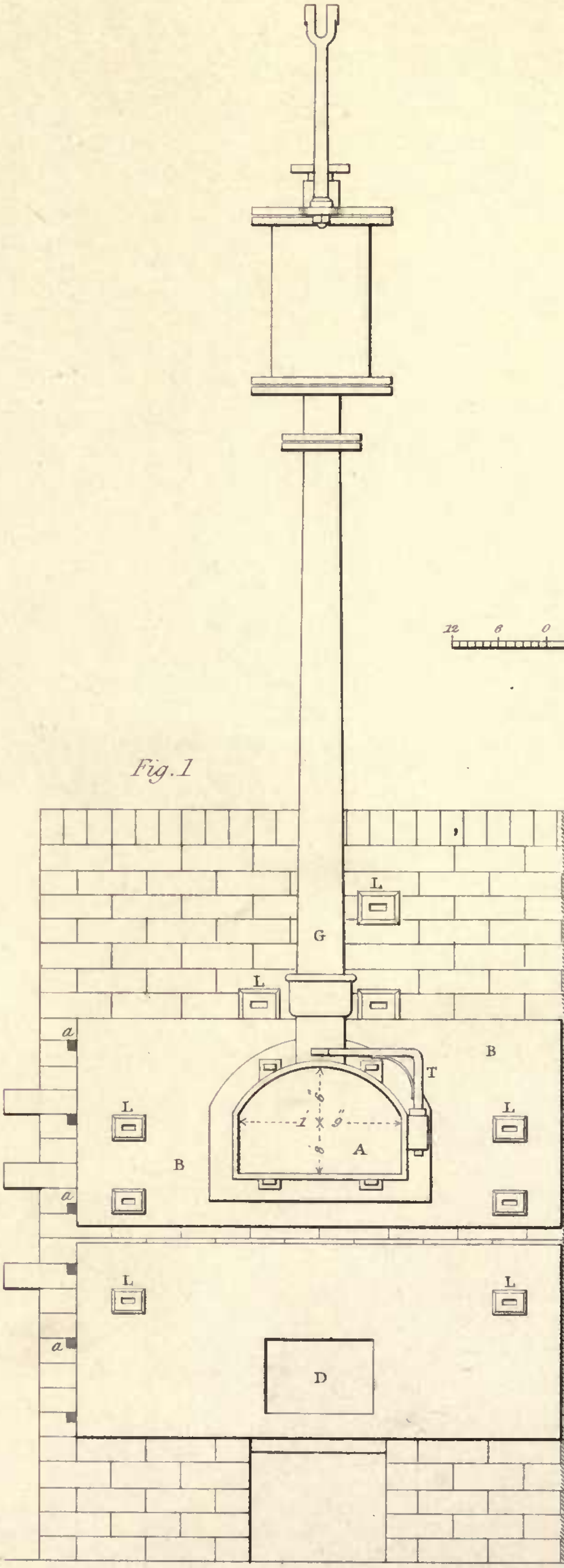
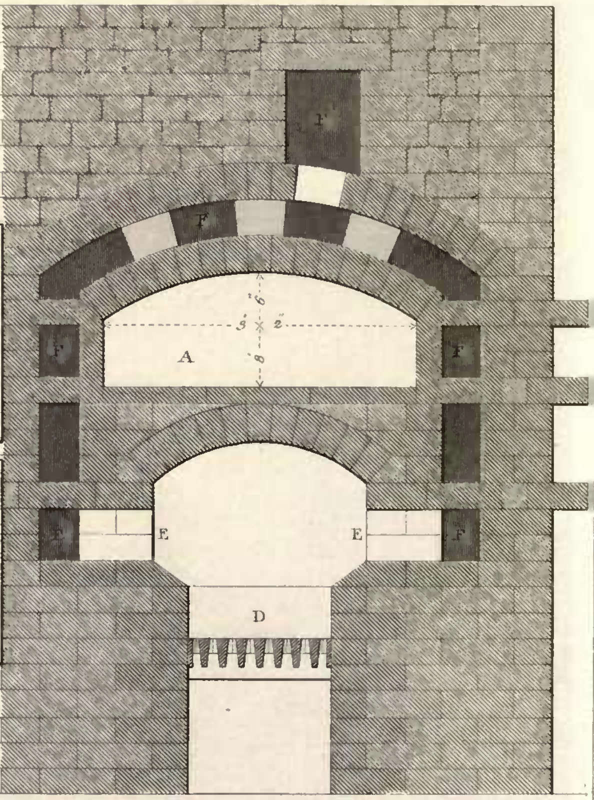


Fig. 2

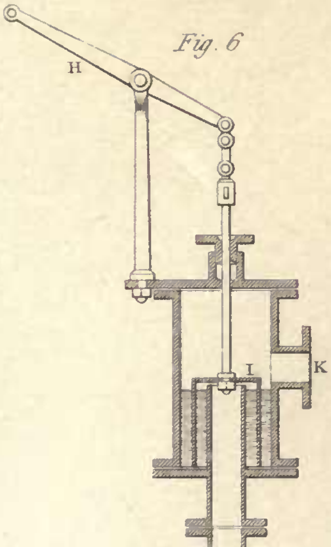


Saml. Clegg Junr. del.

John Weale, Architectur

Plate VIII.

Fig. 6



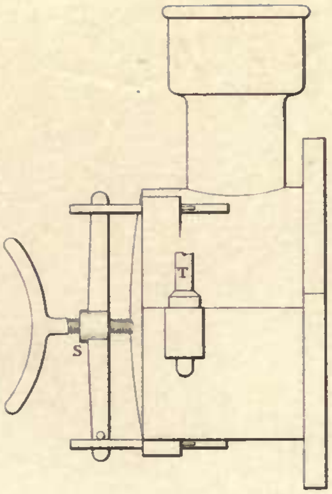
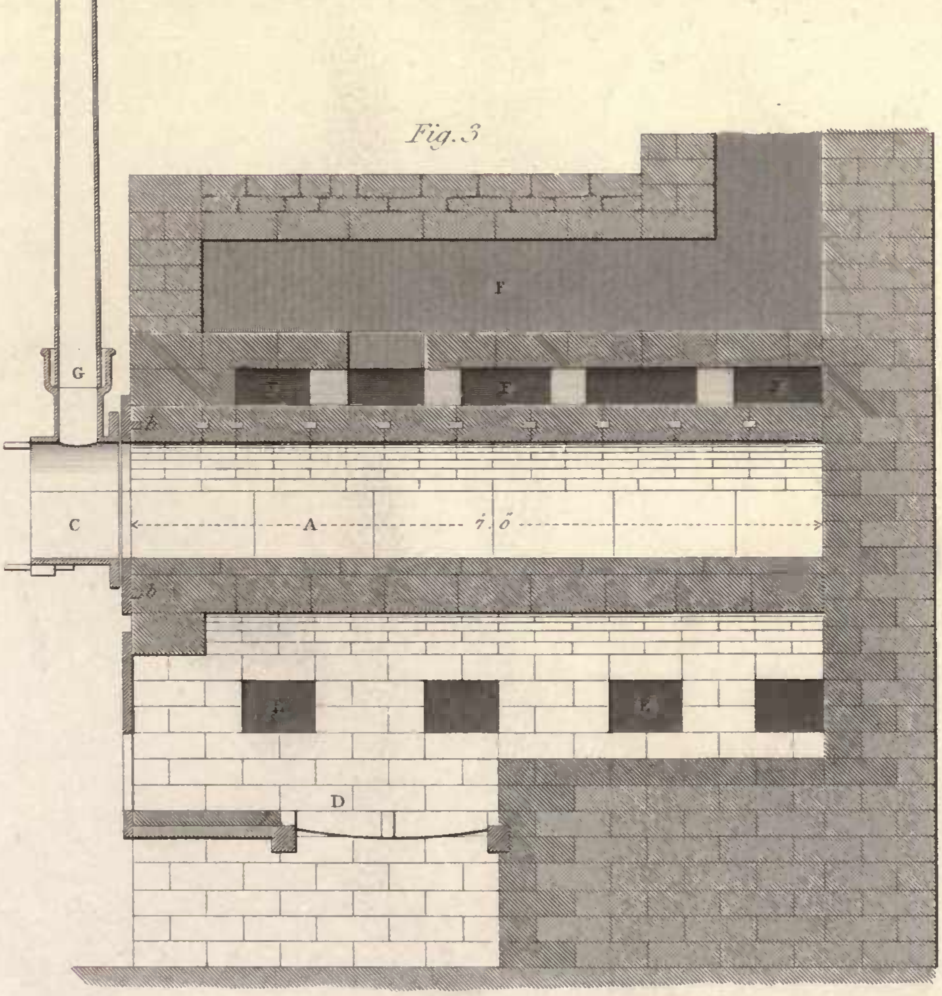


Fig. 5

Scale to Figs. 4 & 5.

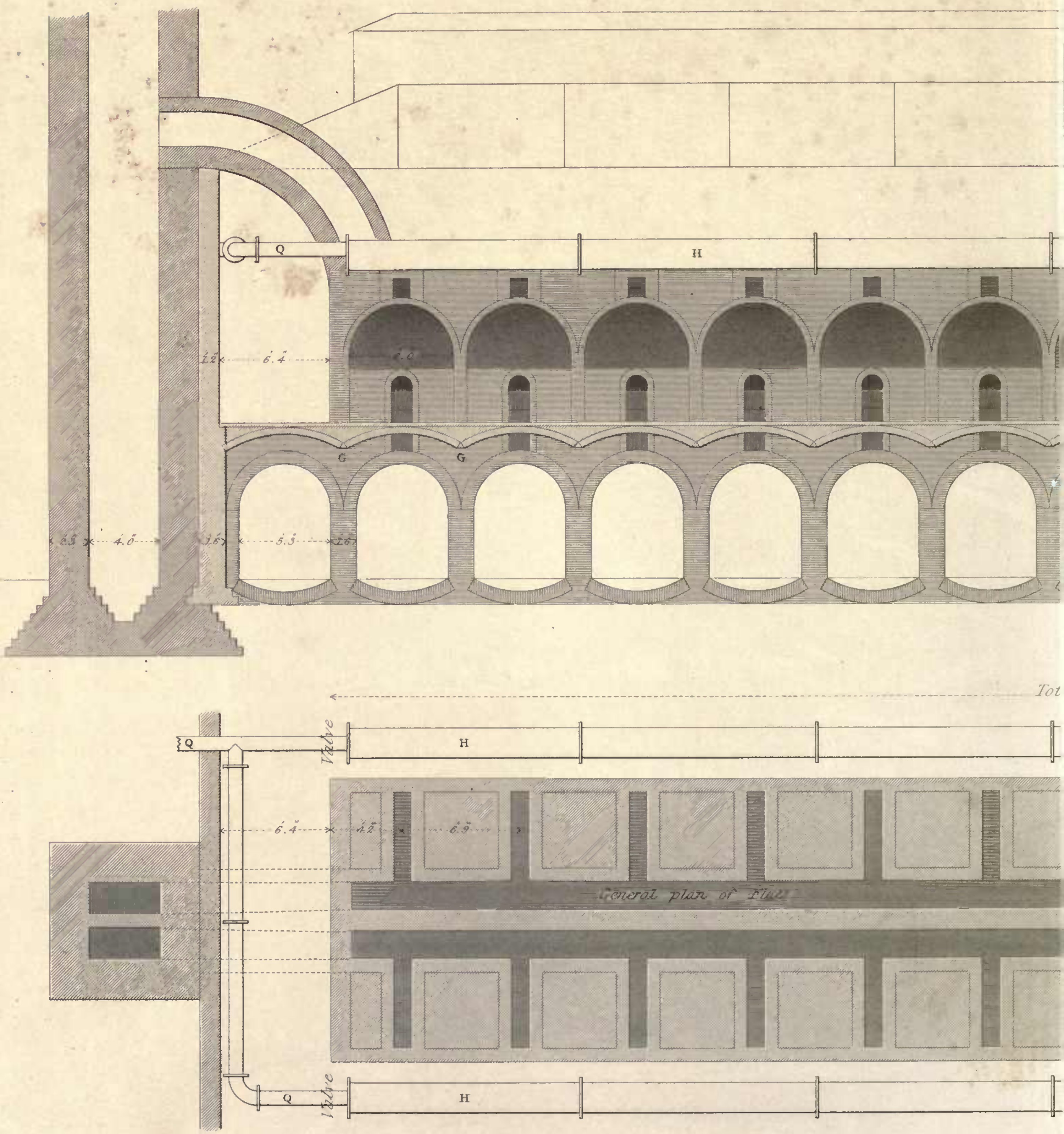
Fig. 3



G. Gladwin sculp.

ibrary. 59. High Holborn.

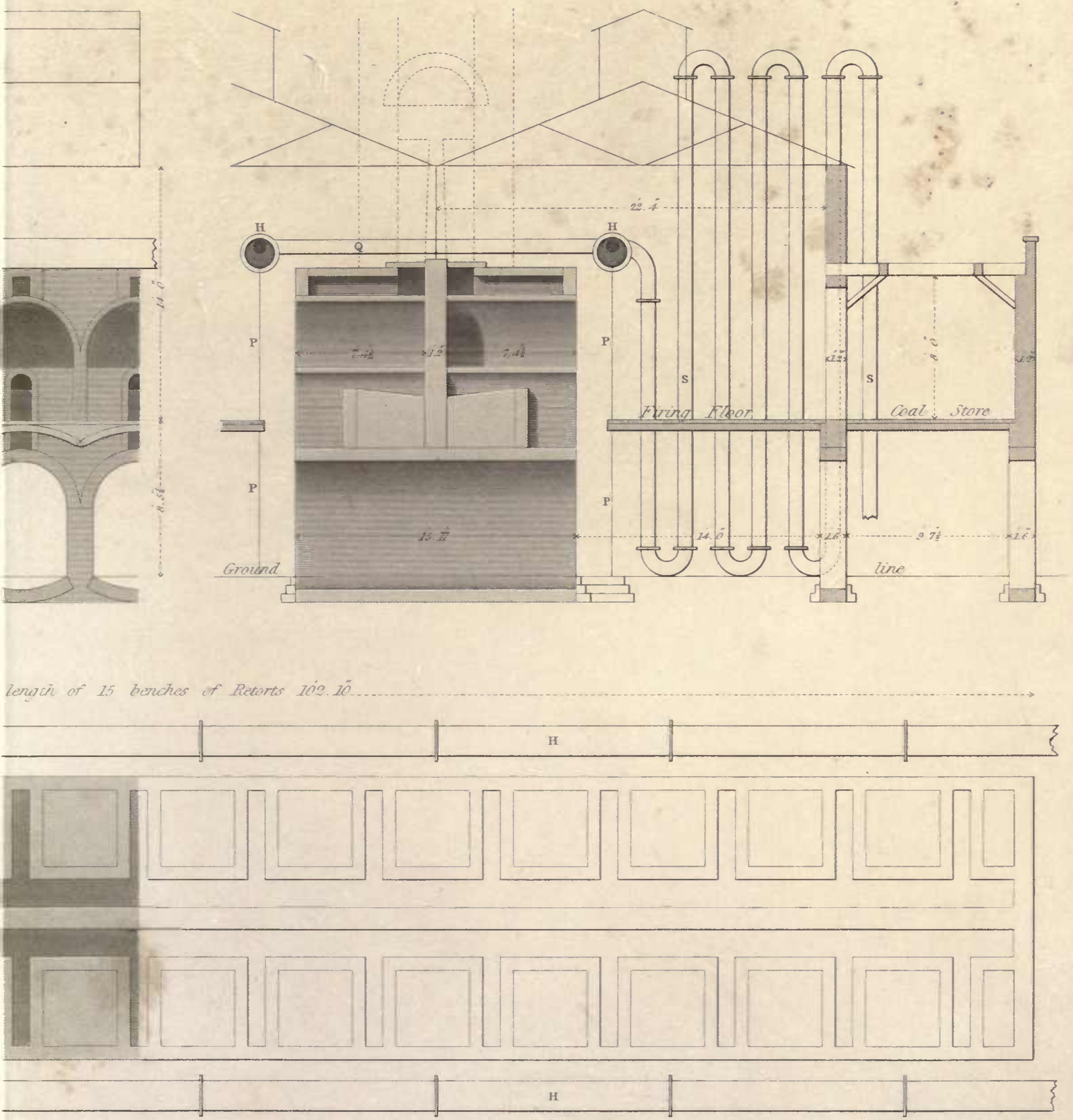
GEORGE BLACKIE & Co



Saml. Clegg Junr. del.

John Weale, Architectur

Plate IX.

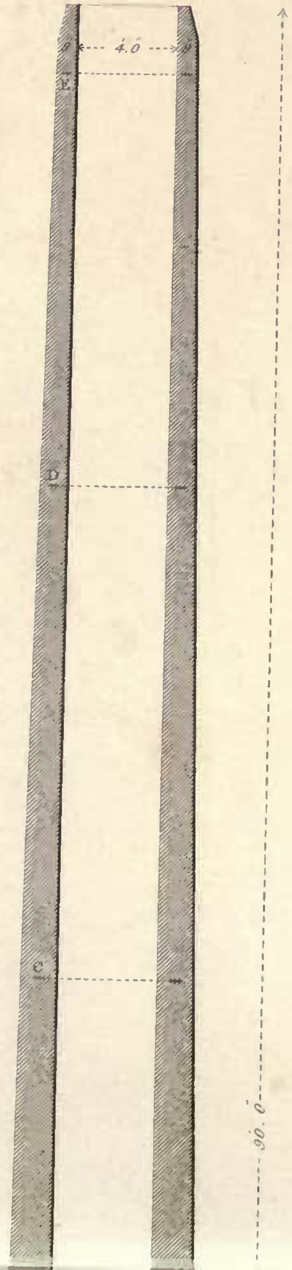


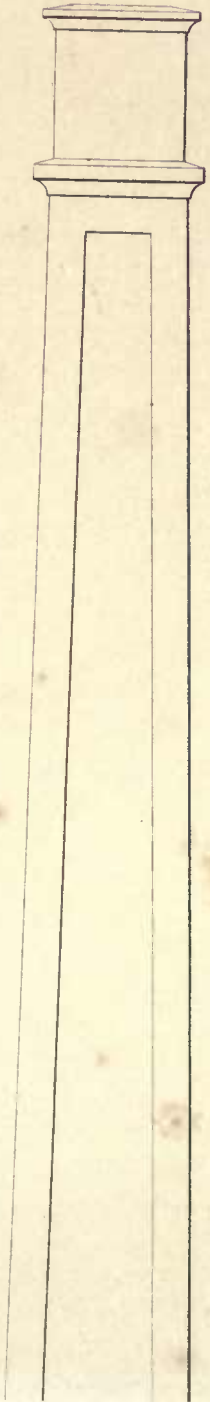
G. Gladwin sculp.

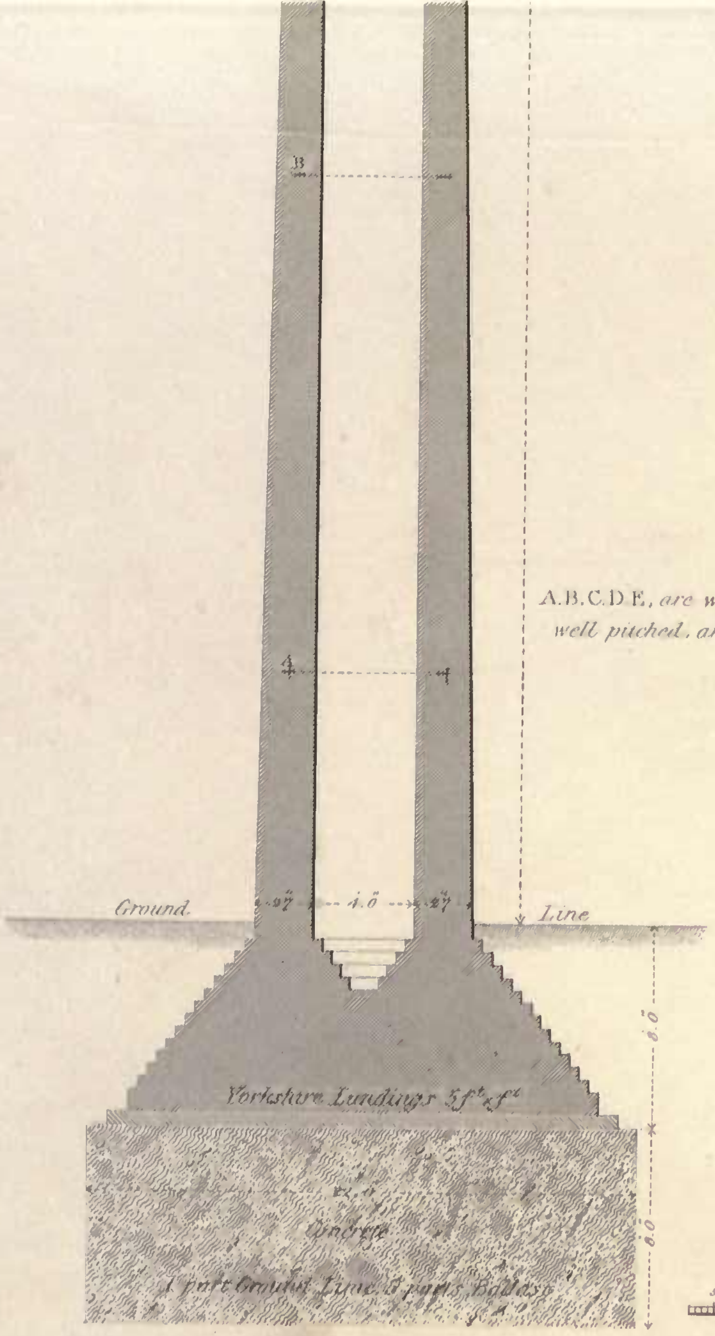
brary. 59. High Holborn

COLLEGE OF AGRIC

Plate X

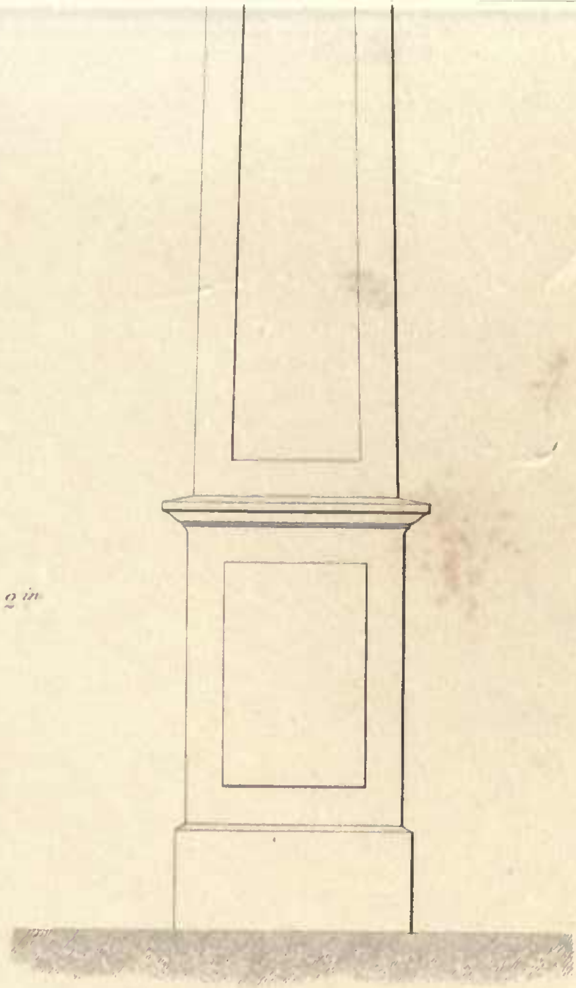




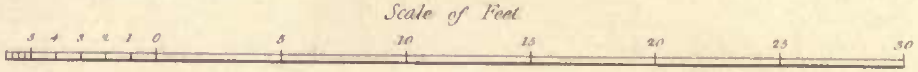


A.B.C.D.E. are wrought Iron hoops ½ x 2 in well pitched, and sanded

Chimney built at Fulham Gas-Works, on a quick sand 1829



Design for same Shaft not Executed

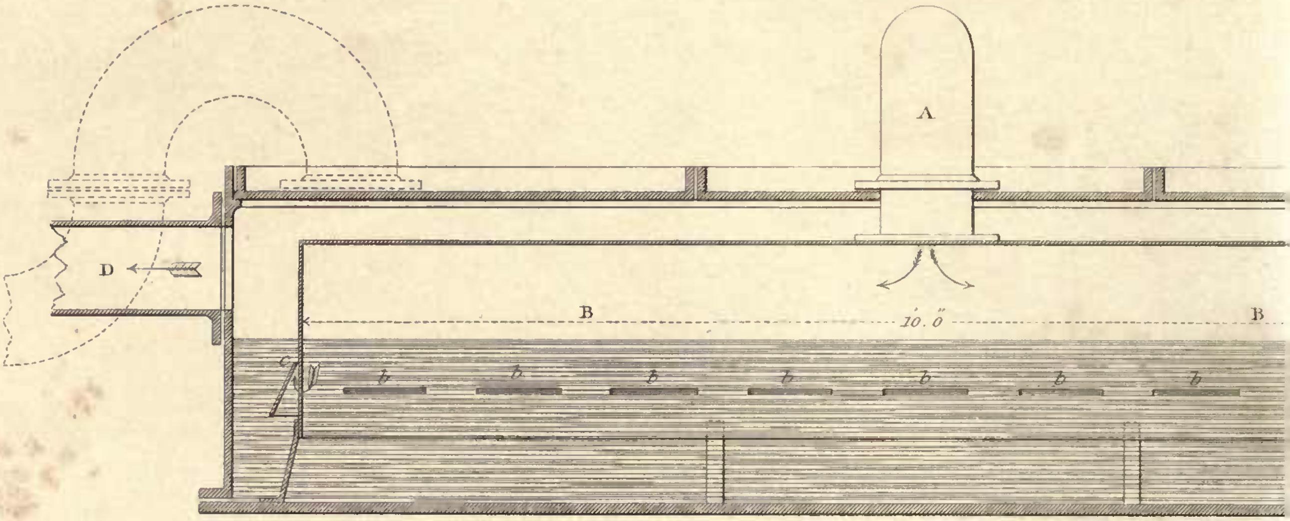


Saml. Clegg Junr. del.

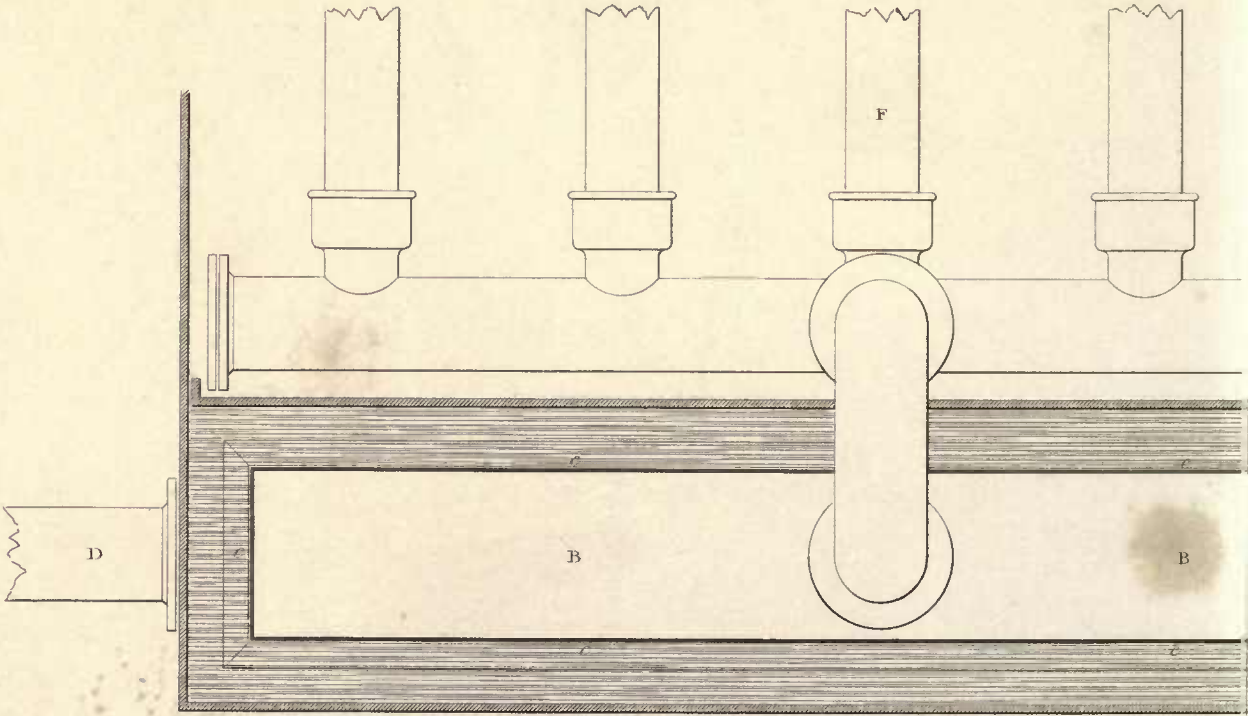
G. Gladwin sculp

John Weale, Architectural Library, 59, High Holborn.

COLLEGE BL



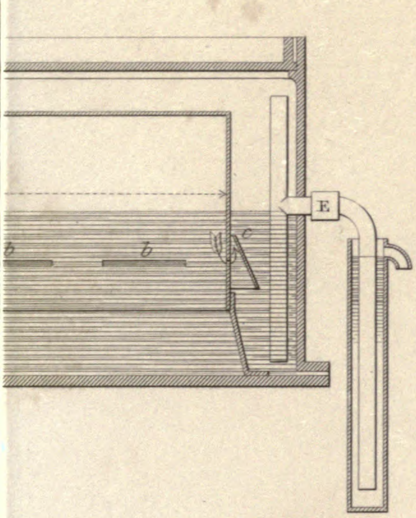
Longitudinal Section



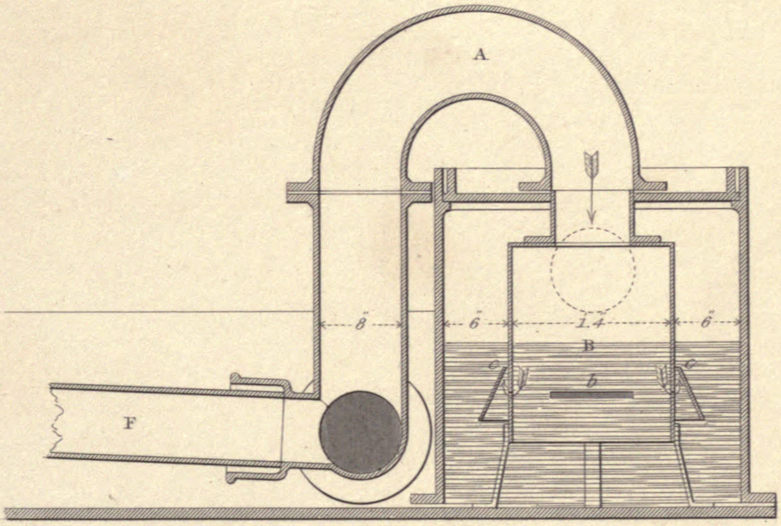
Saml. Clegg Junr. del.

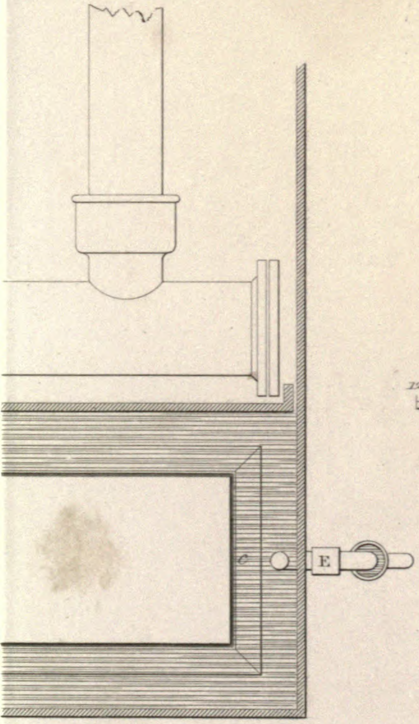
John Weale, Architectu

Plate XI.

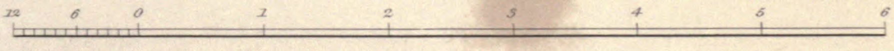


Transverse Section





Scale of Feet



G. Gladwin sculp.

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MORDEN·COLLEGE BLACKHEATH

Fig. 1.

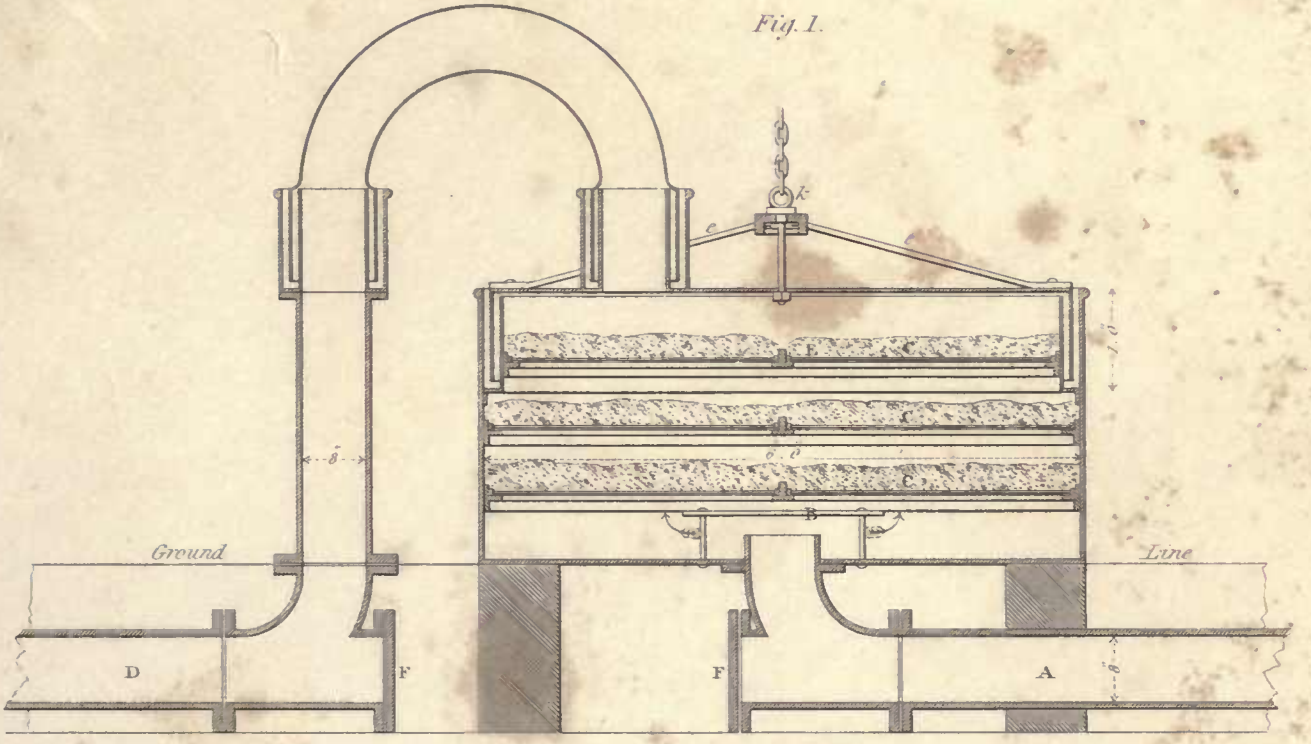
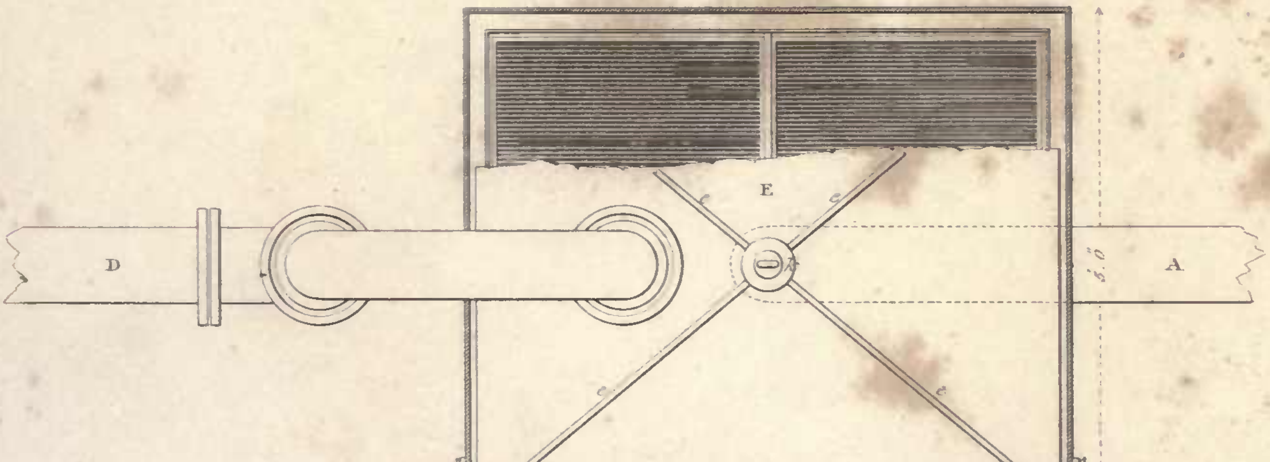


Fig. 2.



Scale of Feet

12 6 0 1 2 3 4 5 6

Sam^{l} Clegg Jun^{r} del.

G. Gladwin sculp

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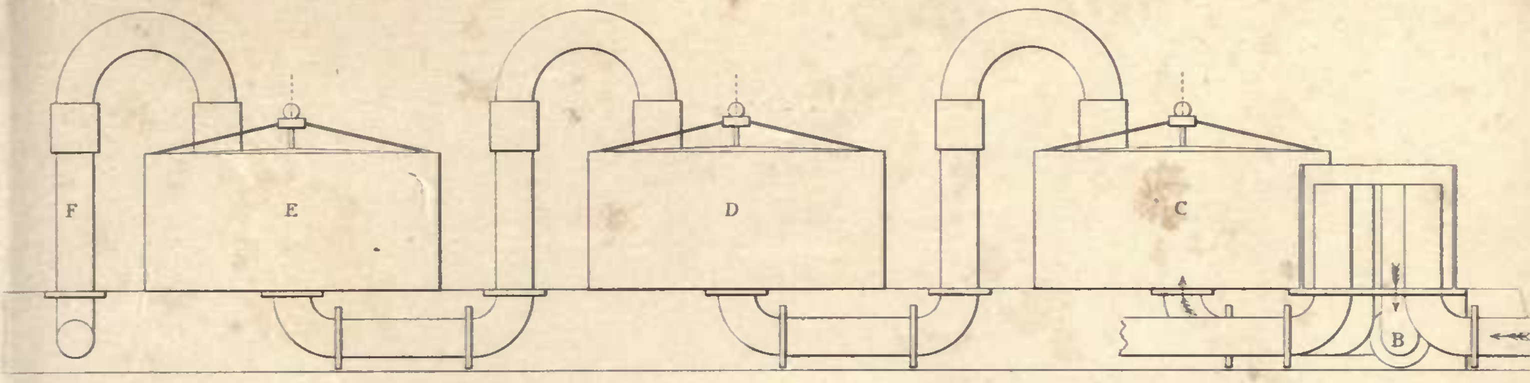
Elevation.



Plan.

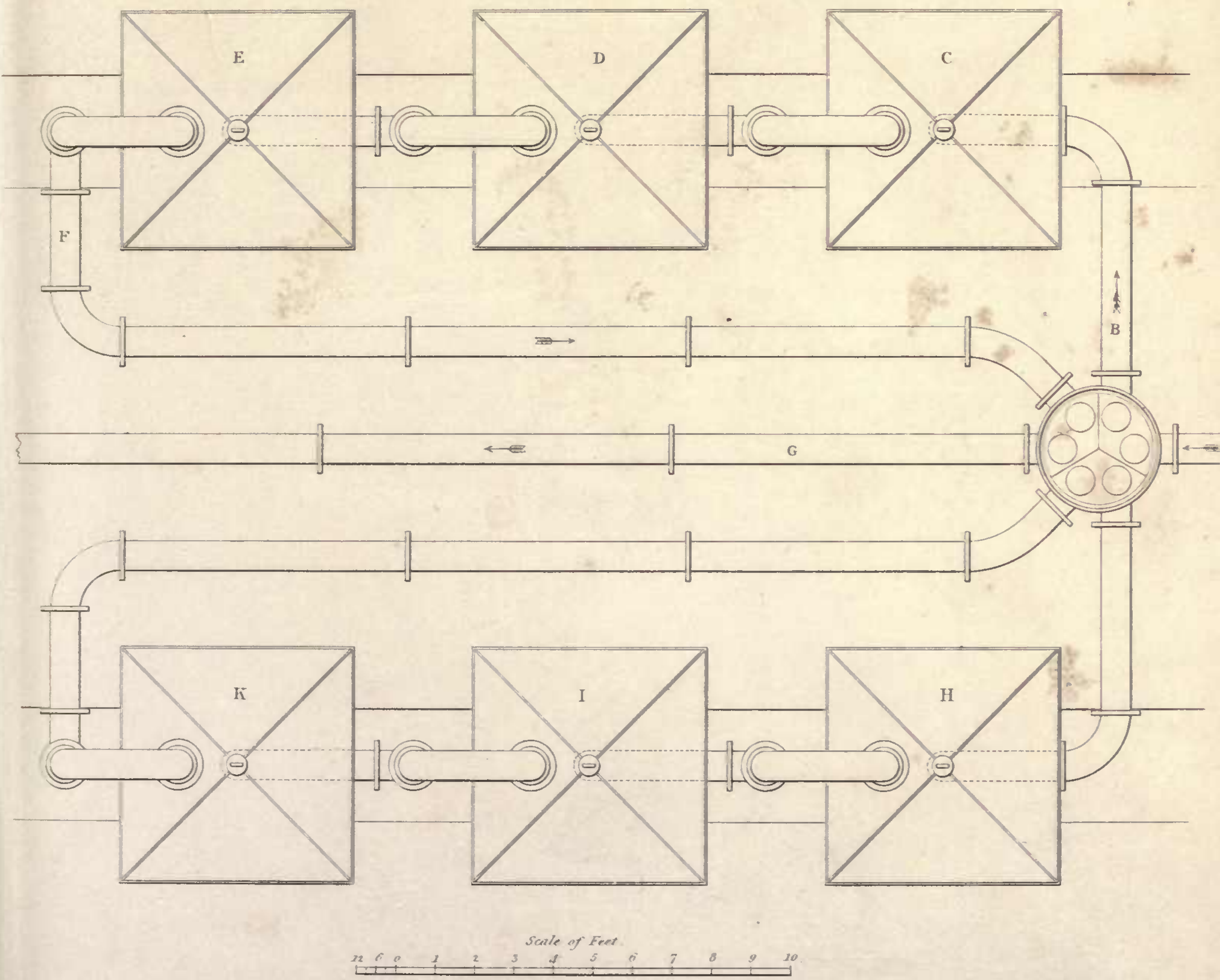


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Fig. 1.

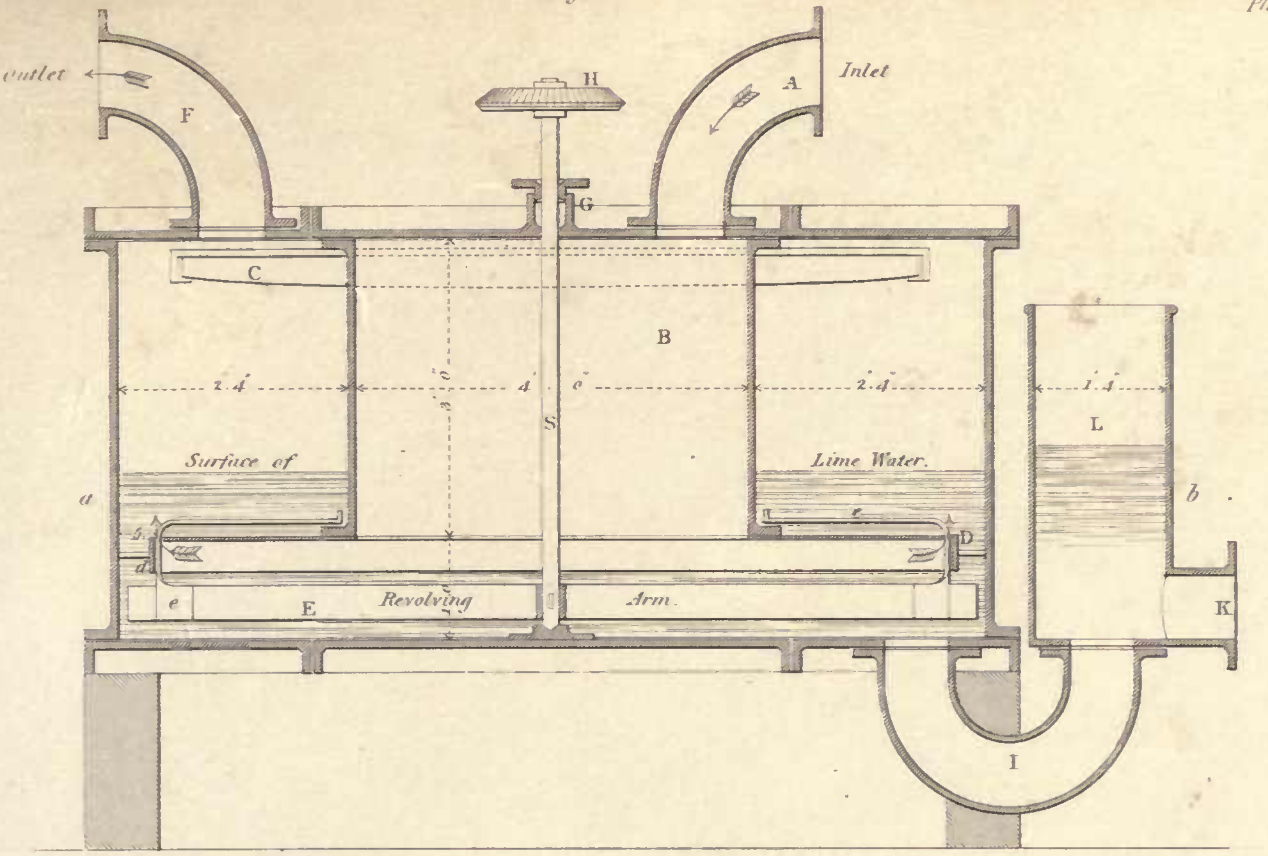
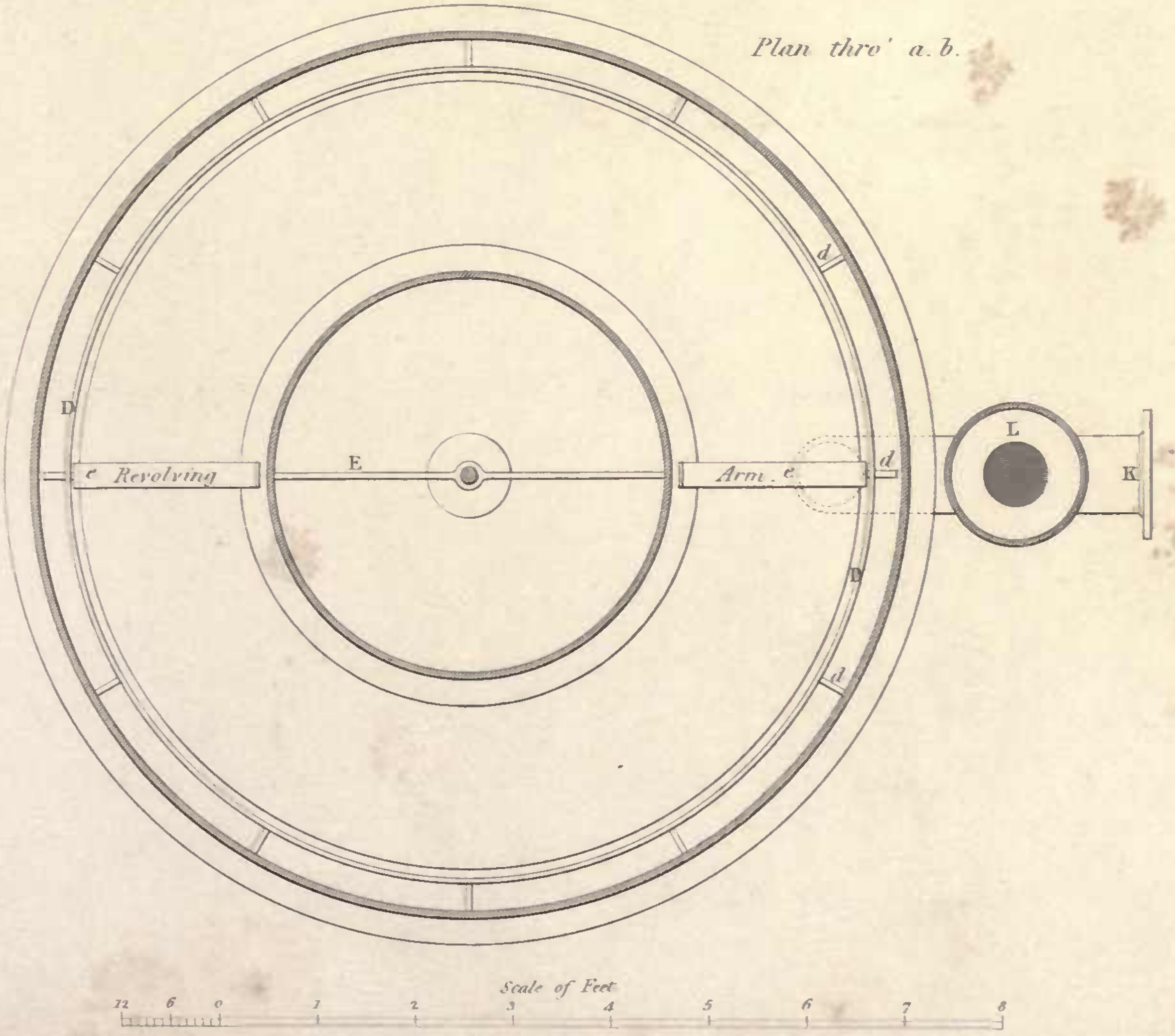


Fig. 2.

Plan thro' a. b.



Saml. Clegg Junr. del.

G. Gladwin sculp.

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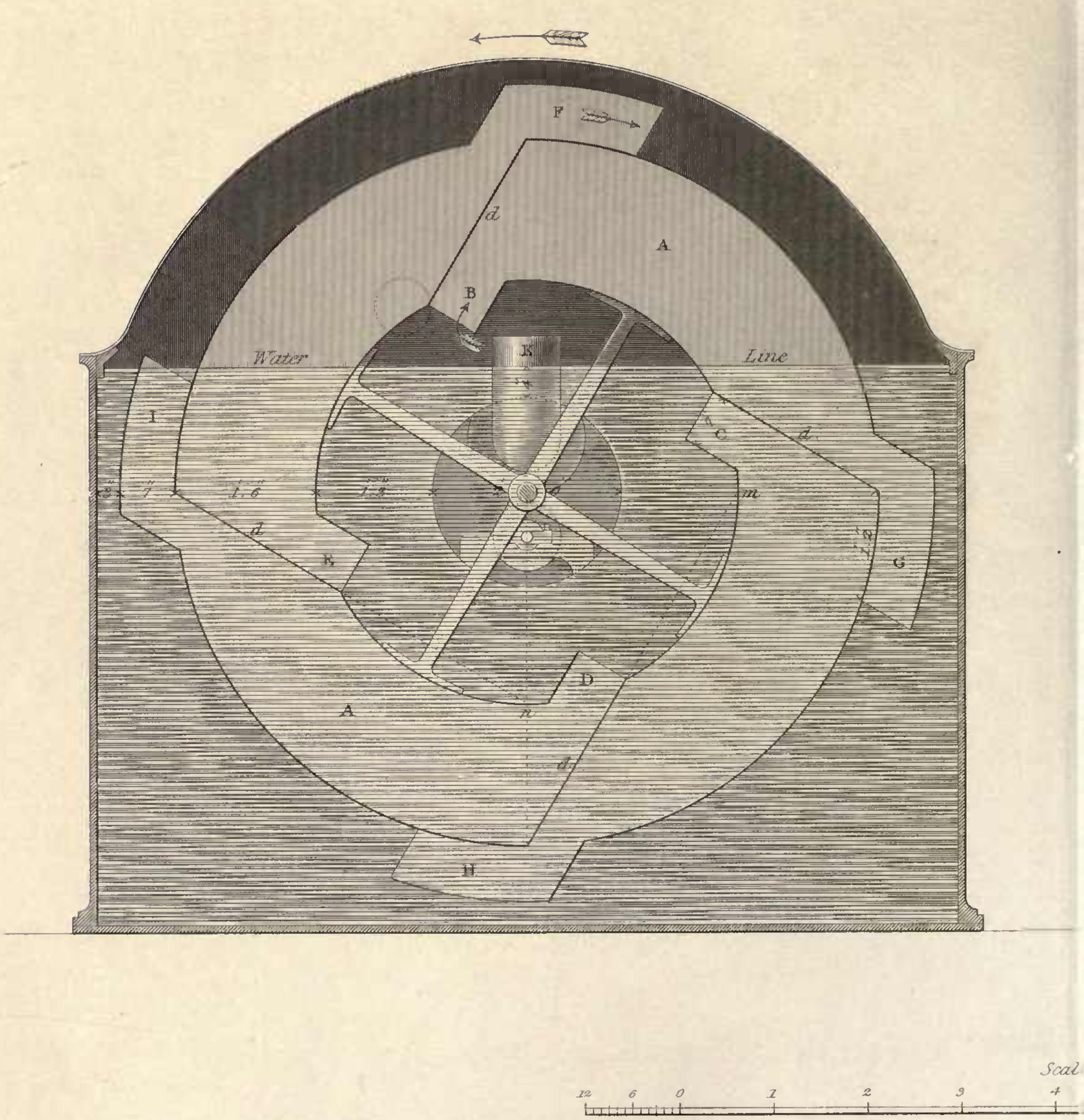
MORDEN COLLEGE

Fig. 1

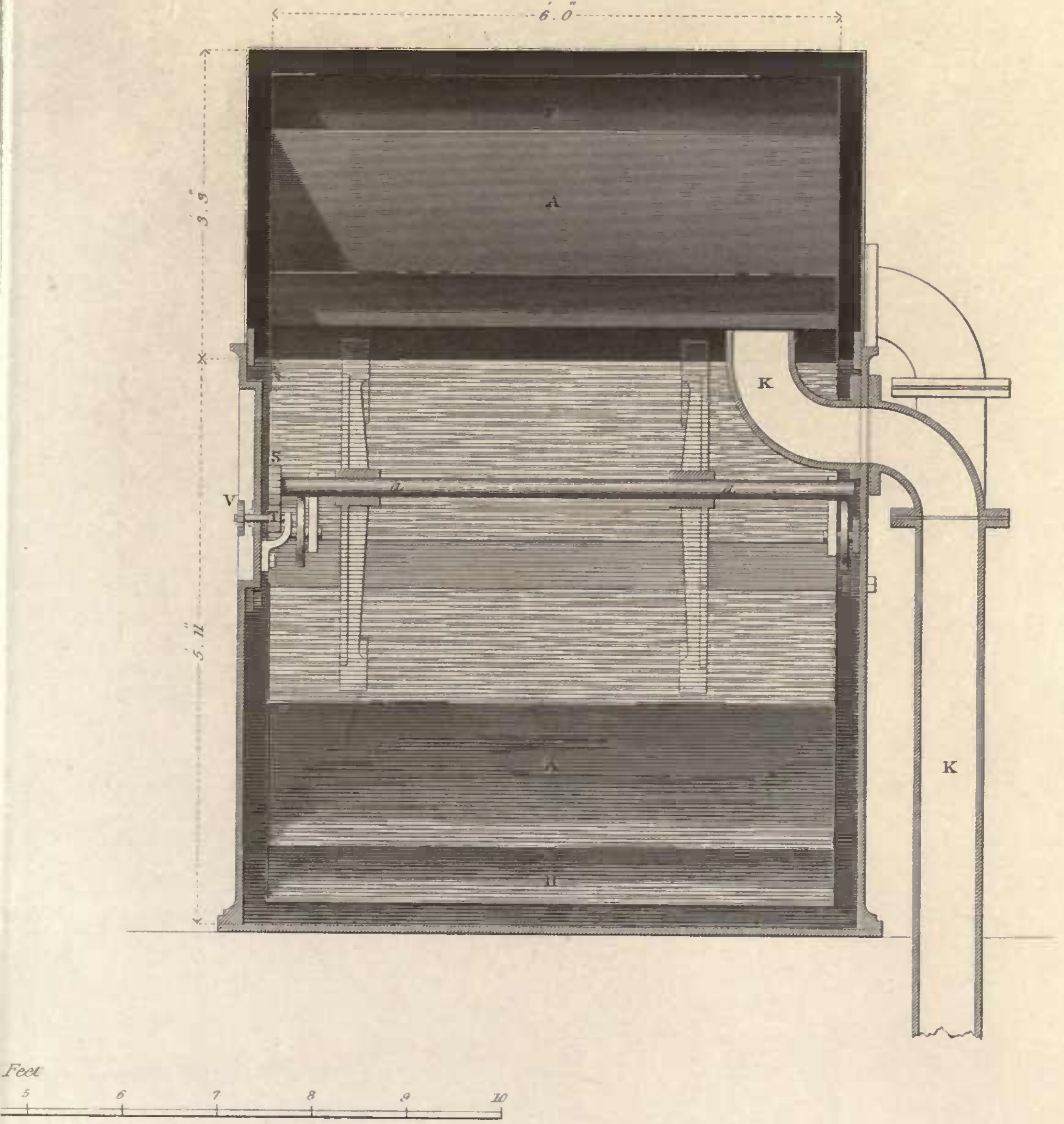


Sam.l Clegg Jun.r del.

John Weale, Architectura

Plate XV.

Fig. 2



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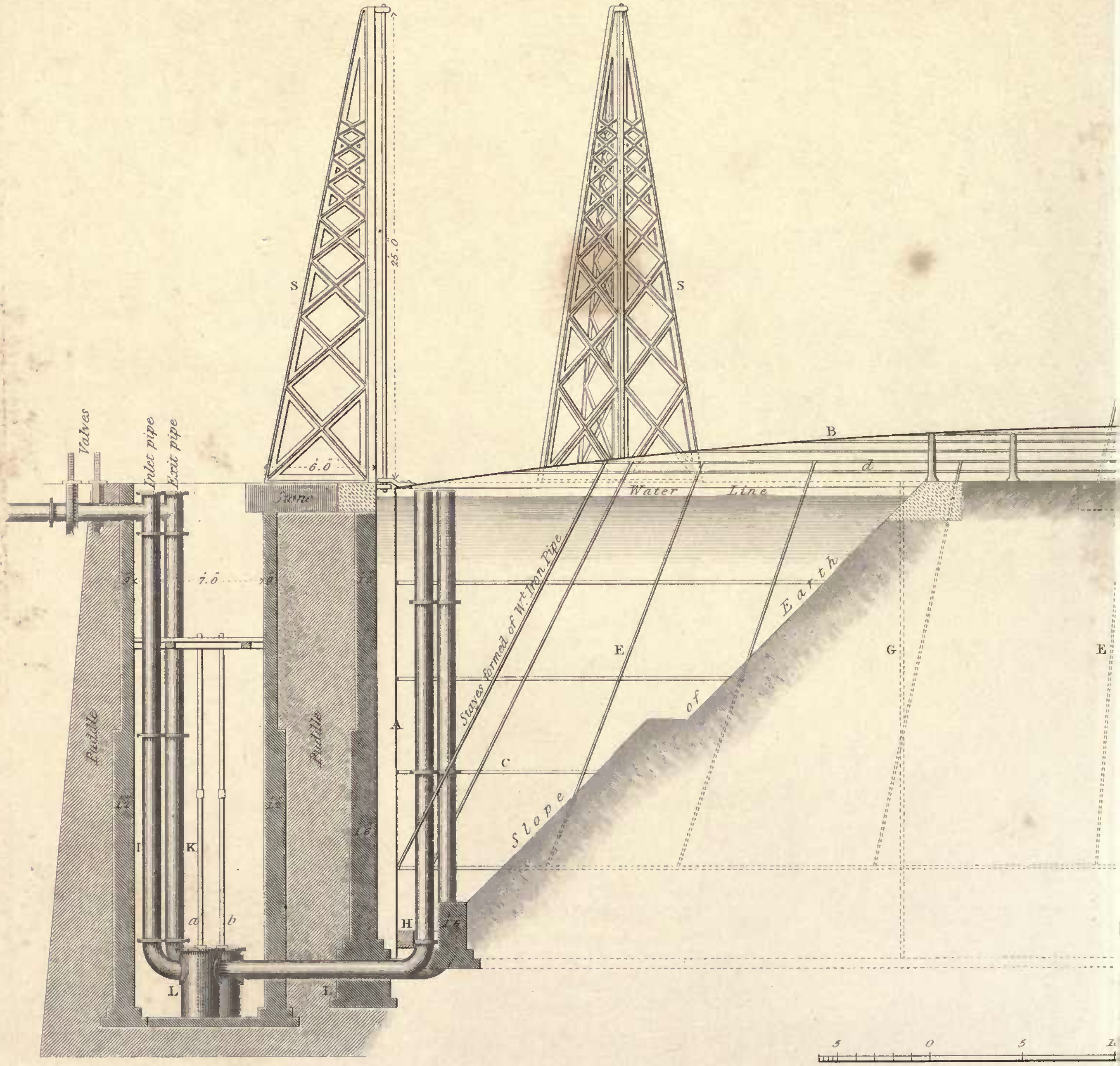
G. Gladwin sculp.

Section of a Gasometer to

Diameter 87′. 6″ _ Height 2

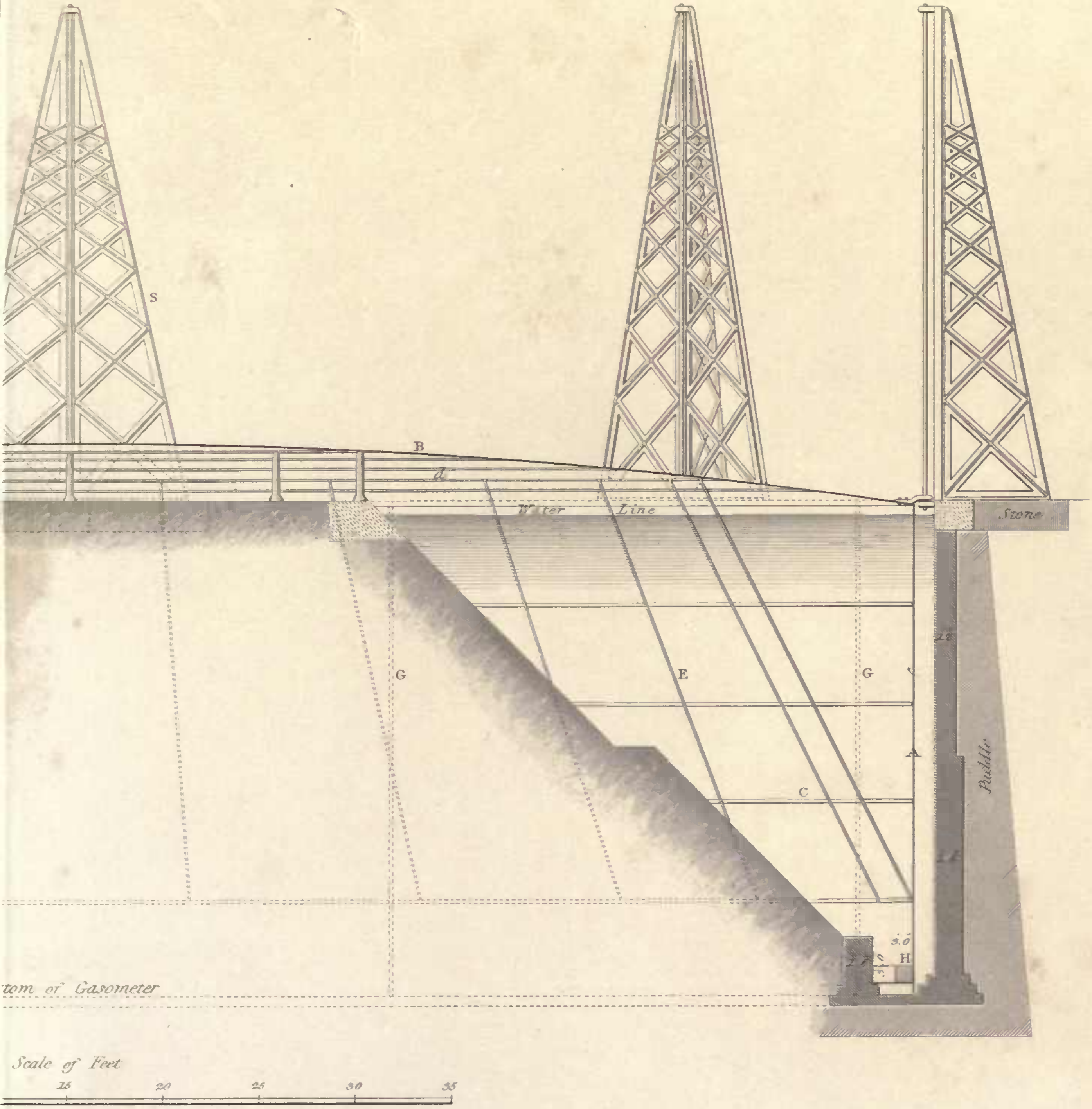


Sam.^{l} Clegg Jun.^{r} del.

John Weale, Architectura

ntain 150,000 Cubic Feet.

et _ Rise of the top 3.6"

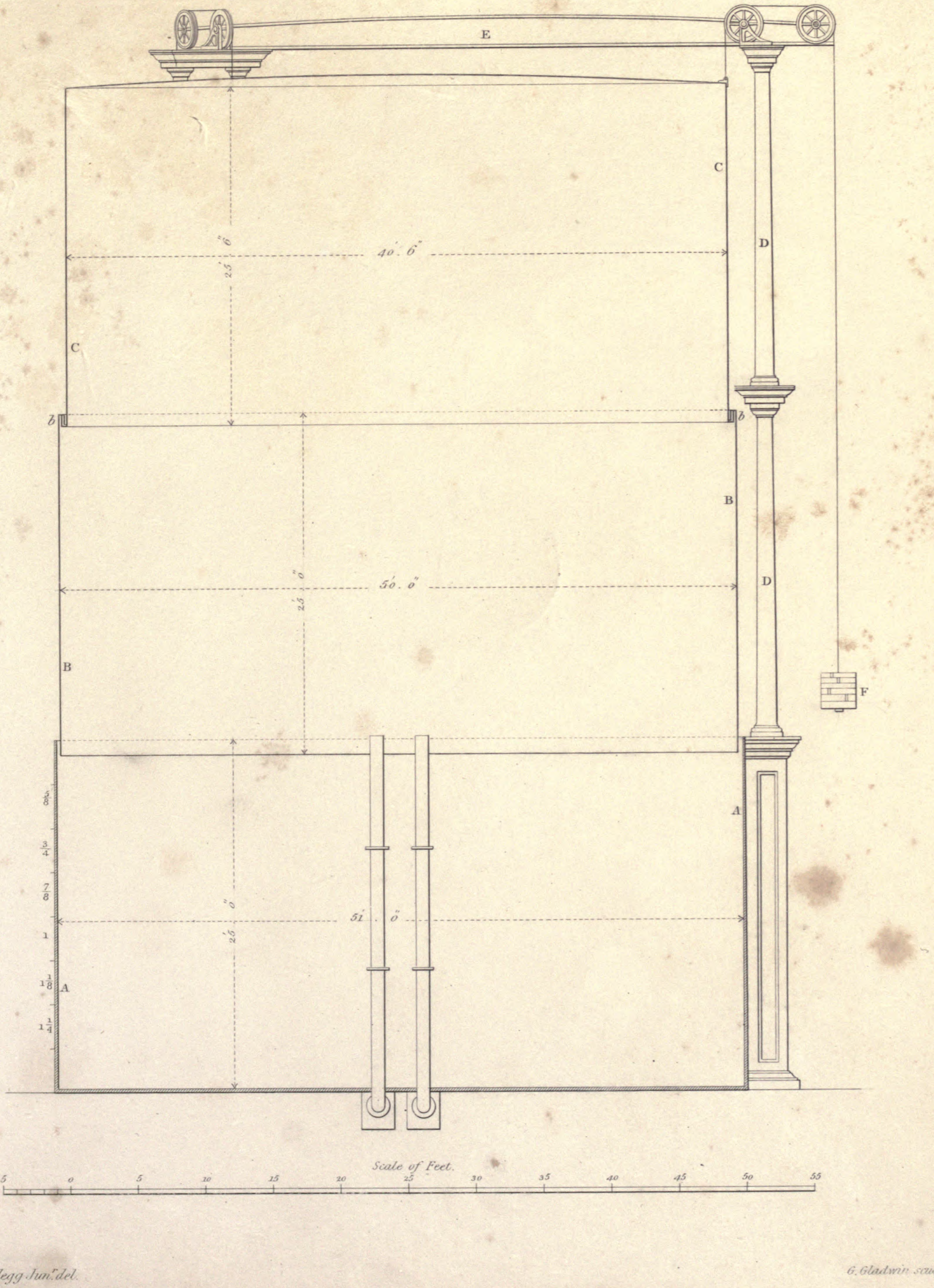


G. Gladwin sculp.

brary, 59 High Holborn

MORDEN COLLEGE BLACKHEATH · S.E.

Plate XVII.



Saml. Clegg Junr. del. *G. Gladwin sculp.*

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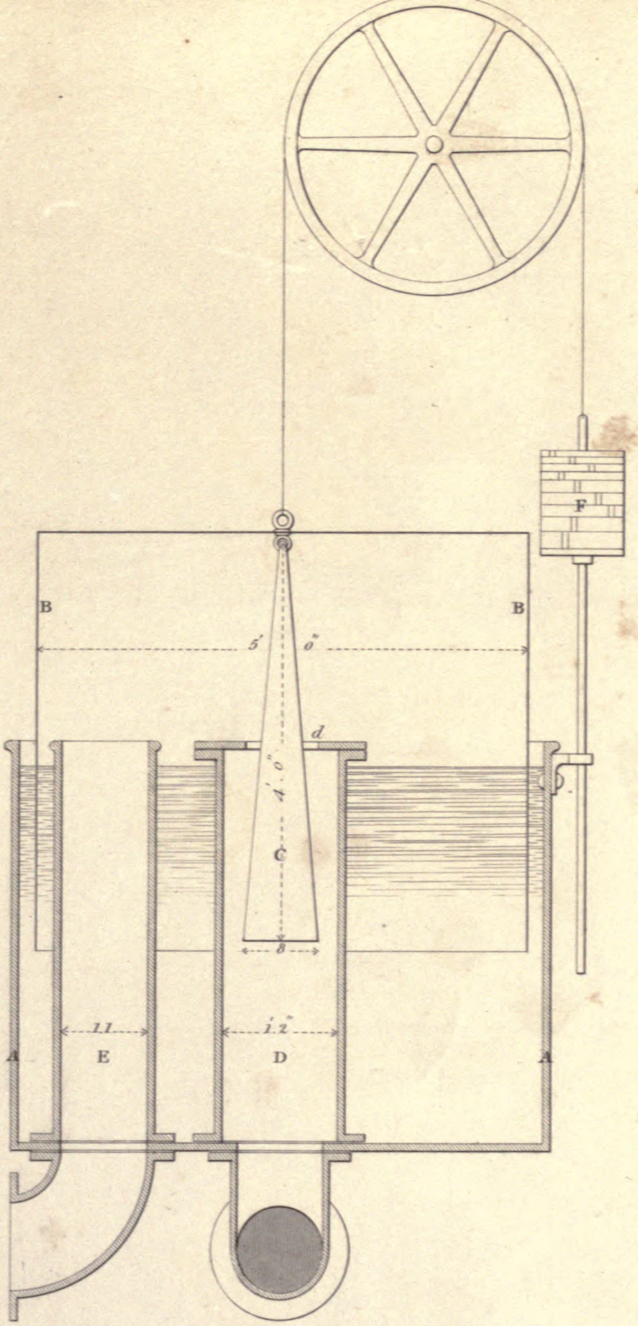
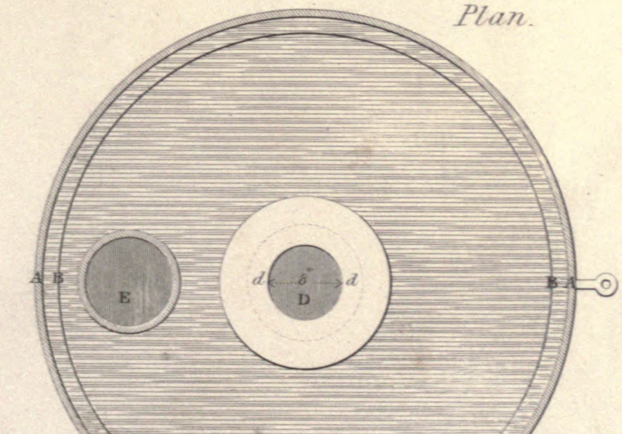
MORDEN COLLEGE BLACKHEATH



Plan.



Saml. Clegg Junr. del.

G. Gladwin sculp.

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Fig. 1

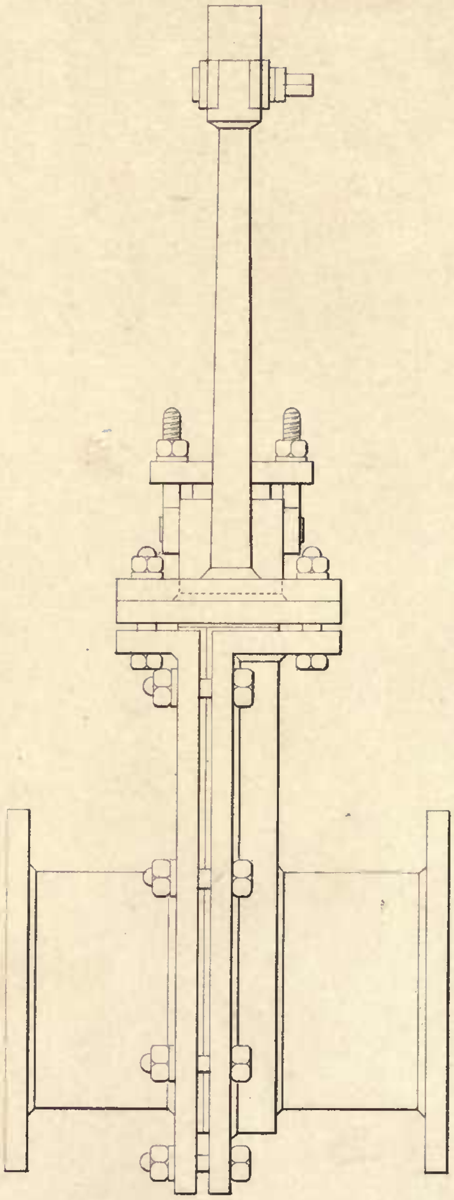


Fig. 2

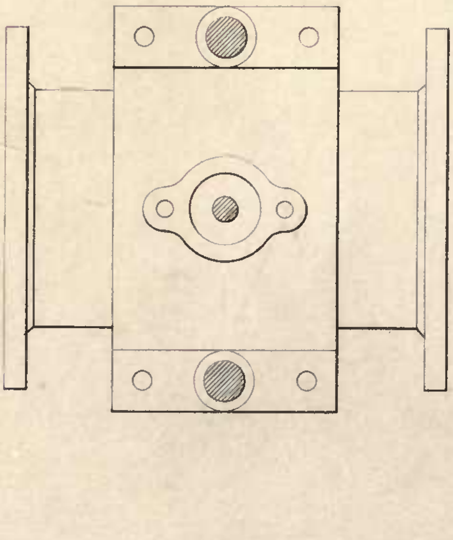


Fig. 3

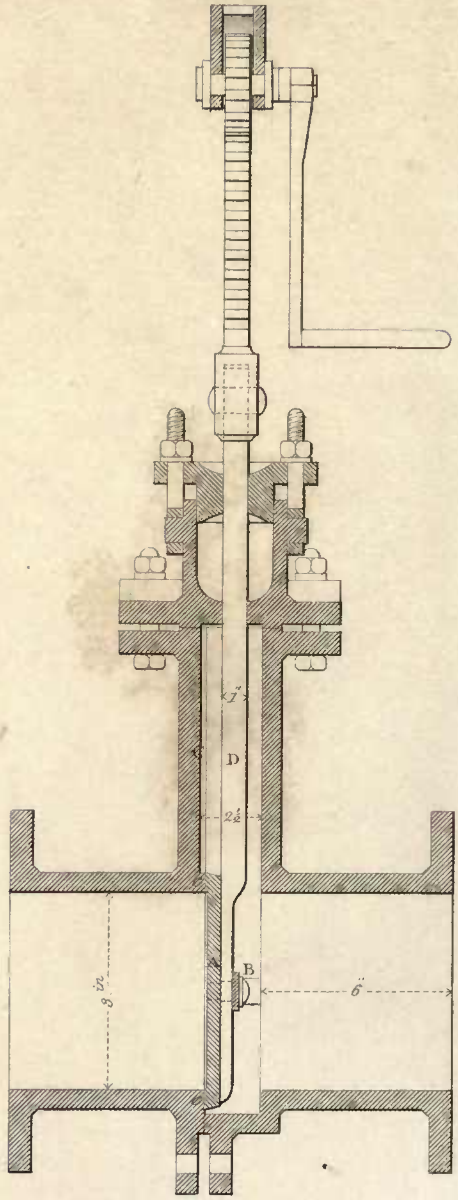
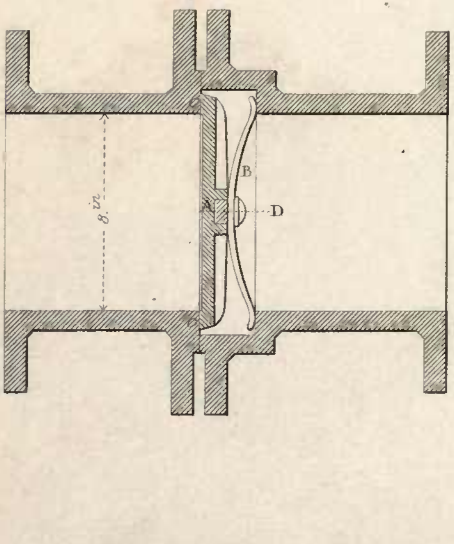


Fig. 4



Saml. Clegg Junr. del.

John Weale, Architectu

Fig. 5

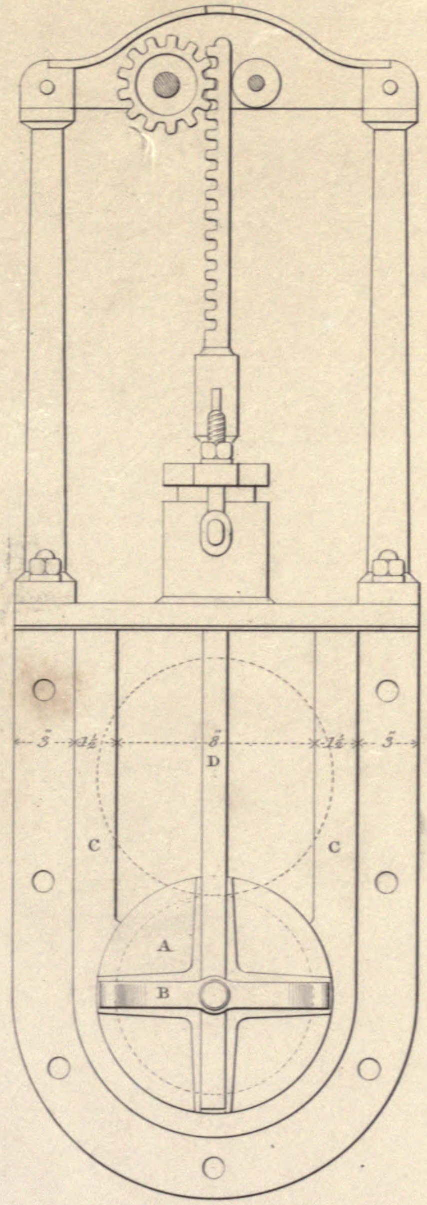


Fig. 6

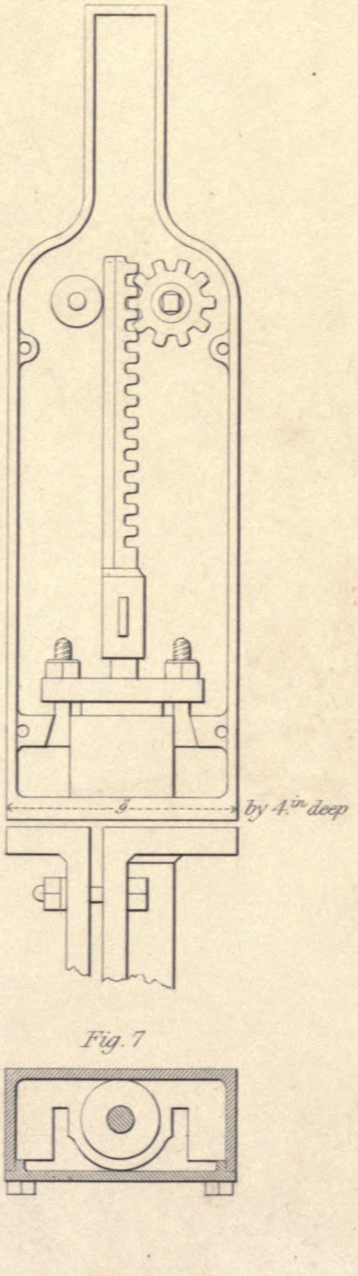
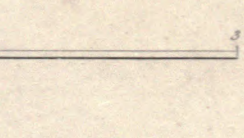


Fig. 7



Scale of Feet

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