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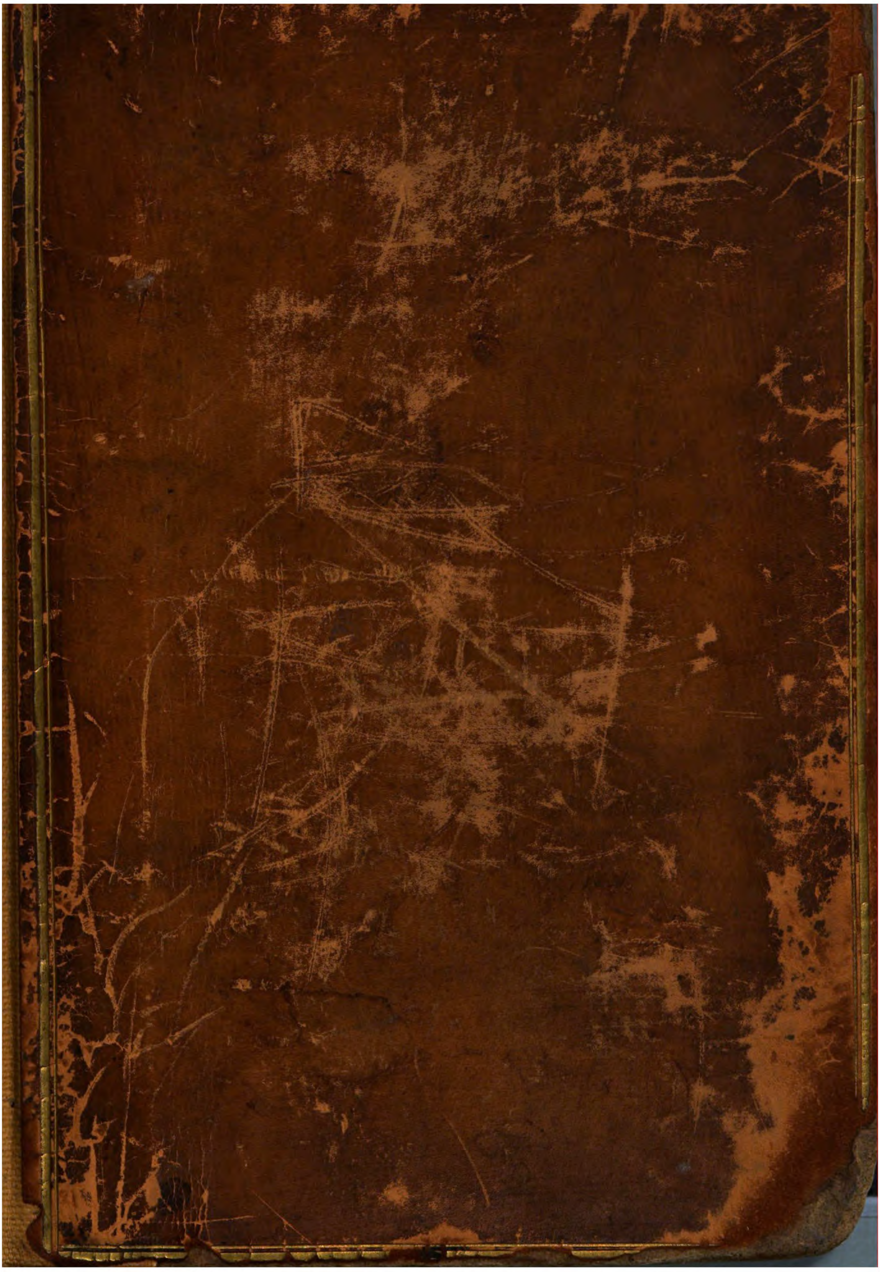

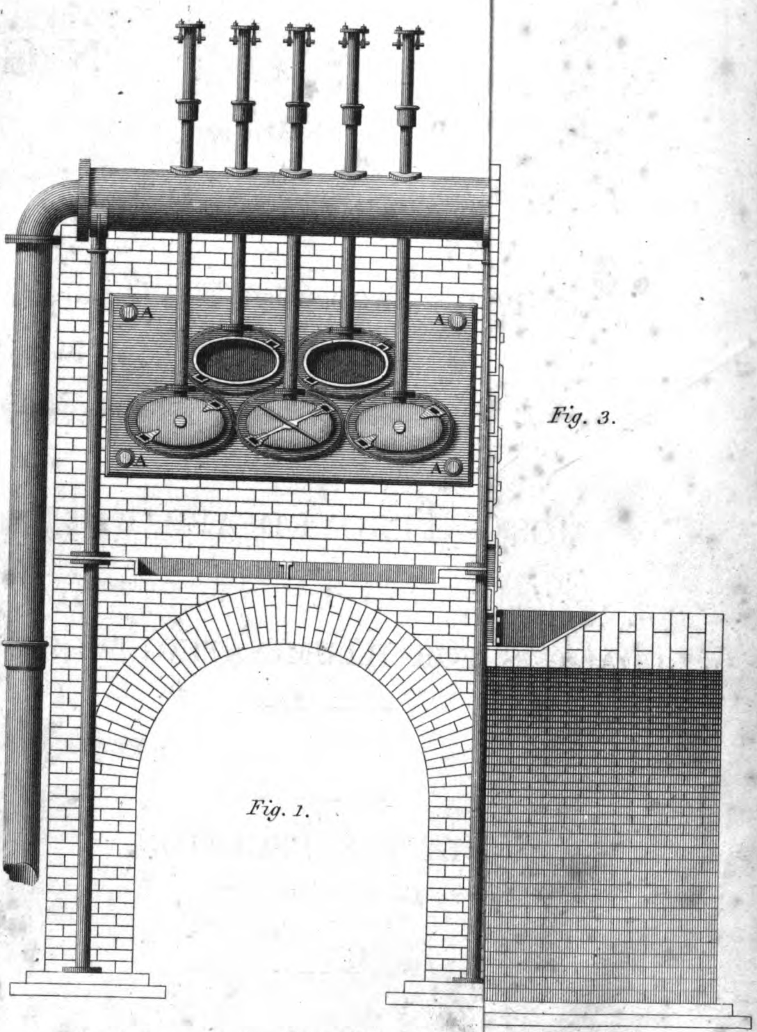

Sections of
at the Charter

Drawn by John Malam.

Engraved by W. Alexander 111 Chancery Lane.

THE

THEORY AND PRACTICE

OF

GAS-LIGHTING:

IN WHICH IS EXHIBITED

AN HISTORICAL SKETCH

OF THE

RISE AND PROGRESS OF THE SCIENCE;

AND THE

Theories of Light, Combustion, and Formation of Coal;

WITH DESCRIPTIONS OF THE

MOST APPROVED APPARATUS

FOR GENERATING, COLLECTING, AND DISTRIBUTING,

COAL-GAS FOR ILLUMINATING PURPOSES.

WITH FOURTEEN APPROPRIATE PLATES.

BY T. S. PECKSTON,

Of the Chartered Gas-Light and Coke Company's Establishment,
Peter-street, Westminster.

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TO

THE HON. COURTNAY BOYLE,

ONE OF THE COMMISSIONERS OF HIS MAJESTY'S NAVY,

&c. &c. &c.

SIR,

THE very attentive perusal which you gave some of my papers, on a former occasion, joined to several friendly attentions claiming my warmest gratitude, have induced me to present this volume to you. If it affords you an hour's amusement during a cessation from official duty, or any information on the subject it treats of, I shall be perfectly satisfied:—at the same time, I must confess I should consider myself fortunate in having the merit of the work stamped by your approval.

I am, SIR,
With the greatest respect,
Your most obliged and devoted servant,
T. S. PECKSTON.

17th May, 1819,
42 *Marsham-street*, *Westminster*.

INTRODUCTION.

OF the many inventions which have tended to benefit mankind, and to administer to their comforts, perhaps no one has been of much greater utility than that which taught them to procure artificial light, for supplying, in some measure, the place of the sun, during the time that he is sunk beneath the horizon.

From the earliest ages we have accounts of fire having been used; and it follows, in consequence, that from time the most remote, man has been able, by means of it, to make the hours of night more cheerful than he could possibly have done had he been unacquainted with its use. It would be useless to inquire how it was first obtained, for although the inquiry might be carried to great length, and with much ingenuity, it could be but theoretical; and were such inquiries pursued by a hundred philosophers, it is probable the results would be numerous, and perhaps not one of them perfectly correct.

Whether, in the first age of the world, man was accidentally led to observe that the friction of one branch of a tree against another generated heat; whether he found that by the collision of hard bodies, sparks of fire were produced; or whether it was not first kindled by the lightning's blaze from heaven, by the very hand of Deity, and carefully preserved till the human mind had become so enlightened as to be able to procure it from bodies where it was latent, the outward appearance of which exhibited no marks leading to expectations of finding it within them, is not the subject to be inquired into. The speculative mind might find much amusement from its endeavours to establish the fact; but, luckily for mankind, the age of theory is at an end, and experiment has taken place of it. We no longer take for granted the different hypothetic systems which have existed without bringing them to the test of experiment. We thus know how to detect what is false, and to estimate the value of truth; for experiment builds upon a sure and safe foundation.

By carefully pursuing our inquiries, whilst making actual experiments, we can hardly fail to obtain the knowledge we may be in search of. Wise men in former times lamented to observe the adorations paid to hypothesis whilst experiment was neglected. They anxiously exerted themselves to introduce the latter, and their endeavours, though not in their own day, have ultimately been crowned with success.

Whilst in rude and uncivilized countries man sinks in the scale of being, we find, in those where science has shed her rays, the mind expanded, and the faculties so enlarged, that, were we to compare an enlightened philosopher of the present day with the uncultivated savage, we should pause, with astonishment, to observe what culture can perform. But, for our greatest improvements in science and the arts, we are indebted to experiment.—Let us turn our inquiries whatever way we please, we shall find it has been resorted to. In the science of chemistry what has it done? In little more than a century it has dispelled the dreams of alchymy, and supplied their place by sober research: it has stripped that science of the jargon of unmeaning words, and so simplified its terms, that, what was once a dry and barren study, occupying the whole period of a man's life, without much real profit in the article of useful knowledge, has become easy, delightful, and instructive to almost every class of society.

But, to return to the subject of artificial light:—we shall, on inquiry, find, that, in uncivilized countries, where travellers have had opportunities of making their observations, the means for procuring it, which are most generally known, are the rubbing pieces of dry wood briskly against each other; thus, by friction, obtaining what is much more easily procured by collision, and still more so by chemical preparations.

When the destructive effects of fire-arms were first witnessed by the inhabitants of the new world, we are told that they looked upon the men who used them as more than mortal: with what astonishment would they have be-held an European obtain light by means of a portable fire-box! and to what pitch would it have been raised had it been possible to have introduced them into a theatre, which, as if by enchantment, blazed forth in a moment with ten thousand lights, and in a moment was again almost in utter darkness!

If we look at the blaze of wood (the only artificial light known to the rude and uncultivated savage, and compare it with the light emitted by a tallow candle, we shall observe how far the use of one exceeds the other; but, going a step further, by comparing it with the light which is obtainable by means of coal-gas, the disparity increases to a degree almost beyond calculation. By reverting to the time when, in this metropolis, the rush-light was the most improved artificial one known, and comparing it with the lights which are now to be found in almost every house, we see how much has been done in our own country; and is it not reasonable to expect that other nations will ultimately be equally enlightened? The steps leading towards improvement are not always rapid; but, when the search is diligent, constant, and persevering, it must undoubtedly be found.

The subject of the following pages, which treat of the theory of the production of artificial light,—the cost of various modes of obtaining it,—the natural history of pit-coal,—its various combinations and uses,—together with its application in the production of carburetted hydrogen for the purpose of illumination, (being the result of experiments, in the large way, can hardly fail of being useful. In no part of them has the author lost sight of those experiments which he has made, with the greatest care and attention, on the generation of gas. He has looked, with the most scrutinizing exactness, at the expenses attendant upon the various modes adopted for the distillation of coal; and, as it has been his duty to attend and to report upon the experiments made, for the purpose of ascertaining which is most likely to answer the purpose of the manufacturer, the information he has gained is such as actual experiment alone can give, when constantly pursued for many months together. In vain may it be attempted, by experiments made in the small way, to come at any thing near the truth; for when those experiments are brought in comparison with the larger and more extended process, experience has taught that no dependance can be placed upon them.

Whilst paying attention to the retorts, and the best mode of working them, he did not neglect to observe improvements that might be made in the different adjustment of pipes leading therefrom, so as to save expense and labour. The condensation of the gas, preparatory to its being submitted to the purifying process, the purification thereof in the best manner and at the least expense, and the construction of gas-holders, on the most approved principles, are subjects which he proposes to speak of. Other minor branches of the science of procuring artificial light, by decomposing pit-coal, will meet with due attention; and, in short, his object is methodically, but plainly, to describe every part of the gas-light apparatus, so as to enable any one who is at all acquainted with mechanics, to erect such, either for supplying his own premises with gas, or for lighting up large manufactories, streets, or even towns.

In performing his task, he trusts he shall be able, on all occasions, to speak of the inventions of ingenious men, who have, by their talents, promoted the interests of the manufacturer, with that candour which ought to be attended to by every writer, not attempting to damp the spirit leading to improvement, where failures have unfortunately happened. He is well aware, that, although much has been already done, that still more is wanted ; and that, as experiment alone can bring the science to perfection, some failures may be expected, and some will doubtless happen.

Knowing that the results of experiments, when thrown into a tabular form, exhibit more strikingly the advantages or disadvantages attendant upon different systems which have been pursued, the author has been particularly careful in selecting such matter as has enabled him to furnish the reader with several on different subjects connected with the science.

He has only further to observe, that in no one instance does he intend to lay before the Public, experiments which have not been made under his own observation ;—unless of such a nature as are likely to be beneficial, and then by stating his authority.

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A

Philosophical and Practical Treatise

ON

GAS LIGHT.

CHAPTER I.

Theory of the Production of Artificial Light, and of the Action of Candles and Lamps; with Directions for ascertaining the illuminating Power of Candles, Lamps, and Gas Lights; and for computing the relative Cost or Value of Light emitted by each.

SUCH flame as issues from any body that is submitted to the action of fire consists of that matter which, if collected, is known by the term hydrogen gas, which is more or less pure according to the matter used for its production, and the circumstances under which it is generated. Should the circumstances under which the combustion of such inflammable matter is carried on be favourable, the flame will be perfect and brilliant; but, if the combustion be incomplete, part of the matter, capable of furnishing light and heat, will pass off in smoke: it therefore follows, that, whereever much soot is found, we are to conclude that the body generating it had not been used to the best advantage. Whenever coal, or other inflammable matter, is used in its natural or crude state, it seldom happens that combustion is carried on advantageously. The fire must be constantly mended, to produce a complete combustion, but such arrangement would be tedious, and, in the end, unprofitable. We find that when coals are used they are generally heaped upon the fire in such way as requires much time to elapse before they are burned through; and, during the process, a dense smoke is constantly thrown out, yielding no profitable purpose. This smoke, were it possible to collect, deprive of its incombustible parts and condense, might, perhaps, be applied to the purpose of generating artificial light. The artificial light afforded by an inflammable body, whether it be a candle, lamp, or any other substance, arises from the flame such body may exhibit when in the act of combustion; and as, from what has been premised, it may be concluded that complete combustion is necessary to the economical production of light, therefore, the question will be,—How are we to produce the greatest quantity of light at the least expense?

The best rule, perhaps, which could be adopted for the purpose would be the allowing no more of the inflammable matter to mix with the surrounding atmospheric air than could be consumed. If it be allowed to exhibit itself in bulky diameters, much of its effect will be lost; for, under such circumstances, the interior of the flame cannot be completely burnt, for want of that due proportion of oxygen which is absolutely necessary to complete combustion. If the matter submitted to combustion be thrown out at a very low temperature, it will not burn in the open air; it is, therefore, of consequence that the matter for producing flame should be produced at a proper heat, and thrown into the atmosphere with that velocity which will allow it to be wholly decomposed by its burning, and so that no smoke may arise from it.

It must, however, be borne in recollection that if the stream of air acting upon the combustible matter be too great, it will defeat the desired effect, whilst the contrary will tend so to weaken the flame as to render it nearly useless. At the mouth of an oven the flame is large and powerful, yet, notwithstanding the matter producing such flame is contained within the oven, the situation is unfavourable to combustion. If, for experiment, we conveyed paper into it, by means of a metal tube, we should find it would not be set fire to; a want of air would prevent it from burning; and the same thing holds good with respect to any gaseous fluid evolved, which never presents itself as flame unless it be mixed with a current of air to support it. The necessity of a proper supply of air for supporting combustion to advantage suggested the idea of the Argand lamp; for in it the matter for combustion is exposed in a thin ring of flame, and the action of the air being on each side of that ring, the process will be perfect.

It must have been observed by those who have been much accustomed to reading or writing by candle-light, that a small flame is always brighter and more luminous than a larger one; and that when a candle has been newly snuffed it yields from six to eight times the quantity of light which is afforded by it when the flame and wick become so lengthened as to make it necessary again to use the snuffers.

It cannot be doubted, that bodies which are capable of producing flame contain such latent matter as supports combustion. Indeed it is well known that light forms a constituent part of some bodies, for from them it is disengaged as they form new combinations:—but, science has not yet discovered a mode for obtaining the basis with which it is combined. That the light evolved by artificial means is derived from the matter submitted to combustion is clear to demonstration; for we need but observe the change of colour which flame exhibits during the process of burning to be certified of the fact. Such variation does not depend upon the medium which supports the process, but is to be attributed solely to the matter of the combustible body. By considering this matter, we can easily comprehend the possibility of tinging the colour of the purest kind of flame, by mixing the body producing it with substances for that purpose. As for the colours of flame exhibited when coals, wood, and other common combustibles are used, their different shades amount but to a few of red, purple, and yellow. These, doubtless, arise from the greater or lesser quantity of watery vapour or smoke which passes through the flame unburnt with other incombustible products.

By observing the flame of a common candle carefully, we shall perceive that the colour of it is not uniformly alike; the lower part, next to the cup formed in the tallow, where the distillatory process is carried on, is always blue—the centre or middle part contiguous to the wick is opake—the exterior to the same height bright and luminous—as it is also to the top, immediately after the candle is snuffed—but when the flame becomes lengthened, and the top of the wick has a fungus-like appearance, the apex will be of a reddish or brownish colour.

Before the theory of the action of candles is spoken of, it may perhaps not be considered altogether foreign to the subject of procuring artificial light should something further be mentioned relative to combustion. By combustion is understood the throwing out of fire from a body in which it existed in a latent state, by which the change of some other body is effected. Air contains the largest quantity of fire, the oxygen whereof being disposed to unite with many other matters, most of the ordinary processes of combustion are the result of its sudden union with some other substance, in which case the fire which was contained in the oxygen of the air is disengaged. With respect to coal, it has but a weak attraction for oxygen compared with some other substances, or to speak in other words, its particles have a stronger attraction amongst themselves. In the ordinary process of exciting common fire, when a quantity of this material is heaped together and fire introduced among it, by the action of fire a part of it is first expanded from a state of solidity into that of inflammable vapour; it comes then necessarily into contact with the pure air of the atmosphere, and the action of the fire still continuing, the fire which the oxygen contained is attracted from it, it unites with the inflammable matter, and both are combined into water, in the form of vapour or smoke. Hence there cannot be combustion without a due supply of oxygen; and therefore the common bellows, by bringing a greater supply of air causes a fire to burn better. Flame is vapour in an ignited state, and that part only of such vapour which is in contact with the air can be inflamed. The flame of a candle may be considered as a cone of fire, the hollow part of which is vapour, and such hollow part is not inflamed. It is precisely the same case with that part of the matter emitted by a candle when lighted which surrounds the wick, which has before been adverted to, when speaking of the flame exhibited at the mouths of furnaces—when compared with the want of oxygen within, which renders complete combustion there almost impossible.

Having observed, in a preceding page, that flame may be tinged of different colours, it may here be noted that

"Spirit of wine burns with a bluish flame.

"Sulphur burns with nearly the same tinge.

"Zinc burns with a bright greenish white flame.

"Preparations of copper, or of the substances with which they are mixed, burn with a bright, vivid, green flame.

"Spirit of wine mixed with common salt, when set on fire, burns with a very unpleasant effect, as may be experienced by observing the death-like appearance of spectators illuminated by such means.

"Spirit of wine and a little boracic acid, or nitrate of copper, stirred together and set fire to, burns with a beautifully green flame.

"Spirit of wine, mixed with nitrate of strontia, burns with a carmine red colour.

"Muriate of lime tinges the flame of burning spirit of wine of an orange colour*."

Having spoken somewhat at length on the mode of procuring artificial light, the next thing which presents itself to notice is the theory of the action of candles, lamps, *&c.* In proceeding to illustrate this theory, it may be observed, that whenever light is to be procured for ordinary purposes, the most ready means of obtaining it is by the process of combustion. The most common method of obtaining light where science has not pointed out the use of candles or of lamps, is by burning masses of wood, or other matter, in their solid state; but, where improvements have gained some footing, artificial light for most general purposes has till of late been obtained by the use of lamps or candles.

When lamps are used, it is necessary that the combustible material should be such as will remain in a fluid state at the usual temperature of the atmosphere. In the use of candles, the case is different, for the matter of which they are formed does not become fluid but by a very considerable application of heat.

---

* *Vide* Experiments, Parkes' *Chemical Catechism.*

Of whatever substance the instrument for yielding light is composed, it is required to be rendered volatile before flame can be produced; for this purpose, however, it is not necessary to volatilize much of the matter at a time, a very small portion of it will be sufficient to afford a useful light. A candle or a lamp contains sufficient combustible matter to last several hours. Either is furnished with a wick, and, by its action, the operation of generating light is effected.

In using the lamp, the oil should be such as will readily inflame, and the wick of sufficient capacity to convey to the place of combustion, by capillary attraction, such quantity of oil as by admixture with the oxygen of the air will be completely consumed. By this attraction, the oil continually flows to the laboratory, where the decomposing process is carried on.

On a candle being first lighted, such a degree of heat is given to the wick as is sufficient to melt the tallow, which is formed into a kind of cup, where it is decomposed. It is in this part that the carburetted hydrogen gas and vapour are mixed with the air, and yield a bluish flame. This, however, communicates so much heat to the higher part of the gas evolved as to give it a yellowish tinge. As the tallow melts, and becomes decomposed by the action of the wick, a fresh supply continues to be given.

The upper part of the wick, which is surrounded by the flame becomes black, owing to part of the carbon and hydrogen entering into its composition having been acted upon by combustion, whilst the wick itself is defended from the action of the air by the flame surrounding it. That from this circumstance it owes its protection there cannot be a doubt, for when, by the consumption of the tallow, the wick becomes too long to support itself in a vertical position, the top projects beyond the flame (which will invariably be the case when it deviates from a perpendicular line,) it will no sooner be exposed to the action of the air than it will burn, and soon be converted to ashes.

Part of the tallow which is volatilized is not burnt, but passing through the centre of the flame it is not acted upon by the oxygen of the surrounding air, it passes off in smoke; hence it follows, when the wick and flame are large, there is proportionately greater waste of combustible material than when the wick and flame are small. Indeed, when a candle is made with a wick of a single thread, though it yields but a very small flame, yet such flame is not only peculiarly bright, but free from smoke; whilst, on the contrary, in common lamps, where a very large wick is used, the smoke is very considerable, and tends to lessen the strength of light, which, from the quantity of matter used, might naturally be expected. As in the process of combustion of candles, the fluid tallow is contained in the cup formed at their top, it follows that the thickness of the wick is a circumstance requiring attention, for, if the wick be not of sufficient capacity for carrying off the fused material, as rapidly as it becomes so, it will run down the sides of them. This inconvenience arising from the nature of the material of which the candle may be formed, it would appear that, as wax is not fusible at so low a temperature as tallow, the wick of the latter description of candle may be made much slighter than that of the former. A candle, with a thick wick, on being first lighted, and snuffed short, yields a flame perfect and luminous, unless the diameter of the wick be very great, in such case the middle of the flame will be opake; for, as has before been observed, for want of a proper supply of oxygen, the combustion cannot be completely effected. But, when the wick becomes lengthened, the distance between its top and the top of the flame given out will be shortened; and therefore the tallow which is decomposed having a shorter distance of flame to pass through, is not entirely burnt, and that part which is not so, passes off in smoke. The wick, if not snuffed, continues to lengthen, till, unable to support the accumulation of soot which is formed round the top of it, (and which arises from combustion being imperfect,) falls on one side, allowing the air to act upon it; or, otherwise, the upper part of the flame given out is so shortened as to expose the top of the wick to the air; however, the combustion which is requisite to snuff it, is not, in this case, sufficient to do so. Here the portion of tallow carried off by the lengthened wick is too great to be entirely burnt, and it takes off a considerable portion of the heat of the flame, as it assumes a state of elasticity. This process tends to diminish combustion, whilst a greater supply of tallow in a fluid state causes soot to accumulate at the top of the wick. When much soot has been there deposited, the candle does not give more than a sixth or an eighth of the light which the materials submitted to combustion, if properly accomplished, would generally produce, and it is from this circumstance, that tallow candles so frequently require snuffing.

When wax candles are used, it is found that as the wick lengthens, the intensity of light decreases; but then, as the wick is very thin in comparison with that of a tallow candle, it sooner falls from the middle of the flame, and the top becoming exposed to the air, is burnt off. When the wick of a wax candle is in the centre of the flame, it is not of sufficient magnitude to cause the diameter of that flame to be so enlarged as to prevent the air from having access to it. It follows, from what has been observed, that as wax is with difficulty fused, a large quantity of it may be burnt by means of a very small wick, which, of course, is pliant, and soon becomes unable to support itself in a vertical position. This position it no sooner loses than the action of snuffing is performed by the method just noticed with greater precision than can be done mechanically.

Taking into consideration what has been said on the subject of wax and of tallow candles, it will appear that the making of the latter so as to be equal to the former cannot be effected, unless by some contrivance, tallow can be rendered as difficult of fusion as wax:—for the advantage which a wax candle has over one of tallow arises from wax requiring a higher temperature to fuse it; consequently, the fusion is not so rapid, and the cup formed by the action of the flame not so soon destroyed. Therefore, to render tallow, when used for generating light, equal to wax, it must either be burnt in a lamp, to avoid the melted material running to waste; the wick must be made of a more pliant material than what is at present used; or otherwise the tallow itself, by some chemical arrangement, must be made less fusible. The attempting to make tallow-candles equal to those of wax, in many points of view, is deserving the attention of the manufacturer.

It is generally supposed by chemists, that the difficult fusibility of wax is owing to the greater proportion of oxygen which it contains. It is intimated by Mr. Nicholson, in the quarto series of the *Philosophical Journal,* volume I. page 70., that the spontaneous snuffing of candles made of tallow, will hardly be effected, unless by some material being discovered for the wick, which, whilst it is of sufficient capacity to absorb the tallow as it melts, will be flexible enough to bend on one side, causing the top to verge through the flame so as to allow the action of the air to play upon it and burn it off.

For ascertaining the illuminating powers of candles, or other luminous substances, recourse must be had to some method different from that of examining the lights themselves, for the organs of human vision are not fitted for such purpose. No one could by only seeing two or more lights of different intensities determine what proportion the light from one bore to that which was emitted by the other. Though from the examination of lights their intensities cannot be ascertained accurately, yet is the eye peculiarly adapted for judging of the strength of shadows—so much so, that, by a proper arrangement, the proportional quantities of light emitted by two or more candles, lamps, or gas lights, may be determined almost to mathematical exactness; and the comparative strength of light emitted by a gas light, compared with what is given out by one or more candles of certain dimensions. Light always travels in straight lines, and in every direction from the body yielding it; therefore, its strength must decrease in proportion to the distance from the point of divergency. Now, supposing two or more lights are placed at such distances from an interposing object as to cause shadows of equal intensity to be cast upon a wall behind it, by measuring the distance of each light from its respective shadow, data is obtained for ascertaining the illuminating power of each. Should it be stated that whatever light is emitted from a candle, or other luminous body, remains undiminished at all distances from that body, the statement may be considered correct. We are therefore to conclude, that whatever light falls upon any body, such light would have fallen upon the place occupied by its shadow, had it not been there; and this position may be established by the following method, which is taken from Dr. Smith's *Optics*, book I. art. 57. Let the light, (suppose of a candle,) which flows from a point A, plate I, fig. 1, and passes through a square hole B, be received upon a plane C, parallel to the plane of the hole; or, let the figure C be the shadow of the plane B; and when the distance C is double of B, the length and breadth of the shadow C will be each double of the length and breadth of the plane B; and treble when AD is treble of AB; and so on; which may be easily examined by the light of a candle placed at A. Therefore, the surface of the shadow C, at the distance AC double of AB, is divisible into four squares, and at a treble distance into nine squares, each equal to the square B, as represented in the figure. The light then which falls upon the plane B, being suffered to pass to double that distance, will be uniformly spread over four times the space, and, consequently, will be four times thinner in every part of that space; at a treble distance, it will be nine times thinner; and at a quadruple distance, sixteen times thinner than it was at first; and so on, according to the increase of the square surfaces B, C, D, E, built upon the distances AB, AC, AD, AE. Consequently, the quantities of this rarefied light, received upon a surface of any given size and shape whatever, removed successively to these several distances, will be but one-fourth, one-ninth, one-sixteenth of the whole quantity received by it at the first distance AB.

PLATE 1.

Fig. 1.

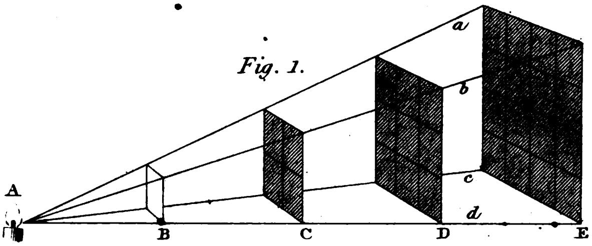


Fig. 2.

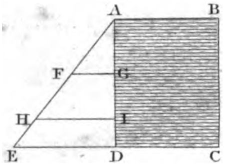


Fig. 3.

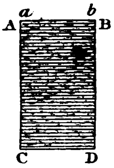


Fig. 4.

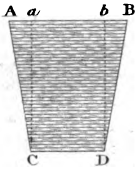


Fig. 5.

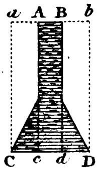


Fig. 6.

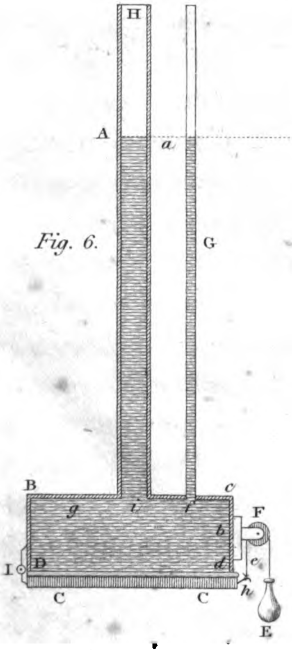
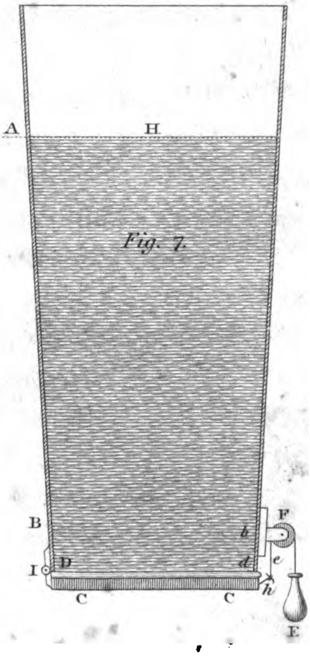


Fig. 7.



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Or, in general words, the densities and quantities of light, received upon any given plane, are diminished in the same proportion, as the squares of the distances of that plane from the luminous body are increased: and, on the contrary, are increased in the same proportion as these squares are diminished.

From what has been said, it follows, that as the shadow of any body at twice the distance of the surface from the point of illumination, will occupy a space four times the area of the interposing object, consequently, the strength of light will decrease as the square of the distance is increased. Therefore, by placing two lights in such situations as to throw shadows of equal densities upon a wall, from some opake substance placed between them and that wall, the intensity of light afforded by each will be inversely as the squares of their distances from the shadows. When two lights of unequal illuminating powers are so placed as to produce shadows contiguous to each other, from an opake interposing body, the stronger light will yield the deepest shadow, and the weaker light the faintest shadow. In making experiments for ascertaining the intensities of different illuminating bodies, it is necessary that they should be so placed as to produce shadows contiguous to each other, and of equal intensity.

When it is required to compare the intensities of light produced by candles of different magnitudes, the process might be after the following manner. Having fixed a sheet of white paper upon the wall of your room, at a convenient height, place a small fire-screen at the distance of a few feet from it, the part which is to cast the shadow upon the paper being raised to a proper height for doing so. Then let one of your assistants take the candle which yields the smallest quantity of light, and proceed to such a distance from the screen as may be convenient, but so as to allow the shadow produced to fall upon the paper. Next, let him who holds the candle yielding the strongest light, proceed in nearly the same direction from the screen as the former, till the shadow from his candle falls nearly upon the same place on the paper as that produced by the weakest light. Should the intensity of shadow from the strongest light be greater than that produced by the weaker, let your second assistant increase his distance from the interposing object, till the shadows from each candle have an equal blackness; this being done, measure the distance of each light from the paper receiving their respective shadows; then say

As the square of the distance of the weakest light from the shadow, is to unity,

So is the square of the distance of the strongest light from the shadow, to the proportion of light it yields in comparison with the former. But, by way of example, let us suppose, that having proceeded on the plan already pointed out, with two candles of different illuminating powers, the distances of each from the shadows were measured, the weaker light was found to be at six feet distance, and the stronger at twelve from the shadow, it is required to know what number of candles of the least illuminating power, if placed in the same situation as the stronger, would produce a shadow of equal intensity therewith, and consequently yield the same quantity of light.

The square of 6 is equal to 36
—— —— 12 —— to 144

Therefore, as 36 : 1 : : 144
1
————
36)144(4 the number of candles necessary to produce the same intensity of light with the larger one.
144
————

This method may be adopted, whenever the illuminating bodies are such as can be moved; but, in some cases, a trifling deviation from it will be necessary. Thus, when one of the bodies emitting light is stationary, as is the case with gas-burners, in making the experiment it will require but one candle to be used, which must be moved backwards and forwards between the interposing body and the burner, till the shadows from each upon the paper are of equal intensity. Then the distances from the gas-burner, and from the candle to the shadow, are to be measured and proceeded upon, as already directed:

Example.

Having adjusted a gas-burner to a flame of two inches in height, and placed an opake object between it and a sheet of white paper fixed to a wall twelve feet distant from the burner, a mould candle, of six to the pound, was introduced between the burner and the body producing the shadow, and moved backwards and forwards till the shadows were of equal blackness; on their being so, the candle was found by admeasurement to be $4\frac{9}{10}$ feet from the shadow produced: it is required to ascertain what number of such candles would yield the same intensity of light as the burner emitted.

The square of 4,9 = 24,01
—— ——— 12,0 = 144,00

Then,—as 24,01 : 1 : : 144 : 6 nearly,—

the number of candles necessary to produce the same intensity of light as given by the burner.

From experiments conducted in this way, it may be determined whether more or less light is obtained by burning several small candles, or one or more of greater dimensions, during a given time, at the same expense; for, by such, the intensity of light afforded by each is ascertained, and the quantity of matter consumed for obtaining it is easily ascertainable. The same thing holds good with respect to lamps or gas-burners. It is easy to compare the illuminating power of each, and to ascertain the relative cost of any substance which may be employed for furnishing light. It is almost needless to repeat that when a candle and a gas light, at equal distances from a wall, produce shadows of equal darkness, the intensity of light afforded by each is equal. As the great command of gas, by turning the stop-cock supplying the burner more or less, is such as to enable the operator to adjust the light to that afforded by a well-snuffed tallow candle, he will easily equallize the lights afforded from each, and, weighing the candle before the experiment is commenced, and again when it is ended, (the price per pound being known) he will ascertain the cost of procuring light by such candle. The quantity of gas consumed, as pointed out by the index to the gas holder, will enable him to ascertain the cost of procuring a similar light by the use of gas. It must be observed, however, that before he can attempt to do so, he must inform himself at what cost a specific number of cubic feet of gas is generated.

It has been determined, from experiments made by Count Rumford for the purpose of ascertaining the quantity of materials necessary to produce a light of a certain intensity, for a given time, that there must be burnt by weight,

Of wax	100 parts.
Of tallow	101 ——
Of oil, in an Argand's lamp	129 ——
Of an ill-snuffed tallow candle	229 ——

By several experiments made on coal gas, it has been found, that about 20 cubic feet are required to produce light equal in duration and in illuminating powers to a pound of tallow candles (six to the pound), if set up and burnt out one after another.

There has been occasion to state, in a former part of this Treatise, that, though the light of a candle is very brilliant when first snuffed, yet the intensity of light very soon diminishes to less than a half, and continues to do so till reduced to as low as one-sixth. This causes the eye to feel uneasy, and induces us to apply the snuffers: it follows, therefore, that if candles could be so made as not to require snuffing, the quantity of light afforded by them in a given time would be more than double what is emitted in the ordinary process of burning them, when the application of the snuffers is so frequently required. It is a very natural conclusion, that, as by using candles which require snuffing, the intensity of light is continually varying, either much reading, writing, or working, by candle-light, must be injurious to the eye; indeed, it is from this circumstance, more than any other, that it has been found so. If a lighted candle is so placed as neither to require snuffing, nor to produce smoke, it may reasonably be supposed that the whole of the matter consumed is converted to the purpose of producing light; and that the intensities of light afforded in a specific time, by candles of various dimensions, must be in proportion to the quantity of matter consumed; or, in other words, when candles made of the same materials are used, that which produces double the quantity of light afforded by another, will, in the same time, lose twice as much weight of matter.

For various experiments, made to prove the truth of what has been advanced, we are indebted to Mr. Ezekiel Walker, who has stated them in the fourth volume of *Nicholson's Journal*, 8vo. series, from whence the following table is extracted, but with a trifling alteration in its arrangement:—

TABLE.

COLUMNS.								
1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.
Number of the Experiment.	Number of the Candles.	Number of Candles to the Pound, Avoirdupois Weight.	Length in Inches.	Number of single threads of fine Cotton in the Wick.	Time of burning.	Weight of the Candles consumed in the said time.	Strength of Light.	Distance of the Candles from the Wall.
					H. M.	oz. dr.		Feet
First	1	14	8,5	10	3 0	0 15	1	7
	2	13	9,0	12				
	3	10	9,74	14	3 0	1 1½	1+	7
	4	8	10,0	20				
	5	6	10,25	24				
	Mould	6	13,0		3 0	0 15	1	7
Second	1	The number of candles to the pound, their length in inches, and the number of threads of cotton to each wick, are the same as expressed against the corresponding number in the first experiment.			2 55	0 15	1	8
	3				2 55	1 0	1+	8
	Mould				2 55	0 15	1	8
Third	1				3 0	0 15¾	1	8
	3				3 0	1 2	1⅛	8,75
	Mould				3 0	1 0	1	8
Fourth	5				3 0	1 5	1,18	8,75
	Mould				3 0	1 1⅛	,80	8

The experiments on which the above table is founded, were performed nearly in the following manner:—

Three candles, such as described in the 3d, 4th, and 5th columns of the table, first experiment, against 1, 3, and mould, in the second column, having been weighed, were lighted at the same instant. At the end of the time expressed in the sixth column, they were all extinguished, and again weighed; the loss of weight of each candle is noted in the seventh column. In this way were all the experiments made, but as the three first were performed under very favourable circumstances, the results come nearer to the truth than is required for useful practice. But, in consequence of the great variability of light emitted by No. 5, making it necessary to move it very often, in order to keep the two shadows equal, it was found necessary to put down the mean distance from the wall by estimation. However, as this was done before the candles were weighed, the mind of the experimentor could not be supposed under any influence of partiality for a system. From this circumstance of the distance of the candle, No. 5, from the wall not being accurately ascertained, in making the fourth experiment, it cannot be so much depended upon as the three former ones. In making these experiments, Mr. Walker adopted a method for ascertaining the intensity of light given out by each candle, somewhat similar to what has been described at page 18 preceding. His experiments were not all made at one time, nor is it to be understood that the mould candle which was made the standard for comparing the lights of the others by, gave the same strength of light in every experiment. When the sign + is placed against any candle, as it is in two instances in the eighth column of the preceding

Table, it is intended to convey an idea that such candle gave a stronger light than the others.

From the results of the experiments contained in the foregoing Table, it appears to be established, where combustion is complete, that the quantities of light produced by tallow-candles are in such proportion to each other as would be expressed by multiplying the time that the candle is burnt, by the quantity of matter consumed. Thus, in the first experiment,

The candle, No. 1, burnt three hours, during which time 15 drams of tallow were consumed.

The candle, No. 3, burnt the same time, and consumed 17½ drams of tallow, and

The mould candle burnt the same time, and consumed the same quantity of matter as the candle, No. 1.

On examining the Table, it will be found, that the strength of light afforded by the Mould and No. 1 candle was equal, whilst that afforded by the candle, No. 3, was greater than either: by calculation, to try how this agrees with Mr. Walker's practice, let the weight of tallow consumed by each candle be reduced to half-drams, and multiplied by the time of burning, and the products will express the proportion of light afforded by each in higher numbers. Thus,

Candle, No. 1.	No. 3.	Mould.
½ dr.	½ dr.	½ dr.
30	35	30
3	3	3
90	105	90

Here it is seen that the lights afforded by the candles, No. 1, and Mould, are equal between themselves, whilst that from No. 3, is one-sixth greater.

Should the law, which Mr. Walker has attempted by experiment to establish, be admitted, we have a standard given by which we may compare the strength of various lights: for, if a small mould candle be lighted, and so placed as neither to produce smoke, nor require snuffing, it will lose in three hours an ounce of its weight. The quantity of light so produced may be expressed by unity. Should it, however, at any other time lose more or less weight in three hours than an ounce, the quantity of light it yields may be ascertained, for, the quantity of light produced in a given time (the combustion being perfect) is always in a direct proportion to the quantity of matter consumed.

From what has been said on the subject arise the two following theorems:—

THEOREM I.

When the quantities of matter of two or more bodies consumed are equal, and times of burning the same, they will give equal quantities of light.

THEOREM II.

When the times of burning two or more bodies are equal, the quantities of light emitted by each will be in direct proportion to the respective weights of matter consumed.

COROLLARY.

Therefore, it follows, as has been before observed, that the light produced by any number of bodies, used for the purpose of generating it, is always in the compound ratio of the time of burning, and weight of material burnt.

Hence we are able to lay down the following rules for investigating these subjects :—

Let

M represent the mould candle,
d its distance from the wall, on which the shadows were compared,
m its quantity of matter consumed in a given time,
t express that time, and
Q the quantity of light emitted by M in the same time.

Let

C represent any other candle,
δ its distance from the wall,
q its quantity of matter consumed in a given time.
τ that time, and
g the quantity of light emitted by C in the same time.

The intensities of light being directly as the squares of the distances of the two candles from the wall, we have

As $d^2 : Q :: \delta^2 : g$, the quantity of light emitted by C in the same time.

Then, supposing the quantities of light to be in direct proportion to the quantities of matter consumed in the time t, we have

As $m : Q :: q : g$, the quantity of light emitted by C in that time.

Therefore $\frac{\delta^2 \times Q}{d^2} = \frac{q \times Q}{m}$, and the quantities of light of M and C are in proportion to the quantities of matter consumed by each in any specific time.

To make this matter easy to every reader, I shall subjoin the two following Rules for solving questions of this description:—

PROPOSITION I.

Given, the distance of one candle from the wall where the strength of shadow is observed, the quantity of light emitted by the same in a given time, and the distance of another candle throwing a similar shadow on the same wall from it; to find the quantity of light which will be produced by the latter in the same time as the former.

RULE.

As the square of the first candle's distance from the wall, is to the quantity of light emitted thereby in a given time;
So is the square of the second candle's distance from the said wall, to the quantity of light emitted by it in the same time

PROPOSITION II.

The weight of one candle consumed in a given time, the quantity of light emitted by the same, and the weight of another candle consumed in a like time, being given (the candles being so placed as to throw shadows of equal intensity upon the same wall,) to find the quantity of light which will be produced by the latter in the same time as the former.

RULE.

As the quantity of matter consumed by one candle in a given time, is to the quantity of light emitted thereby;
So is the quantity of matter consumed by the other in a like time, to the quantity of light which is by it emitted.

These rules may be used for comparing the strength of light of candles of different sizes with each other. They are capable, by transposition, of producing various statings; consequently, when any three of the *data* are given, the fourth can be found—and as they are so easily applied to practice, it is useless to take up further time in explanation.

CHAPTER II.

On a Method for Increasing the Light afforded by Tallow Candles, for obviating the Necessity of snuffing them, and for rendering them more fit Substitutes for Candles made of Wax.

IT has been shewn by by Mr. EZEKIEL WALKER, that if a trifling alteration be adopted in the manner of using tallow candles, they will become very excellent substitutes for candles made of wax. The method which he proposes for obtaining so desirable an end, is by placing the candle in such a direction as to recline thirty degrees from a perpendicular:—for doing this, candlesticks may easily be constructed, or they may be made to hold the candle at any angle which may be desired. A common candle of ten to the pound, with a wick of fourteen single threads of fine cotton so placed and lighted, requires no snuffing; and what is of more importance, it yields a light nearly uniform in strength, and free from smoke.

The position of the candle when placed at an angle of 30° from the perpendicular, is such as will prevent the necessity of snuffing it—for when it burns thus, the flame rises vertically from the upper side of the wick, exposing the top of it projecting beyond the flame to the action of the air. If the candle is placed in front of the observer, so that its inclination is towards his right hand, the flame will appear to him in the form of an obtuse angled triangle—the base of which will be the extreme edge of flame above the wick towards the left—the shorter leg will be parallel to the wick beneath it towards the right—and the longer leg will be also towards the right, rising from the top of the wick to the apex of the flame. It will be evident that, under such an arrangement, the top of the wick will project beyond the flame at the obtuse angle: by its thus becoming exposed to the oxygen of the air it will be burnt to ashes, and thereby be rendered incapable of carrying off any part of the matter submitted to combustion in the form of smoke. By this mode of causing the candle to snuff itself, that part of the wick which is acted upon by the flame must necessarily remain of nearly the same length; and if the wick is uniformly twisted throughout, the flame will remain of the same strength and dimensions. This can never be effected when candles are snuffed by an instrument—for the light afforded by such is very fluctuating, and highly injurious to the eye when, for any length of time, small objects are to be viewed by its light. The wavering of the light is an inconvenience which cannot be remedied by using any shade; but when a candle is so placed as to snuff itself, the light is steady, and at the same time so invariably bright that the eye feels no pain or uneasiness in performing its office:—when the light does not remain uniformly alike, the eye requires such frequent adjustment as cannot fail to be productive of both.

The description of Candles on which Mr. Walker made his experiments are exhibited in the following

TABLE.

Number of the Candle.	Number of Candles to the Pound, Avoirdupois Weight.	Length in Inches.	Number of single Threads of fine Cotton in the Wick.
1	14	8, 5	10
2	13	9,	12
3	10	9, 74	14
4	8	10,	20
5	6	10, 25	24
Mould	6	13,	

The candles No. 1, 2, and 3, when placed to form an angle of thirty degrees with the perpendicular, and lighted, do not require to be snuffed: they afford nearly equal quantities of light, and the process of combustion is carried on with such great regularity, that no part of the matter submitted thereto escapes unconsumed, unless from accident.

The candle No. 4, placed at the above-mentioned angle and then lighted, requires no snuffing—the light it affords is very little stronger than that emitted by the candle No. 1. Its colour is not so white, nor is the flame so steady.

The candle No. 5, placed at an angle of thirty degrees and lighted, does not require snuffing; its flame is rather fluctuant, nor so white as that afforded by No. 4, and the quantity of light it yields is not much greater than what is produced by No. 1. When the air in the room where it is burnt is put into motion by the opening of a door, or other cause, the melted tallow will sometimes overflow the cup; but notwithstanding this inconvenience, by placing it in an inclined position its light is much improved.

If the mould candle be treated in the same manner, it affords a very pure and uniform flame, void of smoke and not requiring snuffing. Its intensity of light is nearly equal to that afforded by No. 1.

There has not been a sufficient number of experiments made to determine with accuracy, whether a candle of given dimensions placed vertically or reclining from the perpendicular, affords the most light at the least expense; but, those which have been made prove, almost to demonstration, that the quantity of light is in direct proportion with the quantity of combustible matter consumed. Therefore, a candle placed in an inclining position must of necessity give a greater proportion of light than one of the same size placed vertically, and for this reason:—When a candle is so placed as neither to require snuffing, nor to allow any part of the combustible matter to pass off in smoke, no part of it is lost; but when it is placed perpendicularly, the light is ever varying—it is sometimes clouded with smoke, and that part of it which is snuffed is thrown away. The loss arising from imperfect combustion, which happens whenever candles are burnt in the ordinary way, is not the only inconvenience attending such mode of using them, and which the method proposed by Mr. WALKER is free from,—the light given on account of its variableness cannot but be bad. Between the times of snuffing a candle, its strength of light seldom remains equal for a minute together. The variation which takes place in the height of the flame of a candle when burnt vertically, is another inconvenience; sometimes the flame is more than three inches high, again it is barely two—and according as the wick lengthens, so does the flame, till it has increased to such length as will not allow the melted tallow to be consumed, which is consequently carried off in smoke; thus lessening the light, wasting the combustible material, and rendering the eye uneasy.

The great variability in the strength of light afforded by candles when used so as to require snuffing has been noticed on a former occasion—and it is to this, Mr. WALKER observes, and not to the nature of candle-light itself, that we are to attribute the injury sustained by the eye of the student and the artist. The injury may easily be prevented by using two small candles placed in such a position as not to require snuffing, instead of one large one used vertically where the snuffers would be required.

In the *Monthly Magazine* for 1805, page 206, are some observations relative to this subject, from whence the following is copied:—

"It is scarcely necessary to observe, that the combustion of candles proceeds the quicker in proportion as the inclination is greater. From the experiments which I have made, I should consider an angle of forty degrees with the perpendicular as the maximum of inclination, beyond which several considerable inconveniences would occur; and I should take twenty-five degrees as the minimum of inclination, less than which does not sufficiently expose the point of the wick to the action of the air.

"By those who are much in the habit of reading or writing by candle-light, it will also be esteemed no inconsiderable addition to the advantages already mentioned, that the trouble of seeking and applying the snuffers is superseded. A candle of common size requires the application of the snuffers forty-five times during its complete consumption.

" But I found an obstacle to the adoption of Mr. WALKER's plan, which, from the inclined position of the candle, it did not immediately occur to me by what means to counteract. Any agitation of the air of the room, occasioned either by the opening or shutting of a door, or by the quick passage of a person near the candle, caused the melted tallow to run over, or, in more familiar language, caused the candle to gutter; which, with the candle in this position, became an insuperable bar to the use of it.

" For the prevention of this inconvenience, I have had a wire skeleton-shade adapted to a rod bearing the same inclination as the candle, and which at the bottom joins the candlestick in an horizontal line of about two inches, terminating in a nozzle fitting that of the candlestick. The distance of this rod from the candlestick, or, which is the same thing, the length of the foot or horizontal line, is of course to be determined by the distance between the two circles which form the upper and lower apertures of the shade. It may serve, perhaps, more familiarly to describe this part of the apparatus, to state that it bears perfect resemblance to the two first strokes of the written figure 4; and the third stroke, if carried up as high as the first, and made sloping instead of upright, will very well represent the situation of the candle.

"When a strong light, for the purposes of reading or writing, is required, white silk or paper may be used, as is common, over the skeleton; but when it is required that the light should be dispersed over a room, a glass of a similar shape may be adopted, for the purpose of preventing the flame from being influenced by any agitation of the air of the room. If the upper circle of the shade be four inches in diameter, the apex of the flame will be within it during more than half the time of the complete consumption of the candle; the shade will not, therefore, require adjusting for the purpose of preventing injury to the silk, or whatever else may be used over the skeleton, more than once during that time.

"Being myself much averse to the interruptions which a candle used in a vertical position occasions, and which, though short, may under some circumstances be highly vexatious, I wish to extend to others a benefit which I prize rather highly."

In the *Repository of Arts*, Vol. I. page 86, LORD STANHOPE published an account of a method of manufacturing candles, which his Lordship represented to be superior to that usually employed. The process depends upon the following principles:

First: When the candle is of wax, or spermaceti, the wick is to contain but three-fourths of the usual number of cotton threads; when of tallow, but two-thirds.

Secondly: The wick must in all cases be perfectly free from moisture, a circumstance but little noticed by the manufacturers of candles in general.

Thirdly: The wick of wax candles must be deprived of all the air which is entangled in its fibres, which may be done by boiling it in melted wax, till neither air-bubbles nor froth appears on its surface.

By attending to the principles, as above stated, in the manufacturing of candles, it will be found that three candles of any size will last as long as four of the same size made by the common method. The light they afford is better and steadier, and whether made of wax, spermaceti, or tallow, do not require so often snuffing. They flame less, and are therefore better for most uses than candles made in the common way. The observations which follow will assist such as may be desirous of trying the candles made on the plan suggested by Lord Stanhope, in ascertaining the merits of his improvements. With them are given the results of some experiments relative to the expense of burning oil in lamps with wicks of eight and of four threads of cotton.

A taper-lamp, fitted with a wick of eight threads of cotton, will consume in one hour 0,50775 oz. of spermaceti oil.

	s.	d.		
The expense of burning such lamp 12 hours, when the oil is at	5	0	per gallon is	11,25 farthings.
	6	0		13,50
	7	0		15,75
	8	0		18,00
	9	0		20,25
	10	0		22,50

This lamp, trimmed with a wick as above specified, yields a light equal to the candle, No. 3, described in the Table at page 24. It requires snuffing but seldom, and casts a steady and strong light.

A chamber lamp, with a wick of four ordinary threads of cotton, consumes in an hour 0,22283 oz. spermaceti oil.

	s.	d.		
The expense of burning it 12 hours, when the oil is at	5	0	per gallon is	5,013 farthings.
	6	0		6,016
	7	0		7,019
	8	0		8,022
	9	0		9,025
	10	0		10,028

Note:—One pint and a quarter of whale oil, when used for the purpose of generating light, by means of a lamp, is found to be equal in illuminating power to a pound of tallow candles, eight to the pound, set up and burnt out one after another.

To enable the reader to determine the real and comparative expense of burning candles of different kinds, and of various sizes, a series of experiments have been made, which are exhibited in the following Table. In it, the description of wick, the number of candles to the pound, the weight of one candle with its durability, and, from thence, the time that one pound of such candles will last, are shewn; from thence, the expense of burning each kind for 12 hours, at a specific price. The time that one candle lasted, as therein expressed, is the average of several experiments made for the purpose of ascertaining the fact.

TABLE.

Description of wick.	Number of candles to the pound.	Weight of one candle.		Length of time one candle will burn.		Time that a pound will last.		Expense of burning candles of each description 12 hours, when at 10*s.* per dozen, in farthings, and 100th parts, which shews the proportional expense when they are at any other price.
		oz.	dr.	H.	M.	H.	M.	
Small wick.	18,28	0	14	3	16	59	25	8,078
	18,96	0	13½	2	40	50	33	9,495
Large wick.	16,51	0	15½	2	40	44	0	10,909
	12,04	1	5¼	3	27	41	32	11,557
	10,66	1	8	3	36	38	22	12,511
	7,76	2	1	4	9	32	12	14,907
	8,00	2	0	4	15	34	0	14,118
	5,68	2	13	5	19	30	12	15,894
	Mould-can	dles	at	12*s.*	per	doz.		
Waxed wick.	5,82	2	12	7	20	42	40	13,502
	4,00	4	0	9	3	36	12	15,911
	3,09	5	2¼	17	30	54	4	10,654

The suggestions of Dr. Franklin, relative to a greater proportion of light being obtained by using two candles in such a position as allows the flames to touch each other, than when they are burnt separately, has been proved by many experiments to extend to the flames of gas lights. These, when combined, yield a much stronger light than they would afford if used in a separate state. Whenever flames for producing light are placed near to each other, the consequences ensuing are always most beneficial, inasmuch as thereby the heat of the flames are preserved; for, they act in mutual defence against the cooling influence of the surrounding air. This principle suggested the construction of the Liverpool lamp, which acts by flat wicks placed so as to exhibit, when lighted, a cylinder of flame. From it unquestionably arose the idea of the Argand burner used by the different gas-light establishments. As the illuminating power of the Liverpool lamp is superior in its effect, and, at the same time more economical than any other, so, much greater advantages arise from burning gas upon a similar principle. By its use, the junction of many flames is effected, without any fear of a loss of light from its not being exhibited in a thin surface; for, as one flame is perfectly transparent to that of another, there cannot arise ar apprehension of the strength of light afforded b a burner or a lamp being diminished on accoun of the flames being by each other covered.

CHAPTER III.

On the Natural History of Coal and its component Parts, as ascertained by Analysis.

COAL, or *pit-coal,* as it is called in mineralogy, is a solid inflammable substance, somewhat shining, dry and light, compared with the strata in which it is found. In this country it is very abundant, and may be considered almost inexhaustible. It is peculiarly adapted for domestic purposes, as well as various uses in the arts. It is found chiefly in the countries lying nearly in the same latitude with Great Britain. It is likewise said to be found in the northern parts of China. In the southern hemisphere, it is stated to be very abundant in New Holland; but we have no distinct account of coal in the continent of Africa. Of this substance, there are

1. *Jet.*

This substance is found in France, Spain, Germany, Britain, and other countries, in detached kidney-form masses of various sizes, from an inch to seven or eight feet in length. The colour is a deep black; internal, glossy, opaque; not so brittle as asphaltum; texture striated; fracture conchoidal; specific gravity 1,259. It has no smell, except when heated, and then it resembles asphaltum in its odour. It melts in a strong heat, burns with a greenish flame, and leaves an earthy residuum. It becomes electric by friction, and when distilled, yields a peculiar acid.

2. *Cannel Coal.*

Cannel coal is found in Lancashire, and in different parts of Scotland. It is of a bright black colour, opaque, structure sometimes slaty; texture compact; it breaks easily in all directions, and if broken tranversely, presents a smooth conchoidal surface. It burns with a lively flame, like a candle, as its name implies, but is very apt in burning to throw splinters to a great distance: it is said, however, to be deprived of this property by being immersed in water for some hours previous to being used. In the coal field at Wigan, there is a stratum of this coal unmixed, nearly four feet in thickness. Cannel coal is susceptible of polish, and, like jet, is often wrought into trinkets.

A specimen of Lancashire cannel coal, analyzed by Mr. Kirwan, contained

75,20	charcoal.
21,68	maltha.
3,10	alumine and silica.
99,98	

A specimen of the slaty kind, from Ayrshire, called splent coal, was composed of

47,62	charcoal.
32,52	maltha.
20,00	earths.
100,14	

The specific gravity of cannel coal is from 1,232 to 1,426. This coal does not stain the fingers.

3. *Common Coal.*

This very useful combustible is never found in the primitive mountains, but only in the secondary mountains, or in plains formed of the same materials with them. It is always in strata, and generally alternates with clay, sandstone, or limestone. The colour is black, more or less perfect, lustre usually greasy or metallic, opaque, structure generally slaty, texture often foliated, fracture various, specific gravity 1,25 to 1,37, usually stains the fingers, takes fire more slowly, and burns longer than cannel coal, bakes more or less during combustion.

Of this species there are many varieties, distinguished in Britain by the names of caking coal, rock coal, *&c.*

Mr. Kirwan analyzed a variety of different kinds of coal. The results of some of his experiments are exhibited in the following

TABLE.

White-haven.	New-castle.	Wigan.	Swansea.	Leitrim.	
57,.	58,	61,73	73,53	71,43	Charcoal.
41,3	40,	36,7	23,14	23,37	Maltha & Asphalt.
1,7	2*	1,57	3,33	5,20	Earths.
100,0	100	100,00	100,00	100,00	

4. *Spurious Coal.*

This species is generally found amidst strata of genuine coal. It is also called parrot-coal in Scotland. The colour is greyish black. Structure usually slaty, texture earthy, specific gravity 1,5 to 1,6; generally explodes and bursts when heated. It is composed of charcoal, maltha, and asphalt., and above ,20 of stony matter.

5. *Anthracite.*

This substance, as Dolomieu informs us, is found exclusively in the primitive mountains. It is commonly amorphous, sometimes crystallized in short hexagonal prisms, colour black or brownish black, structure slaty, fragments rhomboidal, specific gravity 1,3; often stains the fingers. This species burns precisely like the spurious

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* Earth and metallic matter and sulphur.

coal, leaving ,40 of white ashes. According to Dolomieu, it is composed of about

64,0	charcoal
32,5	silica
3,5	iron
100,0	

6. *Kilkenny Coal.*

This mineral has been found in Hungary, Italy, France, Ireland, and Wales. It occurs in stratified masses, or in lumps nested in clay. The colour is black. Opaque. Texture foliated. Specific gravity 1,4 to 1,526. Often stains the fingers. Insoluble in acids. Deflagrates with nitre. Does not burn till wholly ignited, and then consumes slowly without emitting flame or smoke. It consists almost entirely of charcoal and sulphur; the latter is in a very large proportion, which sends out while burning a suffocating effluvia. It does not produce any soot, but whitens the places where the fumes are condensed.

7. *Culm Coal.*

This species of coal has nearly the same appearance as that of common coal, but its texture is more dull. In Sweden it is considered a distinct species: but, what is commonly called culm in England, is the refuse or dust produced by working the different kinds of coal. It will not kindle except in furnaces where there is a great draught of air. It is not subject to the high duty laid upon other kinds of coal.

8. *Sulphureous Coal.*

This is a dull and heavy species of coal—it contains a very considerable portion of pyrites, and produces a great quantity of ashes. There is a great danger in working this coal, for if any considerable quantity is left together, it generates heat, and will set the mine on fire.—Specific gravity 1,5.

9. *Bovey Coal.*

This coal consists of wood penetrated with petroleum or bitumen, and combinations of sulphuric acid. It is found in many parts of the continent, but is most abundant in England at Bovey, near Exeter, from which it derives its name.

The foregoing are the kinds of coal commonly known; but the different qualities and proportions of their ingredients make a number of other varieties used for different purposes. Thus, various kinds of coals are often found mixed with one another under ground, and some of the finer sorts run like veins between those of a coarse kind. On subjecting pit-coal of any kind to distillation, it first yields a watery liquor, then a volatile oil, afterwards a volatile alkali, and lastly, a thick oil; but it is remarkable, that, by rectifying this last oil, a transparent and light oil is produced, which, being exposed to the air, becomes black like animal oils. From this and other observations it is generally supposed, that coals derive their origin from vegetables buried in the earth. "The amazing irregularities, gaps, and breaks," says M. MAGELLAN, "of the strata of coals, and of other fossil substances, evince that this globe has undergone the most violent convulsions, by which its parts have been broken, detached, and overturned, in different ways, burying large tracts of their upper surfaces, with all the animal and vegetable productions there existing. And it is easy to be conceived, that the various heaps and congeries of these vegetable and animal substances, remaining for ages and ages in the bowels of the earth, have obtained various consistencies, and still produce those oily and bituminous juices which find way to gush out, leaving behind their thickest parts on the same places where they are found, and in many others where the industry of mankind will never be able to penetrate." The most diligent investigation must fail in producing any certain conclusions on the subject; for, in pursuing our inquiries, we meet with difficulties which appear to be insurmountable. It is, however, a singular fact, that remains of species of plants are found in the coal mines of Great Britain, which now exist only in the equatorial regions.

Although it is in some measure digressing from the subject, it may not be considered uninteresting to the reader, should something be said on the theory of the earth and of stratifications, the coal strata forming one amongst the various mineral productions, which to account for is found so difficult by theorists. Theories have been various, and some excessively wild; yet, amongst such as have some shew of reason on their side, it is difficult to subscribe to one bearing such striking marks of truth as to leave full conviction of a superior claim to notice.

The mind of man, though exceedingly capacious, and enlarged by experimental research, when engaged in theoretic speculations, which are above human reason, becomes bewildered. Thus the theorist fixes his attention upon what appears to him plausible—argues himself into a belief of its merits, and then sits down to endeavour to convince the world that his theory is true. We are completely lost amidst the contradictory statements that have arisen upon this important subject. Some of these theories we shall here briefly notice.

Burnet's Theory.

The object of this theorist was so to account for the formation of systems, that the opinions he advanced might be in consonance with Scripture; consequently, in no part of his work are arguments to be found which can in any wise militate against the work of creation being effected by an almighty Being. The earth, in its original state, he supposed to have been in form spherical—its surface smooth, the exterior forming a solid incrustation over a fluid interior mass. In short, except as to shape, according to this theory, the earth would in point of construction bear great similarity to an egg,—and it is very well known that amongst the most venerable ancients an egg was the solemn and remarkable symbol of the world, and that nothing was more celebrated in the most early authors than the original 'Ωον Ὄρφικον, which it is most reasonable to suppose was referred to the entire and internal constitution of the earth. He supposes the surface to have been devoid of irregularities, and accounts for those which now exist as arising from the general deluge. According to his theory, the flood was occasioned by the rays of the sun penetrating through the surface of the earth, and so heating the interior waters as to cause a considerable expansion thereof, by which the incrustation was broken, and the water rushing forth in vast torrents formed the different seas. In doing this, it naturally followed that some part of the surface of the earth would no longer be supported by a *plenum*, and where such was the case it would be precipitated towards its centre by this action causing the mountains and valleys which now exist. The latter being in those situations where the waters had escaped from and left a *vacuum*.

Descartes' Theory.

The theory of this philosopher was very similar to that of Burnet: both appear distant from probability, and the basis upon which the evidence rests that is brought forward to support them, so much at variance with sober contemplation of the subject, that they could hardly be expected to stand. It is certain, we may from them contemplate with admiration to what heights a fertile genius will soar; but, whilst we are so doing, we find no substantial proofs from their writings to establish either theory.

Whiston and Dr. Woodward's Theory.

These writers pursue nearly the same track as the former. Whiston, however, alters his theory from theirs in some points, to make it more consonant with certain passages of Scripture according to his interpretation of them—whilst Dr. Woodward differs from Burnet on the subject of the smoothness of the earth's surface prior to the general deluge. Burnet ascribes the origin of rivers to watery condensations in the polar regions. Dr. Woodward attempts to prove that rivers could have no existence were the earth void of mountains.

M. de Buffon's Theory.

The reasonable suppositions and the moderation with which they were advanced by the theorists already mentioned, were such as could not fail to claim some attention; but M. de Buffon's theory so abounds with improbabilities, that we can hardly give him credit for any thing beyond having given the utmost limits to his imagination. He supposes that about 75,000 years ago a comet in performing its revolution struck against the sun; by the violence of the shock a considerable portion of the sun was broken off and carried into the regions of space. On such event occurring, the part so disunited was in a red-hot liquid state—it separated, and was formed into the various planets. By this theory it does not appear that the earth could become cool in less than about 22,000 years—condensation of water did not commence till the end of 25,000 years, and to complete this process it required a lapse of 10,000 more.—After this condensation was accomplished, he allows the creation of shell-fish and the formation of the various strata of the earth in the bosom of the waters. Another period of 15,000 years he considers to have been necessary should elapse before the waters receded—that when such event took place, the valleys were occasioned by different currents, which carried on a regular system of calcareous formations, and formed the beds of alluvium.

" Alluvium," says Mr. Phillips, in his *Outline of the Geology of England and Wales,* " occasionally " covers the more elevated tracts in this country, " but oftener rests upon their sides, and still more " frequently forms the surface of low lands, some- " times to such a depth as hides from observation " the nature of the stratum on which it is de- " posited. It occurs beneath the vegetable soil, " and consists of the ruin of the neighbouring " rocks, or even of distant strata, fragments of " which are often enclosed in the gravel, or sand, " or loam, or mud, or silt, of which the deposition " consists. Some of them enclose the bones of " animals, not in a mineralized state, and occa- " sionally shells, of which it is remarkable that " some have been found more nearly approaching " those now existing in the sea, than such as oc- " cur even in the newest of the regular strata. " The name of this deposite is descriptive of its " undoubted origin; *alluvies,* in the Latin, signi-

" fies a land-flood. This term, however, might " seem to confine the cause that has produced " ruin of so great extent to ancient agency of " almost universal floods: but it is certain that " there exist accumulations of some of the substances already named, which are not of ancient date, but that result from causes even " now operating. Such are the consequences of " mountain-torrents and rivers. These, carrying " down the portions of rocks, detached by the " action of the atmosphere, or of water, sometimes leave accumulations of detritus, which " tend materially to alter the features of a country; and, by reasoning on the smaller operations of nature we are sometimes enabled to " form an estimate of those which are on a larger " scale."

But, to return to *M. de Buffon's* theory.—The creation of man he fixes about 6,000 years back, and accounts for animals having existed, by supposing a number of living atoms, capable of producing new species, and perpetuating those already existing.

Kirwan's Theory.

The opinion advanced by Mr. Kirwan on the subject of the production of the different mountains and rocks, whether stratified or not stratified with valleys, *&c.*, supposes, that, originally, the globe, to a certain extent, was liquid; and that, in consequence, when its upper menstruum was in a state of solution, the revolution of the earth upon its axis produced them.

Dr. Hutton's Theory.

As to the manner in which the earth and sea were originally produced, Dr. Hutton does not seem to give any explanation; but the formation of hills and valleys he ascribes to the continued operation of rivers and currents in general. These, carrying along with them the soil, over and through which they pass, ultimately lodge it in the ocean: there it accumulates to a prodigious extent, and, by the action of subterraneous fire, becomes consolidated: and are we not daily presented with various instances to prove how the water acts upon the soil it passes through? It makes encroachments upon one coast whilst it conveys soil towards another. Considering, therefore, that the revolution of the earth upon its axis is perpetual, and what effects may be produced by immense bodies of water continually rolling backwards and forwards between the poles and the equator, we need not be surprised if extended periods of time produce great changes in the appearance of the earth, and considerable alterations in the structure of mountains, of rocks, and also of stratification in general.

In support of this theory, we might bring, as an argument, that the alluvial formations are, in many parts, constituted of different materials: that some spaces are hard, calcareous, and rounded, whilst others are in an original state of roughness: others, being in some sort rounded, are partly deprived of their sharpened edges, as if they had been brought from such distances as were inferior to that from whence was brought the rounded pebble.

In addition to the theories already noticed, there are others by *Bertrand*, *Humboldt*, *Werner*, *Saussure*, *Cuvier* and *Bakewell.* In *Thomson's Annals* are some very interesting papers, written by *Mr. J. B. Longmire*, on formations and their different phænomena. This gentleman classifies the primitive formations under new names, accordingly as they are stratified or not stratified; the latter he calls "*concrete*," the former of primary formation, "*concrete*, *earth*, *stone*, or by such other name as is significant of the matter of which they are formed.

Cuvier's Theory.

This eminent naturalist very fully examines the organic system of nature, and ascribes the different formations of the earth to the joint operations of fire and water. He is clearly of opinion that the whole of what is described by those who adopt the *Wernerian system*, as secondary formations, has been formed since the creation of fishes and animals, and the primitive rocks were formed before animals were created. According to the system just alluded to, when primitive formations are spoken of, we are to understand such as are devoid of organic remains, or marine impressions: these are to be considered as having been formed antecedent to the secondary, which bear evident marks of organic remains, marine impressions, and vegetable matter. In support of his theory, he states that the primitive rocks bear no marks of organic remains, and have no impressions of shell-fish in their strata, and the oblique direction in which they pass beneath such rocks as are of secondary formation. The manner in which thaws and rains operate in forming new alluvial matter, he explains, and also, when their action is joined with that of rivers, how, in process of time, the forms of rocks, coasts, and valleys, are changed.

"The ground of this theory," says Mr. Holmes, in his *Treatise on the Coal Mines of Durham and Northumberland*, page 65, *&c.*, "appears to be "more generally supported than any other, and "at once opens to the imagination a striking and "wonderful sublimity in the plans of nature. If "we contemplate the slow, though progressive, "revolution of systems; if we unite with them the "frequent and extraordinary effects of volcanic

" eruption, the mind is lost in its ideas of an original creation, and calculates in vain to discover the embryo of nature.

" We can only depend, however, upon our own powers of judgment, and the additional means of evidence which are furnished us for the reconciliation of these theories to our individual suppositions.

" It appears most probable that the different strata have been formed by the mutual cooperation (under various circumstances) of decomposition in the internal laboratory of nature and volcanic eruptions; that subterraneous fires forced a passage through the superincumbent strata, and created a series of formations by the lava, which, descending from the crater, or mouth of the volcano, formed into pyramidical lamina. Supposing these eruptions to have been periodical, depositions of alluvial matter, which, in some cases, might, by compression, become concrete and consolidated, would take place, and produce alternations of soil and strata.

" It is observed in many mountains, particularly the Brocken mountain, in Hartz Forest, Lower Saxony, that the bed which forms the base of the strata in the surrounding valley, is, at the summit, the uppermost stratum. This is supposed to be occasioned by a subterraneous, matter intensely acted upon by heat,

" having forced its way through the several strata " when in a liquid or tangible shape, and thus " caused the elevation of the lower stratum, and " rent the upper ones asunder. This will be " better understood by laying four or five elastic " planes, one upon another, fastened down at " each end, and then force a conic substance un- " derneath up the centre, until the point breaks " through or penetrates the whole of the planes.

" Is it not, however, equally probable that an " eruptive mass might, for a time, accumulate it- " self into a conical mountain; that, by becoming " cool, it would concrete until its central region " was again dissolved by heat, and emitted fresh " eruptions of lava, forming new layers round " the original cone, and so, by alternate cessations " and eruptions, produce many and different sub- " stances? This is the more probable from the " extremities being thinner and more shattery " than almost any other part. These alternating " strata have, in general, the remains of shell-fish " imbedded in them, from whence is deduced an " idea of their having been originally horizontal; " but, according to the theories of *Burnet*, *De-* " *scartes*, and *Demaillet*, these materials might " have been deposited during the earth's im- " mersion in water; so that what would be con- " tradictory in one theory, is reconciled by an- " other.

" But, as it is not my intention, or the object of " this work, to expatiate fully upon the origin of " rocks and minerals, I hope the explanation of " such parts as relate to coal will be found satisfactory, according to the information we have " upon the subject.

" Whatever were the original causes of the " stratifications within the earth, it is certain that " they possess an astonishing resource of different " minerals and fossils, in which the researches of " chemists and mineralogists are daily discovering " some new principle,—some new cause for admiring the wonderful works of a great and beneficent Creator.

" These valuable productions of nature, gradually drew the attention of mankind to explore " the inner regions of the earth, and accelerated " the progress of mining to its present state."

Having spoken somewhat at length on the component parts of coal, as well as on various theories of stratification, perhaps, by dividing the different kinds of pit-coal into fewer classes than those already noticed, the classification will be simplified and rendered more familiar to the reader. Pit-coal may be divided into three classes, according to the proportions of the component parts.

Coals of the First Class.

Such coals, as are chiefly composed of bitumen, are to be considered as belonging to the first class.

Second Class of Coals.

Those which contain a lesser proportion of bitumen and more charcoal, comprehend the varieties of the second class.

Third Class of Coals.

The third class are such as contain very little bitumen, but are chiefly composed of charcoal chemically combined with different earths.

Remarks upon Coals of the First Class.

Those coals which come under the first class, light without difficulty, burn with a bright and yellowish white blaze during the whole process of combustion. They do not cake nor require stirring; neither do they produce cinders, but are reduced to white ashes. Coals of this class are apt to throw out splinters whilst burning; but, as has been before observed, that may, in a great measure, be obviated by wetting them prior to their being used. At the head of this class is to be placed *cannel-coal.* Those of Lancashire, and such as are obtained on the western coast of this island also belong to it. It sometimes occurs in the coal-pits of Durham and Northumberland. Most of the varieties of Scotch coal may also be considered as forming part of it, and more particularly the *splent*, which is an inferior kind of *cannel-coal.*

Although this class of coal generally produces gas in considerable quantity, it is doubtful whether it be worthy of the gas-light manufacturer's notice, and particularly in London; for, when it is submitted to distillation, there is no product of coke, as in coals of the second class; and, what is worse, the gas evolved is of so much greater specific gravity that, unless the gas-holder be worked at an extremely light pressure, it will be highly offensive in the houses where it is consumed. It is not so easily purified as the gas procured from Bewicke and Crastors Wallsend coal, nor is it so beneficial.

Some of the varieties of this class are, the Hartleys, Wylam, Tanfield Moor, Eighton Main, Cowpers Main, Blythe, and Pontops. Of these, Hartleys and Wylam are well adapted for heating retorts,—the latter in particular. Tanfield Moor, though generating a very large proportion of heat, is not so; it is so very subject to clinker, and to destroy the *grate-bars*, as well as the retorts and fire-work, as to render it very unfit for such purpose.

Remarks upon Coals of the Second Class.

Coals of the second class do not burn with so bright a flame as the former. The flame of these coals is of a yellowish tinge. After laying some time on the fire they become soft and swell: they then cake and produce tubercles, from whence issue small jets of flame. When coals of this kind are burnt in an open grate, the passage of the air through them is prevented by the top of the fire caking and closely adhering. The consequence which follows is this; the lower part of the coal contained in the grate is consumed and leaves a hollow, whence, if the upper part were not occasionally broken, the fire would go out. These coals produce a smaller proportion of ashes than coals of the first class. They are of a greyish or reddish colour, according to the quality of the earthy part of which the coal may be constituted. They produce hard grey cinders, which, being burnt over again with fresh coals, produce a very strong heat. The colour of the flame produced from this class of coal is not so white and brilliant as that emitted by cannel-coals, and those of similar properties; and that portion of it which is given out after the bitumen it contains is disengaged, is of a pale blue colour. The gas which they produce during this part of the process of combustion is a mixture of oxide of carbon, hydrogen, and carbonic acid. The coke produced from this class of coal, during the process of generating gas therefrom, when carbonization is properly carried on, is well adapted for domestic and culinary purposes; and, when such coal is manufactured into coke in the ordinary way, it is calculated to be used in the furnaces of iron-founders, and for other metallurgical operations. Coals of this class are, in the market, denominated *strong burning coals.* The coals which may be named under it, are Bewicke and Crastor's Wallsend, Bewicke's Wallsend, Russel's Walls-end, Bell's Wallsend, Brown's Wallsend, Wear Wallsend, Manor Wallsend, Wellington Main, Temple Main, Heaton Main, Killingworth Main, Headsworth, Hebburn Seam, Hutton Seam, and Nesham. Smiths prefer the smaller kind of this class of coals before any other, in consequence of its affording the greatest heat, the best cinders, and standing a strong blast. Swansea coals may be considered as belonging to this class. Some of the varieties contain pyrites, others thin layers of lime-stone and shells: these are found amongst the ashes they afford as slates and stones. When submitted to distillation, a greater heat is required than is necessary for decomposing coals of the first class: but the gas which they afford is easily purified, and is generally better adapted for use than that obtained from coals of the first class.

The aqueous fluid which passes over, during the process, contains sulphate, carbonate, and hydro-sulphuret of ammonia. When coals of this kind are mixed with those of the first class, in the proportion of two-thirds of the former with one-third of the latter, an excellent fuel is thereby formed; and if, in making the mixture, the proportion of coals of the first class be increased, the fuel will be more easily managed, and will burn with greater cheerfulness; but then its durability will decrease in a like proportion.

Remarks upon Coals of the Third Class.

Coals of this class require a very high temperature to bring them into ignition, they do not burn till wholly ignited, and then some of the varieties produce a very weak flame: others, neither yield flame nor smoke, and merely produce a red heat, like that which is generated by charcoal, when under combustion. They contain a very considerable portion of charcoal; they produce only a small quantity of ashes, but these are generally very heavy. When distilled in close vessels, they do not produce much tar, and that portion which is disengaged, comes over in a state nearly resembling melted pitch. Under that process they also yield a gaseous fluid composed of gaseous oxide of carbon, hydrogen gas, and a considerable portion of sulphuretted hydrogen. Considering the nature of the different varieties of this class of coals, it can hardly be expected, that it would be profitable to use them for generating coal gas. The Kilkenny, Welsh, and Stone coal, are varieties forming this class.

In order to form an idea of the probable time that Great Britain may be supplied with coal from the mines of Durham and Northumberland, we are to consider that the seams of coals now worked in those counties are equal to a bed twenty miles long by fifteen miles broad, and that the average thickness of this bed is one yard and a half: also, that from one-fourth to one-sixth is sufficient to be left as props for supporting the tops of the mines. In making our calculation, suppose we state one-fifth to be left for that purpose. Then

$15 \times 1760 = 26{,}400$ yards,

$20 \times 1760 = 35{,}200$ yards, and

$26{,}400 \times 35{,}200 \times 1\frac{1}{2} = 1{,}393{,}920{,}000$ cubic yards of coal contained in the mines above mentioned; from this we are to deduct one-fifth for pillars to support the roof;—thus,

$1{,}393{,}920{,}000 \div 5 = 278{,}784{,}000$, and

$1{,}393{,}920{,}000 - 278{,}784{,}000 = 1{,}115{,}136{,}000$ cubic yards of coal, which may, in process of time, be brought to market; and, as each cubic yard of the various species of coal produced from these mines is known to be equal to one ton, consequently, the number of cubic yards and of tons are equal. Now, as it appears from the register that the total annual consumption of coals, from Newcastle and Sunderland, is 2,300,000 chaldrons, of 27 cwts. each, it follows, that the annual consumption in tons, is 3,105,000.

The total quantity of coals which these mines are capable of supplying, having been stated at 1,115,136,000 tons; therefore, if that number be divided by the tons annually consumed, the quotient expresses the number of years such annual supply can thence be given; thus 1,115,136,000 ÷ 3,105,000 = 359 nearly, and such number of years they will afford a source of consumption.

CHAPTER IV.

On the Economy of using Pit-coal as Fuel—the Heat it generates—the Forms of Grates and Fire-places—with Remarks on the various Abuses practised in the Coal-trade, &c. &c.

WHEN pit-coal is used for fuel in open fire-places, the quantity of heat generated thereby depends very considerably upon the fire being properly managed. If it be allowed to burn clear, it will throw out much heat; but, if the coal be heaped upon it in such a way as prevents a current of air from passing through the mass, it will be smothered up, and produce a very small proportion; most of the heat will be lost by its being employed to give elasticity to the smoke, which rises in great abundance. The combustion, under such circumstances, must be very incomplete; for the carburetted hydrogen gas will be driven up the chimney uninflamed, and therefore the fuel will be used with little benefit. But coal is often thrown upon the fire in this way by servants, by which the flame is frequently many hours in making its way through the top of the fire; and sometimes before it can do so, the fire is actually in danger of going out altogether. Whilst this wasteful process is going on, the fire does not communicate any heat to the room, and the throat of the chimney being filled with a heavy vapour, void of any heating quality, and having but little elasticity, the warm air in the room forces its way up the chimney, and thence escapes more easily than when the fire burns with a degree of brightness. Indeed, where chimneys and fire-places are not constructed with judgment, it often happens, that the current of warm air from the room, on entering into the chimney, so crosses upon the aqueous vapour, which escapes slowly from the fire, as considerably to impede its ascent, and in some cases to force it back into the room; and, from this circumstance it is, that chimneys so often smoke when a large quantity of coal is heaped upon the fire. Such a quantity of coals ought never to be put upon the fire at one time as will prevent the free action of the oxygen of the air through them; consequently, there ought always to be left a sufficient passage for the flame produced. Or, when small coals are used, not more should be laid upon the fire at once than will be quickly so heated through as to give out the gas which they contain in such manner as will allow it to be inflamed as it is generated. By paying attention to the quantity of coals put on the fire at once, and avoiding smothering it up, much will be contributed towards cleanliness and comfort, and more particularly so if the following rules for properly managing it be observed :—

1st. Stirring of a fire is of use, because it makes a hollow, where the air being rarefied by the adjacent heat, the surrounding air rushes into this hollow, and gives life and support to the fire, and carries the flame with it.

2d. Never stir a fire when fresh coals are laid on, particularly when they are very small, because they immediately fall into the hollow place, and therefore ruin the fire.

3d. Always keep the bottom bars clear.

4th. Never begin to stir the fire at the top, unless when the bottom is quite clear, and the top only wants breaking.

Having shewn what is requisite for generating radiant heat, the means for causing the greatest proportion thereof to enter the room for the purpose of warming it, is next to be attended to. The rays which are thrown out from burning fuel possess the properties of generating heat only when and where they are absorbed, and of being reflected without generating heat at the surfaces of certain bodies; therefore, by knowing these properties, we shall be enabled to adopt such measures as cannot fail of producing the effect we may desire, namely, bringing into the room a large proportion of radiant heat. In order to do this, we are to cause as many of the rays as we can that are sent off from the fire, to come directly into the room, which can be effected by bringing the fire as far out as possible, and making the opening of the fire-place as wide and as high as circumstances will admit of. The back and sides of the fire-place ought to be made of such form and such materials as will cause the direct rays of heat from the fire which strike against them to be abundantly reflected into the room. The best form for the vertical sides of the fire-place, or covings, is that of a perpendicular plane, which makes an angle of about 130 degrees with the back of the fire-place. In the construction of many fire-places, the angle formed between the back and the covings is a right one, which, of course, by causing the two sides to be parallel to each other, is in nowise calculated for causing the rays of heat which fall upon their surfaces to be reflected into the room. But, if the back of the fire-place be about one-third of the width of the front, the two covings, instead of being parallel to each other, will each stand at an angle of about 130 degrees from the back of the fire-place; by this means, they will present oblique fronts towards the room, and thence the rays of heat which had fallen upon their surfaces will be reflected into it. As to the materials which may be most advantageously employed for constructing fire-places, it is clear that those are the best which reflect the most or absorb the least of the radiant heat generated. Such bodies as absorb radiant heat are of necessity heated by that absorption; we are, therefore, to find by experiment, what bodies acquire the least heat, by being so placed as to allow the direct rays from a clear fire to fall upon them for a given time; and, having ascertained the fact, we are to consider such body as most fit for constructing the backs and covings of fire-places. As it is well known, that iron and most metals grow very hot when exposed to the rays thrown out by burning fuel, they are the worst materials that can be used for constructing the backs and covings of fire-places: and, as fire-stone and common bricks absorb the heat given out by a fire, when so exposed, in a very small degree, they may be considered as the best materials for the purpose. But, if fire-places are constructed of bricks and mortar, such should have a thin coat of cement given them, which, when dried, ought to be blacked and brushed bright in every part that is not liable to be soiled by the ascending smoke. The interior part of the breast of the chimney ought to be so rounded off, (instead of being left flat, full of corners and holes,) as to allow a free current of air to pass under the mantel-piece into the chimney: under this arrangement, the air will more easily unite with the smoke as it ascends, and be less liable to cross it, and drive it back into the room. As to the height which the back and covings ought to be carried, it will depend on the height of the mantel, and that part of the chimney where the breast ends, and the beginning of the upright canal is formed. The back, and also the vertical covings must be carried about six or eight inches higher than the breast; by their being so, the throat of the chimney will be so formed as to render it altogether unnecessary to carry them higher.

For most fire-places, the throat of the chimney ought to be about four inches wide; but, in cases where the fire-place is small, and the chimney well situated, three may be sufficient: however, it sometimes happens, when the throats of chimneys are very narrow, by putting on the fire much coals at one time, the smoke will be puffed down. Four inches may be considered the best width for fire-places where coal is to be burnt. But in large fire-places, it may be increased to six or seven inches.

Grates, to be used in rooms of the middle size, ought to be from six to nine inches from the bars in front to the back. No grate ought to be less than five inches wide, for any further diminution will cause it to be very difficult to keep the fire made in it from going out.

The size of the coal is an important subject, as it regards the production of heat; for when small coals are used in fire-grates of the ordinary kind, they are very wasteful. Whenever small coals are used, it is found necessary to stir the fire; by doing so, before they are thoroughly caked, a great portion of them pass through the bars, and are taken to the dust-hole without being burnt.

In large grates, small coals may be of some use when thrown on the back part of the fire; but fires made with them are neither so strong or so bright as those made with large coals.

But the loss which is occasioned to the lower orders of society from using small coals is in proportion greater than in the houses of the rich; for, in the large fire-places of the latter, the small coal has a much greater chance of being burnt than in the small grates of the former. The poor cannot afford to keep large fires, and have but little time to spare for preparing their meals; the consequence is, that they must unavoidably stir the fire, and by so doing, waste a considerable portion of coal. But to them the loss is increased by the inferior kinds of coal which they are compelled to purchase, when their supply is frequently obtained by the bushel or peck from the coal-shed. If they are supplied from thence with coals of the first class, the rapidity with which they burn causes them to consume double the quantity necessary; if they use coal of the second class, the slowness with which it burns makes it to them nearly as wasteful—for a great quantity thereof goes to the dust-hole without being burnt.

It is an erroneous opinion, which leads to a supposition that the actual quantity of coal contained in a sack is diminished by screening the small from the large coals; and it is easily confuted by considering that a compact body does not occupy so much room as when it is broken into smaller pieces, or reduced to powder:—the case in question is similar—the screening of coal removes only the dusty part of it; consequently, by that being taken away, room is given for more small pieces of coal being received into the sack than are equal in weight to the dust which it contained prior to the screening process.

" And with regard to the measure of coal as " offered in the market," says Mr. Edington, in his work on the coal-trade*, " it may be remarked, " that many coal-merchants will promise to give " sixty-eight sacks to a room; but here it should " be observed, that much depends on the size and " shape, or, as it is called, the roundness of the " coal, *viz.*, any of the Wallsend, Wellington, " Benton, Heaton, Heborn, Percy Main, Cowper, " Blyth, and Hartley, being all put on board of " ships in large masses and blocks, round as out

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* Pages 91, 92, 93.

" of the mine; it is certain, that in every room of " five chaldron and a half, the in-grain, when the " round are broken, every room will measure out " from six to six and a half chaldron again, equal " to seventy-two or seventy-eight sacks; those of " the inferior kind being so small, will barely " measure out the same measure as they meted in " the Pool. It is now become a general rule, " when a room of coals is bespoke, to send in " sixty-three sacks, and no more, with the meter's " ticket, which, if fairly measured, is all that can " be expected; the overplus the merchant claims " himself.

" In coal-sheds the measure, as well as the " mixing one kind of coal with another, is often scandalous, for the act of parliament does not take " the least notice of the small measures. It is a " known fact, when a fraudulent dealer orders in a " room of coals, for every chaldron of thirty-six " bushels, if he does not send them out at the rate " of forty-two bushels again, he will be dissatisfied with his measure. This is extremely hard " upon the lower class of people, who are only " able to purchase a peck or half a peck at a time; " and let the measure be ever so bad, they have " no means of redress.

" But should the legislature determine to do " away the present erroneous mode of measuring " coals, in which the deception between round and

" small coals is so great, there is no way completely " to remove the evil but to have them sold by " weight, in proportion, which would put it out of " the power of the seller to defraud, even in the " smallest quantity; and as to the coal waggons, " instead of carrying the bushel measure they use, " let them have a pair of steelyards, so that a " sack, or any quantity of sacks of coal could be " easily weighed at the over-end of the waggon, " and if the sack of coals weighs 255 pounds, " after deducting the sack, the purchaser may be " satisfied that he has his measure."

Mr. Edington observes*, " the difference is so " great between round coals, with regard to absolute quantity, and small damp and dry coals, that " no means can be obtained to correct and prevent " abuse. Thus, if a vat of Wallsend coals be " measured from the ship, such measure as the " meter gives,—turn over the vat, and break the " round coals to the size the merchant sends them " out to his customers, then fill up the vat again; " and it will be found to overrun a bushel, more " or less, according to the roundness of the coal. " Secondly, a score is measured out of Wallsend " coals in the Pool, into a barge having four rooms, " each containing five chaldrons, and a half the ingrain; no sooner does the barge arrive at the

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* *Treatise on the Coal Trade*, p.p. 191, 192, and 200.

"wharf, than the round coals are broken, and if "very dry, the coals being wetted, will increase "in bulk; nor is the coal-merchant satisfied if he "does not by this practice send out from six to "six and a quarter, or even six and a half "chaldrons from each room. Thirdly, if coals "were sent out by weight, the deception by "watering them may be supposed to be heavier, "but the contrary is the case: for if a bushel of "Wall's End coals be measured up dry, it will "shew its weight to be from eighty-four to eighty-"five pounds; then try another bushel of the "same coals well wetted, the weight will be found "not so great; for the fact is, a bushel of dry "coals, if ever so round, has always a part "small, which runs like dry sand, and fills up "every cavity, making the whole a solid mass; "whereas a bushel of wet coals only closes up "the hollow cavity, and they clog together and "will not weigh so much as the dry coals. In "meting coals by measure, take a bushel of coals, "dry, turn them up and wet them well; then fill "up the bushel again, and they will over-run the "measure considerably, for, as before observed, "they fill up hollows.

"By the proposed method of adopting the "sale of coal, both by weight and measurement, "justice would be done to the revenue, to the "consumer of coals, and to all coal-merchants "and proprietors of the collieries. But, from the "observations already shewn, it is not to be "wondered that the coal-merchants give so "decided a preference to the round coals, be-"cause the larger they are, by breaking, *&c.*, the "greater the quantity will run over the mea-"sure they receive in the pool; nay, they see "by the certificates put up in the Change on a "market-day, all such cargoes as are loaded by "the spout only, and they will give from twelve-"pence to eighteen pence per chaldron in pre-"ference to large cargoes, even of the same coals; "but from the size, the ship being obliged to take "a part of her lading in by keel, not so round as "those wholly loaded by the spout."

After what has been selected from Mr. Edington's Treatise on the abuses practised in the coal-trade, perhaps nothing could be brought forward with more propriety as a conclusion to this chapter, than the following abridged extracts from the *coal laws.*

"Sea coal brought into the Thames shall be "sold by the chaldron, containing thirty-six "bushels heaped up, according to the bushel "sealed for that purpose at Guildhall.

"Coals within the bills shall be carried in "linen sacks, sealed by the proper officer, which "shall be at least four feet four inches in length, "and twenty-six inches in breadth; and sellers

" of coal by the chaldron, or less quantity, shall " put three bushels of coals into each sack." 3 & 32 Geo. II, c. 26 & 27.

" All sellers of coals are to keep a lawful " bushel, which bushel and other measures shall " be edged with iron and sealed; and using others, " or altering them, incurs a forfeiture of fifty " pounds.

" Any purchaser dissatisfied with the measure " of any coals, may, on delivery to him of the " meter's ticket, have the same re-measured, by " sending notice thereof to the seller, and to the " land coal meter's office for the district in which " the coals were sold; on which a meter (not " being the same under whose inspection the " coals were originally measured) must, within " two hours, attend to re-measure the coals, and " shall re-measure the same sack by sack, in the " presence of the seller and the purchaser (if they " attend), and also in the presence of a meter " from the two other districts (whose attendance " within London and Westminster is enforced by " a penalty of five pounds, but not in Surry); for " this attendance the purchaser is to pay each " coal-meter attending six-pence per chaldron. " If the coals prove deficient measure, the seller " shall forfeit five pounds for every bushel de- " ficient, and also forfeit the coals to the poor. " The meter under whose inspection the coals

" were measured at the wharf, shall also forfeit " five pounds per bushel deficient, to be recovered " (if not in five days) of the principal coal-meter; " and coal-porters two shillings and sixpence " per bushel. The carman is to be paid two " shillings and sixpence for his horses, *&c.*, for " each hour, whilst the coals are re-measuring.

" Any coal factor receiving, or coal owner " giving, any gratuity for buying or selling any " particular sort of coals, and selling one kind " of coals for and as a sort which they really are " not, shall forfeit five hundred pounds." 3 Geo. II. c. 26.

" Owners or masters of ships shall not enhance " the price of coals in the river Thames by keeping " turn in delivering coals there, under the " penalty of one hundred pounds." 4 Geo. II. c. 30. " Contracts between coal-owners, *&c.*, and " merchants of ships for restraining the buying of " coals are void, and the parties shall forfeit one " hundred pounds." 9 Ann. c. 28.

" Wilfully and maliciously setting on fire any " mine, pit, or delph of coal, or cannel coal, is " felony without benefit of clergy." 10 Geo. II. c. 32.

" Setting fire to, demolishing, or otherwise " damaging, any engine or any other thing belonging " to coal mines, is felony, and transportation " for seven years." 9 Geo. III. c. 29.

CHAPTER V.

The Theory of the Combustion of Coal considered, for the purpose of explaining the Nature of Gas Light *and its Production.*

WHEN pit-coal is burnt in an open fire-place it emits flame, which is occasionally exhibited in streams of peculiar brightness. This flame is coal gas in a state of combustion. But, besides this gas, there are expelled from coal, by the action of heat, an aqueous ammoniacal vapour, (which, on being condensed, forms liquid ammonia,) a thick fluid nearly resembling tar, and some non-inflammable gases. The wavering and the changing of the colour of flame proceeding from a coal-fire is occasioned by the variety of products which coal affords, and, as these are evolved, we have, at one time, streams of brilliant light, at another, clouds of dense and aqueous vapour thrown off, as smoke. Seeing then, that when coals are burnt in the ordinary way, we have evident proofs that they contain inflammable gas, which, if collected and properly applied, would serve as a substitute for the lights obtained by using candles or oil, together with other valuable products,—we must be aware, that, should they be distilled in close vessels, the various parts of which they are formed, may be collected. Such part of the coal as is bituminous will melt out, and be exhibited in the form of tar. That which contains ammoniacal salts, will be thrown off as vapour, and, on condensation, will appear as an amber-coloured fluid, more or less charged with ammonia, according to the circumstances under which the distillation may have been carried on, and the quality of the coal. Whilst the above products are evolved, a considerable quantity of carburetted hydrogen gas, and some uninflammable gases are also generated. These having all been freed from the coal by the action of heat, and collected in their respective reservoirs, its base, which is a carbonaceous substance, known by the name of coke, remains in the retort. The coal gas, being freed from the sulphuretted hydrogen, and non-inflammable gases, is fit for use, and may be forced out of the gas-holder, where it is collected, to any distance, by means of cast-iron pipes laid under ground; from whence smaller pipes of wrought iron and copper convey it to the respective houses where it is to be burnt. At the extremity of the pipes are fixed burners, to which, by means of stop-cocks, the gas is admitted, and, through orifices made in the burners, it escapes, and is ignited for the purpose of affording light. Thus, from pit-coal, an article produced in considerable quantities in this country, may be obtained a substitute for lights, which are afforded by using wax, tallow, or oil, but of a superior quality, and at considerably less expense. When this is considered, it cannot but be gratifying to the feelings of every Englishman to know, that within his native country, there are abundant resources for generating artificial light, and that he is no longer entirely dependent on the relations he holds with foreign powers, or on the fisheries, for a supply of such materials as have heretofore been used for producing it.

The promoters of gas-lighting rest their claims to public notice and encouragement on the ease with which the various products obtainable from coal are collected, and the cheap rate at which they can afford them, and, more particularly, the article of gas. They consider that the flame which pit-coal yields when it is consumed in the ordinary way, is turned to very little advantage:—it is confined to one place, and, frequently, is there of much less use than a red heat would be. It is also often obscured and smothered by the quantity of incombustible matter which is thrown off with it, and from which the application of a considerable portion of the coal-gas generated, is not applied to any useful purpose.

If we direct our attention to the process of the combustion of coal, when burnt in a common grate, we shall very frequently observe streams of flame burst out of the clouds of smoke which are evolved:—these suddenly disappear, and fresh ones supply their place, as the quantity of inflammable gas preponderates over the non-inflammable gases and aqueous products. Should we apply a lighted taper to the small jets issuing from that part of the coal from whence the tar oozes and points out as bituminous, they will ignite and burn with a brilliant flame. In short, it is evident that a considerable quantity of gaseous matter, which is capable of generating both light and heat, in open fire-places, must escape up the chimney, whilst but a small portion of it, comparatively speaking, is exhibited as flame.

If we compare the theory of the production of gas-light with the theory of the production of artificial light by means of candles or of lamps, we shall instantly perceive that the principles are similar;—for, in candles or lamps, the wick bears a like situation to that of coal, when submitted to distillation in a close vessel. The wick of a candle serves to convey the melted tallow by capillary attraction to where it is to be consumed. It is there decomposed, and forms carburetted hydrogen gas; as this is made use of, a fresh supply is constantly kept up, which maintains the flame. By a parity of reasoning, it appears, that the burning of oil in a lamp depends on similar circumstances; for the tubes formed by the wick transmit the inflammable gas through them in the same way that the heated retort generates coal gas. The oil of a lamp is drawn up through the wick, and is formed into that carburetted hydrogen gas from whence proceeds illumination. After considering these matters, the question—What does the gas-light system attempt? may naturally be put; and the reply might be given in words something to the following effect:—The gas-light scheme proposes to generate such quantities of gas as may be wanted for supplying that district with artificial light, where the works may be situated, by means of a sufficient number of retorts and gasholders for the purpose; and that this gas is the same sort of material as the flame of a candle or a lamp. That the difference between the one mode and the other is simply this: When coal gas is used as a substitute for light afforded by the combustion of tallow or of oil, the distillatory process for lighting streets, nay, whole towns and large cities, is carried on in one place, perhaps far from whence the light may be wanted; whilst, by the action of candles or lamps, the process is performed wherever such candle or lamp may be used, namely, at their respective wicks.

In concluding this chapter, we are to observe that the system of generating light from pit-coal is supported not only by reason, but now by experience also;—that the discovery ranks highly amongst those which have recently been made in chemistry:—and it appears likely to produce the most favourable results; for, from its application we learn, that those uses to which we have been accustomed to put coal, are not all to which it is applicable. The production of artificial light, as it relates to our comforts, is of peculiar importance, and the source afforded for obtaining it by this new discovery is in this country abundant. By the introduction of the gas lights, the process of analyzing coals is so considerably extended, that what, as far as related thereto, was once confined to the laboratory of the chemist, is now performed with great simplicity in the large way, at every gas-light establishment. Indeed, so much has the scheme extended, that at some works in this metropolis, as many as thirty chaldrons of coals are distilled in twenty-four hours; and the aggregate quantity daily used here for generating gas may be estimated at one hundred and fifty chaldrons, from whence are produced about seventeen million cubic feet of gas, and other valuable products.

CHAPTER VI.

An historical Statement of the successive Discoveries which have been made in decomposing Coal,—and on the Rise and Progress of Coal-Gas being applied as a Substitute for the Light afforded by burning Wax, Tallow, or Oil.

BEFORE entering upon the description of the different apparatus and machinery used for the purpose of generating coal-gas, it cannot but be interesting to most readers, should some account be given of the time when, and the way in which, the idea of applying it to the purpose of affording light originated; and also, to point out, in as concise a manner as possible, the gradations through which it has risen, till it reached its present pre-eminence over every artificial light hitherto known; both as relates to the quantity of light afforded, and the cheap rate at which it can be supplied. From this abridged history will be shewn, that a considerable lapse of time is necessary to mature and introduce new systems, the difficulty with which improvements in science are so established as to become universally adopted, and the slowness with which mankind follow after known principles that forward something which may be considered as an innovation on former and long-established habits.

That a permanently elastic and inflammable aëriform fluid is evolved from pit-coal, appears to have been first ascertained experimentally by the reverend Dr. Clayton. An account of his discovery was published in the *Philosophical Transactions of the Royal Society*, Vol. XLI, for the year 1739, from whence the following extract is made:—" 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 like" wise a *spirit* arose, which I could no ways con" dense; but it forced my lute, or 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 con" tinued burning with violence as it issued out in " a stream, which I blew out and lighted again " alternately for 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 " pipe, 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 re-
" ceiver. 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 inconceiv-
" able 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 consider-
" able time, and endeavoured several ways to
" condense it, but in vain: and, when I had a
" mind to divert strangers or friends, I have fre-
" quently 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.

" But then, I found that this spirit must be
" kept in good thick bladders, as in those of an
" ox, or the like; for, if I filled calves' bladders
" therewith, it would lose its inflammability in
" twenty-four hours, though the bladders became
" not relaxed at all."

In the beginning of the eighteenth century, Dr. Hales* made chemical experiments on pit-coal; and in doing so he found, when it was submitted to distillation in close vessels, nearly one-third of the coal passed off in inflammable vapour.

The Bishop of Llandaff†, in the year 1767, examined the qualities of the gaseous and other products, generated whilst distilling pit-coal; and observed that the carburetted hydrogen gas would not only inflame as produced, when allowed to issue from the distillatory vessel, but that its inflammable quality was retained after passing it through water and allowing it to ascend by means of curved tubes. The other products obtained during the process, were an ammoniacal liquor, a thick oil resembling tar, and coke.

But the applying of coal-gas, for the purposes of illumination, is of more recent date, and the merit of bringing it forward is claimed, and with justice, by Mr. Murdoch. The following account‡ of his discovery is given by Dr. W. Henry, of Manchester.

" In the year 1792, at which time Mr. Murdoch
" resided at Redruth, in Cornwall, he commenced
" a series of experiments upon the quantity and
" quality of the gases contained in different sub-

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* *Vegetable Statics,* Vol. I.

† Watson's *Chemical Essays,* Vol. II.

‡ Thomson's *System of Chemistry,* Vol. I., p. 52.

" stances. In the course of these, he remarked that " the gas obtained by distillation from coal, peat, " wood, and other inflammable substances, burnt " with great brilliancy upon being set fire to; " and it occurred to him, that, by confining and " conducting it through tubes, it might be em- " ployed as an economical substitute for lamps " and candles. The distillation was performed " in iron retorts, and the gas conducted through " tinned iron and copper tubes, to the distance " of seventy feet. At this termination, as well " as at intermediate points, the gas was set fire " to as it passed through apertures of different " diameters and forms, purposely varied with " a view of ascertaining which would answer " best. In some, the gas issued through a num- " ber of small holes like the head of a water- " ing pan; in others it was thrown out in thin " long sheets; and again, in others, in circular " ones, upon the principle of Argand's lamp. " Bags of leather, and of varnished silk, bladders, " and vessels of tinned iron, were filled with the " gas, which was set fire to and carried about from " room to room, with a view of ascertaining how " far it could be made to answer the purpose of " a moveable or transferable light. Trials were " likewise made of the different quantities and " qualities of gas produced by coals of various " descriptions, such as the Swansea, Haverford-

" west, Newcastle, Shropshire, Staffordshire, and
" some kinds of Scotch coals.

" Mr. Murdoch's constant occupations pre-
" vented his giving further attention to the sub-
" ject at that time; but he again availed himself
" of a moment of leisure to repeat his experiments
" upon coal and peat at Old Cumnock, in Ayr-
" shire, in 1797; and it may be proper to notice
" that both these and the former ones were ex-
" hibited to numerous spectators, who, if neces-
" sary, can attest them. In 1798, he constructed
" an apparatus at Soho foundry, which was ap-
" plied, during many successive nights, to the
" lighting of the building, when the experiments
" upon different apertures were repeated and ex-
" tended upon a large scale. Various methods
" were also practised of washing and purifying
" the air, to get rid of the smoke and smell.
" These experiments were continued, with occa-
" sional interruptions, until the epoch of the peace
" in the spring of 1802, when the illumination of
" the Soho manufactory afforded an opportunity
" of making a public display of the new lights;
" and they were made to constitute a principal
" feature in that exhibition."

The general nature of gas-light illumination was exhibited by Mr. Winsor, at the Lyceum theatre, in London, in the years 1803 and 1804; but the apparatus, by the means of which he obtained coal-gas, and the mode of purification which he adopted, he kept a secret. He shewed the manner of conveying the gas through the house, and exhibited various devices for chandeliers and burners. Instead of the copper fittings, which experience has since taught to be the most useful, he proposed long flexible tubes brought from the ceiling or the wall, to the ends of which were attached different descriptions of burners. He proved, experimentally, that the flame of coal-gas, when properly managed (by allowing no more gas to pass the burner than would be entirely consumed), produces no smoke; and that it is not, as the flame of candles and lamps, subject to emit sparks; therefore not so dangerous, nor is it so liable to be put out by sudden gusts of wind, or by heavy rain.

Although the discovery of the inflammability of coal-gas cannot be claimed by any person now living, it appears that both Mr. Winsor and Mr. Murdoch have laid claims to the right of bringing it into notice as a substitute for other lights. We are, however, informed by Mr. Accum that Mr. Murdoch's priority of right was not heard of till more than two years after Mr. Winsor's public exhibition took place; and, from what he says on the subject, one would be led to consider Mr. Winsor as entitled to it. But if we compare Dr. Henry's Statement relative to Mr. Murdoch's discovery, with what Mr. Accum says of the most early period that Mr. Winsor pressed on the public mind the extensive application of gas light; it will appear that Mr. Murdoch had, ten years prior to that time, when making his experiments on the gases contained in different substances, considered, by confining and conducting coal-gas through tubes, it might be employed as an economical substitute for lamps and candles. He distilled his coal in iron retorts, and conducted it through tinned iron, and copper tubes, to the distance of seventy feet. In short, so long ago as 1797 he exhibited his experiments to numerous spectators. In the following year he constructed an apparatus for lighting the works of Messrs. Bolton and Watts; and, in the spring of 1802, these works were illuminated under his direction.

It does not appear that Mr. Winsor's public exhibitions commenced till 1803; how, then, could Mr. Murdoch derive the hint of applying coal-gas from thence? or, how can there be any necessity for observing that the ideas of Mr. Murdoch on the subject may have arisen totally independent of all acquaintance with Mr. Winsor's? Unacquainted with either of these gentlemen, I cannot be supposed to speak with partiality in declaring that from the most circumstantial and respectable testimony, Mr. Murdoch appears to deserve the merit of bringing the new mode of illumination into notice. It is certainly a false mode of reasoning, which leads any person to assert that the claims of invention concern the Public only to a limited extent; for it must be considered, if the inventor is liable to have his right doubted on the vague assertions of another, the spur to exertion of talent is lost, and few, under such circumstances, would have sufficient strength of mind to carry them through the trial. He who wins the palm should be allowed to wear it, but how frequently do we witness the reverse.

Mr. Winsor made no new discovery relative to the decomposition of coal, nor invented the manner of conducting gas through tubes from the reservoir to the place of consumption. He did much, by his exhibitions in this metropolis, towards calling the public attention to the subject of gas-lighting; but, at the same time his publications acted against the scheme. Perhaps it was owing to these that the plan was so long in gaining ground, more than to a want of support from some great name; for who could confidently rely on statements which were beyond all credence, and which later experience has proved were so wide from the truth? But, as Mr. Winsor's experiments must have been made in the small way, we can hardly expect the results would agree with the more extensive practice of succeeding operators.

Mr. Winsor took out a patent in May, 1804, for combining the saving and purifying of coal gas, for obtaining ammonia, tar, and other products of pit-coal with the manufacture of a superior kind of coke; since which time he has taken out another patent for further improvements in the processes.

Mr. Northern, of Leeds, in the year 1805, called the public attention to applying coal gas for the purpose of producing light, instead of candles, *&c.*, an account of which is extracted from the Monthly Magazine for April, 1805:—

" I distilled in a retort fifty ounces of pit-coal " in a red heat, which gave six ounces of a liquid " matter covered with oil, more or less fluid as " the heat was increased or diminished. About " twenty-six ounces of cinder remained in the " retort; the rest came over in the form of air, " as it was collected in the pneumatic apparatus. " I mixed part of it with atmospherical air, and " fired it with the electric spark with a tolerable " explosion, which proves it to be hydrogen. " Whether any of the other gases were mixed " with it I did not then determine. In the re- " ceiver I found a fluid of an acid taste, with a " great quantity of oil, and at the bottom, a sub- " stance resembling tar.

“ The apparatus I make use of for producing light
“ is a refiner's crucible, the top of which (after
“ filling with coal) I close with a metal cover,
“ luted with clay, or other luting, so as to prevent
“ the escape of the gas; a metal pipe is soldered
“ into the cover, bent so as to come under the
“ shelf in the pneumatic trough, over which I
“ place a jar with a stop-cock and a small tube;
“ the jar being previously filled with water, the
“ crucible I place on the common or other fire, as
“ is most convenient; and as the heat increases
“ in it, the gas is forced rapidly through the
“ water into the jar, and regularly displaces it.
“ I then open the cock and put fire to the gas,
“ which makes its escape through the small tube,
“ and immediately a most beautiful flame ensues,
“ perfectly free from smoke or smell of any kind.
“ A larger light, but not so vivid or clear, will be
“ produced without passing the gas through
“ water, but attended with a smoke somewhat
“ greater than that of a lamp charged with common
“ oil.

“ I have great hopes that some active mechanic
“ or chemist will, in the end, hit on a plan to
“ produce light for large factories, and other purposes,
“ at a much less expense, by the above or
“ similar means, than is at present produced
“ from oil.”

About this time, Mr. Samuel Clegg, of Man chester, engineer, communicated to the Society of Arts an account of his method of lighting up manufactories with gas, for which he received the silver medal. To the exertions of this gentleman the gas-light manufacturer is indebted for various improvements in apparatus and machinery.

The rapidity with which the gas-light scheme has since extended has been almost beyond example in any other; for, not only manufactories, but many of the principal towns, in this and other countries have been lighted with gas, together with much the greater part of this metropolis.

The application of gas lights was pointed out in France before it was publicly introduced into England. M. Le Bon had a house entirely lighted up with gas in Paris in the winter of 1802, which was witnessed with admiration by a considerable number of persons. He obtained a patent from the French government for the art of producing light from wood burnt in close vessels.

The ammoniacal liquor and tar have latterly been manufactured on an extensive scale—the former into sulphate of ammonia and various salts, and the latter into pitch, prepared tar, oils, varnishes, *&c.*

Mr. Murdoch, in the year 1808, presented the Royal Society with his account of the application of coal gas—for which the Society complimented him with Count Rumford's medal. The following statement is copied from Mr. Murdoch's paper.

" The whole of the rooms of the cotton mill of " *Mr. Lee*, at Manchester, which is, I believe, " the most extensive in the United Kingdom, as " well as its counting-houses and store-rooms, " and the adjacent dwelling-house of Mr. Lee, " are lighted with 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 " 2,500 mould candles, of six to the pound, would " give; each of the candles with which the comparison was made consuming four-tenths of an " ounce (175 grains) of tallow per hour.

" The gas-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 the 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 amounts to 271 Argand and 653

" cockspurs, each of the former giving a light " equal to that of four candles of the description " abovementioned; and each of the latter a light " equal to two and a quarter of the same candles; " making, therefore, the total of the gas light " a little more than equal to that of 2,500 " candles, six to the pound. When thus regu" lated, the whole of the above burners require " an hourly supply of 1,250 cubic feet of the gas " produced from cannel-coal; the superior quality " and quantity of the gas produced from that ma" terial having given it a decided preference in " this situation over every other coal, notwith" standing 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. Philips and Lee's " mill will be 1250 × 2 = 2500 cubic feet of " gas per day; to produce which, 7 cwt. of " cannel-coal is required in the retort. The " price of the best Wigan cannel coal (the sort " used) is thirteen pence halfpenny per hundred " weight, (twenty-two shillings and sixpence per

" ton,) delivered at the mill, or say about eight " shillings for the 7 cwt. Multiplying by the " number of working days in the year (313), the " annual consumption of coal will be one hundred " and ten tons, and it cost one hundred and " twenty-five pounds.

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

" The 110 tons of cannel-coal, when distilled, " produced about seventy 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 ninety-three pounds.

" 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 " twelve hundred and fifty ale gallons, which not " having been yet sold, it cannot yet be deter" mined its value.

" 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 " five hundred and fifty pounds per annum, in " which some allowance is made for this ap" paratus being made upon a scale adequate to "the supply of a still greater quantity of light than he has occasion to make use of.

"Mr. Lee 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 then stands thus:—

"Cost of 110 tons of cannel-coal	£125
"Ditto of 40 tons of common do. to carbonize	20
In all	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 any thing for the tar, is therefore £ 52

"And the interest of capital sunk, and wear and tear of apparatus............ 550

"Making the total expense of the gas apparatus per annum about 600

"That of candles to give the same light would be about 2,000*l*. For each candle, consuming at the rate of four-tenths of an ounce of tallow per hour, the 2,500 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 aver-
" age of three hours per day, as in most cases,
" would, perhaps, be nearer to the truth, and the
" wear and tear remaining nearly the same as in
" the former case, the whole cost would not ex-
" ceed six hundred and fifty pounds, while that
" of the tallow would be three thousand."

We are informed that Mr. ACKERMANN, printseller, *&c.*, in the Strand, for upwards of four years lighted the whole of his establishment, together with his dwelling-house, entirely with gas for forty pounds five shillings *per annum*, by means of a small apparatus erected on his premises; and he states the annual expense of lighting the same prior to using the gas lights, to have been one hundred and sixty pounds; so that it appears the balance in favour of using the gas lights was one hundred and nineteen pounds fifteen shillings for one year. But since the line of "The chartered Gas Light and Coke Company's" main was laid along the Strand, he declined generating gas for his own use, and has been supplied therewith from the Company's works in Peter-street, Westminster.

Another gentleman, Mr. Cook, manufacturer of metal toys at Birmingham, has stated that for four-pence *per diem* he generated as much gas as afforded light equivalent to what was obtained by burning as many candles as cost him three shillings; besides a saving of thirty pounds *per annum* in candles, oil, and cotton, for soldering, which, since the adoption of gas in his premises has been performed solely by its flame. In short, that he saves annually thirty pounds out of the fifty pounds which his lights formerly cost him.

Messrs. Lloyd, of Queen-street, Southwark, thimble manufacturers and whitesmiths, have also used the gas light for soldering and other purposes, their apparatus being upon a very small scale. From their statement, it appears they gained, as a profit, upon every bushel of coals distilled, the sum of eight shillings and four-pence, if the light afforded was compared with the light of tallow candles formerly used.

The foregoing statements have been mentioned in order to shew that at a very early period of this new era in the science of procuring artificial light there were not wanting individuals who chose to adopt the process. Great numbers of similar experiments might be adduced, if needful; but, the avidity with which the gas light is now almost every where called for, renders the pressing of its superior claims to notice further on the Public altogether useless.

CHAPTER VII.

On the Retorts, and the best Mode of setting them.

THE retorts used for the distillation of pit-coal are of different shapes in different establishments; they are either circular, semicircular, elliptical, or square. There is, however, another description of retort for which a patent has been obtained, and to the manufacturer of coal-gas it is known by the term "rotary retort." I shall speak of these different kinds of retorts in order; but shall confine my observations more particularly to the circular and elliptical ones. The latter being, in my opinion, the most likely to answer the purpose of the manufacturer of gas, will be very fully dwelt upon. The former having, under my own observation, been tried through various modes of setting, I shall state such facts relative thereto as will enable the manufacturer to form a just conception of the comparative value between both, and then leave him to choose which he will adopt.

The circular retorts (for, in adverting to the shape of them, I am to be understood as speaking of that section which is vertical and parallel to the flanches at their mouths) are cylinders of abor t six feet in length and twelve inches diameter inside. These have, till recently, been set on the flue plan, and when set two to one fire, carbonization was carried on at about twenty per cent.; or, to speak in more familiar language, it required twenty chaldrons of coals to keep a sufficient number of retorts so heated as to be capable of carbonizing one hundred chaldrons in a proper manner; when the retorts were worked at eight hours' charges*, with two bushels of coals to one retort each charge.

The fire-place for heating this kind of retort was opposite to its mouth; and, under these circumstances, a retort, cast from metal of the second running, and weighing about ten hundred weight, would last from eight to ten months.

In tracing the steps towards the plan on which cylindrical retorts are now most generally set, and, comparing the advantages arising to the manufacturer by deviating from the plan of setting retorts, as already described, we should naturally suppose that any deviation therefrom would have

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* When we speak of six or eight hours' charges, it is to be understood that so many hours elapse between the time of the coal being introduced into the retort and the coke being drawn from it, during which time the lid of the mouth-piece is closed; and, consequently, the different products evolved must pass off through the hydraulic main to their different reservoirs, the base of the coal being all that should be left in the retort when the lid is removed, preparatory to drawing out the coke.

in view either the decreasing the per centage of carbonization, or the expenses attendant on the wear and tear of retorts; but it will be well if we find, after a careful investigation, that either has been effected.

The first step towards the present mode of setting retorts was by heating three with one fire; on such plan several were set in different works, and on a range of thirty I had an opportunity of making the most particular observations, from the time of their being set till entirely worn out. The fire-places were in front of the retorts, which so much increased the heat there, as to make it almost insupportable to the stokers, particularly during the summer months. One would have supposed that the suggester of such plan had forgotten that the working man possessed any feelings, otherwise he would never have thought of increasing the stoker's labour by intolerable heat; for, unless the situation of the retort-house be so confined as to prevent the fires from being made at the back, instead of the front of the retorts, as was adopted in this plan, nothing can justify it. The engineer of such establishments as these should ever bear in remembrance that it is a very material part of his duty to endeavour to lessen the weight of labour, instead of wantonly increasing it. Setting aside this inconvenience, if the expense of setting retorts three to one fire be inquired into, it will be found that it would cost as much to set any number on that plan as would set a like number two to a fire. The carbonization, instead of being carried on at a lower per centage, would be increased. The retorts on which I made my observations did not heat uniformly. When the extreme end of them was almost at a white heat, that part which was within eighteen inches of the mouth-piece, remained quite black. The coal was not well carbonized—consequently, the proportion of gas to a chaldron was diminished; and, to sum up the evils resulting from this mode of setting, the retorts were burnt out in about two-thirds of the time they had lasted when set two to one fire. When all these things are considered, we shall not be surprised to see this plan fall to the ground—for, from it, expenses and inconveniencies were increased, whilst there was a less return of products of all descriptions for meeting either.

Retorts set three to one fire having, by experiment on a large scale, been proved to answer no desirable end, the next alteration in the mode of setting was that of heating four by one fire. On this plan a hundred retorts were put up at one of the establishments in London—these it was found impossible to heat; for one part of the retort would have actually melted before the other had arisen even to a dull red. A failure in one quarter in no wise disheartened others from attempting to get over the difficulty. A second setting of retorts, in which four were to be heated by one fire, succeeded better than the first, for the retorts heated very regularly—but carbonization was not carried on at so low a per centage as when only two were heated by one fire; it was considerably increased, and, what was still worse, the retorts were sooner burnt out. The carbonization increased daily in its expenses, till at last it rose as high as fifty per cent. This was owing principally to working fewer retorts than the fires necessary to be kept up would have heated, had the retorts placed over each fire in action remained in a working state: for it very frequently happened, when seventy or eighty retorts were working, as many fires were kept lighted as actually heated a hundred, and for the following reason:—The action of the fire not being uniformly directed towards each retort in the series of four, one of them became ineffective; when such was the case, only three out of the four could, of course, be used; soon afterwards a second failed, and then but two remained in use, and so on:—indeed, it was no uncommon circumstance to work but two retorts by that fire which actually heated four, owing to two of them being burnt out. When retorts were set four to one fire, it happened that they were frequently worked under the above disadvantage more from necessity than choice; for, whenever it became necessary to remove defective ones over one fire, it followed that the adjoining fires could not be kept lighted: for if they remained so, the bricklayers could not perform their work—consequently, when it was required to replace a series of four, the use of twelve retorts was lost to the manufacturer till such time as the defective ones over the fire-place undergoing repair were again ready to be brought into action. The pulling down of the defective retorts, and the replacing of them so as to be again ready for charging, in one series, was seldom accomplished in less than a week; therefore, when the manufacturer was unable, from the quantity of gas he had to supply, to dispense with the use of so many retorts, he was compelled to work them under every disadvantage.

As the expense of resetting one retort, when put up in a series of four, for labour and new materials, exclusive of the retort itself, amounted to about eight pounds, or at the rate of thirty-two pounds for each series, it became a *desideratum* to be able to replace a burnt-out retort without pulling down the brick-work, and allowing the retorts next adjoining to remain inactive: actuated by a zeal for promoting the interest of the manufacturer, my attention was turned to the subject; and, after very maturely considering the matter, I hit upon a plan which would enable the operator to remove a defective retort in a few hours, without any expense save that incurred for labour, and a few shillings for bolts and cement to make good the connexions to the pipes leading from the retort to the hydraulic main. Of this plan I shall, in its proper place, give a particular description—suffice it to say here, that at the time I am now writing (March 1819), it has never been applied to any retorts save elliptical ones, where it was most fully proved to answer the end in view. It is, however, equally applicable to every description of retort, whether cylindrical, semicircular, or square.

When retorts were set four to one fire, the top ones invariably failed first, and this led to a supposition that if the top ones were guarded by tiles from the action of the fire in the same way that the lower retorts were guarded, they would be more likely to remain a longer time effective. Retorts were accordingly so set, and whilst the fire-places were continued at that side which was opposite to the side for charging and drawing, they did last considerably longer, but then they were by no means so effective as on the former plan. They fell out of all shape, and consequently were not capable of carbonizing such quantity of coals as would be advantageous to the manufacturer of coal gas. A deviation from this mode was made by placing the fires in front of the retorts, but it failed entirely. The bottom retorts were soon destroyed—the action of the flame playing on the ends of them so forcibly as literally to reduce them into a state of fusion, when the fire was such as to keep the principal part of the retort at a bright red heat.

Although retorts of various shapes had been tried at different establishments, we find no account of any having been set, save on the flue plan, that is, by the fire acting under the retort, and then returning over it on its way to the main flue, till the spring of 1817, when Mr. A. Rackhouse adopted a plan for heating retorts of cylindrical shape set in ovens. This plan has since been known to the manufacturer by the name of the "oven-plan." His first experiment was made at one of the gas-light establishments in London, by heating one retort in an oven. It was reported to heat very uniformly and at little expense. At the same establishment he next set two in one oven, then three, and afterwards five. And it is but proper to observe that cylindrical retorts set in fives on the oven-plan is now by far the most general mode adopted at the different gas-light establishments. Of the cylindrical retorts set in ovens, under the immediate superintendence of Mr. Rackhouse, I have only had an opportunity of making my observations upon twenty; those I consider to have been set without that judgment which was requisite. They were set in four ovens, each oven being heated by three fires; therefore, it followed when all the retorts were serviceable, it required twelve fires to heat twenty retorts. By adopting the oven plan, we shall hardly find that there are any advantages gained; but contrariwise the retorts, instead of lasting longer, were two-thirds of them burnt out in less than two months, owing to the lower ones being placed immediately over the fire, from the action of which nothing was placed to guard them. Their form precluded every hope of carbonization being accomplished in less time than by others of a cylindrical shape; and as to the per centage at which carbonization was carried on, what could be expected, when, after the retorts had been in action about six weeks, it was necessary to keep up twelve fires to enable the stokers to work as many retorts? The twenty retorts set on the oven plan, of which I have just been speaking, were erected about Christmas, 1817, since which time I have had opportunities of making very extensive observations upon retorts set on that plan; but the results arising from them are not such as would induce me to set cylindrical retorts at any manufactory of coal gas of which I might have the management on that plan. I am here to remark, that although Mr. Rackhouse appears to have been the first person who did actually set retorts in ovens, yet to Mr. John Malam, engineer, in the employment of the chartered Gas-Light Company, at their works in Peter-street, Westminster, very great credit is due, for having submitted to the Directory of that Company, without any knowledge of what Mr. Rackhouse's plan was, one of his own for heating retorts in ovens, but which in point of advantages very much exceeds the former. Various have been the alterations made by different workmen in the fire-work to the retorts since the oven plan was adopted, but hitherto most have failed in remedying the very serious evils which must arise from their rapid destruction. Heretofore a retort of the same shape and dimensions, when constantly used night and day, lasted from eight to ten months; but, on the oven plan, the retort seldom remains in a working state more than as many weeks. Indeed, so great has been the desire of making this plan answer, that it has been tried almost under every bearing; and whilst some attempts have promised to answer, others from which much had been expected have failed so far as to cause the retort to be entirely destroyed in three or four days. By referring to what has been already said on the subject of circular or cylindrical retorts, we shall observe that but little improvement has been made in the mode of setting them. The plans recently adopted have only led to a more rapid destruction of the retort, and consequently to increased expenses; whilst from its shape the manufacturer cannot expect from its use by one mode of setting more than another to obtain a greater proportion of gas from a given quantity of coal, and that in a shorter time. Whenever coal may be submitted to distillation in masses of twelve inches diameter, the operation will be very tedious, and equally imperfect; the action of the red-hot retort upon the outer surface of the coal will soon decompose it, and therefore the gas in the first part of the process will pass over very rapidly—but then it acts against the process in the interior part of the cylinder formed by the coal in the inside of the retort; for as the outer surface of the coal is formed into coke, it becomes a coating to that which is within it, and through which the gas must pass ere it can extricate itself from the retort. Whenever such is the case, carbonization cannot be carried on to advantage, nor will it ever answer the most desirable end. The great object which the manufacturer should ever keep in view, is by exposing coal to the action of heat in thin strata, to obtain the greatest quantity of gas in the least time, and at the least expense, but such can never be effected by retorts like these I have already spoken of.

Having thus glanced cursorily at the various modes which have been adopted for setting cylindrical retorts, it may not be improper to notice the rotary retorts of Mr. Clegg's invention. In doing so, we are to observe that Mr. Maiben, of Perth, invented a retort for distilling coal by exposing it to the action of heat in thin strata. From his experience he learnt that the gas evolved during the first part of the process of carbonization was of too aqueous a quality to be fit for combustion, and that evolved during the latter part thereof was so strongly impregnated with sulphur as to be highly objectionable. To remedy those evils, he considered that if the coal was spread in thin layers in the retort, the action of the heat thereupon would be more instantaneous; consequently, the bad gas, evolved in the beginning and towards the end of the process, might, by means of a valve, be prevented from entering into the gas-holder. The retorts he made use of were of a square shape, and of a size sufficient to carbonize twenty-five pounds of coal, when spread in a layer of about two inches deep. The coal was introduced into the retort by means of a sheet-iron box, which was charged and slided in whenever the gas was extracted from the former charge, which, under such management, was generally accomplished in two hours. But this description of retort being much too small to be serviceable in large establishments, led Mr. Clegg to construct a retort of sufficient capacity for carbonizing about one chaldron of coals *per diem*. For this retort he took out a patent, in December, 1816; and, in the *Repertory of Arts*, for that month, No. 175, and for January, 1817, No. 176, a particular description is to be found. The first of them which was ever put up (being eight feet six inches in diameter), as were also the second and third (each of twelve feet six inches diameter), were worked under my observation. Each of these retorts contained fifteen boxes which slided into the retort, upon iron arms, as described in the specification just alluded to. Whilst the arms could be kept up, they were worked without much difficulty. The coal remained in the retort six hours, but was only one-third of that time exposed to the action of a red heat. Five boxes, having passed that, waited for the coal in the five boxes over the red heat being decomposed, which, on being done, the retort was opened, and those five boxes which had passed the red heat, were drawn, and fresh ones introduced upon the arms they had occupied, which process brought the five from the red heat to the situation they had occupied, to wait there till the coal in the next five was decomposed, when the operation of change was again repeated; so that there were continually five boxes lately introduced into the retort, waiting to be brought over the red heat, five over the red heat, and five others ready for being withdrawn from the retort. Had not the expense of erecting retorts of this description been very considerable, and the wear and tear enormous, they would doubtless have been adopted in that establishment where they were first tried; but both were so much against them that every idea of using them was there entirely relinquished. It is but justice to state, that those retorts produced gas at the rate of upwards of fifteen thousand cubic feet per chaldron (twenty-seven hundred weight) of coals; that carbonization was carried on at about sixteen or eighteen per cent.; that the increase of coke on coal, carbonized, was at the rate of fifty per cent.; and, that the process of carbonizing, under those circumstances, was accomplished in about six hours. During the time these retorts were in action, I had an opportunity of observing that the statement of Mr. Maiben, which appeared so reasonable, was verified in practice, even on a large scale; and from thence learnt that the more rapidly the decomposition of coal is effected, exactly in the same ratio we are to expect an increase in the quantity of gas generated from a given quantity of coal: for, when cylindrical retorts, charged with Bewicke and Craster's Wallsend coals, were worked at a low temperature; and, at six hours' charges, were producing but about eight thousand or nine thousand cubic feet of gas, per chaldron, the rotary retorts were producing from fifteen thousand to sixteen thousand cubic feet of gas from the same quantity of coal; three-fourths of which was evolved in one-third of that time.

The distillation of coal when exposed in thin strata to the action of the fire, having been proved, by very extensive experience, to be the most beneficial to the manufacturer, as far as relates to the products obtained; therefore, if the expenses of setting retorts proper for such process, and keeping them in repair, could be accomplished at any thing near the sum requisite for working those of cylindrical form, it would but be natural to expect to see the mode adopted: but, as retorts for that purpose, of the dimensions mentioned by Mr. Maiben, were much too small for extensive manufactories, and the rotary one so very expensive, it was not probable that either would be brought into general use. To overcome the difficulties arising from the use of retorts, such as I have just mentioned, Mr. Malam (of whom I have before had occasion to speak) proposed that elliptical retorts should be adopted, their length being about six feet six inches, their transverse diameter twenty inches, and their conjugate diameter ten inches. From retorts of such shape there was every probability that the results, as far as related to the quantity of gas and coke obtained from a chaldron of coals, would be very similar to those from the rotary retort; whilst the expense of setting them was but little more than would have been incurred by setting an equal number of cylindrical retorts, and not near so much as it would require to set such number as would carbonize equal quantities of coals in equal times. The elliptical retorts had, however, one great advantage over the cylindrical ones,—they were worked off in half the time; and five of them in action, worked with one bushel and a half of coals to each, during a four hours' charge would produce as much gas in a day as ten cylindrical retorts worked at eight hours' charges with two bushels to each retort every charge. The elliptical retorts on which my observations were made, were set in an oven and heated by one fire. They heated remarkably regular, and I can have no hesitation in declaring it to be my belief that these retorts would have lasted ten or twelve months had they been constantly used during such period; for, after being ninety-four days in action, and constantly at a bright red heat, it became necessary to remove them to make room for part of a new building. They were then taken down, but so little injured by the fire that two out of the five were but barely discoloured, and the remaining three not fallen out of shape. At the very time that these retorts were in action, cylindrical retorts, set on the oven plan, were almost always entirely burnt out in less than two months.

Having spoken rather at length upon the cylindrical, rotary, and elliptical retorts, I shall make a few observations upon the semicircular and square ones; and, having done so, describe the different modes of setting retorts, as exhibited in Plates 2, 3, and 4. I shall afterwards give a table exhibiting at one view the advantages and disadvantages arising to the manufacturer from the use of each kind of retort, and with that conclude this Chapter. The semicircular retort, from its form, is likely to answer the manufacturer's purpose, if set with judgment, next to the rotary and elliptical ones; that is, as far as the generation of gas and the production of coke are concerned; but, from its shape, its durability cannot be expected to be equal to the latter. The action of the fire upon the lower edges will very soon destroy it; for, it must be obvious, to any one at all acquainted with fire-work, how very powerfully the flame strikes upon any angular points. This, in the elliptical retort, is, of course, done away with, whilst the advantage arising from its shape is retained.

The square, or parallelopipedal, retort, is twenty inches in breadth, thirteen inches high, and six feet long, inside. It has a rib cast along the middle, on the inside of that part which is, when set, the bottom. This rib rises to the height of three inches, but does not approach nearer to the mouth-piece than about eighteen inches. It is for the purpose of strengthening the bottom of the retort, and preventing it from falling out of shape; but, when we consider the mode in which square retorts are set, it will not appear to be necessary. These retorts, when set six in one bed, and that number heated by one fire, are placed close alongside each other. The fire-place, being at one end of the range, is so contrived as to admit of the flue being carried under the whole range towards their mouths; it is then brought over the top of them, and again under and over in the like way, previous to its being allowed to enter into the main flue. Under this arrangement, square retorts, weighing about thirteen hundred weight, being set and worked at six hours' charges, with one bushel and half of coals to each as one charge, at such a heat as causes ten thousand cubic feet of gas to be generated from a chaldron of Bewicke and Craster's Wallsend coal (twenty-seven hundred weight), are found to remain serviceable one year. The carbonization is, when they are once brought to a working state, carried on at about twenty-five per cent.; but they require to be fired for a fortnight or three weeks before they are at a proper temperature for carrying on that process.

The retorts themselves do not fall out of shape more than cylindrical ones; indeed, from several which I examined that had been in constant action from ten to twelve months, I could not observe that any of the sides had fallen in, and the tops of them appeared very little injured.

The disadvantages which attend the use of those retorts are, first, that they are more expensive in the first instance than cylindrical ones: secondly, the length of flue passing under and over them being extensive, and of but small dimensions, it frequently becomes choked up, and requires, for clearing it out, various openings. When, therefore, it is found necessary to examine those flues, it generally happens that the heat of the retorts is very considerably decreased; and when we consider the time requisite for heating them in the first instance, we must be aware that such a diminution cannot be overcome but by a considerable expense of fuel, and carrying on the process very unfavourably and imperfectly. Lastly, when the retort is burnt out, the cost of replacing it is nearly equal to the first cost of setting; whilst in using cylindrical ones, a retort is generally replaced for about three-fifths of its first cost.

I am here to notice, that, on the 5th of August, 1817, a patent was obtained by Mr. John Perks, now in the employment of "the City of London Gas Light and Coke Company," for arrangements of gas apparatus, of which I shall speak under their proper heads. Since commencing to write this Chapter, I have been favoured by the patentee with a sight of the various drawings described in his specification; and, amongst the rest, with the different sections of his mode of setting retorts. His arrangement is such as to cause thirteen retorts, each capable of carbonizing a bushel and a half of coals in six hours, to be heated by one fire.

The retorts are so placed, that, when the observer stands in front of them, twelve of the number form a circle round the thirteenth, which is cylindrical, the centre thereof occupying the position of the common centre of the surrounding ones. The shape of these retorts will be best understood by supposing two circles struck from the centre of the mouth-piece of the thirteenth retort; the inner one forming one side of the series of twelve, and the outer one the other. If, then, either of these circles be divided into twelve equal parts, and lines drawn from the inner to the outer circle, radiating from their common centre, the transverse vertical section of them will be exhibited. It is evident, that, under this arrangement they form a complete circle of large diameter. The mouth-pieces are formed like those which are used with the square retorts (as described *Plate* 2*d*, *Fig.* 5), and, of course, the conducting pipes and H pipes leading to the hydraulic main, are nearly similar to those used for either cylindrical or square retorts. The fire-place is in front of these retorts, and as they are all enclosed in a circle of brick-work, which is divided into four equal parts by fire lumps laid horizontally, and so brought out of the circle as to be in contact with the adjoining retort; and that part which is between the central retort and the others, being divided in a similar way, the action of the fire is under three, and then, turning over their ends, it comes over them towards their mouths, where it finds an opening leading above the next three; and, passing their ends downwards, it is brought towards the mouths a second time, and so on in like manner, till it has traversed round the whole series, when it passes into the main flue.

Wherever the manufacturer may be led to prefer the mode of carrying on the distillatory process by submitting his coal thereto in masses, before that of exposing it in thin strata, I should apprehend that the retorts of which I am now speaking would be found to answer his purpose better than either the cylindrical or square ones.

There can be little doubt but carbonization would by them be carried on at less expense, and the deterioration of the retorts themselves decreased in a similar ratio. For, if we consider the dimensions of the circle by them formed, and the uniformity with which the flame acts through the flues, we must set it down, as consonant to reason, that their durability will be equal to, or greater than, cylindrical ones, when set on the flue plan and two are heated by one fire.

Perhaps I may be considered premature in thus giving an opinion on retorts which have not yet been tried. In doing so, I most unquestionably deviate from the track pursued by some writers, who seem fearful to hazard theirs, and averse to speaking of any thing till experience has stamped its merit: but it would appear that he who follows such a line of reasoning must be a very child in science. We know that like causes produce similar effects; and if we reason from causes, the deductions drawn will not only be philosophical but true. In speaking thus I would have the reader to understand that I am not actuated by any self-interested motives; but, having in the introduction to this work pledged myself to speak candidly of the inventions of ingenious men, I take this opportunity of doing so.

PLATE II.

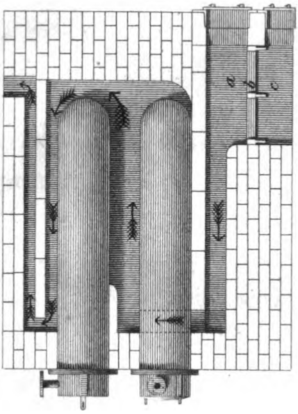


Fig. 3.

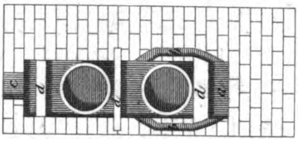


Fig. 2.

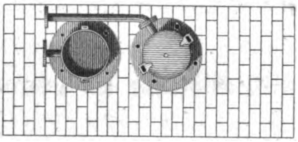


Fig. 1.

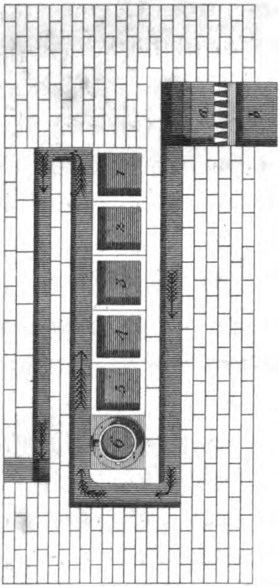


Fig. 4.

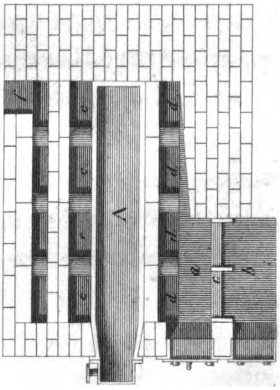


Fig. 5.

William Alexander sculp.

Description of the Method of setting two cylindrical Retorts on the Flue plan, so as to be heated by one Fire, as exhibited in Plate II, *Figures*, 1, 2, *and* 3.

Figure 1 represents a front view of two retorts set to one fire on the flue plan. In it the manner in which the conducting pipes are connected to the retorts is exhibited: these lead to the hydraulic main in a similar way to what is shewn in *Figures* 1 and 3, Plate III.

Figure 2 is a vertical section of the same retorts, supposed to be drawn about midway of their lengths. In this section *a* represents the end of that part of the flue leading from the fire under the lower retort which rises near the mouth-piece thereof through the openings *b b*, and, passing between the two retorts, rises over the end of the upper one; and, being brought over the top of it, by means of an opening *c*, about nine inches from the mouth-piece, enters the upper flue and thence passes into the main one. *d d d* are end sections of the fire-tiles; on the two lower lines of them the retorts are supported, and the upper one forms the base of the top flue.

Figure 3 exhibits a longitudinal section of these retorts. In it, *a* is the fire-place, *b* a section of the fire-bars, and *c* the ash-pit. The direction taken by the flue is pointed out by small arrows.

Description of the Method of setting six parallelopipedal Retorts, so as to be heated by one Fire, as exhibited in Plate II, *Figures* 4 *and* 5.

Figure 4 represents a transverse section of parallelopipedal retorts, in which six are heated by one fire. These retorts are twelve inches square inside, and six feet in length. The fire-place *a* with the ash-pit *b* is placed at one end of the series, but so as when the observer stands in front of the retorts he shall be in front of the fire-place also. Under this arrangement, the retorts 1 and 6 heat the best and 5 the worst. If the reader compares the situation of the flues, as exhibited in *Figure* 5 of this Plate, he will observe that there are four which communicate with the fire-place. These are divided by lumps laid edgewise across the whole series of retorts, forming the flues marked *d d d d, Figure* 5. This range of flues is covered by fire-tiles, and upon them the retorts are placed close alongside of each other. Over the top of the retort is a range of flues *e e e e,* which corresponds with the lower ones, and these are covered with fire-tiles and a course of fire-bricks. Upon the latter is a third series of flues of about two-thirds the depth of the former ones, and these rise by the opening *f, Figure* 5, into the main flue. In *Figure* 4 the transverse direction of the flues is shewn by the arrows leading from the fire-place.

The mouth-pieces of these retorts are circular, as shewn upon retort 6.

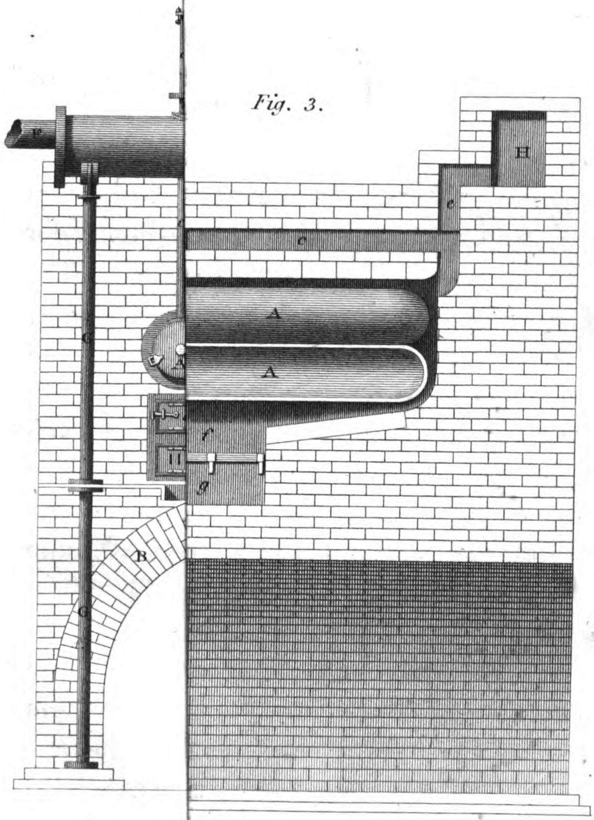
Figure 5 represents a longitudinal section of these retorts, in which the flues and action of the fire have already been described. A is the retort, *a* the fire-place, *b* the ash-pit, and *c* the fire-bars.

Description of the Method of setting five cylindrical Retorts in one Oven heated by three Fires, with Sections of the hydraulic Main and Dip-Pipes, as exhibited in Plate III, *Figures* 1, 2, *and* 3.

Figure 1 represents a front view of the retorts AAAAA, as set and in a finished state. In it the two upper retorts are shewn without the lids of their respective mouth-pieces: the two outer lower ones with the lids on, but without their being secured by the cross-piece shewn upon the middle one. The bed of these retorts is supported by an arch of brick-work marked BB. It is brought so far forward as to allow room enough for the stokers to charge and draw the retorts, and for a sufficient quantity of coals to be kept for supplying two or three charges, with fuel for present use, luting, tools, *&c.* Immediately in front of the retorts is introduced, instead of part of the key-stone for the arch, a cast-iron frame of about three feet and a half long and two feet broad at the top, with an iron door fitted to it. The bottom of the frame is struck to the radius of the arch, and of course the sides taper inwards in proportion to that radius. The situation of the opening is expressed at C. This opening is for the purpose of allowing the red-hot coke when drawn from the retort to fall into the archway at D. *aaa*, the doors of the fire-places, *bbb* the doors of the ash-pits. These doors are furnished with three perpendicular slits of about two-thirds their length and five-eighths of an inch in diameter for allowing a current of air to pass to the fires. The dimensions of these slits can be decreased by another piece, made with openings to correspond, which slides horizontally in grooves in a line with them, so as to regulate the admission of air to such a degree as the operator may desire. *ccccc* are the conducting pipes which convey the gas as it is evolved from the retorts towards the hydraulic main. *ddddd* front sections of the H pipes. *eeeee*, front sections of the dip-pipes, with the saddles through which they are bolted to the hydraulic main. E the hydraulic main, F the main pipe for conveying the gaseous and other products evolved towards their respective reservoirs, GGGG cast-iron columns fitted with crutches at the tops of the upper ones for supporting the hydraulic main.

Figure 2 is a section of the same retorts,

Fig. 3.



William Alexander sculp.

which supposes them to be cut through from the top to the bottom about the middle. In this section the hydraulic main, dip, and conducting pipes, are not shewn. AAAAA the retorts. *aaaaaa,* such part of the arch forming the oven and brick-work contiguous to the fire-places, all of which require to be constructed of Welch fire and arch bricks. The crown of the oven is flattened by means of Welch fire-tiles as at *b*. At the extreme end of the oven are two openings, which lead into the two small flues *cc*. These flues pass above the top of the oven towards the front of the retort, and then each turns towards the centre flue *d*, which having entered, that one leads towards the main flue H, which it enters through the opening *e*. *fff* are the fire-places, and *ggg* the ash-pits. *hhh* are fire-lumps placed beneath the lowermost retorts for protecting them from the action of the fire. The two upper retorts are supported near their middle by wrought-iron belts, which are brought through the upper part of the oven, and passing through a cast-iron bearing bar placed above it, are secured, by means of nuts, in the situation wanted.

When the oven-plan was first introduced, the retorts were supported by cast-iron props bedded in the brick-work, crutch-shaped at the top, and rising to a proper height to receive them. They are not now used, and therefore not shewn in the plate.

Figure 3 is a longitudinal section of cylindrical retorts set on the oven plan. AA are the retorts, the mouth-piece of the lower one being secured by the lid and cross-piece; the upper one is shewn without the lid. *f* is the fire-place, with the position of the grate-bars. *g* is the ash-pit. The action of the fire is the same in this section as has already been described by *Figure* 2: the flame having exerted its force in the oven, rises by the opening shewn at the extreme end of the retorts, and passes along the flue towards their mouths till it comes to *d*, when it enters the middle flue lying parallel to the flue *c* ; that leads into the rising part *e*, and thence into the main flue H. *h* is the conducting-pipe which conveys the gaseous and other products from the retorts to the H pipe *i*, and that carries them into the dip-pipe *k*, which enters into the hydraulic main E. In this section of the hydraulic main, the fluid by which the dip-pipe is sealed is shewn as at *l*, through which the gas bubbles up as it is evolved, and passes along the upper part of the hydraulic main towards the main pipe F (as shewn in *Figure* 1) on its way to the condenser. The hydraulic main is supported in this section in a similar way to what was shewn in *Figure* 1'; but instead of a brick arch for supporting the floor in front, *m* is one of a range of beams for supporting a cast-iron floor. *n* is the opening for allowing the coke when drawn from the retorts to fall on the floor *o*. This opening is covered by an iron door, which is closed at all times save when the retorts are drawing.

Description of Mr. John Malam's Method of setting Five of his Elliptical Retorts in one Oven heated by three Fires, with Sections of the Hydraulic Main and Dip-Pipes as exhibited in Plate IV, *Figs.* 1, 2, *and* 3.

Figure 1 represents a front view of the retorts, as set and in a finished state. The arrangement of the retorts, hydraulic main, dip and H pipes, being nearly similar to that described in Plate III, a repetition of description is not necessary here: we shall, therefore, only describe such parts as differ from the former mode of setting. In front of these retorts is a cast-iron plate AAAA, against which the flanch of the retort rests. At each corner of this plate is a hole for receiving a bolt. This passes through the brick-work to the back of the retorts, which is supported by a plate of similar dimensions to that in front, cast with openings opposite the end of each of the retorts. These openings are secured by plugs, which are removed when it is requisite to replace a retort that may be worn out. In it are also openings for the sights. The bolts stated to pass through the front plate pass through this also, and both are secured together by screwing up their respective nuts. Under this arrangement, and by a contrivance described hereafter, when speaking of *Figures* 3 and 4, *Plate* VII, it is not necessary to disturb any of the brick-work, when, from a retort becoming ineffective, it requires replacing. The fires for heating these retorts are placed at their back.

Figure 2. Is a section of the same retorts which supposes them to be cut through from the top to the bottom about the middle. *aa* are fire-lumps placed edgewise so as to divide the distance between the exterior lumps *bb* into three equal parts corresponding with the fire-places. *ccc* are the ends of the arches over the respective fire-places as they meet the dividing lumps *aa*. *ddd* are three fire-tiles resting upon the lumps *b aa b*; these tiles form a bridge from one side of the oven to the other. *ee f ee* is a section of the oven, the rising part on each side marked *ee* being constructed of Stourbridge arch bricks, and the flattened part *f* of Welch lumps or fire-tiles. *gg* are sections of the two horizontal flues which rise near the mouth of the retort, and pass towards the main flue.

Figure 3. Is a longitudinal section of elliptical retorts set on Mr. Malam's plan. AA are the retorts. *b* is the fire-place. *c* is a section of the grate bar. The lower edge of this bar is chamferred off and of a circular form. It is of sufficient depth to allow the action of the cool air through the ash-pit to have full effect upon it, thus preventing the very rapid destruction which generally attends cast-iron grate bars. *f* is the ash-pit. *a* is a section of the lump for dividing the flames from the different fire-places. *d* is a section of the tiles which form the bridge. The flame acting under the arch *c*, as expressed in this and the former figure, passes between the dividing lumps under the range of tiles *d*, and there divides itself in the direction of the two arrows, by this means causing the heat to act uniformly in the oven. The opening flue is expressed at *g*—it passes along *h*, and rises at *i*, preparatory to entering the main flue. These retorts are cast with a cylindrical projecting end, which is received into the brick-work: they are also supported by cast-iron props (bedded in the brick-work beneath them) crutch-shaped at the top. The section of the hydraulic main, dip, and H pipe, as also of the floor, is the same as shewn in the longitudinal section of cylindrical retorts set on the oven plan, to the description of which our readers are referred.

As from the smallness of the scale on which these sections are drawn, it would be difficult to explain the mode adopted by me for removing a defective retort, I have, therefore, in *Plate* VII, exhibited it on a larger one, which is here described.

Figure 3. Is a transverse section of the couplings which surround the retort when it is set. The face of the couplings is brought close up to the flanch of the retort.

Figure 4. *aa* is a longitudinal section of the couplings, they are wedge-shaped. A is a section of part of the retort. *bb* the iron plate in front of the oven, cast with flanches verging inwards so as to fit to the couplings when brought to their places by the flanch of the retort coming close to the plate. *cc* part of the brick-work in front of the oven, so angled off as to allow the heat to approach as near the mouth-piece as the couplings will permit.

When this plan is adopted, it is evident that, by introducing the couplings nearly to their places, and bedding them in cement, the bringing of the retort to its situation in the oven will force them up, and form a complete joint round it. On the contrary, when a retort becomes defective by displacing the plug opposite to the end, and bringing a purchase upon that end by means of an iron bar, (the joint between the mouth-piece and gas conducting pipe being first broken) it will be forced out of the situation it had occupied and loosen the couplings. When the retort has been moved about a foot, they may be taken away, thus leaving sufficient room for the retort to pass: it may be drawn out by a purchase made fast to an eye-bolt in the wall opposite thereto, and a new one introduced into its place, the whole operation being performed in two or three hours.

A TABLE, exhibiting at one View the Advantages and Disadvantages which arise to the Manufacturer from the Use of different Kinds of Retorts variously worked.

Reference to Description of Retort.	Durability in Days.	Usual Charge in Bushels of 84 lbs. each.	Time allowed for working off one Charge.	Gas produced from one chaldron, the retort being worked at a bright red heat.	Per Centage at which Carbonization is carried on.	References to the Mode of setting the Retorts.
				Cubic Feet.		
A	270	2	8	10,000	20	*a*
A	180	1½	6	9.000	30	*a*
A	180	1¼	4	8,500	30	*a*
A	180	2	8	9,000	25	*b*
A	120	1½	6	8,500	33	*b*
A	120	1¼	4	8,500	35	*b*
A	180	2	8	10,000	25 to 50	*c*
A	120	1½	6	9,000	do.	*c*
A	120	1¼	4	8.500	do.	*c*
B	63	2	8	10,000	16 to 40	*d*
B	42	1¼	5	9,500	do.	*d*
C	270	1½	4	15,000	30	*e*
D	300	1½	6	10,000	25	*f*

In the first column of the foregoing table from A is to be understood that the results expressed in a line with that letter arise from the use of cylindrical retorts of the dimensions, *&c.*, as hereafter mentioned, that is to say,

Dimensions.—6½ feet long; 1 foot diameter inside.

Weight, cwt. 10 : 2 : 0

Price, per ton, £12.

First cost of setting, including retorts, brick-work, labour, hydraulic main, and connexions, with coke hearth, complete £23

Cost of replacing one that may be worn out 15

Those marked B in the first column are of the same dimensions, price, and weight.

Those marked C are elliptical and of the following dimensions, *&c.*:

Length 6½ feet.

Transverse diameter inside, 20 inches.

Conjugate diameter inside, 10 inches.

Weight, cwt. 13 : 2 : 0

Price, per ton, £13

First cost of setting, including retorts, brick-work, labour, hydraulic main, and connexions, with coke hearth, complete £25

Cost of re-setting, when the oven in which they are placed requires to be rebuilt 18

Those marked D are parallelopipedal shaped, and of the following dimensions, *&c.*:

Length, 6 feet.

Breadth inside, 20 inches.
Depth inside, 13 inches.
Weight, cwt. 13.
Price, per ton, £12.

First cost of setting, including retorts, brick-work, labour, hydraulic main, and connexions, with coke hearth, complete	£21
Cost of re-setting	18

The letter *a* in the last column of the Table implies that the results opposite thereto are from retorts set on the flue plan, two being heated by one fire at the back of the retorts.

The letter *b* in the same column,—retorts set on the flue plan, three being heated by one fire in front of them.

The letter *c*,—retorts set on the flue plan and four being heated by one fire at the side opposite to their mouths.

The letter *d*;—retorts set on the oven plan, five being heated by three fires immediately beneath the front of them.

The letter *e* implies that the retorts are elliptical and set on Mr. Malam's plan, five being heated by three fires at the back of them.

The letter *f* relates to parallelopipedal retorts, twelve being set in one bed and heated by two fires; the flues passing under and over six retorts from each fire.

When cylindrical retorts are set two to one fire, so as to produce, when worked at a bright red heat in the proportion of 10,000 cubic feet of gas to a chaldron, if the temperature be decreased they will not produce much more than 8,000 cubic feet to the chaldron; but their durability will be extended to twelve months; and such decrease of temperature under any of the arrangements exhibited in the foregoing Table, when working cylindrical retorts, will cause a proportionate decrease in the quantity of gas generated, and an increased durability to the distillatory vessel.

Whilst cylindrical retorts, worked at a low temperature, are producing but 8,000 cubic feet of gas from a chaldron of coals in eight hours, the rotary retorts would in six hours produce from 15 to 16,000 cubic feet of gas from the same quantity of coal; and the elliptical retort from 14 to 15,000 in four hours.

When cylindrical retorts are set on the flue plan, and four heated by one fire at the back, should they be fitted with my apparatus for removing a defective one, they would always work eight hours' charges of two bushels to each retort at 25 per cent., producing 10,000 cubic feet of gas to the chaldron; and, when worn out, might be replaced for about seven pounds each.

CHAPTER VIII.

On Carbonization, as far as relates to the most beneficial Time for working the Retorts, and the per centage at which it may be carried on.

AS on the pursuing a proper mode of carbonizing, the very existence of any gas-light establishment very materially depends; therefore, the pointing out such errors as may have crept into the system, and giving plans likely to answer the manufacturer's purpose, are subjects of considerable importance. In almost every establishment for the manufacture of coal gas, experience has pointed out, to those who had the direction of it, the necessity there was for every attention being paid to the subject; and so numerous have been the experiments made for the purpose of decreasing the expenses which arise from the destruction of the retorts; for carrying on the process of carbonization at a low per centage; and for obtaining the greatest quantity of gas in the least possible time, and of the best quality; that it is really astonishing greater improvements have not arisen out of them.

As the different shapes of the retorts, with the general results arising from the use of each, have been spoken of in the preceding Chapter, I shall now confine my inquiries more particularly to the most beneficial time for working the retorts, and the per centage at which, in every well-organized establishment, carbonization ought to be carried on.

In the early period of this new mode of obtaining light, it was not at all uncommon to hear of attempts to decompose coal in such prodigious masses as would require more than twenty-four hours to work off one charge. When such was the case, more coal was used for heating the retort than the quantity it contained, from which gas was to be extracted. Retorts of as much as twenty inches in diameter have been heard of, and the time alluded to is when such were used.

When these were filled with coal, and submitted to the distillatory process, every one must be aware that a considerable time would elapse before the coal became heated through; and, as the outer surface would first become so, it would, after being decomposed, become so close a coating to the more central part of the coal in the retort as to render the passage of the gas from that part very difficult: and it would follow, that, although the quantity of gas evolved during the first two or three hours of the process might be very considerable, it would hourly decrease, and so much so, that, during a very considerable time of the latter part of the process, there would not be so much gas procured as would repay the manufacturer for the coals necessarily used for keeping his retort at a working heat. A system like this could not be expected to continue for any length of time: its errors were too palpable to remain unnoticed. When it was practised, such as were conversant in the science considered that if they could once reduce the expense of carbonizing to less than fifty per cent. on the coals carbonized, further improvement could hardly be expected. A very few years' practice has proved how little was then known of the subject; for, instead of carbonization being carried on at 50 per cent., it has actually been reduced to as low as 16 per cent., when working retorts on a very extensive scale. This reduction was not, however, all at once, nor was it altogether effected without increasing the expenses in the wear and tear of retorts, or, otherwise, by a loss in quantity of gas procured from a chaldron of coals. The retorts have been reduced from the diameter just mentioned to about twelve inches, and such are the most in use: but, even with these, it has been no uncommon circumstance to work at an enormous per centage, as I have before had occasion to mention, when speaking of the different modes of setting them.

It became a question with some, whether the manufacturer would not increase his profits by working his retorts at a lower temperature than was necessary to obtain at the rate of about 10,000 cubic feet of gas from a chaldron of Bewicke and Crastor's Wallsend coal, the length of time necessary for the process being accomplished being eight hours; each retort being charged with two bushels of coal, and the heat worked at that of a bright red by day-light. To ascertain the fact, numerous experiments were made at different establishments, and with retorts of different shapes; the results of all which tended to prove decidedly in favour of eight hours' charges in all places where, as in London, the price of coal is high. Where coals were very cheap, working the retorts at a low temperature, might answer; but, generally speaking, such mode ought to be avoided. When it is considered that by working the retort at a low temperature, not more than about eight thousand cubic feet of gas can be expected from a chaldron of the same coal, which, if decomposed at the higher temperature produces ten thousand, there evidently arises a loss upon each chaldron, in the production of gas only, of two thousand cubic feet, which, in proportion to the light obtainable therefrom, compared with that obtainable either from oil or tallow could not be had for less than thirty shillings. Under such circumstances, it will not be difficult to conceive that even where coals are cheap, it is a doubtful case whether it would be advantageous to the manufacturer to adopt the plan of working his retorts at a low temperature. For myself, I must confess, when I take the profits on one part, and compare them with the losses on the other, I am ready to pronounce, that with cylindrical retorts it will always be the most advantageous to charge with two bushels, and work with such a heat as will from a chaldron of coals (twenty-seven cwt.) give the average quantity of 10,000 cubic feet.

Whilst experiments were pursuing by some for ascertaining the above point, others conceived it would be more profitable to work the retort at six hours' charges, decreasing the quantity of coals to be carbonized by each retort during one charge from two bushels to a bushel and a half, or even a bushel and a quarter. They were led to think that advantages would arise from such mode of working, from considering that in the charge of eight hours, four-fifths of the gas was evolved during the first six hours of the process; and that such was in reality the case, the following table, being the results of numerous experiments made in the large way under my own observation, will very clearly demonstrate. It may not be improper to observe, that I was led to make these experiments during the summer months of 1816, from having found it difficult to ascertain the quantity of gas generated during the short days of the preceding winter, when the street valve frequently did not remain shut during one entire charge. As one part of my duty was to report on the quantity of gas daily generated, I considered that, by a series of experiments made on different kinds of coal, I might obtain such a knowledge of the manner in which the gas passed over, as would furnish me with proper data for making my calculations from, even if the communication between the street-mains and gas-holder was not shut off more than half the time of one charge.

TABLE,

Exhibiting the Ratio at which the Gas is evolved from Bewicke and Crastor's Wallsend Coal, when the Retorts are worked at eight hours' Charges.

			Cubic Feet of Gas.	
During the	1st.	hour of the process	2,000	are generated.
,,	2nd.	,,	1,495	,,
,,	3rd.	,,	1,387	,,
,,	4th.	,,	1,279	,,
,,	5th.	,,	1,189	,,
,,	6th.	,,	991	,,
,,	7th.	,,	884	,,
,,	8th.	,,	775	,,
		Total	10,000	cubic feet

obtained during the process from one chaldron of coals. If, therefore, this total be considered as unity, the cubic feet of gas as therein stated to pass over during each hour of the charge will be decimal parts of it. And it follows that if the quantity of gas actually generated be known, for any part of the process, the entire quantity may be known also, by dividing that which is known by the sum of the decimals corresponding in the table with the hours on which the observation may have been made. Thus, for example, supposing such a number of retorts charged as produced from the beginning of the second to the end of the fifth hour of the process 6,741 cubic feet of gas, to ascertain the quantity produced during the whole time of that charge.

By referring to the table, it will be found that,

			Cubic Feet of Gas.	
During the	2d.	hour of the process,	1495	are generated.
„	3rd.	„	,1387	„
„	4th.	„	,1279	„
„	5th.	„	,1189	„

Their sum ,5350 in this case will be the divisor.

Then 6,741 ÷ ,5350 = 12,600 the gas produced.

But to return to the subject of profit expected to arise from working the retorts at six hours, or shorter charges, however plausible it might appear in theory, when it was brought into practice an entire failure was the consequence. That a greater proportion of the gas is evolved during the first part of the process, the table I have just given will explain—and from it almost every one, who had not an opportunity of convincing himself to the contrary by actual experiment, would consider such mode advantageous. It is now my business to shew that it is not so.

When working eight hours' charges, one chaldron of Bewicke and Crastor's Wallsend coal (the retorts being at a bright red heat) will produce 10,000 cubic feet of gas; and when working six hours' charges, the retorts being at the same heat, one chaldron of coals of the same quality does not, as appears from the results of at least forty experiments made in the large way, yield more than about 8,300:—therefore, supposing eighteen retorts should be worked for one day at eight hours' charges, they would produce 30,000 cubic feet of gas. To produce the like quantity of gas by working six hours' charges, four more retorts would require to be worked:—for eighteen being worked at six hours' charges could not in that time carbonize more than three chaldrons of coals; nor, with the same heat as that used in the process of eight hours, produce more than 24,900 cubic feet of gas—it being found necessary to decrease the quantity of the charge in proportion to the time for carbonizing; and when these short charges, of which I am now speaking, were worked, more than a bushel and a half of coals was never submitted to the distillatory process in one retort at one time. That small quantity of coal was not, however, well carbonized, nor was the increase of coke on coal carbonized near so great as when working eight hours' charges. The coke was not so good, it was more subject to waste and unfit for many purposes to which other coke was applicable.

To point out the disadvantages arising from working six hours' charges, I do not know that I can adopt a better method than that of stating the actual expenses of coals, *&c.*, and products obtained therefrom when working six hours' charges during one week, and comparing the results with those given when working the retorts at eight hours' charges, so as to obtain a like quantity of gas.

Distillatory Process. Six Hours.

REPORT A.

WEEK. DAY.	Retorts in Use.	COALS.				GAS.	
		Submitted to the Distillatory Process.		Used for heating the Retorts.		Produced.	Proportion obtained from 1 chaldron of coal, 27 cwt.
	No.	Ch.	Bu.	Ch.	Bu.	Cubic Feet.	Cubic Feet.
Monday....	87	10	30	4	24	94,987	8,768
Tuesday....	88	14	24	6	8	128,597	8,784
Wednesday	88	14	24	6	8	122,188	8,331
Thursday ..	94	15	24	6	26	131,176	8,373
Friday	96	16	0	6	32	127,696	7,981
Saturday ...	96	16	0	6	20	127,536	7,971
Sunday	96	15	18	6	4	125,487	8,092
		103	12	43	14	857,667	8,300

Expenditure.

103 ch. 12 bu. B. & C. Wallsend coal carbonized at 51*s*. 6*d*.	£266	1	8
43 ch. 14 bu. Hartley's coal used for heating the retorts at 42*s*. per chal.	91	2	4
Wages of two additional Stokers (not required had the retorts been worked at eight hours' charges) at 36*s*. each per week	3	12	0
Total Expenditure	£360	16	0

Products.

Coke, 103 ch. 12 bu. at 27*s*. per ch.	£139	12	0
Breeze, 6 ch. 9 bu. at 18*s*.	5	12	6
Tar, 7¾ tons at £8. per ton	62	0	0
Ammoniacal liquor, 1,864 gallons at 3*d*. per gallon	23	6	0
Gas, 857,667 cubic feet at 15*s*. per thousand	643	5	0
Total for Products	£873	15	6

Here the amount of expenses of fuel, coals, *&c.*, for procuring 857,667 cubic feet of gas is £360 16 0—the products in value are £873 15 6, and the average proportion of gas obtained from one chaldron of coals 8,300 cubic feet.

Distillatory Process, Eight Hours.

REPORT B.

WEEK. DAY.	Retorts in Use.	COALS.				GAS.	
		Submitted to the Distillatory Process.		Used for heating the Retorts.		Produced.	Proportion obtained from 1 chaldron of coal. 27 cwt.
	No.	Ch.	Bu.	Ch.	Bu.	Cubic Feet.	Cubic Feet.
Monday....	57	9	18	2	13	94,987	10,000
Tuesday....	77	12	31	3	8	128,597	10,000
Wednesday	73	12	8	3	2	122,188	10,000
Thursday ..	79	13	4	3	10	131,176	10,000
Friday.....	76	12	27	3	7	127,696	10,000
Saturday ...	77	12	27	3	6	127,536	10,000
Sunday	75	12	20	3	6	125,487	10,000
		85	27	21	16	857,667	10,000

Expenditure.

85 ch. 27 bu. B. & C. Wallsend coal, carbonized at 51*s.* 6*d.* per chal.	£220	16	1½
21 ch. 16 bu. Hartley's coal, used for heating the retorts at 42*s.* per chaldron	45	1	8
Total Expenditure	£265	16	9½

Products.

100 ch. of coke, at 27*s*. per ch...	£135	0	0
3 chal. of breeze, at 18*s*. „ ..	2	14	0
6 tons 8 cwt. of coal tar, at £8. per ton	51	4	0
1,536 gals. ammoniacal liquor, at 3*d*. per gallon	19	4	0
857,667 cubic feet of gas, at 15*s*. per thousand	643	5	0
Total for Products	£851	7	0

From the result of this process, it appears that at the expense of £265 16 9½, the value of the products is £851 7 0.

By comparing the two preceding reports, the reader will observe that the same quantity of gas was generated each day, notwithstanding there were fewer retorts in use and less coal carbonized by Report B. than by Report A:—and that the expense of fuel for heating the retorts in use, when the distillatory process was extended to eight hours, was considerably less; and the proportion of gas, obtained from a chaldron of coals in such case, greater than when that process was only continued six hours.

Now if from the products per Report A,
£873 15 6
we take 851 7 0 the products per Report B,
the difference is 22 8 6 which being substracted from the difference between the expenditure, as specified in the reports alluded to
thus, Report A. £360 16 0
B. 265 16 9½
Difference 94 19 2½
less 22 8 6
leaves £72 10 8½ as a balance in favour of working eight hours' charges for one week, and producing a like quantity of gas as had been obtained by working six hours' charges.

Thus, having compared the quantity of coals actually used when working six hours' charges, with what was used to produce a like quantity of gas from eight hours' charges, I shall next point out, in Report C, the quantity of gas generated when working the same number of retorts at eight hours, which had been worked at the process of six hours.

Eight Hours' Process.

REPORT C.

WEEK. DAY.	Retorts in Use.	COALS.				GAS.	
		Submitted to the Distillatory Process.		Used for heating the Retorts.		Produced.	Proportion obtained from 1 Chaldron of Coal 27 cwt.
		Ch.	Bu.	Ch.	Bu.	Cubic Feet.	Cubic Feet.
Monday.....	87	14	18	3	22	145,000	10,000
Tuesday....	88	14	24	3	24	146,667	10,000
Wednesday	88	14	24	3	24	146,667	10,000
Thursday ..	94	15	24	3	33	156,666	10,000
Friday......	96	16	0	4	0	160,000	10,000
Saturday....	96	16	0	4	0	160,000	10,000
Sunday.....	96	15	18	3	32	155,000	10,000
		107	0	26	27	1,070,000	10,000

Expenditure.

107 ch. of B. and C.'s Wallsend coals, carbonized at 51*s.* 6*d.* per chaldron...............	£275	10	6
26 ch. 27 bu. Hartley's coal, used for heating the retorts, at 42*s.* per chaldron	56	3	6
Total expenditure..	£331	14	0

Products.

Coke, 124 chaldrons, at 27*s.* per chaldron	£ 167	8	0
Breeze, 4 ch., at 18*s.* per ch. ..	3	12	0
Tar, 8 tons, at 8*l.* per ton	64	0	0
Ammoniacal liquor, 1,945 gallons, at 3*d.* per gallon..........	24	6	3
Gas, 1,070,000 cubic feet at 15*s.* per thousand	802	10	0
Total for products	£ 1,061	16	3

Recapitulation.

Products, per report C, ..	£ 1061	16	3
Ditto ditto A,	873	15	6
Difference ..	£ 188	0	9

Expenditure, per report A,	£ 360	16	0
Ditto ditto C,	331	14	0
Difference	£ 29	2	0

From the above recapitulation, it will appear that by working equal numbers of retorts at six and at eight hours' charges, the balance is considerably in favour of the latter; for, from the foregoing statements, there appears to be on the latter an increase of products amounting to

£188 0 9
obtained at 29 2 0 less expense

consequently there is a balance of } £217 2 9 in favour of working the retorts, as specified in report C, over that shewn in report A; and in such proportion, let the number of retorts worked be what it may, an advantage will always be gained by working cylindrical retorts at eight hours' charges in preference to adopting the shorter process.

After the reader's examining the reports A, B, and C, it will not be necessary to say much more on the subject of decreasing the time for working off one charge of the retort; for, as these reports are the results of experiments made by me, with great care and attention, they shew more than can be done by any mode of argumentation. However, if we refer to reports A and B, and pursue our calculations a step further, we shall find greater advantages arising to the latter; for it has been proved that when retorts are worked as specified in report A, they do not last more than about two-thirds of the time that they remain serviceable when worked at the eight hours' process. This more rapid destruction of the retort arises principally from the necessity of working it at a higher temperature than would be required were it otherwise worked; for, unless it be kept almost at a white heat, in the shorter process, the frequent charging and drawing so cools the retort as would, were it not kept so, render it altogether unqualified for carbonizing the coal in so short a period. By thus keeping up the fires, the grate-bars are more rapidly worn out also, and the destruction of every part of the fire-work, very much augmented.

The following statement is made for the purpose of bringing before the reader the annual balance in favour of working eight hours' charges over those of six hours, when it is required to produce the average weekly quantity of 857,667 cubic feet of gas by either process.

At page 157 the balance in favour of working eight hours' charges, for one week, over those of six hours, the quantity of gas, as above-mentioned, being produced, is 72*l.* 10*s.* 8½*d.*; or, at the rate of 3,771*l.* 16*s.* 10*d.* per annum. This balance is for coal, products, and labour.

The first cost of setting one retort on the flue plan, four being heated by one fire, including pipes to the hydraulic main, coke-hearth, *&c.*, complete, is 23*l.*, or 92*l.* for a series of four.

The cost of replacing a retort is about 15*l.*, or, at the rate of 60*l.* for a series of four.

By the six hours' process it would require eighty-eight retorts to be kept constantly at work to produce 857,667 cubic feet of gas per week. Retorts so worked would not, at an average, remain serviceable more than four months; consequently, 264 would be burnt out in a year: the cost of replacing each being 15*l.* amounts to £3,960

Wear and tear of grate-bars.......... 140

£4,100

By the eight hours' process it would require seventy-six retorts to be kept constantly at work to produce 857,667 cubic feet of gas per week. Retorts so worked would remain serviceable six months, consequently there would be but 152 burnt out in a year: the cost of replacing each being 15*l.*, amounts to £2,280

Wear and tear of grate-bars.......... 80

£2,360

Balance in favour of the eight hours' process, as far as relates to wear and tear of retorts, fire-bars, *&c.*, ...£1,740

Now, the balance for coal, products, and labour, being, as already stated,........................ £3,771 16 10

If to that we add

The balance for wear and tear of retorts, grate-bars, *&c.*......... 1,740 0 0

their sum, £5,511 16 10

is the annual balance in favour of working eight hours' charges, when it is required to produce, in that time, by either process, 44,598,684 cubic feet of gas.

Considerable as is the advantage gained by the manufacturer from working his retorts at eight hours' charges instead of six, both as it regards the products, and also the wear and tear of retorts, as has been clearly demonstrated; yet, from an erroneous opinion resting on no well-grounded principle of sound economy, the practice of working the retorts at six hours' charges has so gained ground that it is now very generally adopted. Before I quit this subject, it is necessary I should remark that although I have stated the durability of the retorts when worked at six hours' charges, to be four months, which was actually the case when they were set four to one fire; yet, from observations made during twelve months upon retorts set on the oven plan, I find their average durability, when so worked, not to be so much as two months.

The cause which, perhaps, first induced the manufacturer to work cylindrical retorts at less than eight hours' charges, was a want of room in the gas-holders equal to the light he had to supply, which induced him to conceive it better to shorten the duration of the process of carbonization, in order that he might obtain a greater proportion of gas in a shorter time. This, I think, has been proved could not be the case in the preceding pages; and, if it was not, what other advantages could he gain? Certainly none. Instead of his obtaining a greater quantity of gas in a given time, from equal numbers of retorts, when worked at six, than could have been, had he worked them at eight hours' charges, he could not possibly obtain so much, and, what was still worse, the least quantity was obtained at more expense than the greatest.

We shall presume that on all occasions where cylindrical cast-iron retorts are used, the eight hours' process is the most advantageous, and reason must point out how far any other lessens the profits of an establishment.

Were it requisite to go into calculation upon the different modes of working the retorts, taking the results of experiments made at different times and under various circumstances as data, it might be most clearly proved how much in all cases the longer process excels the shorter.

In order, in some measure, further to elucidate this point, I am to observe, that, whenever pit-coal is to be submitted to the process of distillation, the time for the process cannot be shortened to less than eight hours, unless we have the means of exposing the coal to the action of heat in thin strata,—say four inches; and, when coal is so exposed in cylindrical retorts, that retort which, when worked at the eight hours' process is capable of carbonizing two bushels of coal would only carbonize about three-fifths of a bushel. The segment of a circle, whose altitude is four inches and chord eleven inches and a quarter, bearing such proportion to the capacity of the retort, the diameter of which is about twelve inches. We are told by those who have the management of carbonizing in different manufactories, that when the six hours' process is adopted, the charge is from a bushel and a quarter to a bushel and a half. In such case the mass of coal is by no means sufficiently diminished so as to cause the process to be performed with advantage. When the retort is so charged and worked, the heat verging from all directions towards the centre, will meet with nearly the same obstacles to prevent the extrication of the gas as if it had been fully charged.

With respect to these shorter charges when worked off by cylindrical retorts set on the oven plan, the same arguments which have been already advanced will hold good in favour of the eight hours' process, but with considerably more weight, inasmuch as the wear and tear of the retort will be proportionably greater. We may, therefore, from what has been said, draw this conclusion, namely, that whenever cylindrical retorts are used, let the mode of setting be what it may, the operator ought never to work off his charge in less than eight hours, and that with such heat as would produce from one chaldron of Newcastle coal (twenty-seven hundred weight) the average quantity of ten thousand cubic feet of gas.

When semicircular or elliptical retorts are used, either will admit of the charge being worked off in much less time than can be effected with cylindrical ones. For, in using the first, it would be advisable to introduce the coal into the retorts by means of sheet-iron trays nearly of their length and breadth, and about four or five inches deep. By having two sets of trays for the retorts in action, the time usually lost in charging would be greatly decreased, as would also the stoker's labour. By the mode most generally practised, the raking the ignited coke out of the retort is not only very laborious, but also attended with much loss of time—both which would be avoided by the mode suggested; for by using the trays, the spare ones might be charged with the proper quantity of coal preparatory to the time for drawing, and by that means almost the only time occupied in the operation would be that required for breaking the joints of the mouth-pieces and making them good again.

Carbonization, when carried on by means of semicircular retorts, if properly set, has a decided preference over cylindrical ones:—for, as the great art of making gas to advantage depends upon exposing coal to the action of heat in thin strata, such kind of retorts are particularly adapted to the purpose. They have, however, one disadvantage which has not passed unnoticed. The action of the flame upon the angles at their base tends towards destroying them with considerable rapidity. To guard against such destruction the angular part has been rounded off so as to present an arc of a circle to the fire, instead of an acute angle, and such alteration was doubtless for the better. Were such retorts set on the plan of an air-furnace, in which every part of them could be regularly heated without directing the heat more forcibly against one particular part than another, they could hardly fail of answering a very desirable end to the manufacturer of coal-gas. From the numerous experiments made on the distillatory process, on the plan of submitting the coal thereto in thin strata, it can hardly be doubted but retorts of this description, if set with judgment, would remain serviceable from six to eight months, being charged every four hours night and day with two bushels of coal each, and worked at such heat as to produce from a chaldron of coals the average quantity of thirteen thousand cubic feet of gas, with an increase of coke (particularly adapted for parlour fires as well as culinary purposes) of 40 per cent upon the quantity of coal carbonized; consequently, that five retorts of this description would produce as much gas during the space of twenty-four hours as would require twelve cylindrical retorts to be worked at eight hours' charges with two bushels of coals to each every charge, or sixteen cylindrical retorts worked the same time with a bushel and a half of coals to each retort for one charge.

As what has been said on the subject of carbonization when carried on by means of semi-circular retorts is in almost all respects applicable thereto when square retorts are used, it therefore will not be necessary to take up the reader's time by speaking of it here.

The next mode of carrying on the process of carbonization is by means of elliptical retorts, for which purpose it would be difficult to find a better. The elliptical retort combines in it the durability of the cylindrical one with the advantages obtained by exposing the coal thinly to the action of heat upon a large surface, and, therefore, when it is used, the process will be accomplished in about four hours. Upon retorts of this description I have had opportunities of making observations, the result of which leads me to pronounce such well adapted for promoting the interests of the manufacturer. Five elliptical retorts are capable of carbonizing forty-five bushels of coals *per diem,* and of generating from that quantity of coal about seventeen thousand cubic feet of gas, or at the rate of fourteen thousand cubic feet per chaldron. From one chaldron of coal, when elliptical retorts are used, will be produced a chaldron and a half of saleable coke. The elliptical retorts on which my observations were made, were set five to one fire, and so well was the heat disposed of, that from one end to the other they remained, whilst in action, at a bright cherry redness; being kept so night and day for more than ninety days, they were not much injured—from their appearance, there could be little doubt but they would remain serviceable nearly twelve months. They were charged and drawn in the usual way; but, notwithstanding the charging and drawing was more frequent, the stokers found it more easy to work them than a like number of cylindrical retorts. Their shape allowed room to rake out the coke more rapidly than could be done from those of cylindrical form, and the coke not being so compact when produced in the elliptical retort, required considerably less labour to clear it from thence.

It would be no exaggeration to state the results, arising from the use of these retorts to bear similar proportions of advantage over the cylindrical ones to those stated when speaking of semicircular-shaped retorts at page 168:—however, as I apprehend more favourable results would arise to the manufacturer by charging elliptical retorts with a bushel and a half of coals to each, and working such charge off in four hours, I shall from such data make a calculation on the number of elliptical retorts necessary to be worked for producing 857,667 cubic feet of gas in one week—the coal it would require for producing it, and for heating the retorts—with the products obtained—and, after having stated the annual cost for retorts and grate-bars, strike the balance between the most favourable mode of working cylindrical retorts, so as to produce an equal quantity of gas with elliptical ones, and by retorts of the latter description.

ELLIPTICAL RETORTS.

Distillatory Process: Four Hours.

Report D.

WEEK. DAY.	Retorts in Use.	COALS.				GAS.	
		Submitted to the Distillatory Process.		Used for heating the Retorts.		Produced	Proportion obtained from 1 Chaldron of Coal, 27 Cwt.
	No.	Ch.	Bu.	Ch.	Bu.	Cubic Feet.	Cubic Feet.
Monday	27	6	28	2	6	94,987	14,000
Tuesday	37	9	7	3	0	128,597	14,000
Wednesday..	35	8	26	2	30	122,188	14,000
Thursday....	38	9	13	3	0	131,176	14,000
Friday	36	9	4	3	0	127,696	14,000
Saturday	36	9	4	3	0	127,536	14,000
Sunday......	36	8	34	2	27	125,487	14,000
		61	8	19	27	857,667	14,000

Expenditure.

61 ch. 8 bu. B. and C. Wallsend coals, carbonized at 51*s*. 6*d*. per chaldron, ...	£157	12	0
19 ch. 27 bu. Hartley's coal, used for heating the retorts at 42*s*. per ch.,	41	9	6
Total expenditure . .	£199	1	6

Products.

Coke, 90 chaldrons, at 22*s.* per ch. . . £	99	0	0
Breeze, 5 chaldrons, at 18*s.* per ch. . .	4	10	0
Tar, 3½ tons, at 8*l.* per ton	28	0	0
Ammoniacal liquor, 1,200 gallons, at 3*d.* per gallon	15	0	0
Gas, 857,667 cubic feet, at 15*s.* per th.	643	5	0
Total, for products £	789	15	0
To work the number of retorts stated to be in action in report B, it required ten stokers by day and ten by night; but to work the number specified in report D, it would require but five day and five night stokers; consequently there would, in the latter case, be ten less in pay; these, at 36*s.* each per week	18	0	0

This sum being in reality a saving, arising to the manufacturer by working elliptical retorts, it must be added to the products, as above stated; and we shall then have . . . . £807 15 0 as the total for products obtained at a cost for coal of 199*l.* 1*s.* 6*d.*, as stated in the preceding page.

Now, if from the products per report B,
£851 7 0
we take 807 15 0 the products per report D,
the difference is £ 43 12 0 which, being subtracted from the difference between the expenditure as specified in the reports alluded to,

		£	s.	d.
thus, report B,		£265	16	9½
„	„ D,	199	1	6
	Difference	£ 66	15	3½
	less	43	12	0
	leaves	£23	3	3½

as a balance in favour of working elliptical retorts at four hours' charges for one week, and producing a like quantity of gas as had been produced by working cylindrical retorts at eight hours' charges, or at the rate of £1,135 1 3½ per annum on coals, products and labour.

At page 162, the annual expense of cylindrical retorts, when worked at eight hours' charges, together with the wear and tear of grate-bars, is stated to be, when worked so as to produce 44,598,684 cubic feet of gas, 2,360*l*. It has been already stated, that when elliptical retorts are used as above specified, one retort will remain in a sound working state about twelve months; if, therefore, we calculate the expense of elliptical

CHAPTER IX.

On the Hydraulic Main and Dip Pipes.

BY the term "Hydraulic Main," as used in gas-light establishments, is understood that cast-iron pipe which is supported by columns in front of the brick-work enclosing the retorts. It is so situated as to lay parallel to the top of that brick-work at a distance of from twenty inches to two feet from it. Its use is to receive the "Dip Pipes," through which the gas, as it is evolved from the retort, passes, together with the other products, on its way to the condensing main, or to the vessel employed for condensation, as the case may be. The diameter of the hydraulic main is various in different establishments; in some it is ten inches, in others twelve or fourteen. In works where not more than from forty to sixty cylindrical retorts, six feet and a half long and one in diameter, are set in one retort-house, a diameter of twelve inches will be sufficient.

It is generally constructed of flanch pipes in lengths of nine feet each. One end of it is closed by a blank flanch so as to be perfectly air-tight, the other has a semi-flanch placed across it of sufficient height to prevent the liquid introduced into the main from sinking below a certain level:—it is of advantage that similar semiflanches be placed between every length of pipe forming the hydraulic main. These flanches should rise two inches and a half above the line of the bottom of the dip-pipes; by such means the gas as it is discharged from the retort will always have to pass through such depth of fluid, before it can enter into the hydraulic main.

The use of the hydraulic main, as has been already stated, being for receiving the dip-pipes, we are to consider what end they may be intended to answer.

A section of the hydraulic main, with the most approved dip-pipe, is given in *Plate* V. *Fig.* 2. The dip-pipe is about two feet in length and three inches diameter inside—at the top is a socket for receiving another pipe of the same diameter. At about eight inches from the spicket-end of the dip-pipe is a circular saddle of about nine inches diameter, cast to the radius of the exterior surface of the hydraulic main. This main being tapped for the reception of such a number of dip-pipes as there are retorts to work into it, they are jointed upon it by means of iron cement in the usual way: when that is done, it is evident that the range of the spicket-end of these pipes will equally descend, and, of course, supposing the hydraulic main to be placed perfectly level, which it always ought to be, should one of them be immersed two inches and a half in any liquid that it may contain, each one of the range will be so.

Now, when it is considered that if there were not some contrivance for preventing the gas returning from the main pipes towards the retorts, when the mouth-pieces are removed in the operation of drawing, either by stop-cocks on each of the "gas conductors," or other means, the process would not only be very wasteful, but extremely hazardous; for, as the gas would be passing over by means of the conducting pipes to the hydraulic main, in a range of sixty retorts, from fifty-two of them, whilst eight were drawing, it would follow that the whole quantity of gas then generating would escape at the mouths of the retorts that had their lids taken off, and burst forth with such a flame as no one could come near; if not attended with still more serious consequences by the admission of atmospheric air which might cause the most violent explosion.

The necessity of means being adopted for preventing such things happening is obvious; and a more simple, and at the same time safe, method than that of the hydraulic main and dip pipes could hardly have been thought of; for, had stop-cocks been used, they would have been attended with considerable trouble and always liable to get out of order; so much so that no dependence could be placed upon them; for, the tar and ammoniacal salts would, in a few days, so clog the plugs as to render them immoveable.

It must be clear to every reader, that unless the pressure upon the hydraulic main from the purifying vessel be greater than the distance between the bend of the H pipe, and the spicket end of the dip pipe in the hydraulic main, the gas, after having once entered that main, cannot be forced back to the retort.

In mentioning the pressure from the purifying vessel, it is to be understood, that whatever depth of lime in solution the gas, after entering it, has to rise through before it can escape to the gasholder, is considered to be the pressure at which it is worked. Thus, for instance, the most usual depth of the purifying mixture through which the gas bubbles up in the process of purification being ten inches, the purifying vessel is said to be worked at ten inches' pressure. The length of the dip pipe has been stated at two feet: from the top of it to the centre of the bend part of the H pipe, may be stated at six or eight inches more, making altogether about two feet and a half; consequently, before the pressure in the lime vessel can be of sufficient power to force back the gas from the hydraulic main through the conducting pipes to the retorts undergoing the operation of drawing, it would require to be three times greater than what the vessel is usually worked at.

But, as there is a possibility, when the purifying vessel is ill constructed, of its being choked up, there should be some contrivance for indicating to the workmen when such was the case, or when the pressure there was so considerably increasing as to endanger the safety of the retorts; and this might be done by fixing a pressure gauge in such situation as could always be consulted, or by means of a small bell so connected as to ring and give the alarm.

The main, of which I have been speaking, with the dip pipes, form a series of hydraulic joints, than which, in the manufacture of so elastic a fluid as coal-gas, nothing could be so well adapted, —nothing could be so safe.

It is of considerable importance that this main should be constructed of pipes of the best quality; that the joints should be sound, and the work altogether well turned out of hand. Previously to its being brought into action, it may be filled to the height at which it is proposed to be worked with any fluid: water will answer as well as any thing else; for, should that be put into the main, before the retorts have been long worked it will have been forced over the semiflanch by the tar and ammoniacal liquor which have passed over in the distillatory process. The specific gravity of each being greater than water, they will, of course, occupy its place, forcing it over the semiflanch to the reservoir for condensible products.

Accidents have been heard of, occasioned by the gas in the hydraulic main exploding and forcing the glans from the top of the pipes perpendicular thereto (usually called the H pipe, from its similarity to that Roman letter), but such accidents must have arisen from great carelessness on the part of the operator, or from the clogging up of the purifying vessel; for, by attending to the observations made, as to the situation of the hydraulic main and the manner of putting it up, no accident could possibly happen.

It is a very erroneous principle which has induced some constructors of retort furnaces and their appendages, of which the hydraulic main is one, to place that nearer to the mouths of the retorts than we have described: by its being so, the gas-conductors being more contiguous to the heat of the furnace, so heat the tar on its way to the hydraulic main as to form it into pitch before it can get there. The consequences resulting therefrom are, that the glans of the H pipe require to be removed, the joint of the retort lid broken, a loss of all the gas that is generating from that retort till a man has been able, by pushing an iron bar down the gas-conductor, to clear the passage, and afterwards to make the joint good between the glan and pipe. Owing to the gas-conductors being of small diameter in the early stages of this new branch of science, their choaking up was very frequent, and where there were forty retorts in action it was not uncommon to notice almost as many pipes to clear in the course of twenty-four hours. These pipes were not more than bare two inches diameter inside, till Mr. Malam, on introducing his elliptical retorts, increased it to three inches. His pipes were made very slight, not brought so near to the fire-work, and, being of greater diameter, they were not once choked up. The action of the air on their exterior keeping them so cool as to prevent the tar from adhering to their sides as when smaller ones were used. It condensed, and, returning to the retort was there decomposed; afterwards it went over with the gaseous products, by which the proportion of gas obtained from a chaldron of coals was increased. In short, by increasing the diameter of the pipes alluded to, which are but ramifications from the dip pipes, their choaking up was avoided; and consequently the gas, instead of being frequently wasted, was increased in quantity, and the expense attending the labour of clearing them avoided.

PLATE V.

Fig. 1.

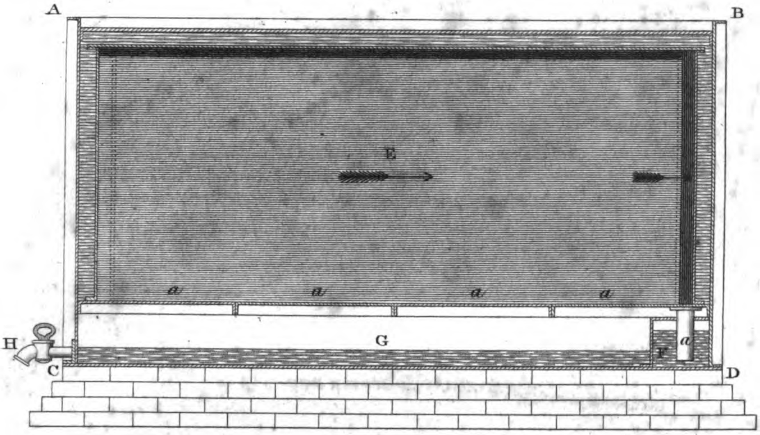


Fig. 2.

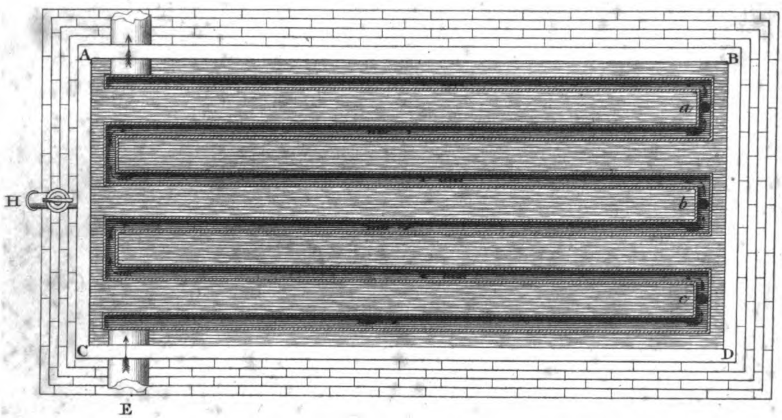
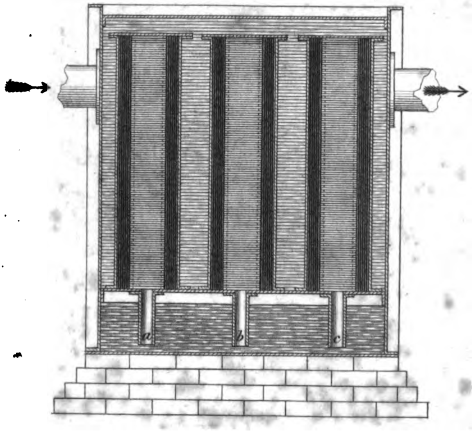


Fig. 3.



CHAPTER X.

On the condensing Main, and various Methods of Condensation.

THE gas, when evolved, being mixed with tar and ammoniacal fluid, in a state of vapour, which pass over with it from the retort to the hydraulic main, it becomes necessary that, *as much as possible*, these two products should be condensed and lodged in the proper receptacle before the gas reaches the purifying vessel. In order that this condensation may be properly effected, the products generated should be exposed to a large surface of some cold body on their passage to the purifier; by this means the tar and ammoniacal liquor are separated in a great measure from the gas, and, being of so much greater density, fall to the bottom of the pipes, and drain from thence to the vessels appropriated for their reception. The gas is also cooled and made much more fit for the lime to act upon than if it were brought directly from the hydraulic main to the lime vessel in a hot state; for, whenever it is so it is impregnated with the tar and oleaginous particles which very soon render the purifying mixture useless. The consequence following is, that a much greater portion of lime will be required for the purifying process, or otherwise that the gas will pass through the lime vessel into the gas-holder without being acted upon. The use of impure gas ought, on all occasions, to be avoided, for whenever it is used, it is almost impossible to obtain a good light; when it is submitted to combustion it is smoky, and emits a disagreeable odour; the plugs of the stop-cocks on the fittings in houses become choaked up with tar, which, however surprising the case may be, has been found in situations at a mile and a half distant from the manufactory, after having passed through various pipes of different sizes and at different levels.

The great preventive against receiving impure gas into the gas-holder, depends almost as much upon a proper condensation having been effected before it reaches the purifying vessel, as upon the process of purification which is then accomplished; for whenever gas is purified by lime in solution, or as a semi-fluid, it becomes a matter of the highest importance that it should be deprived of the tar, oils, and ammonia, which were generated at the same time with it before it enters that vessel. Even where other methods are adopted for the purification of gas, whether it be by passing it through red hot tubes, into which clippings of sheet-iron are introduced, or by dry lime, *&c.*, the same reasoning will hold good; and it may be considered as a general rule, which the manufacturer ought ever to observe, let the mode he adopts for purification be what it may, never to submit his gas to the purifying process till it has been well condensed.

Experience having taught the manufacturer the necessity of attending to the subject of condensation, he, of course, adopted such means as he considered most advisable for accomplishing it. In some manufactories it was thought that the gas would be sufficiently condensed from its being conveyed from the hydraulic main by a pipe laid in a direct line from the retort-house to the purifier—in others, the gas was conveyed to the lime-vessel through a worm-pipe placed in the tank of the gas-holder—and again, in others, by a range of pipes laid parallel to each other at a considerable depth, and with a certain declivity from one end of the works to the other;—whilst some, in addition to these contrivances, proposed a tank, into which the range of pipes, as last specified, should convey the gas at the bottom, and by means of a contrivance something similar to the shower-bath, have it washed there before it could make its exit towards the purifier. Most, if not all, of these modes, have been tried by different operators, and have been found more or less effective. The first could hardly be expected to answer, unless the distance from the retort-house to the purifying vessel had been much greater than is generally the case—the others, being on similar principles, produced results proportionally analogous to the length and temperature of the main through which the gas was conveyed. But all of them were expensive, and attended by inconveniences which it became the province of the experienced mechanist to avoid. By any of the methods spoken of, one very great evil was likely to happen, namely, the choking up of the condensing main, and more particularly so when the works were extensive and its diameter of inadequate size, which might be the case when the condenser had been laid down without taking into calculation the particular extent to which it was possible the works were likely to be carried—such circumstance, when the science was in its infancy, could attach blame to no one; but now, when the mode of obtaining light from coal-gas has become so general, the managers of establishments know what lights they will have to furnish before they begin to erect their apparatus, and will therefore, in consequence, guard against it by making their condensing main of so sufficient a capacity as almost to preclude a possibility of accident. Should the condensing main, however, become choked, the most serious consequences might

PLATE VII.

Fig. 1.

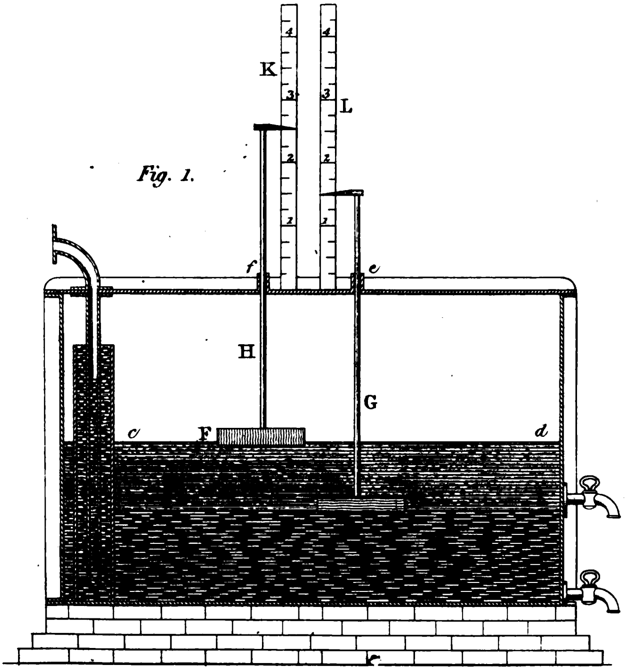
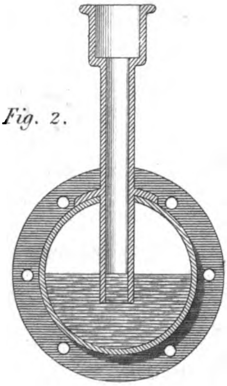


Fig. 2.



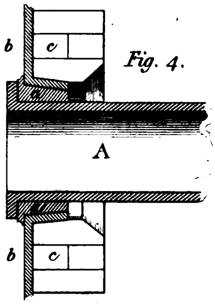


Fig. 4.

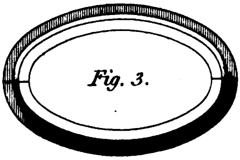


Fig. 3.

William Alexander sculp.

London, Published by I & G. Underwood & Ogle & Cº May, 181 ensue; for, whenever it was so, the pressure upon the hydraulic main would accumulate to an alarming degree, and, in short, so as to force the fluid it contained over the H pipes towards the retorts, and endanger the whole of them, unless their safety was effected by removing the lids from the mouth-pieces; an operation which, under such circumstances, it would be no easy matter to perform. The great objections against condensing mains are their being laid down at an enormous expense, and failing to perform the process of condensation equally with other methods carried into effect at one-third of the expense and perfectly safe in their operation.

The first deviation from the beaten track was by [*] proposing a vessel made of cast-iron, with a bottom divided into square compartments of about twelve inches deep by as many square—over this part of the vessel was placed a covering of the same metal, with two holes tapped into it over every square, save the first in the series, where the gas was introduced into it, and the last from whence it made its exit, each of which had but one. Over these holes were brought cast-iron flanch-pipes bolted down to the bottom, and the one which had been jointed over the first hole in the series was connected to the pipe over the first hole in the

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[*] Mr. John Perks obtained a patent for a condensing vessel of this description, 5th August, 1817.

second square by means of a semicircular flanch bend. The second pipe in that square was connected in the same way to the first pipe in the third square, and so on from square to square till brought to that from whence the gas was to make its exit from the vessel. Supposing, therefore, the vessel to be twelve feet deep and eighteen feet square, and fitted with pipes as above described, the gas would in that small vessel have to travel through a space of 7,700 feet before it left it. Now, as when the vessel was brought into action, it would be filled with water—the pipes rising in it would be kept constantly cool, and the condensible products would fall into the square recesses at the bottom, from whence, by a contrivance of the inventor, they were conveyed to the proper receivers.

The next was invented about the same time by Mr. Malam, of whom I have had occasion to speak before. It is also a square cast-iron vessel, about nine feet long, five wide, and four deep. Into this vessel are introduced plates at the distance of from six to eight inches from each other, with raised edges of about three inches in height; these are bolted to the sides of the vessel, and are perfectly parallel to each other; they are in length about eight feet six inches, so that being secured to the sides of the vessel and one end of it, the other end will be at the distance of about six inches from that end of the vessel to which it is contiguous. The lowermost of these plates being connected to one end of the vessel, the next plate above it will be connected at the end opposite thereto—the third plate the same as the first—the fourth as the second, and so on alternately till all the plates are fixed. This being done preparatory to bringing the condensing vessel into action, water is introduced at the top, which filling the uppermost shelf to the height which the projecting part of it allows, it runs over and fills the second, from thence the third is filled, and so on till the whole range are so. From considering this matter, it is evident that if the entrance pipe be at the bottom of the vessel to the right, should gas be introduced there by means of it, it will pass over a sheet of water equal to the area of the lower shelf, and as the next shelf above approaches no nearer than six inches to the end towards the left, it will by that opening rise above it and pass towards the right, where it will find an opening from the third shelf, and so it will pass alternately to right and left till it reaches the exit-pipe placed at the top of the vessel. The condensible products are carried from the respective shelves by means of small bends projecting from one end of this vessel; but as I am of opinion it will be likely to answer the purpose of the manufacturer both as relates to its first cost, durability, and action, I shall describe a condensing vessel of this kind capable of performing what is required where about 100,000 cubic feet of gas is generated daily.

The condenser we have just described is that which Mr. Malam first proposed for answering the purpose of condensation; but, as he has since made several alterations in that vessel, and we trust the description alluded to is so clear to every reader as not to require elucidation by drawings, we shall proceed to describe his improved condensing vessel as exhibited in *Plate* V.—ABCD, *Figure* 1, is a longitudinal section of this condenser. The vessel is a parallelopipedon made of cast-iron plates, supported upon a bed of brickwork. At about one foot from the bottom is a range of plates, *aaaa*, together of the same dimensions therewith, which are jointed to the side of the vessel. Upon these stand a row of plates of the same material, one of which is shewn as at E. Their bases occupy such situation as is expressed in the plan ABCD. *Figure* 2. In that plan the pipe which conveys the gas into the condenser is shewn at E: having there entered, it passes between the upright plates in the direction of the arrows till it reaches the exit-pipe F, and that pipe leads to the purifying apparatus. It is to be noticed that these upright plates do not rise to the top of the condenser—there is a space of about six inches left between it and the plate which fits over them. The entrance and exit-pipes E and F are placed about a foot from the top of the vessel, as shewn in the transverse section *Figure* 3. The range of cast-iron plates, *a a a a*, which we have already had occasion to mention, do not lie perfectly horizontal, but with a small declivity to the right, by which arrangement the condensible matter drains towards the openings *a b c*, *Figure* 2, and thence by the pipe *a*, *Figure* 1, and *a b c*, *Figure* 3, is discharged into the receptacle E, which runs across the vessel, and is filled with water for the pipes to dip in, and form an hydraulic joint. It follows, therefore, that as the condensible products accumulate, they overflow the partition which forms the part F, and run into the chamber G, from whence, when it is necessary, they are drawn off by the cock H, *Figures* 1 and 2.

ABCD, *Figure* 2, is a plan of this condenser, the arrangement of which is already described; and *Figure* 3 is a transverse section of the same vessel.

Plate VI. Exhibits different sections of the condenser, for which Mr. Perks obtained a patent.

Figure 1 is a plan of the top, shewing the situation of the bend-pipes, *&c.*

Figure 2 is a plan of the under side of the plate on which the upright pipes are supported, shewing the openings into the lower chambers, and the position of the upright partitions.

Figure 3 is a side view (in elevation) of the vessel, the side plates being supposed to be removed. The pipe and bend beneath are for carrying off the condensations. The dotted line shews the height at which the fluid will be constantly kept in the vessel. An opening is made, or left at the bottom of each partition, which allows the condensed matter to flow from one to another, and to be carried off by the pipe.

Figure 4 is an end view of the vessel (in elevation) the plate being supposed to be removed.

In considering the merits of either of these vessels, the most striking are the facility with which any obstruction to their operation may be removed, and the very efficient means they afford for answering the purpose of the manufacturer, as far as relates to the gas generated being well condensed before it is brought to the purifying apparatus. We have already stated the distance which the gas would have to travel in passing through a condenser constructed on Mr. Perks's principle; and, when we consider that the pipes therein are always surrounded by cold water, we can hardly doubt of its effect. In his vessel the bends at the top are easily removed in the event of any obstruction presenting itself, and by forcing down each of the pipes a rod for the purpose, the passage is cleared. As there is a sufficient opening left at the bottom of each of the partitions in the lower vessel, the obstructing matter can be withdrawn from thence. In Mr. Malam's condenser the top can be removed, and after it is so, the cast-iron plate which rests upon the upright ones can be withdrawn also: so that the operator has it in his power by drawing an instrument made for the purpose between the plates (for the passage of the gas) to clear them out and to open the holes through which the condensations descend into the lower chamber. It would appear that Mr. Malam, in the construction of his latter vessel as well as the former, had considered when gas passes through circular pipes, that which is near the centre, would be little, if at all, acted upon by the cold medium surrounding them; and he has, therefore, compensated for that defect by causing the gas to present itself in such thin sheets as cannot fail to be affected by the coldness of the adjoining surfaces: thus giving a greater probability to the condensation being well performed.

CHAPTER XI.

On the Situation and Construction of Vessels for receiving the Tar and Ammoniacal Liquor, with the Description of a Contrivance for shewing the exact Quantity of each Product from a given Quantity of Coal.

As every chaldron of coal when submitted to distillation in close vessels, for the purpose of collecting the gas evolved and its other products, produces from 1¼ to 1½ cwt. of tar, and from fifteen to eighteen gallons, ale measure*, of ammoniacal liquor, it becomes necessary that they should be received into some vessel, after being deposited in the hydraulic main; for otherwise they would fill the line of pipes between that main and the purifying vessel, and consequently stop the process. To prevent this, a small cast-iron pipe of two or three inches diameter is sometimes connected to one end of the hydraulic main, distinct from that connexion which leads to the purifying apparatus, from whence it falls with a gentle declivity to the vessel appropriated for receiving the condensible products. This vessel is called "the tar cistern."

The tar cistern should be erected at the greatest

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* 282 cubic inches = 1 ale gallon.

distance from the hydraulic main that the works will allow, in order that the condensation may be properly effected before the tar and ammoniacal liquor are allowed to enter into it. In most cases the tar-cistern is so situated as not to receive the tar and ammoniacal liquor till they have passed through the whole range of condensing main, or through the vessel for condensation. Under this arrangement there is but one connexion to the hydraulic main, instead of two, which conveys away from it all the products evolved, and all pass together to be condensed; after which process the arrangement of pipes is such as to allow the gas to enter the purifier and to carry the tar and ammoniacal liquor to the tar-cistern. In this case the tar-cistern must be situated below the level of the purifying vessel; for if it is not so, the tar and ammoniacal fluid will be carried into it. As in another Chapter the laying of main pipes and the manner of making various kinds of joints and connexions will be fully treated of, the reader is referred thereto for information on the subject of arranging pipes for the purpose; and, after carefully perusing what is there said, he cannot be at a loss how to proceed.

The vessel for receiving the condensible products may be of any convenient shape and constructed of cast-iron or wood. In either case it ought to be closed at the top (except a very small aperture) so as to prevent the ammoniacal liquor from losing its strength by exposure to the air.

When the tar-cistern is so situated as to receive the tar from the hydraulic main without allowing it to pass through the condenser, it is generally placed upon brick piers, so as to stand about thirty inches from the ground, and to admit of casks being brought under the cock near the bottom for drawing off the tar. It must be furnished with two or more cocks, so that the upper ones may be used for drawing off the ammoniacal liquor: this fluid being specifically lighter than the tar, floats at the top of it: however, we are informed that the tar produced from some of the species of cannel-coal is lighter than the ammoniacal liquor. Which ever way this is, the same arrangement must be attended to; for, as both these products are lodged in the same vessel, it is in that the heavier subsides and can be drawn off without being mixed with the lighter, or *vice versâ.*

To prevent the gas from entering into, or escaping through, the tar-cistern, the pipe which brings in the tar descends from the hydraulic main towards the top of it, and thence to nearly the bottom inside the vessel; it is furnished with a flanch, by which it is bolted to the top. This pipe is surrounded by another of about two or three inches greater diameter jointed to the bottom which rises nearly to the top of the vessel. When the distillatory process commences the tar and ammoniacal liquor drain down the inner pipe, and, having filled the surrounding one, the upper edge of which being considerably below the bend outside the top of the vessel, the pressure forces the products over and continues so to do till the process is ended.

The arrangements, as far as relate to conveying the tar into the cistern, and for preventing the gas escaping through it, when it is situated below the level of the purifier, is nearly similar to what we have just mentioned; but, as the vessel will then be sunk into the ground, it must, when full, be emptied by means of pumps.

It being necessary that the gas-light manufacturer should ascertain the quantities of the respective products obtained from coal at all times, for the purpose of keeping systematic and correct accounts, and more particularly when making his experiments in the large way upon different species of that article, the question presenting itself is this: As the tar and ammoniacal liquor are both received into one vessel, in what way may the exact quantity of each produced be ascertained without drawing it off?

In the course of my practice, having had to report the exact quantity of each produced daily from various kinds of coal, I found the trouble and inconvenience which attended the drawing off of these products greater than could be effected without more expenses for casks and labour than the products in that stage of the business were worth. Indeed, when it was absolutely necessary to adopt such plan, the truth could seldom be obtained unless it was attended to with greater care and attention than is generally to be found amongst the lower class of labourers to whom the drawing off of the tar and ammoniacal liquor is generally intrusted.

To any one at all acquainted with the practice of manufacturing coal-gas, many objections will present themselves to the adoption of such mode. Amongst many others are the following; namely, The necessity of stopping the process of generating gas whilst the tar and ammoniacal liquor are drawing off: the time thereby lost: the waste of fuel for keeping the retorts heated so as to be ready for charging when the cistern is emptied: and the impossibility, after all, of drawing the products off separately, owing to their not being allowed sufficient time for subsiding.

To remedy the evils, and to obtain a correct account of these products I constructed a table for shewing the exact number of ale gallons contained in the tar-cistern at every inch dip; the application of which shall be shewn after describing the apparatus attached to the cistern.

PLATE VI.

Fig. 1.

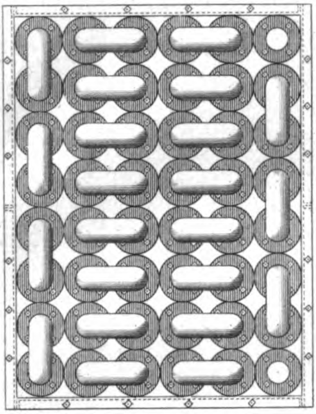


Fig. 2.

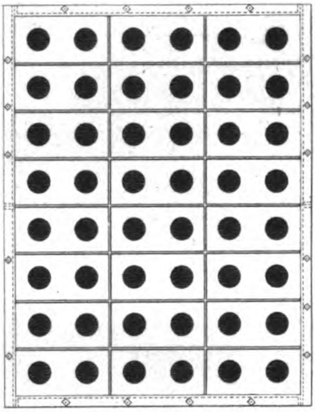


Fig. 3.

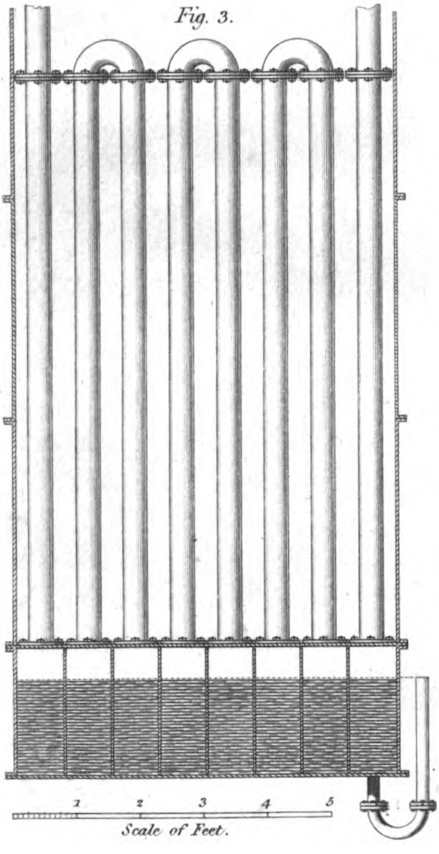
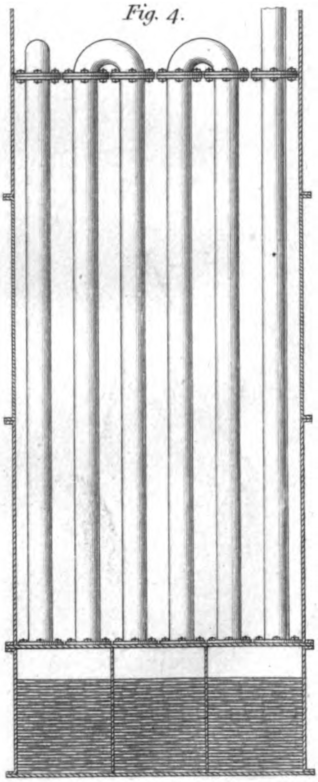


Fig. 4.



William Alexander Sculp.

London. Published by T. & G. Underwood & Ogle & C° May, 1819.

Considering that the specific gravities of tar and ammoniacal liquor were different, and that a body which would sink in the latter would swim upon the surface of the former, I proposed that two floats should be made and attached to rods for shewing the respective heights to which each product rose in the cistern.

A B C D, *Fig*. I, *Plate* VII, is a section of the tar-cistern.

a b, surface of the tar.

c d, surface of the ammoniacal liquor.

E, a float of sound dry oak, twelve inches square and three inches thick (the specific gravity of which being greater than that of ammoniacal liquor will displace its bulk of that liquor and rest upon the surface of the tar), to which is fixed (G) a small rod of round iron with a light index at the top for pointing out the height of the tar in the cistern against the graduated rod I.

F, a float of cork swimming on the surface of the ammoniacal liquor, fitted with a rod H, and an index for shewing on the graduated rod K the number of feet and inches the surface of that fluid is distant from the bottom of the cistern.

The difference between the heights, as pointed out by the indexes on the graduated rods I and K, is the feet and inches of ammoniacal liquor in the vessel.

e and *f* are two raised openings on the upper plate of the vessel of about five or six inches in height, through which the rods G and H slide up and down. By this contrivance they are steadied and always kept in a vertical position.

This description of apparatus will answer for any tar-cistern; but as that vessel may be of different dimensions in different establishments, the table for use must be calculated accordingly.

Application of the Table.

Example.

The index of the rod G pointing to two feet six inches on the graduated rod I, required the number of gallons of tar answering thereto?

Look for two feet in the side column, and run your eye along the line till you come under six inches in the top one; you will there find 3,080 the number of gallons sought.

To find the Gallons of ammoniacal Liquor.

Subtract the height pointed out by the rod G from that shewn by the rod H, and with the remainder enter the table as above directed; and you will find what number of gallons of ammoniacal liquor are in the cistern.

Example.

The rod G stands at two feet six inches, the rod H at four feet; what number of gallons of ammoniacal liquor are there in the cistern?

Ft. In. Ft. In. Ft. In.
4 : 0—2 : 6=1 : 6, opposite to which in the table you will find 1,848, and such number of gallons of ammoniacal liquor is in it.

CHAPTER XII.

On the purifying Vessels, and the best Mode of purifying Coal-Gas.

DURING the process of decomposing coals in close vessels, it is found, that, on their being heated to a certain degree, a part of the carbon of which they are formed unites with part of the oxygen and produces carbonic acid; this, by means of caloric, is formed into carbonic acid gas. Whilst this process is going on, a part of the hydrogen of the coal is combined with another portion of carbon and caloric which forms carburetted hydrogen gas. Olifiant gas, carbonic oxide, hydrogen and sulphuretted hydrogen are also produced. According as the component parts of the coal submitted to distillation varies, so will the quantities of these products vary also.

When the gas produced from coal is burnt without being purified (that is, deprived of the sulphuretted hydrogen and carbonic acid gas which it contains) or if it be not properly purified, it throws out sparks and produces a sulphureous acid, owing to the oxygen of the air uniting with the sulphur burnt with the gas. Such gas sends forth a suffocating odour that is not only highly offensive but injurious to health. Its levity carries it to the uppermost part of the room, where it is burnt, and there it is easily perceived. It tarnishes all metallic substances, and discolours paintings wherever metallic oxides may have been used in their execution.

The general way of freeing it from sulphuretted hydrogen and carbonic acid, and rendering it fit for use, hitherto adopted, has been by passing it through a solution of lime and water of the consistence of cream. It may also be purified by passing it through very dilute solutions of subacetate of lead, green sulphate of iron, or hyperoxymuriate of lime.

For the purification of coal-gas, when it is manufactured in the large way, various methods have been adopted. The following are those most noticed:—

1st, By passing it through lime in solution,

2d, By allowing it to be acted upon by lime in a semi-fluid state,

3d, By pressing it through dry lime, and

4th, By passing it through red hot tubes into which are introduced clippings of iron.

The purification of coal-gas seems to have been first effected by passing it through lime in solution. This was done by means of a cast-iron square or cylindrical vessel enclosing another vessel of the same shape, but of smaller dimensions, which was secured to the top of the outer one in such manner as to be perfectly air-tight. The inner vessel had no bottom, and the sides of it, to the height of about six inches from the lower edge, were drilled full of holes.

When the purifier was of a circular shape an upright shaft stepped in the centre at the bottom of the vessel and was brought through a stuffing-box at the top. At the head of the shaft was fixed a horizontal bevel-wheel to be driven by a pinion on one end of the axis, to which the winch to be turned by hand was applied at the other. The speed at which the upright shaft was driven was about ten revolutions in a minute. The lower extremity of the upright shaft, at the distance of four or five inches from the bottom, was fitted with four or more vanes, each of which was in length about three inches less than the semi-diameter of the outer vessel, and in breadth about four inches. Their use was to stir up the lime and keep it from subsiding. This was effected by the action of the winch, which gave motion to the pinion, and, consequently, to the shaft on which the vanes (or, as the gas-light manufacturer terms them, the agitators) were fitted.

In using this kind of purifier, it is necessary there should be a vessel of sufficient capacity for mixing the lime and water for one charge, situated at a height that will allow it to be turned, by means of a cock or valve, into the purifier, whenever it is necessary to charge it. And this vessel must be fitted with agitators similar to those of the purifier, so that the mixture may be properly effected before it is allowed to enter into the purifying vessel. The entrance of the mixture into the purifier is accomplished by means of a small vessel attached to the outside of it, the top thereof rising to the height to which it is desired the mixture should rise inside. Between this vessel and the purifier is a slide valve, opened for the purpose of charging, but kept shut when the purifier is in action.

Having mentioned the manner of charging and discharging the purifying vessel, we are next to consider how the gas is brought into it, acted upon whilst there, and allowed to pass from thence into the gas-holder. In Chapter X, "on the condensing main and various methods of condensation," is described how the gas passes from the retorts to that part of the apparatus and from thence to the purifier. From the condenser it is brought, by means of cast-iron pipes, through the top of the purifying vessel into the interior chamber, which we have described. And as, when this vessel is charged, the purifying mixture ascends about eleven inches above the lower edge of the interior vessel, it is evident that the gas will accumulate therein till the capacity becomes too small for its bulk, which, continually increasing, forces its way beneath the inner vessel and through the holes in its vertical sides, and bubbles up through the purifying mixture into the space unoccupied by the lime and water in the outer vessel; from whence, by means of pipes properly arranged, it is conveyed to the gas-holder. It is evident, then, that no gas can pass from the retorts into the gas-holder without first passing through the purifying mixture; and, as this mixture is constantly kept in agitation, it so acts upon the crude gas, by a chemical affinity, as to retain the sulphuretted hydrogen, *&c.*, and to allow the carburetted hydrogen to pass.

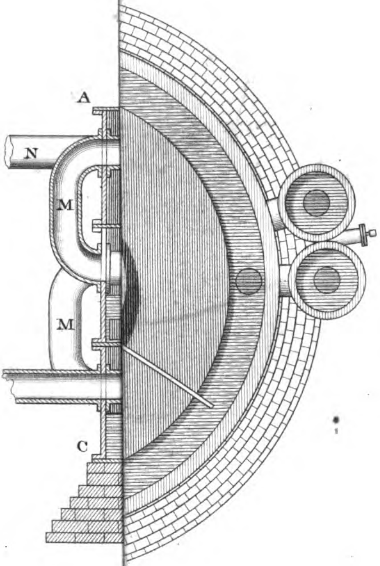
What has been stated on this subject is not only applicable to the cylindrical purifier, but also to the square one. In some establishments the purifier is of a parallelopipedal form, and when so, it is furnished with two upright shafts and double sets of agitators. But either of the latter shaped vessels are less serviceable than the former; for in them the angular points cannot be affected by the agitators, and, consequently, a considerable portion of the charge is lost to the manufacturer; and this cannot happen in the cylindrical one, where every part of the mixture is brought into use.

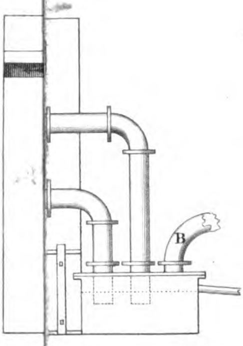
Of the cylindrical vessels used for purifying coal-gas by means of lime in solution, one constructed under the direction of Mr. Kemp, a Director of the Chartered Gas-Light and Coke Company, has been in action under my observation upwards of eighteen months. It admitted the gas through several bend-pipes into the vessel from a circular pipe situated over the top of it, by this means effecting a more equal distribution of the matter to be purified towards every part of the purifying mixture. The contrivance is ingenious, and does considerable credit to the inventor.

But as purifiers of the description spoken of were but single vessels, and the greater proportion of gas being generated during the first period of distillation, such part of the gas as came over first would be more acted upon than that which was evolved during the latter part of the process, when the purifying mixture became saturated with sulphureous particles. It was proposed by some operators to employ a series of purifiers: the first one would then receive the gas in its most impure state; after passing through it, it would enter into a second, where it would again be submitted to the purifying process, and so on through any number of vessels. Under this arrangement the first vessel would require to be more frequently charged than the second, and that than the third. Others considered that one purifying vessel was sufficient, provided the gas was washed by passing through water previous to entering into it, and again before it was deposited in the gas-holder. In small establishments, one purifying vessel may be sufficient; but in works where two or three hundred thousand cubic feet of gas are daily generated, no single vessel can perform the operation effectually.

We are, therefore, to consider, that for the effectual purification of coal-gas in establishments of magnitude, more than one purifying vessel must be employed; and we are now to inquire which is the best arrangement for placing two, three, or more purifiers, so that they may be the most effective, and at the same time the most economical. The best arrangement for these vessels which has fallen under my notice, as well as the construction of the purifier itself, was effected by Mr. Malam, of the Westminster Gas Works. ABCD, *Figure* 1, *Plate* VIII, is a vertical section of his treble purifier, placed upon a foundation of brick-work: and *Figure* 2 of the same plate, is a plan thereof. EE, FF, GG, *Figure* 1, are sections of the three interior chambers, bolted to the tops of the respective vessels by the flanches expressed in the plate. It will be observed that the bottoms of these vessels branch out with a kind of flanch, by which means the gas is acted upon by a greater proportion of the purifying mixture than if the vertical sides of it fell in a perpendicular line.

HH is the axis on which the agitator II is fixed.





William Alexander sculp.

KKK are three cylindrical vessels for the purpose of charging the respective vessels into which the purifying mixture is introduced by the bends LLL.

MMM are the pipes which convey the gas into the interior chamber.

N is the pipe which conveys the purified gas to the reservoir after it has passed through the series of vessels.

O—the feed-pipe for bringing the purifying mixture from the vessel where it is prepared into the purifying apparatus.

PPP exhibit the openings near the bottoms of the cylindrical vessels KKK, for emptying the respective vessels, which is effected by the slide-cocks QQQ.

In the figure the height to which the purifying mixture rises, is shewn in the two lower vessels; but the upper one is not charged.

The agitators are driven by hand in the same way as has been already described when speaking of the single purifiers.

When this purifier is first brought into action, the purifying mixture is turned into the uppermost vessel K, from whence it enters into the uppermost purifier by the bend L, till it rises to the height of the uppermost edge of the vessel K. When such is the case, by opening the uppermost of the slide-cocks Q, that charge is emptied from the first into the second vessel, which being done, the uppermost purifier is again charged. The middle cock Q is then opened, which allows the charge in the second purifier to enter into the lowermost one, and whilst this is performing, that in the uppermost one is emptied into the second. The mixture is at the same time entering into the uppermost one, which is known to be properly charged, when the mixture rises to the top of its supplying vessel K. This being performed, the gas in its crude state is allowed to enter into the interior chamber of the lowermost purifying vessel by the pipe M, which being filled, it blows underneath the flanch part of it into the outer part of that vessel which is unoccupied by the purifying mixture: from thence, by the next pipe M, it is conveyed into the interior chamber of the middle purifier, where the action is the same as in the lower one; and thence, by the uppermost pipe M, it is conveyed into the highest vessel, where having again undergone the purifying process, it is allowed to enter the gas-holder by the pipe N.

On examining the plate, it must appear obvious that the gas enters into the lowermost purifier in its most crude state; where, having been acted upon, it rises into the second in a purer state, and from thence into the top one. Under such circumstances, it follows, that the charge in the lowermost vessel is rendered useless first: on its being so, it is turned off by opening the bottom cock Q; whilst this is performing, the gas generated has to pass through two vessels before it can enter into the gas-holder: but, in the single purifier during the time of charging, the gas passes into the gas-holder in an impure state, thus, by mixture with the pure gas, deteriorating its quality. The bottom purifier being emptied, the mixture in the second is turned into it, and that of the top into the second, when the top one is recharged. The lowermost vessel then always contains the mixture which has been most acted upon by the gas.

By the vessels being placed in this way, a considerable saving in the expense of erecting them is effected: for, the top of the lowermost vessel answers as a bottom to the second, whilst the top of the middle vessel is the bottom of the upper one. The saving is not there alone; for, if the vessels were placed separately, they would require to be fitted with a number of valves and connexions under this arrangement altogether unnecessary.

Where the manufacturer has plenty of room on his premises for erecting a series of single purifying vessels, the extra expenses arising from the adoption of such plan not only consists in the first cost, but afterwards also, by requiring a man to work the agitators of each vessel; consequently, when three vessels were used, three men would be required for the purpose, whilst in Mr. Malam's purifier one man with ease works the three sets of agitators. His arrangement possesses another capital advantage, for in most large towns where coal-gas manufactories are established, it is of considerable importance to save room, and nothing can be better adapted for doing so than his triple purifier.

To go further into detail on the means of purifying coal-gas by passing it through lime in solution would be quite unnecessary; for, though by different operators different shaped vessels might be used, yet as all must allow the gas to pass through a sufficient column of the purifying mixture for the action to be effectual, so long as that is accomplished the manufacturer's views are answered. That this is the best means for purification hitherto adopted on the large scale, there is hardly a shadow of a doubt, and when the lime-refuse can be got rid off, it stands far above any other that has yet been tried.

In some cases, however, the refuse-lime has been found so troublesome, that means have been tried for purifying the gas by lime in a semifluid state*, thus decreasing the quantity of this objectionable matter; but the vessel which my obser-

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* Mr. Clegg took out a patent for a purifying vessel of this description.—*Vide Repertory of Arts*, No. 176, second Series for January 1817.

vations were made upon was found inadequate for accomplishing the purpose of purification.

For purifying coal-gas by means of dry lime, Mr. Reuben Phillips, of Exeter, obtained a patent; but as his mode has not been tried on a large scale, under my observation, I cannot speak sufficiently decisive as to its merits. I can here only observe, that from the construction of his purifying vessel and the manner of its arrangement, it would appear very doubtful if it could be adopted with safety and economy on an extended scale of operation, two things of very considerable importance to the manufacturer.

We come now to speak of a mode of purification differing in principle and practice from any we have yet mentioned. The manner of performing the operation is by causing the crude gas to pass through retorts of a particular description worked at a red heat just visible by day-light. Mr. G. H. Palmer, lately in the employment of the Chartered Gas-Light and Coke Company, and now residing at No. 8, Regent-street, Westminster, has obtained a patent for this invention. *Plate* VIII, *Figure* 3, represents a longitudinal section of Mr. Palmer's purifier. *Figure* 4 is a transverse section thereof, and *Figure* 5 a front view of the same, with the mouths of the upper purifier closed, and the lower one open. This purifier is constructed of cast-iron, and it is set in brick-work under such an arrangement as admits of its being heated to the temperature required. In the plate just referred to there are two purifiers heated by one fire. In no establishment can the process be carried on with a less number; in large works it would not only require the magnitude of the purifier to be increased, but it would also be requisite to employ a greater number of purifiers also. The purifiers are of an elliptical shape, and each one is divided into two equal parts by a vertical partition, which runs along its centre from the mouth-piece to within a few inches of its end. The mouth-piece is double, that is, it admits of two lids being applied to it, one of which is to the right of the partition we have just spoken of, and the other to the left. The lids of these mouth-pieces are secured in the ordinary way by means of luting and cross-pieces. As it is intended that but one of these purifiers should be brought into action at one time, the apparatus is provided with the double mercurial valve A, *Figure* 5, the rod of which being attached to one end of a chain (running over a pulley) at the other end sustaining a counter-balance weight, the gas is allowed to enter into the upper or lower purifier as occasion may require. The valve being so contrived, that when the crude gas is admitted through it into one purifier, it is effectually excluded from the other. It is of considerable importance to the purification of gas by this mode, as well as every other, that it should have effectually undergone the process of condensation, and as the admission of any of the condensible products into the purifier will materially tend to clog it up and to prevent the play of affinities required in this mode of purification, the patentee advises that the pipes conducting the gas from the condenser should rise towards the purifying apparatus. In *Figure* 5 the entrance and exit pipes are exhibited: the latter dip into a square box containing water, into which they are immersed so as to form an hydraulic joint between the purifying apparatus and the gas-holder. This box is furnished with a pipe for conveying off any products which may be condensed after the gas has passed the purifier, and it will of course require another vessel for receiving them, which must be constructed on a plan somewhat similar to the tar cistern, but on a smaller scale.

When this purifying apparatus is to be brought into action, it is to be at such a temperature as we have already stated, not that it is essential towards effecting the purification of the gas, but tending to the preservation of the vessel. This being effected, each compartment thereof is to be half or three-fourths filled with fragments or refuse clippings of sheet-iron, with tinned iron plates, argillaceous iron ore, iron stone, *&c. &c.* It is to be noted, that whatever material may be used in this purifying vessel, such must be arranged in it so as to lie loosely together, in order that the gas may act upon as much of its area as possible, and that the sulphuretted hydrogen and carbonic acid gas may be thereby arrested. Should the black oxide of iron be used in the purifier, which appears to be preferred by Mr. Palmer, the operator should be careful as to the manner in which he disposes of it: always recollecting that a sufficient space should be left at the end of the purifier to allow the gas to pass round the divisional partition.

The purifier being charged with any of the materials as above specified, the lids are to be secured and the valve opened towards the one so charged by raising or lowering the counter-balance weight of the valve, according as the upper or lower purifier may be brought into action. The gas then enters into that compartment of it which is to the left, and passing over the iron, or whatever else may be introduced round the divisional plate, is allowed to pass from the purifier by means of the pipe which is connected to the mouth-piece, which is to the right, into the hydraulic box, and thence by the pipe B to the gas-holder, to be stored up for use as occasion may require.

It is requisite that tests should occasionally be taken, in order that it may be known when the fragments of iron, *&c.*, become inadequate for the purpose of purification. When they are so, the other purifier is to be charged in a similar way, the mouth-piece secured and the valve opened into it, which, as we have before observed, will shut off the communication to that which had been in action. When this is done, let the lids of the purifier which is out of use be removed, so as to admit the atmospheric air into it, the action of which will, prior to the purifier in action being rendered inadequate to perform its office, so far restore the materials to their proper tone, by reducing the sulphuret of iron again to a metallic state, as to allow the change of purifier to be again effected, and the process to be carried on to advantage.

The operator is invariably to follow the mode pointed out, by using his purifiers alternately, till it is ascertained that the iron, or whatever substance may have been introduced, will no longer retain the sulphuretted hydrogen, *&c.* When such is the case, the contents of the purifier must be removed and replaced by fresh material, and the process proceeded upon again, in the manner we have already described.

This mode of purifying has not yet been brought into practice on an extended scale. In the small way it has been proved to perform the office of purification effectually; and, from what it has done there, we cannot doubt of its effect in the large way. Mr. Palmer has recently erected an apparatus at Macclesfield for purifying the gas generated for lighting that town, which is exhibited by *Figures* 3, 4, and 5, *Plate* VIII; but, owing to the works of that place not being in a sufficient state of forwardness to allow of its being brought into use, it had not been tried there at the time this sheet was sent to the press. We are here to observe, that, in situations where there is a difficulty in getting rid of the lime refuse, Mr. Palmer's mode of purifying we apprehend might be adopted to advantage; and, when we consider how often such is the case, we can hardly doubt of seeing it very generally used.

The ideas of explosion being to be apprehended from its becoming leaky, rest on so unstable a basis that it is really astonishing how they could have originated; for, by a parity of reasoning, explosions would daily happen in every gas-light establishment when a retort became burnt through: but, whilst there is a pressure in the retort, or in the purifying vessel, which there always is, the admission of atmospheric air into either is prevented; and, without a very considerable proportion thereof, we know that no explosion can happen.

In concluding this Chapter, we are to observe that when lime in solution is used for the purification of gas obtained from most of the species of

Wallsend coals, a bushel and a half (Winchester measure) or 3225,63 cubic inches of unslacked lime is found sufficient for purifying 10,000 cubic feet; its value, at fourteen shillings the hundred, being about eight pence. In the same proportion must the purifier be charged for either greater or lesser quantities of gas generated. However, as the qualities of coals vary considerably, perhaps no specific quantity can be put down as a general rule. The operator will very soon ascertain the fact, for his tests will prove whether the gas be pure, and he will charge his vessel accordingly.

TABLE

Shewing the Comparison between the Lime Hundred and Winchester Bushel, &c.

A hundred of lime is equal	to 21,696, or $21\frac{5}{7}$ Winchester bushels of 2150,42 cubic inches each.
	to 27 cubic feet.
	to 46656 cubic inches.

Most kinds of quick lime double their bulk by slacking.

CHAPTER XIII.

On the Gas-holder (Gasometer)*; its Construction, and Descriptions of such as would best answer the Purpose of the Manufacturer.*

THE gas-holder (or, as it is more commonly, though improperly, called, the *gasometer*) is that vessel in which the purified gas is stored up for use. It has been of various sizes and shapes: that most generally adopted in large works is from 15,000 to 20,000 cubic feet in capacity. It is a cylinder; the diameter being from thirty-three to forty feet, and the height from eighteen to twenty-three feet.

When speaking of the gas-holder, we are to consider it as composed of two distinct parts: that is to say, a capacious inner vessel, in large works generally made of sheet-iron, which is closed at the top and open at the bottom; and a cast-iron tank or wooden vat of about a foot or eighteen inches greater diameter for containing water, into which the gas-holder sinks as it is emptied of gas, and out of which its lower edge, when full, cannot rise. By this contrivance the gas is prevented from escaping.

PLATE IX.

Fig. 1.

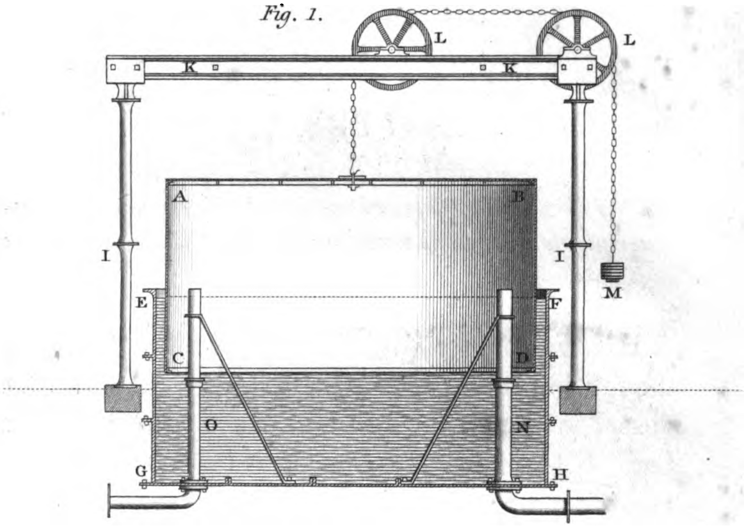
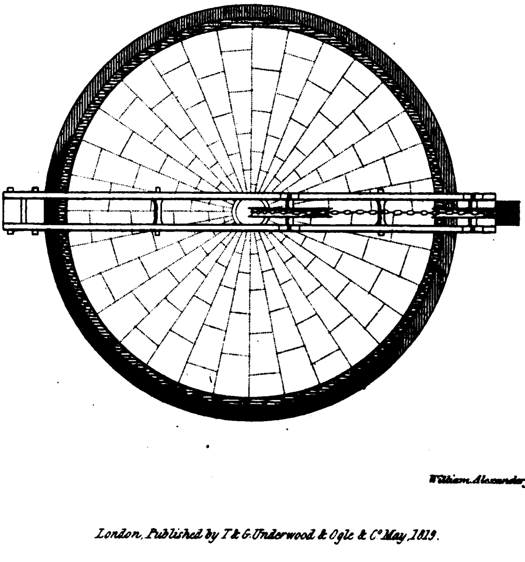


Fig. 2.



William Alexander sculp.

London, Published by T & G. Underwood & Ogle & C° May 1819.

The gas-holder is suspended by a chain over two grooved wheels fixed on a cast-iron frame placed over it; one end of which chain is made fast to an eye-bolt at the centre of the top of the gas-holder, and to the other is attached a frame supporting weights nearly equal to the weight of the gas-holder. It is to be observed, that by putting more weights upon the balance support, or frame, the gas-holder works at a less pressure, and, consequently, does not force the gas into the street mains with such velocity as when the weight is there decreased: for, if the balance-weight and weight of the gas-holder were very nearly equal, there would be little or no impetus for discharging the gas; it would, in consequence, escape with such languor at the orifices of the burners as to afford but a very feeble light. To obtain a good light, the gas-holder should never be worked at less than about two inches' pressure; or, in other words, the surface of the water inside the gas-holder should be about two inches below the surface of the water contained between the outside of the gas-holder and the tank, or vat, in which it is suspended.

If we suppose the tank to be filled with water, and the gas-holder partly filled with gas, we can so adjust the balance-weight as to produce an equilibrium between it and the gas-holder: in that case, the external air will not enter into the gas-holder, nor will the gas therein escape from it. When the balance-weight is so adjusted, the water will be at the same level inside the gas-holder, and between its outer surface and the inside of the tank. But, by diminishing the balance-weight, the gas-holder will, by its gravity, have a tendency to descend; and the greater that tendency may be, so much more will the water descend within it. Under these circumstances, the included gas will be compressed beyond the pressure of the atmosphere in exact proportion to the weight of a column of water whose height is equal to the difference between the surface of the water inside the gas-holder, and the surrounding surface thereof within the tank or vat.

For ascertaining the pressure at which the gas-holder works, a small pressure-gauge may be attached to the top of it, and secured from accident by a wrought-iron case. When, from the gas being turned into the gas-holder, it has risen but a few feet out of the water, the operator, by inspecting the graduated scale on the pressure-gauge, can see what pressure the gas-holder is then working at; and, by diminishing or increasing the counterpoise, or balance-weight, regulate the pressure to what may be desired. One of the uses of the gas-holder is to regulate the emission of the gas towards the burners, which could not be effected without such contrivance,—

the gas being evolved from the retorts in very unequal proportions during the different periods of the distillatory process, as was noticed at page 150.

On considering the matter a little closely, it will appear that the weight of the gas-holder is continually increasing as it fills with gas: for we know that " a body immersed in a fluid will sink " to the bottom if it be heavier than its bulk of " the fluid; and, if it be suspended in it, it will " lose as much of what it weighed in air as its " bulk of the fluid weighs." The case is precisely the same with the gas-holder; for, when the gas first begins to enter into it, its top is level with the water, it will therefore be counterpoised in such situation by a weight that wants as much of the absolute weight of the gas-holder as the quantity of water weighs which is thereby displaced: as the gas is allowed to enter the gas-holder, the latter rises out of the water; and, of course, as it does so, its weight increases: therefore, if the balance-weight be barely sufficient to support the gas-holder, so that it may work at a certain pressure when it first begins to rise; it follows, that, according as it rises, the pressure increases by the increasing weight of the gas-holder. If, then, the gas-holder is worked without some contrivance for regulating the pressure, the quantity of gas it may contain cannot be ascertained; nor can that gas, when admitted to the burners, be uniformly supplied, so as to keep the flame at a stated height during the act of combustion, for when the gas-holder is nearly full, the pressure will be much greater than when it is nearly empty; the consequence therefore is, that the flame will be much longer in the first case than in the last, without a possibility of its being kept uniform. Indeed, if there were not some contrivance in works, conducted on an extensive scale, for keeping the gas-holder at an uniform pressure at all the heights of its rise, the most serious inconveniences would follow.

In the more early stages of this new science, a spiral pulley was adopted for the chain to work on for counteracting the evils attendant upon this want of uniformity in the pressure of the gas-holder. It answered the desired purpose; but, it was clumsy, inconvenient, and expensive. A deviation therefrom was made for gas-holders working on the ordinary principle. The plan was built upon what we have already mentioned, that is to say, "a body immersed in a fluid loses as much weight as an equal bulk of the fluid weighs." It will doubtless appear evident to our readers, that the only mode for effecting the purpose (when gas-holders are encumbered with the specific gravity apparatus) is by increasing the weight which is suspended as a balance over the friction-wheels in a direct proportion with the weight of water displaced by the descent of the gas-holder: and, therefore, as the balance-weight itself remains the same, it must be done by a compensation of weight in the chain supporting it. In short, every foot of the chain should be equal in weight to the weight of water displaced by the gas-holder being immersed to that depth therein. Therefore, if there be given the weight of that part of the gas-holder which is immersed in water when it is out of action, and the specific gravity of the material of which it is composed—the specific gravity of water being known to be 1,000, we can easily ascertain what the weight of chain ought to be that is the same length as the height of the gas-holder by the following

RULE.

As the specific gravity of the material of which the gas-holder is composed, is to the weight of that part of it which becomes immersed in water—when it is weighed in air:

So is the specific gravity of water, to the weight of an equal bulk of water to what the gas-holder displaces—consequently, to the weight of that part of the chain supporting the balance-weight, which is equal in length to the height the gas-holder rises when full of gas.

EXAMPLES.

Given the specific gravity of sheet-iron 7,645, and the weight of that part of the gas-holder, formed of such material, which becomes immersed in water, 861 lbs., to find the weight of that part of the chain of the gas-holder measured downward, from the axis of the wheel over which it passes, which is equal in length to the height of the gas-holder,—and consequently, the weight of water displaced by the gas-holder?

	Spec Grav. of Sheet Iron,		Wt. of Gas-holder in lbs.		Spec. Grav. of Water.		Weight of Chain in lbs.
Say, as	: 7,645	:	861	:	1,000	:	112,6

nearly.

Given the specific gravity of sheet copper 9,000, and the weight of that part of the gas-holder formed of such material which becomes immersed in water, 1,792 lbs. to find as in the preceding example.

	Spec. Grav. of Sheet Copper.		Wt. of Gas-holder in lbs.		Spec. Grav of Water.		Weight of Chain in lbs.
Say, as	: 9,000	:	1,792	:	1,000	:	199,1

nearly.

This matter having, I trust, been made sufficiently clear to the reader, I shall here introduce something on the pressure of fluids, a subject of importance to those who may have to construct tanks, or other vessels of magnitude, for the gas-holder to work in. I am induced to do so from having observed how very frequently *weight* and *pressure* are confounded by those who are not thoroughly acquainted with the laws of Hydrostatics.

PROPOSITION I.

If any part of a Fluid be raised higher than the rest, by any Force, and then left to itself, the higher Parts will descend to the lower Places, and the Fluid will not rest till its Surface be quite even and level;

For, the parts of a fluid being easily moveable every way, the higher parts will descend by their superior gravity, and raise the lower parts, till the whole come to rest in a level or horizontal plane.

Corol. 1. Hence water, which communicates with other water, by means of a close canal or pipe, will stand at the same height in both places. In the same way should a glass syphon be held with the bend part downwards, and water poured into one of the legs, it will pass through the bend and stand at the same height in each of its legs.

Corol. 2. For the same reason, if a fluid gravitate towards a centre; or in other words, if it be received into an inverted cone, it will dispose itself into a spherical figure, the centre of which is the centre of force. Like as the sea in respect of the earth.

PROPOSITION II.

When a Fluid is at rest in a Vessel, the Base of which is parallel to the Horizon, equal Parts of the Base are equally pressed by the Fluid.

For, upon every equal part of the base there is an equal column of the fluid supported by it. And as all the columns are of equal height, by the last proposition, they are of equal weight, and therefore they press the base equally; that is, equal parts of the base sustain an equal pressure.

Corol. 1. All parts of the fluid press equally at the same depth:

For, if a plane, parallel to the horizon, be conceived to be drawn at that depth; then, the pressure being the same in any part of that plane, by the proposition, therefore the parts of the fluid, instead of the plane, sustain the same pressure at the same depth.

Corol. 2. The pressure of the fluid at any depth, is as the depth of the fluid:

For, the pressure is as the weight, and the weight is as the height of the fluid.

PROPOSITION III.

When a Fluid is pressed by its own Weight, or by any other Force; at any Point it presses equally, in all Directions whatever.

This arises from the nature of fluidity, by which it yields to any force in any direction. If it cannot recede from any force applied, it will press against other parts of the fluid in the direction of that force. And the pressure in all directions will be the same. For, if it were less in any part, the fluid would move that way, till the pressure be equal every way.

Corol. 1. In a vessel containing a fluid, the pressure is the same against the bottom as against the sides; or even upwards at the same depth.

Corol. 2. Hence, and from the last proposition, if A B C D (*Plate* I, *Fig.* 2) be a vessel of water, and there be taken, in the base produced, D E to represent the pressure at the bottom; joining A E, and drawing any parallels to the base, as F G, H I; then shall F G represent the pressure at the depth A G, and H I the pressure at the depth A I, and so on; because the parallels F G, H I, E D, by similar triangles, are as the depth A G, A I, A D; which are as the pressures by the proposition.

And hence the sum of all the F G, H I, *&c.*, or area of the triangle A D E, is as the pressure against all the points G, I, *&c.*, that is, against the line A D. But, as every point in the line C D is proved with a force as D E, and that thence the pressure on the whole line C D is as the rectangle E D, D C, whilst that against the side is as the triangle A D E or ½ A D, D E; therefore the pressure on the horizontal line D C, is to the pressure against the vertical line D A, as D C to ½ D A. And hence, if the vessel be an upright rectangular one, the pressure on the bottom, or whole weight of the fluid, is to the pressure against one side, as the base is to half that side: and therefore the weight of the fluid is to the pressure against all the four upright sides, as the base is to half the upright surface. And the same holds true also in any upright vessel, whatever the sides be, or in a cylindrical vessel. Or, in the cylinder, the weight of the fluid is to the pressure against the upright surface, as the radius of the base is to double the altitude.

Moreover, when the rectangular prism becomes a cube, it appears that the weight of the fluid on the base, is double the pressure against one of the upright sides, or half the pressure against the whole upright surface.

Corol. 3. The pressure of a fluid against any upright surface, as the gate of a sluice or canal, is equal to half the weight of a column of the fluid whose base is the surface pressed, and its altitude the same as the altitude of that surface.

For, the pressure on a horizontal base equal to the upright surface, is equal to that column; and the pressure on the upright surface is but half that on the base, of the same area.

So that, if b be the breadth, and d the depth of such a gate or upright surface, then the pressure against it, is equal to the weight of the fluid, whose magnitude is $\frac{1}{2} b d^2 = \frac{1}{2}$ A B, A D^2.

If the fluid be water, a cubic foot of which weighs 1,000 ounces, or 62½ pounds; and, if the depth A D be 12 feet, the breadth A B 20 feet; then the content, or ½ A B, A D^2, is 1,440 feet, and the pressure is 1,440,000 ounces, or 90,000 pounds, or 40⅕ tons weight nearly.

PROPOSITION IV.

The Pressure of a Fluid, on the Base of the Vessel in which it is contained, is as the Base and perpendicular Altitude, whatever be the Figure of the Vessel that contains it.

If the sides of the base be upright (*Plate* I, *Fig.* 3), so that it be a prism of an uniform width throughout, then the case is evident; for then the base supports the whole fluid, and the pressure is just equal to the weight of the fluid.

But, if the vessel be wider at the top than bottom, then the bottom sustains, or is pressed by, only the part contained within the upright lines *a* C, *b* D (*Plate* I. *Fig.* 4.) because the parts A C *a*, B D *b*, are supported by the sides A C, B D; and these parts have no other effect on the part *a b* D C than keeping it in its position by the lateral pressure against *a* C and *b* D, which does not alter its perpendicular pressure downwards; and thus, the pressure on the bottom is less than the weight of the contained fluid.

And, if the vessel be widest at bottom, then the bottom is still pressed with a weight which is equal to that of the whole upright column A B D C (*Plate* I, *Fig*. 5): for, as the parts of the fluid are in equilibrio, all the parts have the same pressure at the same depth; so that the parts within C *c* and *d* D press equally as those in *c d*, and therefore equally the same as if the sides of the vessel had gone upright to A and B, the defect of fluid in the parts A C *a* and B D *b* being exactly compensated by the downward pressure or resistance of the sides *a* C and *b* D against the contiguous fluid. And thus, the pressure on the base may be made to exceed the weight of the contained fluid, in any proportion whatever:

So that, in general, be the vessels of any figure whatever, regular or irregular, upright or sloping, or variously wide and narrow, in different parts, if the bases and perpendicular altitudes be but equal, the bases always sustain the same pressure; and as that pressure, in the regular upright vessel, is the whole column of the fluid, which is as the base and altitude, therefore the pressure in all figures is in the same ratio.

Corol. 1. Hence, when the heights are equal, the pressures are as the bases; and when the bases are equal the pressure is as the heights; but when both the heights and bases are equal the pressures are equal in all, though their contents be every so different.

Corol. 2. The pressure on the base of any vessel is the same as on that of a cylinder of an equal base and height.

Corol. 3. If there be an inverted syphon, or bent glass tube, the legs of which are of different lengths, containing two different fluids that balance each other, or rest in equilibrio, then their heights in the two legs above the point of meeting will be reciprocally as their densities: or,

As the height of one fluid is to the height of the other,

So is the density of the latter to the density of the former:

So, if the longer leg of the syphon contain water to the height of fourteen inches, it will be kept in equilibrio by introducing quicksilver to the height of one inch in the shorter leg; quicksilver being nearly fourteen times heavier than water. If the quicksilver be raised to two inches, it would balance a column of water twenty-eight inches high; and so on.

Since, then, the pressure of fluids of equal densities is directly as their perpendicular heights, without any regard to their quantities, it appears that whatever the figure or size of vessels be, if they are of equal heights, and if the areas of their bottoms are equal, the pressures of equal heights of water are equal upon the bottoms of these vessels; even though the one should hold a thousand, or ten thousand, times as much water as would fill the other. To confirm this by an experiment, let two vessels be prepared of equal heights, but very unequal contents, such as A B (*Plate* I, *Fig.* 6,) and A B (*Plate* I. *Fig.* 7). Let each vessel be open at both ends, and their bottoms D *d*, D *d*, be of equal widths. Let a brass bottom, C C, be exactly fitted to each vessel, not to go into it, but for it to stand upon; and let a piece of wet leather be put between each vessel and its brass bottom, for the sake of closeness. Join each bottom to its vessel by a hinge I, so that it may open like the lid of a box; and let each bottom be kept up to its vessel by equal weights, E and E, hung to lines which go over the pulleys, F and F, (whose blocks are fixed to the sides of the vessels at *b*), and the lines tied to hooks at *h* and *h*, fixed in the brass bottoms opposite to the hinges I and I. Things being thus prepared and fitted, hold the vessel A B (*Fig.* VII.) upright in your hands, over a basin on a table, and cause water to be poured into the vessel slowly, till the pressure of the water bears down its bottom at the side *d*, and raises the weight E; and then part of the water will run out at *d*. Mark the height at which the surface H of the water stood in the vessel, when the bottom began to give way at *d*; and then, holding up the other vessel A B (*Fig.* 6) in the same manner, cause water to be poured into it at H; and you will see that when the water rises to A in this vessel, just as high as it did in the former, its bottom will also give way at *d*, and it will lose part of the water.

The natural reason of this surprising phenomenon is, that since all parts of a fluid at equal depths below the surface are equally pressed in all manner of directions, the water immediately below the fixed part B *c* (*Fig.* 6) will be pressed as much upwards against its lower surface within the vessel, by the action of the column A *i*, as it would be by a column of the same height, and of any diameter whatever; and therefore, since action and re-action are equal and contrary to each other, the water immediately below the surface B *c* will be pressed as much downward by it, as if it was immediately touched and pressed by a column of the height *i* A, and of the diameter B *c*; and therefore, the water in the cavity B D *d c* will be pressed as much downwards upon its bottom C C as the bottom of the other vessel (*Fig.* 7) is pressed by all the water above it.

To illustrate this a little further, let a hole be made at *f* in the fixed top B *c* (*Fig.* 6) and let a tube G be put into it; then if water be poured into the tube A, it will (after filling the cavity B *d*) rise up into the tube G, until it comes to a level with that in the tube A, which is manifestly owing to the pressure of the water in the tube A, upon that in the cavity of the vessel below it. Consequently, that part of the top B *c* in which the hole is now made, would, if corked up, be pressed upward with a force equal to the weight of all the water which is supported in the tube G; and the same thing would hold at *g*, if a hole were made there. And so, if the whole cover or top B *c* were full of holes and had tubes as high as the middle one A *i* put into them, the water in each tube would rise to the same height as it is kept into the tube A, by pouring more into it, to make up the deficiency that it sustains by supplying the others, until they are all full; and then the water in the tube A would support equal heights of water in all the rest of the tubes. Or, if all the tubes except A, or any other one, were taken away, and a large tube equal in diameter to the whole top B *c* were placed upon it, and cemented to it; and then, if water were poured into the tube that was left in either of the holes, it would ascend through all the rest of the holes until it filled the large tube to the same height that it stands in the small one, after a sufficient quantity had been poured into it:—which shews that the top B *c* was pressed upward by the water under it, and before any hole was made in it, with a force equal to that wherewith it is now pressed downward by the weight of all the water above it in the great tube: and therefore, the reaction of the fixed top B *c* must be as great, in pressing the water downward upon the bottom C C, as the whole pressure of the water in the great tube would have been if the top had been taken away, and the water in that tube left to press directly upon the water in the cavity B D *dc*.

After what has been said on the pressure of fluids, it can hardly be necessary to add more.

The things appear so plain, that to give further examples upon them would be but taking up the reader's time without answering any useful end. I am here to observe that the four foregoing Propositions are, in substance, the same with what is given by Dr. Hutton in the second volume of his *Course of Mathematics*; and, that for the experiment to elucidate the equality of pressure in vessels of unequal capacity, but of equal heights, and having bases of equal area, I am indebted to the lectures of the ingenious Mr. Ferguson.—Under the sanction of two names so eminent in their respective writings for perspicuity, addition would be useless,—explanation unnecessary.

It may not, however, be improper again to repeat, that when it is required to construct tanks for gas-holders to work in, it would be running the manufacturer into a needless expense, should the upright plates be made of the same thickness from the top to the bottom. For it has been demonstrated, PROPOSITION III. *Corol.* 2, that in square vessels the weight of the fluid is to the pressure against all the four upright sides as the base is to half the upright surface; that consequently, if a right angled triangle be formed, having double the height of the vessel for its perpendicular, its base being equal to the side of the vessel, lines drawn parallel to that base, at twice such distances asunder as the plates forming the sides of the vessel may be in depth, so as to cut the hypothenuse, will shew the proportional pressure against each, and, consequently, the proportionate thickness of the respective tiers of plates. Should we therefore suppose the base to represent the thickness of the lower tier of plates, say an inch, or any other specific measure, then the parallel lines will be proportionals thereto, and, if measured from the same scale, will shew the thickness of each tier of plates respectively. This mode of ascertaining the strength of plates for forming the sides of cast-iron tanks, whether they should be square, parallelopipedal, or cylindrical, will be found as correct as is required in practice.

But, in cases where it may be thought expedient to erect brick-tanks, the dimensions of the brick-work will vary with circumstances. When a brick tank is sunk into the ground, the lateral pressure of the earth against its exterior will act so as to cause a diminution in the thickness thereof to be effected with safety:—But, when the tank rises above the surface of the earth, should the brick-work be of the same thickness from the top to the bottom, its actual weight must be greater than one-half the weight of water the tank is intended to hold, and so it must be if the base of the brick-work is such as to allow its decrease so as to form a triangular appearance: for, unless the leverage, from the centre of gravity of the wall, be somewhat more than that from the centre of gravity of fluid in the tank, the constructor of such cannot reasonably expect either tightness or durability.

When wooden vats are constructed in lieu of tanks, the same rules will hold good, in many respects, with what we have noticed as to the construction of cast-iron vessels. In the vat, the difference not being so much in the thickness of the staves forming it, as in the greater number of hoops within a certain distance near to the bottom, in proportion to what are requisite within a like distance near the top; but, as the construction of vessels of this description would not be attempted, save by the back-maker, it will be for him to warrant the durability of the vat for some specific period, and then of course he will construct it of such materials and workmanship as will prevent, on his part, any failure in the terms of his contract.

Having given an outline of the principles necessary to be attended to in the construction of tanks, *&c.*, for the gas-holder to work in, I shall give the dimensions of the cast-iron plates for constructing a tank of thirty-four feet diameter, and eighteen feet deep. The plates forming the bottom are segments of circles; these plates are three-fourths of an inch in thickness. The plates forming the sides of the tank are about eight feet in length by six feet in depth. The lower tier are seven-eighths of an inch, the middle three-fourths, and the upper five-eighths, of an inch thick. The breadth of the flanches round each plate is three inches and a half from the inside, and the thickness is equal to the thickness of the plate. In putting this tank together, the joints are made with iron cement and screw bolts, in the way mentioned for jointing flanch-pipes (*vide* Chapter XV. *On laying the Street Mains.*) The screws are five-eighths of an inch in diameter: in the bottom and lower tier they are placed about five inches asunder, in the middle tier six inches, and in the upper one seven. The lowermost tier of plates is generally surrounded by three wrought-iron belts, the middle one by two, and the upper tier by one; these are drawn tight by means of wedges. Between these belts and the side of the tank are placed pieces of wood, rising to the same height with the flanches upon the body of the respective plates, by which an equal pressure upon each hoop is obtained in every part of its bearing. In the course of my observations I have witnessed as many hoops put round a cast-iron tank, as would be required for a wooden vat; but it would be misleading the reader, and an insult to his understanding, were he informed such practice was worthy of imitation. A greater number than what I have just mentioned for a tank of such dimensions, might be profitable to the smith, but by no means so to the gas-light manufacturer.

It will be obvious to the reader that the tank of which I have been speaking is a single vessel; and, therefore, in the construction of single vessels of larger or smaller dimensions, he will be able, from the data and instructions given, to calculate upon the metal it will be necessary to use:—but latterly there has been introduced a kind of cast-iron tank part of which may be constructed of lighter plates. The tank alluded to is formed so as to exhibit its boundary lines in the plan by two concentric circles: the radius of the outer one being about nine inches more than the semi-diameter of the gas-holder: of the inner one about nine inches less. It is only between these that water is introduced for the gas-holder to work in. This species of tank possesses some advantages over the former, especially where water is not very plentiful. In it the interior range of plates will not require to be of so much strength as the exterior; it is a mistaken notion, which leads some persons to suppose that the exterior plates might with safety be made more slight in this, than in a vessel constructed on the ordinary principle, to be entirely filled with water.

Circular-shaped tanks are to be preferred to any other, for various reasons, amongst which the most prominent one is, the uniformity of pressure at equal depths upon every part of their upright surfaces; for, in square tanks, the angular points will, of necessity, be liable to give way; and the making of such, to contain the necessary fluid, will be attended with difficulties which never present themselves in cylindrical vessels.

The next subject presenting itself to notice, is, the construction of gas-holders of such dimensions as are required in large manufactories. Those containing 15,000 cubic feet are generally made of plate-iron (number 16 wire gauge, weighing about 2 lbs. 11 oz. the square foot) rivetted together with quarter-inch rivets, seven-eighths of an inch asunder. When gas-holders of magnitude were first constructed, they were encumbered with either a heavy wooden frame that answered no useful purpose, or otherwise so loaded inside with iron stays as made it necessary to use an immense balance-weight; thus removing one evil by introducing another: but such will ever be the case when we commence upon wrong principles. In machinery of all descriptions the merit of invention rests not so much upon performing a certain purpose as in effecting it by simple and natural means; for, when a man sets out with a wrong principle he is compelled to resort to various expedients to bring it back to something natural; but, in doing so, he generally fails of finding the end he had in view answered. Were we but to profit by the lessons which Nature is ever giving us, we should generally do much better than by trusting to our own powers of judging: for, it is no new observation that in human inventions a thousand movements frequently fail in performing one purpose, whilst in the theatre of nature we find one producing its end whilst it is promoting some other. Experience has now taught the manufacturer that he cannot construct his gas-holder too light. Instead of the cumbrous wooden frame, or weighty iron stays, that vessel consists now of nothing save the plate-iron rivetted together, and one small breadth of angle iron at the bottom and another round the top, inside, for keeping it in form, together with six or eight small rods which project from the eye-bolt by which the gas-holder is suspended, to within about a foot of its circumference. Under this arrangement, the gas-holder is light, and consequently costs much less in the first instance,—it requires a smaller balance-weight, lighter friction wheels and pulleys, and, in short, under all its bearings, it is attended with benefits. In the construction of gas-holders, of which I have been speaking, it is supposed that they are to be suspended by chains over pulleys, and worked by means of balance-weights; but, by recent improvements, the more scientific gas-light manufacturer considers the expensive frame-work, chains, weights, *&c.*, as things not wanted.

To decrease the pressure of the gas-holder, and thereby to prevent the necessity of using balance-weights, it has been proposed by Mr. Clegg to increase the diameter of that vessel. Thus, for instance, were it required to construct a gas-holder capable of containing 15,000 cubic feet of gas; instead of making it thirty-three feet in diameter, and seventeen feet deep, which would weigh about $3\frac{3}{4}$ tons, and, if unencumbered with specific gravity apparatus, would, when full of gas, act at about $1\frac{9}{10}$ inch pressure; were the diameter increased to forty-two feet, it would require to be about eleven feet in depth, would weigh about four tons, and, under similar circumstances with the former, would perform at an inch and a quarter pressure. Indeed, as the diameter of the gas-holder is increased, the capacity being the same, the pressure upon every square inch will be diminished in a similar ratio.

We may ascertain these facts by attending to the following

Rule.

There being given the diameter and depth of the gas-holder, the weight of a superficial foot of the plate-iron, of which it is constructed, and the extra weight for angle-iron, stay-rods, and rivets, to find the pressure at which it will work, supposing it unencumbered with chains, weights, *&c.*

First, find the area of the top by multiplying the square of the diameter by ,7854.

Then, to find the superficial feet arising from its height, say

as 7 : 22, so is the diameter of the gas-holder to its circumference.

The circumference, so found, multiplied by the height of the vessel, gives the number required; to this number add the area of the top of the gas-holder, in superficial feet; the sum will express the number of square feet of plate-iron required for constructing it, less an allowance for the lapping over of the plates.

Multiply the number of square feet of plate-iron required for constructing the gas-holder by the weight of one square foot of the material of which it is constructed, and to the product add the weight of rods, rivets, angle-iron, and an allowance for the lapping over of the joints; the sum will be its absolute weight.

Reduce the absolute weight into ounces, and the area of the top of the gas-holder into square inches, by multiplying each superficial foot by 144.

Divide the weight in ounces, by the area of the top of the gas-holder, in square inches, the quotient will shew the pressure upon every square inch in ounces.

But as we speak in other language, saying the gas-holder works at so many inches' pressure; if we divide the pressure upon each square inch in ounces, by the weight of a cubic inch of water, ,5787, the quotient will express the pressure in inches and decimals of an inch; and, according to this mode of proceeding, the two foregoing results were obtained.

It will appear evident to the reader that under this arrangement the pressure of the gas-holder will not be uniform through all the heights it rises; it will be the greatest when it is full of gas, and the least when it is empty. To counteract this evil it is proposed that the gas, after leaving the gas-holder, should pass through a regulator before it is allowed to enter into the street-mains; by this contrivance preserving an uniformity of pressure upon them and answering the manufacturer's purpose. As I shall hereafter have occasion to speak of the "Regulator," the reader will, in the Chapter thereon, find its description and its various uses noticed.

After what has been already said on the gas-holder I shall give a description of such as have been used, are now in use, and are proposed to the gas-light manufacturer's notice. Square or parallelopipedal-shaped gas-holders appear to have been most used in the very early stages of gas-lighting. The objections against them I have already noticed; I shall not add more here, save that such are now very rarely erected. These were followed by cylindrical ones, but with encumbrances of wooden frames, or heavy iron stays, which so loaded them as to make their action very heavy. After these was introduced a gas-holder on a rotary principle. It was invented by Mr. Clegg, and erected at the Westminster gas works, under his direction. The axis of this gas-holder is constructed of flanch-pipes of ten inches diameter. It is supported at each end by carriages and friction segments, which relieve it from a very considerable part of the friction which might otherwise be expected. From this axis radiate towards the gas-holder a number of iron stays, which, with wooden braces, placed so as to form triangles, obtuse angled at the gas-holder and acute with the axis, tend to give stability to the whole. To these braces and stays the inner circle of the gas-holder is attached. The axis of this gas-holder lying horizontal, it follows that as it is secured thereto by means of the stays and braces just mentioned, it must, as the axis revolves upon its bearings, move with it. If we suppose two concentric circles to be struck, with pencil lines, the one with a radius of ten feet, the other with seventeen, and either divided into four equal parts; then, by drawing lines from one circle to the other, radiating from the common centre, to touch the divisional points of one quadrant, and afterwards with the distances above-mentioned, drawing in ink three-fourths of each circle, so as to meet the radiating lines (the lines in pencil being rubbed out), the figure will represent the end view of the gas-holder, as if the observer stood opposite one end of its axis. The length of this gas-holder is thirty-five feet. The inner and outer circles (a transverse section of which would be exhibited by the figure we have just described) are constructed of plate-iron in a similar way to the ordinary gas-holders; so also are both the ends and the distance between the two concentric circles on that side which is to the left when the gas-holder is empty. The space between these two circles on its opposite side is left open for the purpose of allowing the water to enter into it, so as to shut off all communication between the gas that may have entered and the atmosphere, and for the high pressure gas to exert itself upon in the action of filling.

Before the action of this gas-holder is described, it will be necessary to observe that the axis is open at one end, which is received into a square stuffing-box placed at the top of an upright pipe for conveying the gas from the purifier. About midway of the axis a pipe branches off in the direction of that part which is open, and it is there connected to a bend-pipe of the radius of the outer circle of the gas-holder. This bend is received at the closed side of the vessel, and it is there open; its other end is closed. This gas-holder works in a brick tank constructed so as to form the longitudinal segment of a cylinder, the diameter of which is about thirty-five feet. The depth of the middle of the tank being eleven feet, the water, when it is filled, will rise about six inches above the interior circle of the vessel. At one end of this gas-holder is fixed a grooved ring of eight feet in diameter, its centre being in a line with the centre of the axis: over it runs a chain to which a balance-weight is suspended for the purpose of forcing the gas out of the vessel, when it is wanted for supplying the street-mains. The action of this balance-weight is contrary to that used for vessels working vertically: in the latter, by increasing the balance-weight, the gas-holder works at less pressure—in the revolving gas-holder, should the weight be increased, the pressure will be increased also.

When the revolving gas-holder is first launched, preparatory to being brought into action, the part of it which is open is first immersed in water, and, as the water rises above the inner circle, it is received between that and the outer one. The balance-plates being placed in their situation and all the valves closed, the top of the stuffing-box at the end of the axis is left partly open, the air which had occupied the interior is forced out by this means as the weight causes the vessel to revolve upon its axis, till the side of it which is closed comes to the water's edge in the tank. The stuffing-box is then secured, and the gas-holder ready for receiving the gas. If then the valve, which is placed on the main between the purifier and gas-holder be opened, the gas rises into the stuffing-box, and passing into the axis is thence conveyed by the adjoining pipe and bend between the closed side of the gas-holder and the surface of the water. The pressure between these as the gas accumulates causes the vessel to revolve towards the left till the open side is nearly level with the water to the right. In that situation the gas-holder is full, the valve of supply is then shut, and the vessel remains stationary till its contents are required for use. When such is the case, the valve allowing it to be discharged being opened, the pressure of the balance-weight forces the gas out with the impetus wanted, and, as it empties, it revolves to the right, until the closed side is brought down to the situation it occupied prior to the gas being admitted.

After what has been said on the subject of the revolving gas-holder, it may be thought needless to add more:—I cannot, however, quit the subject without observing that at the early period when this improvement was introduced, it unquestionably outstripped all others for answering the required purpose. The nice adjustment of proportion throughout is such as it would be difficult to improve, for if the distance between the inner and outer circles had been increased, the capacity of the gas-holder would not have been enlarged but at the expense of constructing a wider and deeper tank. The arcs of the circles forming it would have been shortened, and the proportions lost altogether. As it is, a gas-holder of this description for containing 15,000 cubic feet occupies a space of but thirty-five by thirty-four feet. The tank of a cylindrical gas-holder of the same capacity is about thirty-four feet in diameter. The expense of erecting the revolving gas-holder with the tank, *&c.* complete, is not more than two-thirds of what would be required for putting up a cylindrical one. Its action is in all respects as uniform, and it is as little liable to be out of repair. In short, had not the improvements in the gas-holder working vertically enabled the manufacturer to construct it at much less expense than formerly, and when required to double its capacity upon the same base, the revolving gas-holder would before this time have probably been in general use.

Were it required to ascertain the capacity of gas-holders of this description it would be necessary first to find the area of the circular ring or space included between the two concentric circles:—The whole process is exemplified by the following

RULE.

Multiply the sum of the diameters of the inner and outer circles by their difference, and that product by ,7854 for the area of the whole circle: as the end of the revolving gas-holder exhibits but three-fourths of a circle we must multiply the area of the whole circle by 3, and divide the product by 4 for the area of that part—and this quotient multiplied by the length gives the capacity.

EXAMPLE.

Given the length of a revolving gas-holder (forming three-fourths of a circle) 35 feet, the diameter of the inner ring 20, of the outer 34 feet, to find its capacity:—

PLATE X.

Fig. 1.

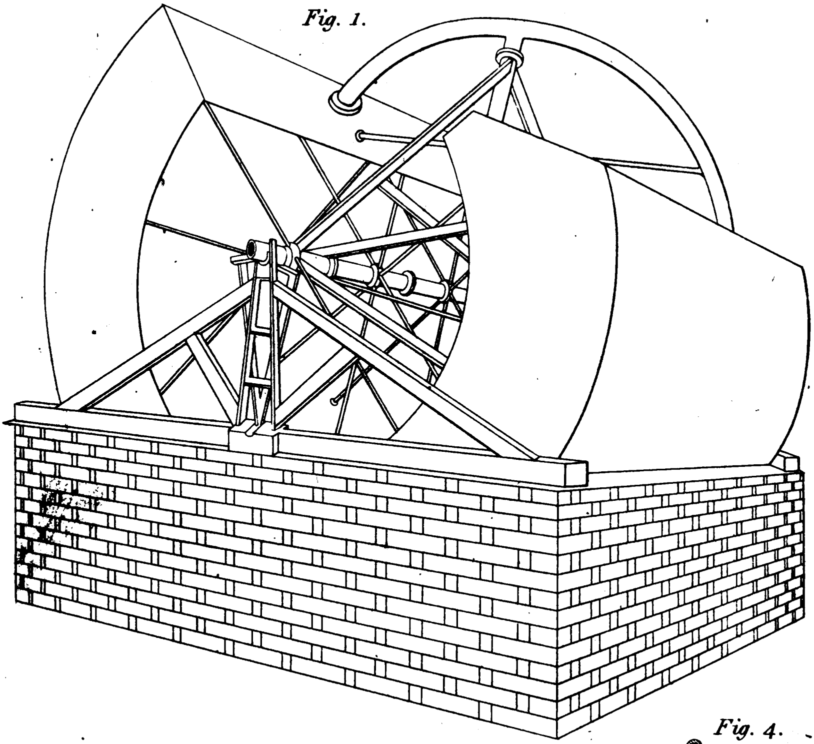


Fig. 2.

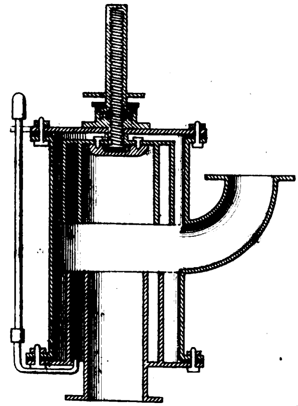


Fig. 3.

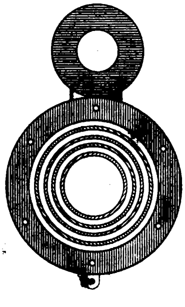


Fig. 4.

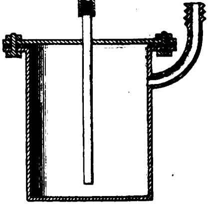
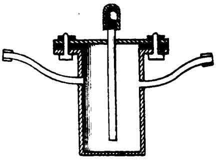


Fig. 5.



William Alexander sculp

London, Published by T & G. Underwood & Ogle & C^o May. 1819.

First 34 + 20 = 54 sum
34 — 20 = 14 difference.

Then 54 × 14 × ,7854 = 593,7624 the area of the whole circle.

And 593,7624 × 3 ÷ 4 = 445,3218 the area of one end of the gas-holder bounded by the two concentric circles, and lines radiating from the axis.

Therefore 445,3218 × 35 = 15586,2630 cubic feet, the capacity of the gas-holder.

Plate X. *Figure* 1, is a representation in perspective of the revolving gas-holder, which being compared with what has been already said on the subject will not require further explanation.

I am now to describe the cylindrical gas-holder. *Plate* IX. *Figure* 1, is a vertical section thereof, and of the tank, *&c.* As the construction has been spoken of, I have here only to notice the particular parts as exhibited. ABCD is a section of the gas-holder, EFGH, a section of the tank, I I, cast-iron flanch-pipes jointed together in the usual way as columns for supporting the frame KK. Upon this frame are placed carriages for bearing the grooved wheels LL, over which runs the chain suspending the gas-holder and balance-weight M. N is the pipe bringing the gas into the gas-holder after it passes from the purifying apparatus. O, another pipe similar to the former, by which the gas is discharged into the mains when wanted for use. It need hardly be remarked that these pipes must rise a few inches above the level of the water in the tank, to prevent a possibility of water getting into them. Upon the horizontal parts of the pipes N and O are placed valves for shutting off the respective communications when the vessel is full, or when it may be desired not to work into it. The Figure represents the gas-holder as if it were about half filled. *Plate* IX. *Figure* 2, represents the plan of the gas-holder just described.

This is the most simple construction of gas-holders for working on the ordinary principle that has hitherto been adopted. I have in some instances witnessed such immense frame-work for supporting the wheels for the chains to pass over, as would leave any engineer at a loss to account for the principles on which they were constructed. Such are attended with great expense, and when put up are neither ornamental nor mechanical.

Mr. Malam, to obviate the necessity of having all this heavy frame-work, proposed to erect gas-holders working with the specific gravity apparatus without it: and, to shew the possibility of doing away therewith, in the spring of 1817, he constructed a model. If we consider the tank and gas-holder to be such as have been just described, the following description will explain his principle. In the centre of the tank he proposed to form a cylinder of about four or five feet diameter, of cast-iron flanch plates, with the flanches inwards, so as to present an even surface outside. This cylinder was to be made tight to somewhat above the height of the tank: it was then to be carried by open castings to above the height that the top of the gas-holder might rise. The top of it was cast with a strong broad flanch, strengthened by vertical flanches underneath it—thereon were bolted carriages for supporting two small wheels in a right line with each other and with the centre of the cylinder. Over these wheels run two light chains, by which the gas-holder and balance-weights were suspended. It will be clear that, under such arrangement, as the gas-holder rose out of the water the balance-weights would descend in the cylinder I have been describing; and, as it would be sufficiently capacious for them to pass up and down in, they would be quite out of the way, which in many cases is a desideratum. The expense of the cylinder would be considerably less than the most common frame could be put up for, and it would answer instead of steadying columns, without which gas-holders working vertically are very liable to swing towards one side of the tank, and, falling out of a vertical position, to hang, or to work very unpleasantly.

In a tank of thirty-five feet diameter and eighteen feet deep, the gas-holder will hold about 15,400 cubic feet of gas, when constructed with the frame-work, *&c.* in the usual way. By Mr. Malam's arrangement, should the gas-holder be made of the same diameter, having a cylinder of five feet diameter for the balance-weights to work in, it will still contain 15,000 cubic feet, so that its capacity is not thereby considerably lessened. By it the first cost of erecting a gas-holder of 15,000 cubic feet capacity will be decreased 200 or 250*l.* It will, of course, require that the gas-holder should in this case be made so as to exhibit in the plan two concentric circles: one of which would be the diameter of the gas-holder, and form its sides—the other, or interior, that which clipped round the cylinder, and of so much greater diameter as would allow it to slide up and down upon it freely. It would be rivetted to the top of the gas-holder in the same way as the outer one, and made firm by one piece of angle-iron going round its top, and another round the bottom.

But this gentleman, on pursuing his inquiries still further, proposed to work the gas-holder without using chains or balance-weights; yet in such a way as to have the pressure uniform at all its heights; and, to exemplify the possibility of the thing being effected, he constructed models of different dimension. By describing *Figure* 1,

PLATE XI.

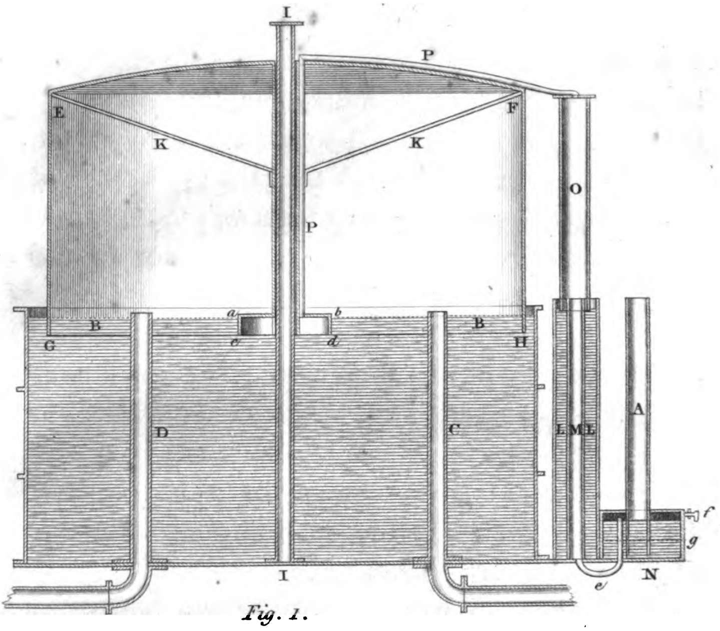


Fig. 1.

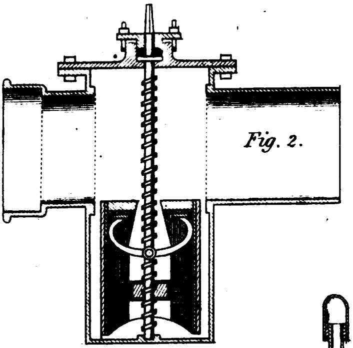


Fig. 2.

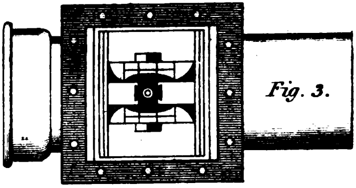


Fig. 3.

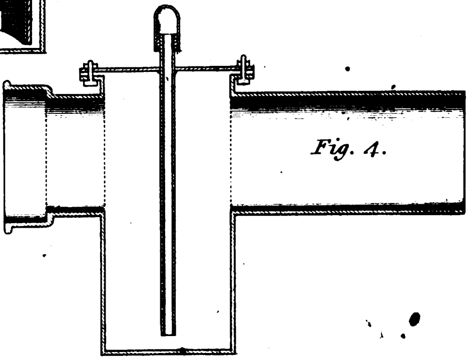


Fig. 4.

William Alexander sculp.

Pub. by T. & G. Underwood & Ogle & Co. May 6. 1819.

Plate XI, which is a vertical section of this gas-holder, the reader will understand the principles on which it is constructed so clearly as to render it quite familiar. The tank for this gas-holder is in all respects similar to that used for others which work vertically. It is filled with water to the height expressed by the dotted line B B. C is the pipe which brings the gas into the gas-holder, and D the pipe of exit therefrom. The gas-holder E F G H, when of 15,000 cubic feet capacity, is constructed of No. 16 wire gauge plate iron. It is concave-shaped at the top, in order that if it should be erected in the open air, no lodgment of water, *&c.*, may remain upon it so as to increase the pressure. From the centre of the bottom of the tank rises a cast-iron column I I, of about thirty-five feet in height; this acts as a guide for keeping the gas-holder in a vertical position, which is effected either by a pipe (whose inner diameter is about half an inch more than the outer diameter of the column) bolted to the top of that vessel inside, and braced to the upper edge thereof by a sufficient number of rods as K K, or, otherwise by a tube of plate-iron of the same dimensions secured in a similar manner. At the centre of the bottom of the gas-holder is placed an air-vessel *a b c d*, constructed of plate-iron, the top of which is to be situated at such a height as to be level with the surface of water in the tank when the

107 cubic feet of water is equal to 107000 ounces,
or to tons 2 19 2 13.

Then tons 3 15 0 0.—Tons 2 19 2 13 =
Cwt. 15 1 15 or 27568 ounces.

27568 ÷ 1000 = 27,568 cubic feet, the capacity of the air-vessel.

27,568 ÷ 1 = 27,568, the area of the base of the air-vessel in square feet.

To find the diameter, say

As 355 : 452 : : 27,568 : 35,1, the square of the diameter.

$\sqrt[2]{35,1} = 5,92$ nearly,—

therefore, for a gas-holder of the dimensions and weight as above given, and working at inch and half pressure, it would require an air-vessel one foot deep and five feet eleven inches in diameter.

A vessel of the size just described would be sufficient so to buoy up the gas-holder when full, as to allow it to stand at a certain pressure; but as it descends into the water in the action of discharging its contents, its weight would decrease from the circumstances explained heretofore, when speaking of gas-holders working by weights and chains; therefore, unless the air confined in the vessel could in some way be disposed of, the pressure would be continually changing. To obviate this difficulty, Mr. Malam proposes the following appendages to the gas-holder. A pipe L L of eight inches diameter, equal in height to the height of the tank, enclosing within it another pipe of the same height of two inches diameter, marked M in the figure. From the pipe M there is a communication to the vessel N by means of the small bend-pipe *e*, which rises to nearly the top of that vessel. Through the top of the closed vessel N is brought the vertical pipe A, which descends nearly to its bottom and rises to a height equal to that of the tank of the gas-holder. This pipe is of such a diameter as to make it equal in capacity to the water displaced by the gas-holder when quite down.

In forming rules for calculating the capacity of the compensating pipe A, and the vessel N, we proceed as follows:—

First, find the circumference of the gas-holder thus, as 7 : 22 : : the diameter to the circumference:—then multiply the circumference by the depth of the gas-holder, and that again by the weight of a square foot of the material of which it is to be formed, adding the necessary weight for rivets, and the weight of that part which will be immersed in water will be known.

To find its bulk, say

As the specific gravity of the material of which the gas-holder is composed
Is to the weight last found reduced into ounces
So is one cubic foot
To its magnitude in cubic feet.

This magnitude divided by the height of the pipe A, will give the area of its base. The diameter of which may be found by the rule already given for finding that of the air-vessel.

EXAMPLE.

Given the diameter of the gas-holder 33 feet, the depth to which it is immersed in water 17 feet, the weight of a square foot of the material of which it is formed (plate-iron) 2 lbs. 11 oz.:—its specific gravity being 7645—to find the diameter of the compensating pipe A, its height being 17 feet:—

First: as 7 : 22 :: 33 : 103,7 the circumference
103,7 × 17 = 1763 nearly.

Then 1763 × 2 lbs. 11 oz. = 4838 lbs., to which, if we add 762 lbs. as an allowance for rivets, *&c.*, we have 5600 lbs., or 89600 ounces, for the weight of that part of the gas-holder which becomes immersed in water.

To find its bulk, say

As 7645 : 5600 :: 1 : 11,72 cubic feet nearly.

11,72 ÷ 17 = ,69 (nearly) the area of the base of the pipe in question.

For the diameter,

As 355 : 452 : ,69 :: ,8785 the square of the diameter

$\sqrt[2]{,8785} = ,937$ or 11¼ inches nearly.

Therefore the compensating pipe for such a gas-holder would require to be 11¼ inches in diameter.

As the vessel N is connected by the bend *e* to the upright pipe M, and that to the air-vessel by the pipe O (which rises and falls with the gas-holder between the pipes L and M, the space being filled with water so as to form an hydraulic joint) and the small pipe P P, which runs along the top of the gas-holder, and from its centre descends into the air-vessel, it will be evident that if this gas-holder be brought into action, it must be prepared for use in the following manner. We will suppose the gas-holder to be down in the tank, which is filled with water. The pipe L L is also filled with water to within a few inches of the top. Then into the vessel N let water be poured by means of the upright pipe A till it runs out at the cock *f*, that cock being situated at such a height as will indicate when, by pouring in more water, it would descend into the bend *e*. Things being thus prepared, attach the condensing apparatus to the cock *f*, which is fitted with a screw for receiving it, and inject air till such time as the water from the vessel N rises to the same height in the pipe A as it is in the tank of the gas-holder. When such is the case, part of the vessel N from the top to the dotted line *g* will be filled with air, as will also the bend *e*, the pipes M and O, and the small pipe P. Whilst this is performing, it is evident that the air will be thrown into the air-vessel, for if we suppose the water to have risen to the same level in the pipe A that it is in the tank, there must be the same pressure upon the air in the vessel N as in the air-vessel *a b c d,* and the air will be equally condensed in each. But the air-vessel will not then be filled with air, it must be considered under like circumstances with a vessel of any sort inverted into water. If a vessel be pushed or let down to any depth in that fluid, then by the pressure of the water some of it will ascend into the vessel, but not so high as the water without, and will compress the air into less space according to the difference between the heights of the internal and external water. Should the tank be about thirty-four feet in depth, the air-vessel would, with such pressure, have the weight of two atmospheres upon it, and the air therein would be compressed into one half the space it would occupy when the gas-holder had risen to its greatest height, and the top of the air-vessel was level with the surface of water in the tank. This compression would in a similar ratio be increased or diminished with a greater or lesser depth. Considering these points, it follows that the capacity of the vessel N must be such as to contain a sufficiency of water for filling the pipe A between about two inches below the top of the bend *e,* and as much above the bottom of the pipe A, when the gas-holder is worked at inch and half pressure. The cock *f* being shut, and the condensing apparatus removed, if gas be allowed to enter into the gas-holder, the vessel will be caused to rise in the tank, and as it rises the column of water in the pipe A is depressed, and the air out of the vessel N passes into the air-vessel *a b c d*, thus increasing the buoyancy of the gas-holder in proportion to its rise till it has attained its greatest height, and then all the air has been discharged from the vessel N into the air-vessel. This contrivance is well adapted for keeping up a regularity of pressure, and so simple is the mode that it may on all occasions be recommended.

There have not been wanting other contrivances for working gas-holders by means of air-vessels, amongst the rest a patent was obtained by Mr. Perks for one of this description; but, on his plan, the air-vessel was closed, and attached to the interior of the lower edge of the gas-holder. It was so constructed, as by the opening and shutting of valves to increase or diminish the pressure, by the admission of water or by letting in of air.

Another patent was obtained on the 23d March, 1819, by Mr. John Outhett, residing at No. 10, Vauxhall Terrace, Lambeth, for a gas-holder working with air-vessels. His plan differs from both the former. The vessel for giving buoyancy to the gas-holder, being constructed of strong materials, is closed, and the air in it condensed to a very considerable degree, whilst the other, which answers for the compensating apparatus, is open. Both these vessels are placed a little above the céntre of gravity of the gas-holder.

Mr. Outhett was led to adopt this plan from having ascertained, by actual experiment, that the buoyancy of air is in an exact proportion with its bulk, and not to its quantity; or, in other words, that in vessels of the description of which I am now speaking, if ten cubic feet of uncompressed air will sustain a body in a fluid, it would require the same number of cubic feet of compressed air to sustain the same weight. As, therefore, the air admitted into his open air-vessel, when the gas-holder is at its greatest rise, would fill it, it would be compressed gradually in its descent, and thus compensate for the loss of weight arising from the immersion of the gas-holder, by this means preserving an uniformity of pressure at all its heights. This contrivance is, perhaps, the best that could have been adopted for answering the purpose; and when the mechanical arrangement is considered it proves the inventor conversant with those branches of science which ought always to be known by such as take a leading part in the management of gas-light establishments.

In addition to the list of gas-holders is one of Mr. Clegg's invention, with a very shallow tank into which the lower edge is immersed. This gas-holder occupies a greater area of base than such as have already been mentioned. When it is full of gas the end view is represented by an equilateral triangle, the bearings being from the angle opposite to the base. This gas-holder is so constructed that the sides have a tendency to close with each other, and therefore when the valve of supply is opened, such tendency expels the gas. In this gas-holder it is evident that some part of each end must be constructed of flexible materials. It is known to the gas-light manufacturer by the term "Collapsing Gas-holder."

Were all the different kinds of gas-holders which have been proposed to the notice of the manufacturer to be mentioned, it would take up much time, and answer no useful purpose. Enough has been said on those most likely to answer the views of the manufacturer, and it will be for him to judge of thei rrespective merits, and adopt for use that which he may think the best. In concluding this chapter, however, I consider it right to submit to the manufacturer's consideration a mode for doubling the capacity of the gas-holder without increasing the dimensions of the original tank. In works where it is requisite to turn the ground to account (particularly when the demand for light has increased beyond the expectations of the manufacturer) this mode will be found worthy of attention.

Mr. William Stratton, of Gutter-lane, Cheapside, has obtained a patent for this invention. The tank he proposes is formed of two upright ranges of plates at about two feet asunder, connected together by plates at the bottom. When this tank is filled, it forms a ring of water into which the gas-holders dip. The arrangement requires two gas-holders, of which more will be said hereafter. The tank is supported by brick piers, within the interior circle of it is left a space equal to its diameter, which may be used for the reception of castings or other heavy stores. The entrance and exit pipes to gas-holders constructed on this principle, are situated between the inner and outer rings forming the tank, and rise between the two gas-holders, which are bulged out for the purpose. At equal distances round the tank are placed four columns for supporting a semi-circular-shaped frame. Upon this frame are placed two carriages for supporting grooved wheels, over which the gas-holders are suspended.

For a tank of eighteen feet in depth, the outer gas-holder will be about thirty-five feet deep, and the inner one about seventeen feet six inches. At the centre of the top of the outer gas-holder is a stuffing-box through which is introduced a cast-iron pipe of about three or four inches diameter, with a flanch at the bottom, by which it is bolted to the top of the inner gas-holder. To the upper end of the same pipe is fastened the chains passing over the grooved wheels just mentioned,—the other ends of which are attached to the top of the outer gas-holder. Such being the case, it follows that the interior gas-holder acts as a balance-weight to the exterior and *vice versâ.*

If we suppose this double gas-holder to be empty, it will be evident that the outer one will be about seventeen feet and a half above the tank, and the inner one very nearly the same height. If, then, gas be allowed to enter, the outer gas-holder will rise, and, as it does so, the inner one must, of necessity, descend; because they are connected together by means of the suspending chains, and therefore the inner one will sink as much as the other rises:—so that when the outer one has risen seventeen feet and a half, the inner one will have descended through a like space, and then there will be a space of thirty-five feet between the outside of the top of the inner and the inside of the top of the outer, and this space will be occupied by gas, thus giving nearly a double capacity to the vessel acting in the same tank as when a single gas-holder is used. The centre supporting pipe which has been mentioned, is open both at the top and bottom, so that when the double tank is used there cannot be any apprehension of a lodgment of gas beneath the lower gas-holder, as from its levity it will be sure of escaping through this pipe should there be any leak in the vessel.

In using this gas-holder, the compensation is well effected and the pressure is regular at all its heights; for, by considering the nature of the arrangement it will be evident that as one vessel rises the other descends; so that if it is constructed to work at a given pressure at one height, it will be so at all others.

It may be asked, what advantage is gained by the manufacturer constructing gas-holders of this kind, beyond that of saving room? To which I reply, that the reservoir is constructed at a less expense than when single vessels are used: for, the inner range of tank-plates do not require to be cast so heavy, nor do they form so large a circle, whilst one entire bottom and a very considerable part of another is saved. With respect to the gas-holders, it may be said that, except one top, there are three used for performing the work of two; but it must be remembered that the expense of a gas-holder, when complete, bears but a small proportion to that of the tank, so that after all there is a saving of expense. However, it is to be understood that the gas-holder now spoken of is more particularly recommended for works where gas-room has fallen short, than for these which are but beginning, and where the manufacturer can take precautions against it.

CHAPTER XIV.

On various Kinds of Valves, Syphons, and Tar-Wells.

THE necessity of adopting effectual means for shutting off all communication between the gas-holder and street-mains, as well as from one ramification of main to another, suggested the propriety of introducing valves upon the line of main-pipes. Those originally used by the gas-light companies were slide-valves, similar to what are used by the water companies; but, such have now been long out of general use, and hydraulic, or pneumatic, valves, or combinations of both, have supplied their place. The valve seems to have undergone more changes in its structure than almost any other part of the gas-light apparatus; it appears to have been within the reach of most men, and, according to the abilities exerted it has been altered. In some cases, change appears to have been the sole object in view, for alterations which did not lessen the expenses of construction, decrease the dimensions of the valve, or render it more effective, could not be termed improvements. In far the greater number of valves which I have noticed, these defects were easily discernible.

The first species of hydraulic valve was that of a square box, to one side of which was bolted a flanch socket, and to the other a pipe (somewhat similar to the ess pipe) which came beneath the bottom of the box, and rose through it to the height of about six inches. If it be supposed that water is introduced into this valve to within about an inch of the height to which the pipe rises, it follows that, should the cup be let down over it, the gas would have to blow through the column of water therein before it could pass through. If, then, the gas-holder were worked at two inches' pressure, and the depth of water and cup were six inches, it would not be probable that the valve would fail in its operation.

For lowering or raising this cup a spindle descended through the top of the valve, a stuffing-box being placed there to prevent the escape of gas; this spindle passed through the top of the cup, to which it was attached, and by means of a screw, below the stuffing-box in which it worked, the cup was lifted or lowered as occasion required. It is evident, as the gas passes through the pipe which enters at the bottom of the valve, that when the cup is lowered the passage to the exit (or flanch socket) at the side is shut off, and that when the cup by means of the spindle is lifted a passage is effected.

The great objection to the use of this valve does not appear to be against the principle but the construction; for, had the spindle been made stouter, and screwed with a strong square thread, the complaints arising from its use would perhaps never have been heard of: but, on examining the small diameter of the spindle and the fineness of the screw, it will not appear at all surprising to find the thread strip, or the screw become so rusted, as to render it immoveable. Under such circumstances the valve was no longer useful: if the cup was down it could not be lifted, and if up it could not be lowered. This valve had, however, a decided preference over others which have, in some instances, been substituted in its place. It was not near so large, and consequently was not so expensive:—it was more easily laid down, and unquestionably more adapted for general use. Of all the preposterous castings that could have been thought of, there could hardly have been one more out of the way than that which superseded the single hydraulic valve. It was thrice the dimensions, price, and weight, of the former for pipes of the same diameter, and more than double the size and price of others which would have been equally effective.

It will not be necessary to take up time in describing all the various kinds of valves which have been and are now used: I shall describe but two, namely, an hydraulic and a pneumatic valve;

the former being well adapted for use in the manufactory, and the latter for the street-mains. *Plate* X. *Figure* 2, is a vertical section of an hydraulic valve, invented by Mr. Malam, which is particularly useful in the connexions about the purifying vessels, and on the works. This valve is cylindrical, flanched at top and bottom, and cast with a flanch quarter bend projecting upwards from one side, of the diameter required. At the bottom is bolted a double cup, which rises to the height of the lower part of the bend just mentioned. Through the centre of this cup is an opening of the same diameter with the bend. This centre part projects a few inches below the bottom of the valve, and is furnished with a flanch for jointing it to the pipe by which the gas is brought into it. Through the bottom of the valve is brought a bend of wrought-iron tube, as expressed in the figure, which is connected to an upright pipe of the same material, rising to the top of the valve, for introducing water into the double cup. The top of this supplying pipe is covered with a cap, which is screwed on, save when it may be necessary to furnish a supply of water. The top of the valve is covered with a blank flanch, which is jointed and secured thereto by screw-bolts in the usual way. At the centre of the top is fixed a stuffing-box, the bottom of which is tapped for receiving the square thread lifting-screw. This screw is surrounded by a wrought-iron case with a thread inside for receiving it. The case is moveable in the stuffing-box, and of sufficient height to allow the lifting-screw to rise to the greatest height that may be required. It is furnished with two handles, which with it serve as a wrench for raising or lowering the screw. The bottom of this screw is secured to a double inverted cup, as shewn in the figure, and therefore that is lifted or lowered with it. The inverted cup is so constructed, as when let down to fall between the two circles forming the lower one, and thus; if we suppose the bottom cup to be nearly filled with water, and the upper one immersed into it, it follows that the valve so constructed is capable of sustaining double the pressure of that which is constructed with but a single cup, and under such arrangement it will not occupy more than half the room of the former to be equally effective.

It may be worthy of remark, that the objections to the sufficiency of this valve have been most fully answered by eighteen months' experience. The action and counter action of the inner and outer of the lower cups being reciprocal between each other, as must appear evident on examining the figure, renders it altogether safe. *Plate* X. *Figure* 3, is a plan of this valve, which, from what has been said, does not require further description.

Plate XI. *Figure* 2, is a vertical section of Mr. Malam's pneumatic valve, which, from the stuffing-box at the top, to the step for the spindle at the bottom, is somewhat more than twice the diameter of the main on which it is to be used. Thus, for instance, from the top to the bottom inside of a fourteen inch valve of this description, will be about three feet, and in a similar proportion for smaller or larger ones. The body of the valve is square, as shewn in the plan, a few inches from the top of which is at one side a socket, and in a direct line with that is placed at the other side a spigot, in order that it may be introduced into the range of main-pipe as necessity requires. The inner faces of the socket, as well as spigot, project about an inch inward, and require to be chipped and filed so as to present perfectly plane surfaces. Through the top of the valve, which is fitted with a stuffing-box, is introduced the spindle, in such a way that the lower end of it rests in the step at the bottom of the valve, and the boss beneath brass couplings, or a collar in the bottom of the stuffing-box. So that when the stuffing-box is fitted, and the glan bolted down, should the wrench or key be applied to the square top of the spindle, it will turn freely round but without being raised. If we then suppose the valve to be open, as shewn in the figure, there will rest upon the bottom two wedge-shaped pieces with their points downwards, and between them the frustum of a square. The spindle passes through the latter, which is fitted with a screw for receiving it, and it is thereby raised or lowered, and the valve shut or opened. Upon the centre-piece, at a convenient distance from the top, is bolted a spring, which is also connected to the side-pieces, so as to act between the top of them and the fastening bolt. In its natural position it has a tendency towards drawing the side-pieces together, and of pushing the middle one downwards. This contrivance allows the three pieces to be lifted together, without being rubbed against the inside of the valve, till the outer pieces touch the top. The further ascent of the outer pieces being then arrested, the middle one continues to be raised by the screw till they are completely wedged up against the interior of the socket and spigot. And as these wedge-shaped pieces are faced with cork or leather, the pressure can be carried to such pitch as effects an air-tight joint upon each, thus effectually preventing the passage of the smallest portion of gas. When the valve is in such position, the spring will be elongated horizontally, and so remain till the screw is turned for lowering the interior pieces, when it again resumes its former form, and thus draws the side-pieces towards each other, and pushes the middle one downwards. *Figure* 3, *Plate* XI. is a plan of this valve. It exhibits the flanch to which the top is bolted, the socket and spigot shewn in the former section, and the top of the inner pieces with the facings of cork. That this is an effective and simple valve, appears evident from barely inspecting the figure. It is of small size, and can be got up at a very trifling expense, when compared with others more generally adopted.

To say more on the subject of valves here is not to the purpose. I cannot, however, refrain from making the following observation; namely, that, though amongst the numerous kinds of valves which I have noticed, many have betrayed great want of talent in the contriver, yet there are, at the same time, several, evincing from their arrangement not only mechanical ability in the inventor, but very considerable ingenuity, and such might be used to good purpose.

Having said thus much on the subject of valves, the next thing presenting itself to notice is " the Syphon," but why so called I could never learn. Indeed, the gas-light manufacturer's vocabulary appears to have been arranged without set rules for naming any thing, or why call a vessel for receiving the condensations from the main pipes by such name; or another, rather different in shape, but used for the same purpose, " a tar-well." In other sciences, the word chosen for expressing the name of a thing conveys the idea of what is meant, and could hardly be mistaken if used in any language. Here the reverse is the case; for, should we mix in company with men unacquainted with gas-light machinery, and talk about syphons and tar-wells, as if in the manufactory, not one in a thousand would have an idea of what was meant, nor is it likely they should.

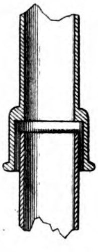
Syphons are of two kinds: the larger sort are distinguished by their diameters, two, three, or four inches, *&c.*, syphons; the smaller, which are used on the service-pipes, are generally termed "gun-barrel syphons," or "bottle syphons." The shape of the vessel itself is similar in each case, but the furniture and use are different. The larger sized syphon is a cast-iron cylindrical vessel of about a foot deep, and of the diameter inside agreeable to its distinguishing name. It is flanched round the top, and to this flanch is bolted a blank flanch. Through the centre of the blank flanch a hole is drilled and screwed for receiving a piece of wrought-iron tubing which descends nearly to the bottom, and projects a few inches above the top. Another piece of similar tubing is bent and screwed also into the top; thence, rising nearly perpendicular, it is connected to the bottom of the main-pipe, from whence the water of condensation descends by it into the syphon. This is occasionally removed by means of a portable pump, which screws upon the upright wrought-iron pipe for the purpose. *Figure* 4, *Plate* X. represents a vertical section of this syphon.

The gun-barrel syphon is, in shape, nearly similar to that just described, but its dimensions are much smaller; namely, about eight inches deep, and four in diameter. Through the blank flanch at the top is introduced a piece of wrought-iron tube descending nearly to the bottom, generally called "the suck-pipe." On each side of this syphon is a piece of wrought-iron tube, bent as shewn in the figure. This syphon is used upon the service-pipe to answer a like purpose there to what the larger one is employed for upon the street-mains. *Figure* 5, *Plate* X. is a vertical section of the gun-barrel syphon.

Figure 4, *Plate* XI. is a section of the tar-well. On referring thereto it will be observed that it is a cylindrical vessel of about ten inches diameter inside, by twelve inches deep, when used upon all mains of less than ten inches diameter; but, when it is used upon larger mains, the diameter of the body of the tar-well must be about two inches greater than the diameter of such main. This vessel is cast with a socket at one side, and a spigot at the other, similar to those of the pipes with which it is to be used; therefore, a tar-well with a socket and spigot, similar to a two-inch pipe, is called a two-inch tar-well, one for a three-inch pipe, a three-inch tar-well, and so on.

From the condensation which takes place in the main, it is found necessary to lay the large pipes, as well as the smaller, or service-pipes, with a small declination; in order that the condensations may, from the inclined position descend to the lower parts, and there the syphons and tar-wells are placed for receiving them. Over each of these vessels is placed a wooden block, bored out at the centre, and fitted with a cast-iron bush and lid at the top, for the purpose of unscrewing the cap of the suck-pipe, and connecting the pump when that is required to be used.

PLATE XII.



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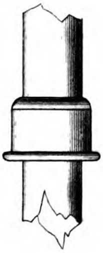

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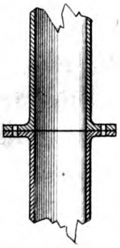

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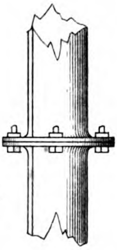

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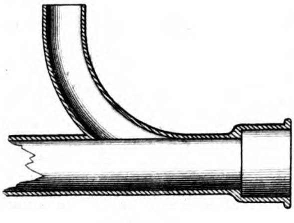

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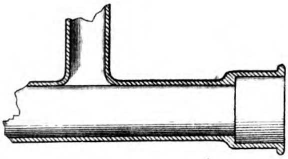

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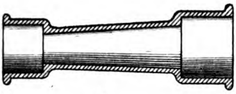

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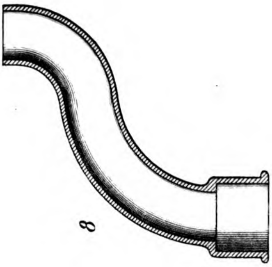

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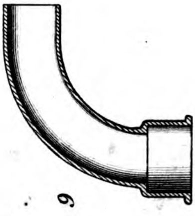

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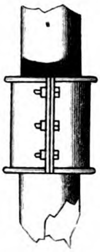

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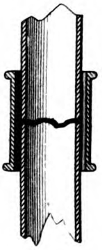

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William Alexander sculp.

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CHAPTER XV.

On the laying down of Main-Pipes in the Streets, the Arrangement of Diameters, and Remarks thereon.

HAD not some cases presented a great want of attention in the mode of arranging the street-mains, I should not have considered it necessary to have written on the subject of laying them down. It would strike the most superficial observer, as contrary to reason, were he to observe a water-pipe of two inches bore laid for supplying one of six or eight inches diameter, and the latter another of still greater. But, absurd as the system may be, a similar one has been resorted to for laying the street-mains from some of the gas-light establishments. We can only account for it from considering that the formation of the principal establishments was at a very early period of the science, when the extensive range of main-pipes which are now laid could hardly be contemplated.

A very few years ago, had any one advanced, as his opinion, the possibility of lighting, from one gas manufactory, a combination of streets of many miles in length, he would have been looked upon as little better than a madman. Indeed, when the gas was first conveyed to the distance of about half a mile from the manufactory it was considered as a wonderful performance. At that time, a gas-holder of twenty thousand cubic feet capacity was held up for admiration: but, such have been the rapid advances in the science, we now talk of those that are of twice the capacity as of things with which we are quite familiar.

A more just, and, at the same time, striking, exemplification of the mode of arranging the street-mains can hardly be found than by comparing their various ramifications to the veins in the human body. In it, those which are near the heart are of large diameter; but, as they branch off, they decrease in size, till, at the extremities, they become so fine as hardly to be perceptible. The arrangement shews the wisdom and goodness of the Contriver, and reads us a lecture, from which, even on such a subject as this, we can gather information. We can easily perceive that the arrangement is good, although in our practice we frequently forget to benefit from those hints which Nature is ever giving us. They are overlooked from being common.

In the business before us, the first object that the operator ought to contemplate should be the whole range of streets that he intends to light from his manufactory. He should furnish himself with a plan of them on a large scale. He will next ascertain, as near as possible, the probable number of lights required in each street, and their descriptions. From thence he will gather the quantity of gas to be supplied for one hour's consumption; and, consequently, for any other specific period. These points being established, he will naturally cause the first range of mains, laid down from the works, to be of such diameters as to give areas equal to all the pipes which branch immediately from them: and he will, when it is practicable, let his pipes branch off with a curve in preference to a right-angle; At the same time, he will bear in recollection that should he lay down a ten-inch valve, for supplying a fourteen-inch main-pipe, he can hardly expect that main to fill easily unless he increases the pressure of the gas-holder.

It may be considered as a general rule which should never, in practice, be deviated from, that the supplying valve be, in capacity, equal to the pipe proceeding from it. When such is not the case, the gas meets with an obstruction which is more particularly felt when the mains are to be first filled; and which operates more or less, according to circumstances, ever after.

The pipes branching off from the largest size of main admit of such a number of smaller ones being connected with them as are jointly equal in area to the supplying ones, and those of still is a thing which is also to be considered; for, if that be not in proportion to the diameter of the pipes, it can hardly be expected that there will be sufficient support between them. If we suppose the surface of the spigot end of one pipe, and the inside of the adjoining socket to form concentric circles, the distance between them, as well as the depth of the sockets for pipes of from two to eighteen inches diameter is exhibited in the following

TABLE.

Inner Diameter of the Pipe in Inches.	Space to be allowed for lead to form the joint.	Depth of the Socket in Inches.
2	⅜ of an Inch.	2½
2½	⅜ ”	3
3	⅜ ”	3
4	½ ”	4
5	⅝ ”	5
6	¾ ”	6
7	⅞ ”	6
8	1 Inch.	6
9	1⅛ ”	6
10	1¼ ”	6
12	1½ ”	7
14	1½ ”	7
16	1½ ”	8
18	1½ “	8

The centres of the adjoining pipes must be brought into a line, by means of the gasket first used, before the lead is attempted to be introduced; for, should such precaution not be taken, the body of lead will not be equal throughout, and, consequently, more liable to become leaky than when the joints are made in a workmanlike manner.

Roman cement has recently been adopted for making good the joints of socket-pipes, and, as far as tried, is found to answer the purpose. In making the joints, according to this method, all that is required is, to bring the centres of the adjoining pipes into a line; and then to introduce the cement, just mixed, between the socket and spigot, by means of a blunt instrument forcing it up, so as to entirely fill the cavity. The property of this cement is such as to cause its bulk to be increased by drying; consequently, it is forced into the pores of the iron, and gives that compactness which effectually forms the joint. It has been proved, by experiment, that cast-iron pipes, thus connected together, are less liable to be broken at the joint than in any other part.

Figure 2 is a view of socket-pipes when joined together.

Figure 3 is a longitudinal section of flanch-pipes, in which the manner of connecting them together is shewn. The joint is made air-tight by introducing rope-yarn, or any pliable material, and iron-cement between the flanches, which are screwed up by means of the bolts and screw-nuts.

To make iron-cement for this purpose, take iron turnings, or borings, and pound them in a mortar till they are small enough to pass through a fine sieve: then, with one pound of these borings, so prepared, mix two ounces of sal ammoniac in powder, and one ounce of flowers of sulphur, by rubbing them well together in a mortar, and afterwards keep the mixture dry till it may be wanted for use. When it is so, for every part thereof, by measure, take twenty parts of iron borings, prepared as above-mentioned, and mix them well together in a mortar, or other iron vessel. The compound is to be brought to a proper consistence by pouring water gently over it as it is mixing; and, when used, it must be applied between the flanches by means of a blunted caulking-iron. The affinities between the ingredients being such as to cause a degree of action and reaction amongst them, and also between them and the surfaces of the iron flanches, which ultimately causes the mixture, and these surfaces, to become a species of pyrites, cohering together with considerable strength and compactness.

Figure 4 is a view of flanch-pipes joined together.

Figure 5 represents what is called a " branch-pipe." It has a socket at one end and spigot at the other, between which a pipe branches off with a curve ; and, according to the diameter thereof, it is called a two, three, four, or five-inch, *&c.*, branch-pipe. Its use is to lead off from the larger mains, into streets at right-angles to them. The pipe itself being of like diameter with the larger main, and the branch answering to the socket of that which may be laid from it. When a pipe of this description has a branch from each side, it is called a double branch-pipe.

Figure 6 is a cast-iron pipe for the same purpose as the former; but, instead of branching out with a curve, the pipe leads off at right-angles. Pipes of this description are termed " outlet-pipes."

Figure 7 represents what is called a " diminishing-pipe." It is used when it is required to decrease the diameter of the range of main-pipes. The socket at one end answering to that of the larger main, and at the other for receiving the spigot end of the smaller.

Figure 9 is a bend-pipe. It is called a quarter-bend, eighth, or sixteenth-bend, as it forms such part of the circle of the radius with which it may be struck.

Figure 8. When a pipe is cast so as to form a double bend, or somewhat to resemble the Roman letter S, it is called an "ess-pipe." The uses of this and the former are too obvious to require any explanation.

It is sometimes necessary to make a junction between the spigot ends of two socket-pipes. This may be effected by means of the thimble-joint, as exhibited in *Figures* 10, 11, and 12; or by a double socket, which is a short pipe of somewhat greater diameter inside than the outer diameter of the pipes to be connected: it is brought over the pipes to be joined in a way similar to what is expressed in the thimble-joint (*Figure* 12), and jointed with gasket and lead, in the ordinary manner, or by means of iron-cement.

When it is required to carry a smaller main from a larger one already laid down, a part of the main pipe has, in some instances, been cut out, and a branch-pipe introduced; but this is more easily effected by tapping the main; and, by means of castings which clip round it somewhat like the thimble-joint, one of which, being cast with a pipe of the diameter wanted, attached thereto, allows others to be connected to it; thus answering the end required at much less expense and with less trouble.

Thus, having described the various kinds of pipes, I shall make a few remarks upon those which are generally used for the conveyance of gas. It would appear reasonable to most readers, that the main-pipes for the purpose might, with safety, be constructed much slighter than pipes of like diameter for conveying water: instead of such being the case, the prevailing practice seems to countenance the use of pipes, in all respects, as stout as what are used by the water-companies, and to prove that they will sustain a pressure equal to what is required for water-pipes, although the internal pressure in gas-pipes is very seldom more than an inch and a half. From the depth at which they are generally laid, there can be no apprehension of accident from external pressure: and, as to their durability, their situation, when laid down, precludes almost all possibility of their oxidizing. We might naturally ask, then, what end is answered by their being so constructed? To such a question it would be difficult to give an answer. It cannot be to resist either the internal or external pressure, nor from an apprehension of their durability being so considerably diminished, from their slightness, as to require the mains to be relaid at a much more early period.

To enable the reader to form an idea of the strength of socket-pipes used by some of the gas-light companies, I subjoin the following Table:—

TABLE.

Internal Diameter in Inches.	Length of each Pipe in Feet.	Weight of each Pipe.		
		Cwt.	qrs.	lbs.
2	6	0	2	0
2½	6	0	2	10
3	9	1	0	14
4	9	2	0	0
5	9	2	2	0
6	9	3	0	0
7	9	3	2	0
8	9	4	0	0
9	9	5	0	0
10	9	6	2	0
12	9	8	1	0
14	9	9	2	0
18	9	16	3	0

On the weights specified in the preceding Table, I am to remark that they may generally be considered as about one-sixth greater than is absolutely required.

With respect to the sizes of mains for conveying gas from the works, I have, from the results of numerous experiments, ascertained the quantities which will pass through pipes of different bores from two to eighteen inches.

TABLE, exhibiting the Number of Cubic Feet of Gas passing through Pipes of different Diameters in one Hour, when the Gas-Holder is worked at Inch Pressure; together with the Number of Argand Burners, each consuming Five Cubic Feet of Gas per Hour, which each Description of Main is capable of supplying, with a like Pressure of the Gas-Holder.

Internal Diameter of Pipe	Number of Cubic Feet of Gas passing through it.	Number of Burners thereby supplied.	Internal Diameter of Pipe	Number of Cubic Feet of Gas passing through it.	Number of Burners thereby supplied.
Inch^{s}.			Inch^{s}.		
$\frac{1}{4}$	20	4	7	24,500	4,900
$\frac{3}{8}$	50	10	8	32,000	6,400
$\frac{1}{2}$	90	18	9	40,500	8,100
$\frac{5}{8}$	160	32	10	50,000	10,000
$\frac{3}{4}$	250	50	12	72,000	14,400
$\frac{7}{8}$	380	76	14	98,000	19,600
1	500	100	16	128,000	25,600
2	2,000	400	18	162,000	32,400
3	4,500	900			
4	8,000	1,600			
5	12,500	2,500			
6	18,000	3,600			

After what has been already advanced, the reader will not be in want of data for determining the sizes of mains required for works where the quantity of gas to be daily used is known. I shall, therefore, proceed to make a few observations on the laying down of main-pipes, which it is indispensable should be most strictly attended to. In a former chapter it was observed that a considerable condensation was effected in the main-pipes:—if, therefore, these were laid perfectly horizontal, they would with difficulty be kept clear of water. To facilitate the getting rid of condensations it is necessary that the pipes should be laid with a fall of about an inch in twelve yards' run. By this means it would follow, that for every 150 yards there would be a fall of about one foot:—if then the first 150 yards of main-pipe be laid with such inclination, the next similar length of pipe would rise with a proportionate ascent. Under such an arrangement the water of condensation would fall to the lowest part, and a syphon or tar-well being there placed, would receive it; and thus the pipes would always be kept clear of such a quantity of water as might impede the passage of the gas. Were this rule at all times strictly attended to, the introduction of many syphons and tar-wells on the range of main-pipes might often be dispensed with. In some cases, the very uneven surface where the pipes are laid will not admit of such practice, but it may frequently be observed, that a want of care, as to this matter, on the part of the pipe-layer, is strikingly evident.

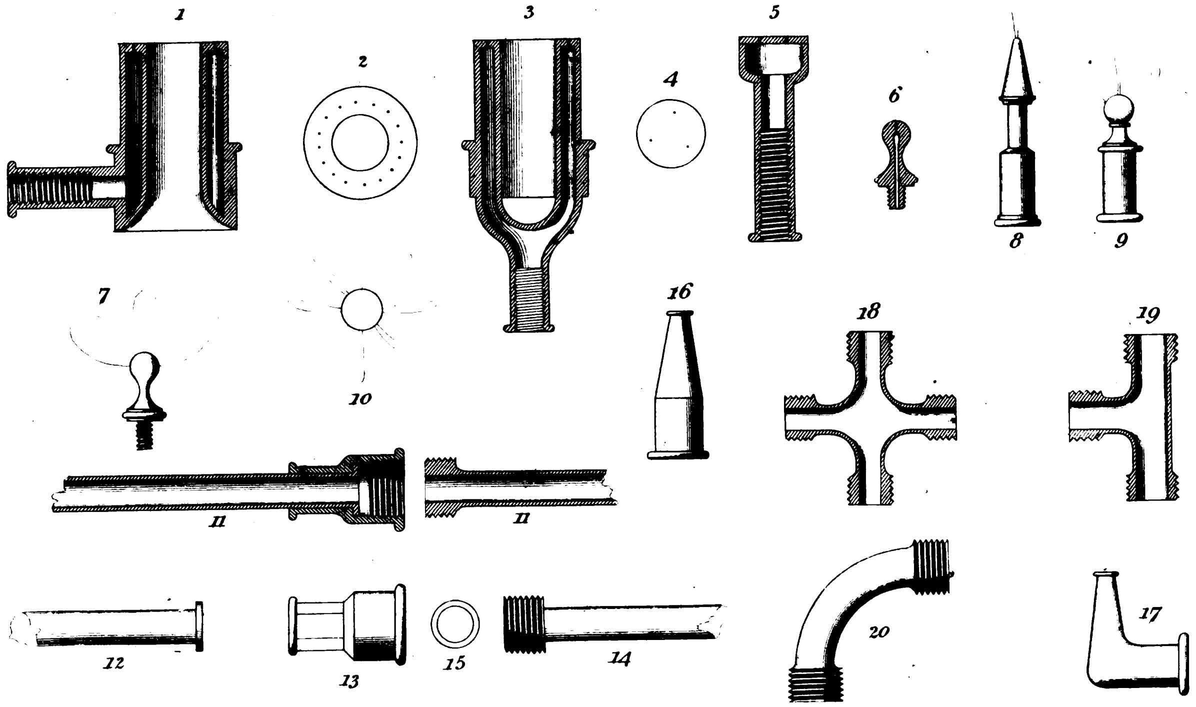
When the levity of gas is considered, it is by no means surprising to find with what celerity it finds its way to the higher part of the mains. So striking is the effect, that it must have attracted the notice of the most superficial observer; for in some situations in this metropolis, which are very remote from the manufactory, when there has been an abundant supply of gas, others much nearer have had but a very feeble light. If it were asked, from whence did such variability arise, I should state that the more distant were situated on much higher ground than the nearer, and that, from such circumstance, the gas would naturally have a tendency to press towards such points.

This levity of the gas has been particularly observed in some of the theatres; for it has often been remarked there, when the lights to the lower tier of boxes have burnt very feebly, those near the top of the house have required to be turned down. The thing is so plain that it speaks for itself. Considering then the tendency which gas has to ascend, what are we to think of the diameter of the pipes being increased when placed in elevated situations. It is evident that with a smaller pipe there would be an ample supply of gas, therefore the laying down a larger one can only tend to increasing expenses where they might be avoided.

When towns are to be lighted with gas which vary considerably in their level, it will always be necessary to lay pipes of larger diameter in the lower parts, gradually decreasing them as they proceed towards the more elevated, and *vice versâ*, if it be intended that the gas should issue from burners in both situations with the like impetus.

In concluding this chapter I am to observe, it has as frequently happened that complaints of a want of gas have arisen from ill arranged lines of main-pipes, as from want of power at the works. The subject requires the most serious attention of the manufacturer, for although pipe-laying has hitherto been considered as work fit only for common men, perhaps there is no arrangement connected with the gas-light establishment which requires more powerful abilities for carrying it profitably into effect.

PLATE XIII.



London, Published by T & G. Underwood & Ogle & Co May 1819.

CHAPTER XVI.

On the Service Pipes and Fittings-up, with the Sizes and Descriptions of Burners in general Use.

THE whole of the apparatus from the retort to the gas holder being ready for use, and the street-mains laid, the manufacturer will necessarily be induced to think of obtaining a return for the money he may have sunk:—to do this his gas must be brought to market. It is supposed that previous to his commencing any part of his works, he had ascertained what householders were desirous of using the gas-light, and the number of burners each might want. If, however, such information had not been obtained, which would certainly have been a great oversight on his part, it is now high time for him to ascertain it. This being done, he must prepare to bring the gas into the houses by laying the service-pipes. These are wrought-iron welded tubes, of about three feet in length, screwed at one end, and furnished with a screwed socket at the other, so that two or more lengths may be easily connected together so as to be perfectly gas-tight. But as it seldom happens that the service-pipe can be brought in a straight line from the street-main into the house where the gas is to be used, the most general practice is by drilling and tapping the main so as to receive a bend with a coarse screw at one end and a fine thread at the other, the former for screwing into the main-pipe and the latter for connecting with the service-pipe. There are also used on the line of service-pipe, when circumstances require, bends made of similar tubing therewith, also short lengths of tubing furnished with double sockets, connecting pieces; that is to say, pieces of tubing of from six to eighteen inches in length, with a male screw at one end and a female screw at the other,—wrought-iron tee-pieces for branching off from the principal service-pipe in two directions, and gun-barrel syphons. The service-pipes, bends, connecting and tee-pieces, when made of wrought-iron, are of different diameters, from half an inch to an inch and a quarter. Pipes and bends of larger diameter are seldom made of wrought-iron.

The service-pipe requires to be laid sloping, so as to allow the condensations to drain off, either into the main-pipe or the gun-barrel syphon. With wrought-iron tubing a junction is made between the main and interior of the house to be lighted:—so much being done, a wrought-iron cap is screwed over the end of the tube to prevent an escape of gas till the Fitter-up has prepared his inside work.

By consulting the table at page 295, Chapter XV., it will appear that a pipe of a quarter of an inch bore is sufficient for supplying four Argand burners, each consuming five cubic feet of gas per hour. Whence then has originated the idea of laying a three-quarter inch service-pipe for supplying most shops having more than two lights. It has been established beyond the possibility of doubt that two such burners will not consume more than about ten cubic feet of gas per hour, and a three-quarter inch pipe, if left open at one end, the other being connected to a gas-holder working at inch pressure, would permit 250 cubic feet of gas to pass through it in the like time. If such sized service-pipe is necessary, it must be under an idea that the gas-holder is to be worked at so light a pressure as will inevitably cause every customer of the manufacturer to complain of his lights:—such as are situated upon the lower part of the mains will get no light from their burners. This mode of procedure must ultimately fail, for complaints will arise which no increased size of service-pipe or fittings will remedy; and it will be in vain for the manufacturer to throw blame upon the fitters-up, for these will rebut the charge by observing that when fewer lights were used, the very fittings complained of were more than adequate for the supply of gas wanted. They may perhaps go a step farther, and say, Work your gas-holders with a proper pressure, and the complaints will cease.

There is one thing to be observed here which is not easily got over; I mean the necessity held out of using half-inch or five-eighths of an inch tubing to where the brackets or other brass-work is connected, when the aperture in the latter is, in some instances, not more than one-eighth of an inch. By such mode the friction in the pipes is lessened till the junction with the brass-work is made:—but, would any reasonable man suppose (the gas-holders being worked under equal pressures in each case) were the brackets or other brass-work contiguous to the burner, a quarter of an inch bore in one case and but one-eighth in another, that the the same quantity of gas would pass in equal times through each! Certainly not. Yet is this the very doctrine which some, even to this very day, strenuously endeavour to establish. To elucidate this by comparison, if we suppose two vessels of equal capacity filled with any fluid: a cock of an inch bore being placed at the bottom of one, and another of half-inch bore at the bottom of the other, the former would be emptied in about one-fourth of the time of the latter: consequently, let the size of the copper-fittings and service-pipes be what they may, should the plug of the cock, or the apertures of the brass-fittings, such as pillars, branches, *&c.*, which come between the tubing and the burner, fall off to a sixteenth of an inch, or perhaps less, the effect will be very nearly the same as if such diameter had been continued from the main-pipe. To set aside this mode of reasoning, it has been advanced that the larger size of tubing is beneficial inasmuch as it lessens the friction. It must be allowed that such mode of argumentation in some measure holds good; but, when the operator goes a step beyond that, and causes the consumer to remove all his fittings under a pretence that they are too small—yet afterwards allows a gas-cock, with a sixteenth of an inch aperture, to be placed upon the larger ones, he certainly has led him into expenses which were unnecessary, and founded upon principles altogether absurd.

Every one burning a gas-light has it in his power, at one time or another, to observe that a gas-cock with one-sixteenth of an inch aperture, is amply sufficient for supplying one Argand burner of the size generally used in shops;—for, although at certain times, when it is opened to its full bore, the light emitted may be feeble and bad, yet there are times when, if he were to light it, he would be compelled to decrease the aperture to less than half, by turning the plug of the cock, to keep the flame below the glass. It may be set down then that an insufficient light is, in many cases, owing to a want of power at the manufactory. This, however, is not always the case: in some instances a want of light is owing to the fittings-up being badly executed; but, as it is the manufacturer's duty to look into that before he furnishes a supply of gas, such defects argue either want of abilities or inattention in the persons he may employ as inspectors; for if the service-pipe be laid properly, and the fittings-up sound, such thing could hardly ever happen. The joints on the service-pipe ought to be perfect, as well as those on the copper-fittings inside. The lengths of the latter should invariably be connected together by means of the union-joint which will be hereafter described; and there ought not under any pretence to be a joint allowed to pass the inspector, which is effected by means of soft solder, or where white lead has been used. Such kind of joints are less expensive in the first instance, but much more so in the end. The union-joint admits of a facility in unconnecting the work, should it at any time be found necessary, and for soundness it can be well relied on. Joints otherwise made are subject to be leaky, consequently offensive; and in the event of any obstruction arising in the pipes, they are troublesome and expensive in unconnecting. They ought in all cases to be exploded.

The tubing for inside fittings most in use is made of copper—this ought to be with the joint folding over (or, what is generally called "lap-over-joint") for the facility of bending it; which jump-joint tubing will not allow of. The weights of different sized copper tubing are expressed in the following

TABLE.

Inside Diameter in fractional parts of an Inch.	Weight per foot in Ounces Avoirdupois.
$\frac{1}{4}$	3
$\frac{3}{8}$	5
$\frac{1}{2}$	6
$\frac{5}{8}$	8
$\frac{3}{4}$	10

The following directions for laying service-pipes, and relative to fittings-up, have been suggested, *viz.*: That the size of mains leading into houses should be three quarters of an inch in their internal diameter, for any number of lights under fifteen: but, when that number of lights were used, or the service-pipe was required to be a hundred yards in length, it should be increased to one inch. This has, again, been further defined by fixing the diameters of the service-pipes required for any number of lights from four to one hundred, at from six to two hundred yards' distance from the street-mains.

TABLE, shewing the Diameters of Service-Pipes necessary for supplying different Numbers of Lights, when situated at different Distances from the Street-Mains.

Distance from Street-Main not exceeding.	Number of Lights used.	Internal Diameter of Service Pipes.	**Remarks.**
Yards.		Inches.	
6	4	½	The Pipes leading off from these Mains should be ⅜ or ½ Inch.
12	6	⅝	
25	12	¾	
50	25	1	
80	50	1¼	
140	75	1½	
200	100	2	

The service-pipes should be of such material as has been already mentioned; and it will be highly advisable to give it a good coating of tar-varnish, preparatory to its being used. In some cases, lead-pipe has been introduced, but this ought never to be immediately connected to the street-main, nor used except where it can be protected from injury and well supported. The fall with which the service-pipe, as well as the internal fittings, are laid, ought not to be less than about a quarter of an inch for one yard in length of pipe.

It frequently occurs that the brass-work, though appearing of good quality, is very defective, and the tubes thereof so small as considerably to impede the passage of the gas: indeed, in some cases, brass-work has fallen under my observation with apertures of not more than one-twentieth part of an inch. It is necessary that particular attention should be paid for preventing such being put up; and it would be to the manufacturer's interest were he to cause all of it to be examined by the inspector before it is allowed to be fixed. The gas-way in the moveable joints should also be carefully noticed.

In leading off from the street-mains, it would be well to follow the mode proposed for the larger pipes, that is, by allowing the service-pipe to branch off with a curve instead of a straight line; and so, also, towards the respective burners: for, whatever may have been said of elbow-joints, no one would think of introducing them when a bend could be used without disfiguring the work; but there are cases where the elbow would come in and look better; in such it may be used, but in no other.

In making further observations upon the kinds of pipe used by different fitters-up, it may be noticed that, in some cases, sheet-iron brazed pipe has been recommended: others have proposed lead; whilst others, again, have made use of copper tubing lined with lead: but, perhaps, taking every thing into consideration, none will be found more likely to answer than "lap-over-joint"—copper tubing. It is connected without difficulty, it is easily bent to any shape that may be wanted; and, for inside work, it is very durable. It does not answer so well as iron tubing for street-lights, or in any place where it is exposed to the weather. For such purposes none is so serviceable as wrought-iron welded tubing; which, though it may be more expensive at first, is, in the end, far the cheapest.

Having said thus much on the subject of the service-pipes, and fittings-up, I am now to describe the various *figures* exhibited in *Plate* XIII. In doing so, I am to observe, that, as the description commences with the burners now in use, some notice should, perhaps, be taken of the progressive improvements in the manufacture of that article, till brought to its present state. In the more early period of the science of gas-lighting, the burner appears to have been merely a brass tube closed at the top, and drilled with one, two, or three, small holes, so as to exhibit single, double, or treble, jets of flame; nor was it till some time had elapsed that the Argand burner seems to have been adopted. This, in its first stage, was constructed of two concentric circles of brass or iron closed together at the bottom, and a small slit left open round the top, from whence the gas escaped, and there it was ignited. These were rudely shaped and ill proportioned. When used without a glass to prevent the percussions of the air which rushed towards the flame as the surrounding atmosphere was taken up, the flame was very unsteady, and, tapering upwards, exhibited the appearance of a cone. Some alterations were afterwards made in the construction of the burner, and a perforated cap was affixed to its bottom. It was also drilled with holes round the top for the gas to escape through, instead of the slit above-mentioned. These, and various other modifications, were attempted by different workmen; but it was not till experience had fully proved it, that it was thought necessary to make the opening at the centre of the burner, and the distance between the exterior thereof and the glass, of equal areas. To have an uniform and agreeable flame, this rule must invariably be attended to. Of all glasses used for burners, the cylindrical one seems to answer the purpose best. With it, the flame is of the same diameter from top to bottom. Such effect cannot be obtained with glasses of different shape, the reason of which is too obvious to require explanation.

Plate XIII., *Figure* 1, exhibits a vertical section of the Argand shank burner. This burner is used when the fittings are brought towards it in an horizontal direction. It will be observed that it is constructed of two concentric circles of metal, joined to a small tube, near the bottom, at one side, for screwing upon the bracket or other fitting. These two circles are connected together at the top by the circular steel plate, as shewn at *Figure* 2, which is drilled with the number of holes wanted. *Figure* 3 is a vertical section of the Argand crutch-burner. The body of this burner is similar, in all respects, to that of the shank-burner; but, as it is intended to be used at the top of an upright pillar, the tubing is joined to the bottom, in a crutch-formed shape, from whence it derives its name. The reader cannot fail, from a mere inspection of the figure, to observe the proportion of parts maintained in its construction; but, to give him further explanation on the subject, I shall subjoin the dimensions of the particular parts of the body of the Argand burner, whether shank or crutch, now most used.

Dimensions of the No. 4 Argand burner, or of that which, when burnt in shops from sun-set till nine o'clock, is charged 3*l.* a-year for:

Outer diameter of top....	$\frac{13}{16}$ of an inch
Inner diameter of top....	$\frac{15}{32}$,,
Diameter of circle of holes	$\frac{5}{8}$,,
Diameter of each hole...	$\frac{1}{32}$,,

This burner is drilled with 12 holes, $\frac{5}{32}$ of an inch from centre to centre.

Diameter of the bottom of this burner $\frac{7}{8}$ of an inch.

The bottom is bell-mouthed inside, as shewn in the figure.

Height of this burner, 1 inch and $\frac{7}{8}$.

Distance from the top to where the glass-holder is supported, 1 inch.

Dimensions of the No. 6 Argand burner, or of that which, when burnt in shops from sun-set till nine o'clock, is charged 4*l.* a-year for:

Outer diameter of top....	$1\frac{1}{16}$ inch.
Inner diameter of top....	$\frac{19}{32}$ of an inch.
Diameter of circle of holes	$\frac{3}{4}$,,
Diameter of each hole ..	$\frac{1}{32}$,,

This burner is drilled with 15 holes, $\frac{3}{16}$ of an inch from centre to centre,

Diameter of the bottom of this burner $1\frac{1}{8}$ inch.

The bottom is bell-mouthed inside, as shewn in the figure.

Height of this burner, 2 inches.

Distance from the top to where the glass-holder is supported, 1$\frac{1}{4}$ inch.

Figure 4 is a plan of the top of the street-burner, and *Figure* 5 is a vertical section thereof; the dimensions of which are as under, *viz.:*

Diameter of the top, $\frac{5}{8}$ of an inch.

Drilled with three holes each, $\frac{1}{32}$ of an inch in diameter, and $\frac{3}{8}$ of an inch asunder.

Length of burner, 1$\frac{3}{8}$ inch.

Figure 6 is a vertical section of the bats-wing burner. This burner is made of steel. In it is drilled a hole of about $\frac{1}{16}$ of an inch in diameter, to within a small fraction of an inch of its top, from whence is a slit across the burner, falling about half-way of its length. When the gas is turned to the burner, and ignited, it exhibits itself in a flame somewhat similar to the shape shewn in the profile, *Figure* 7. From this shape of flame it has derived its distinguishing appellation.

Figure 8 is the profile of a burner from whence issues a single jet of flame.

Figure 9.—Profile of a burner yielding three jets of flame.

Figure 10 is the section of a fancy burner producing eight jets.

Figure 11.—Section of the union-joint and tube for connecting. As I have already noticed the utility of this contrivance, it is but justice I should here remark, that it was introduced to the notice of the gas-light manufacturer by Mr. John Perks:—*Figures* 12, 13, and 14, are profiles thereof. *Figure* 12 shews a part of the copper tubing: at the end which is intended to be introduced into the socket, is soldered, or screwed, a brass collar. *Figure* 13 is the socket, tapped for receiving the adjoining length of tubing, upon which is soldered a screw fitting into it. This part is shewn by *Figure* 14. When the joint is to be made, the workman introduces the tubing, *Figure* 12, through the socket, *Figure* 13, so that the collar may rest against the bottom of the socket. Upon this is placed a leather collar, similar to *Figure* 15, and upon this, again, is screwed the tubing shewn at *Figure* 14. It is evident, when this is screwed up, that the joint will be perfectly gas-tight.

By examining the bat's-wing burners exhibited at *Plate* XIII., *Figures* 6 and 7, it will be seen that they are screwed round the bottom, outside, for the purpose of connecting upon a socket. When the tubing, to which they are to be attached, rises vertically, the upright socket, *Figure* 16, is screwed upon the top of it. This socket is tapped at each end, the larger screw being that which is joined to the tubing when connected; the smaller one receives the burner. But, when the tube of supply lies in an horizontal position, the elbow-socket, *Figure* 17, is substituted for the former. This socket is also fitted with two screws similar therewith.

Figure 18 exhibits a brass cross, used in forming connexions. It is introduced when the fittings branch off in three directions. To form the junctions therewith, four union-joints would be required. Each point of this cross is furnished with a screw, similar to that shewn at *Figure* 14 of this plate. These screws are intended for answering a like purpose therewith.

Figure 19 shews the brass tee-piece. It is used when the fittings branch off in two directions. There are provisions made in this for joining with the tubing, similar to those described when speaking of the cross, and the joint is made good in the like manner.

Figure 20.—A brass bend used upon the fittings-up. Each end of it is fitted so as to connect with an union-joint.

Many devices might have been here introduced of pillars, brackets, pendants, chandeliers, candelabras, *&c.*, but they would only swell up the work without increasing its usefulness. In the present stage of the science, there are as many as would fill a volume; for now, every fitter-up is furnished with a variety of patterns.

PLATE XIV.

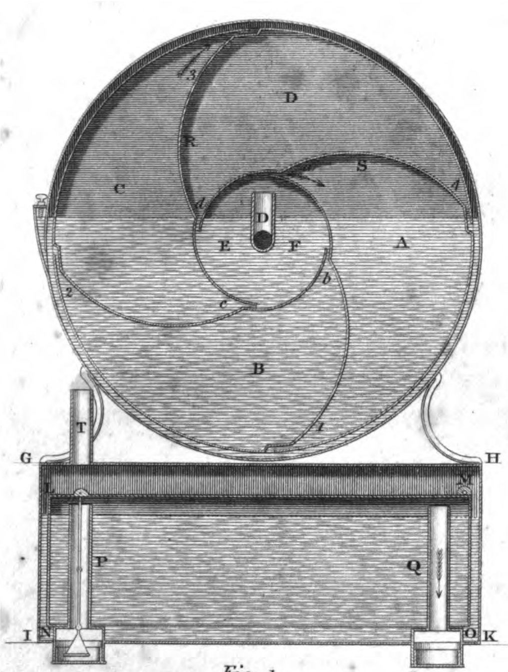


Fig. 1.

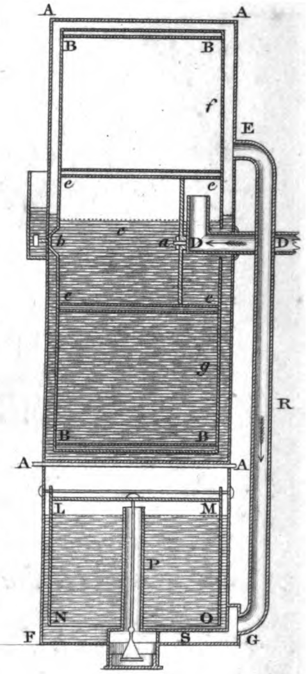


Fig. 2.

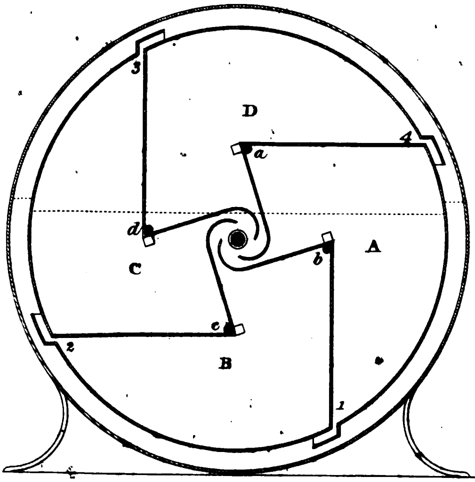


Fig. 3.

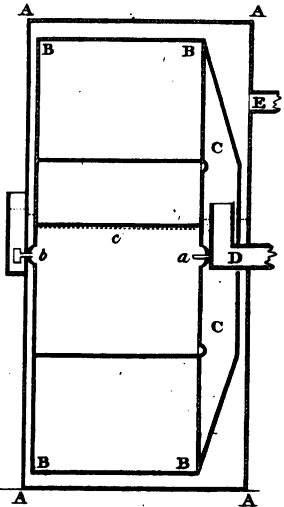


Fig. 4.

William Alexander sculp.

Pub. by T. & G. Underwood & Ogle & Co. May 6. 1819.

CHAPTER XVII.

On the Gas-Meter.

OF all the improvements which have been added to the gas-light apparatus, perhaps, there is not one of greater importance to the manufacturer than the gas-meter. If used between the purifying-vessels and gas-holders, it measures and registers the quantity of gas fit for use which may be generated:—if between the gas-holder and street-mains, the quantity of gas supplied for use from the station is ascertained, and if constructed on a smaller scale and fixed in the houses of the respective consumers, it points out the number of cubic feet of gas that each may have burnt in any given time. These are the uses which the manufacturer would at first sight consider as most beneficial; it has, however, several others, which will be spoken of hereafter.

Before going into detail on the uses of this simple piece of machinery, it may not be uninteresting to the reader should the history of its origin be given, and the various changes it has undergone, till brought to its present form. The general mode of charging the customers of the different gas-light companies for light is at a certain sum per annum for burners of given dimensions, burning from sun-set till nine, ten, or eleven o'clock, *&c.* But this mode neither answers the end of the supplier or consumer. The former is left in a great measure at the mercy of the latter, and it by no means unfrequently happens that one person uses nearly twice the quantity of gas which is used by another from the same sized burner and in the same time. The evil rests not here—the consumer contracting for light till nine o'clock sometimes burns it much later; and, although officers may be appointed to inspect and report upon such mal-practice, they will be found insufficient to prevent it.

They have no authority to enter into private-houses, and therefore in such where would be the check against an improvident use of gas? Even in such places as are open to inspection, it would be no easy matter to induce the consumer to abide by the terms of his contract as to the height of flame to which he ought to adjust his burner:—for although experience might prove that a flame of two and an half or three inches in length emitted the greatest proportion of light, and that light free from smoke or smell—yet, notwithstanding, instead of such being attended to, the stop-cock would be opened to its full bore, and the flame allowed to rise to a length of from six to nine inches. When such is the case, and how very frequently it is so every person passing along the streets of the metropolis in the evening must have noticed, a great quantity of gas is allowed to escape through the burner without being consumed—and this consequently passes off in smoke, which not only tends to blacken the cielings, but to cause a disagreeable smell. Thus the consumer of gas, either from ignorance or ill nature, has it in his power to waste as much gas as would be sufficient to supply twice the number of lights he might have:—and, under such circumstances, it becomes a subject of very serious consideration to the manufacturer to check the evil.

The idea of selling the gas by measure, instead of the very inaccurate method of disposing thereof by the time of burning and size of burner, seems to have originated with the Chartered Gas-light Company in the year 1815—for, in the latter end of that year, or very early in the ensuing one, Mr. Samuel Clegg, who was at that time its engineer, constructed a gas-meter of the following description:—To a wooden frame were attached two small cylindrical vessels, in which worked two gas-holders, each containing, we will say, for the sake of speaking of a specific quantity, one cubic foot. The pipes supplying these gas-holders were connected to the gun-barrel leading into the house where the meter was to be used. By means of a beam and a mercurial valve, the action was as follows:—The gas being turned on from the street, filled one of these gas-holders; and when it became so, the beam acting upon a smaller one attached to the valve, shut off further supply from the one that was full, and opened a communication to the empty gas-holder as well as to the pipe supplying the burners. By the time this second gas-holder was full, the gas in the first was consumed, and therefore it was down in the tank, and the other being full, performed the action of change as the former had done when in its situation—thus they alternately filled and emptied themselves, and the number of times they did so was pointed out by an index, which consequently shewed the number of cubic feet of gas that had passed through the meter. Had this answered the end in view, it would doubtless have been adopted:—the process in theory appears simple, and likely to do so; but, if we examine the nature of the valves and the nicety of workmanship necessary, we shall not be surprised to see it fail in practice. It did so after very considerable expenses had been incurred in endeavouring to bring it to perfection, and much time spent upon it, and it was ultimately thrown on one side as altogether useless.

Mr. Clegg next attempted to make a gas-meter having a rotary motion, instead of a vertical one. It consisted of a cylinder divided into several chambers, revolving on a hollow axis, enclosed in another which served as its case. For this meter he obtained a patent, the specification of which is given in the thirtieth volume of the *Repertory of Arts*, second series*, to which the reader is referred for its description: it is probable he will find some difficulty in understanding its action; for, perhaps, for a thing which we shall in due time find performed by a method exceedingly simple, and beautifully mechanical, nothing of a more complicated nature could have been thought of. The various ramifications of scrolls, and the friction arising from the axis of this meter, that being in stuffing-boxes, were both highly objectionable; and, when we consider the light pressure with which it was to work, we shall be surprised to find, under such circumstances, that it ever made one revolution. These were not the only objections against it—it was too large to be introduced into the shops of tradesmen in general, who seldom have much room to spare; and, although it was put up in some places where many lights were used, it failed in performing so as to be relied on, and was in consequence removed.

When Mr. Clegg quitted his employment as engineer to the Chartered Gas-light and Coke Company (on the 1st April, 1817), the most im-

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* Nos. 176 and 177, for January and February, 1817.

proved of his meters were from necessity used with stuffing-boxes, and although he had done away with several of the scrolls shewn in the drawing attached to his specification, he had still two left in each chamber. Indeed so far was he from appearing to contemplate any other mode of introducing the gas into the meter than by a hollow revolving shaft, that he had meters so made up to that very time. On the 4th April, 1817, Mr. John Malam submitted a drawing of his meter (similar to that shewn by *Figures* 3 and 4, *Plate* XIV.) to the committee of works of the Gas-light Company's station at Peter-street:—on the 7th of that month he exhibited a model thereof before them, and put it in action. Previous to the 13th of the same month Mr. Clegg appears to have heard that Mr. Malam was making gas-meters, for on that day he wrote to Mr. Malam to guard him against infringing upon his patent; but, from the tenor of Mr. Clegg's letter, it appears he had then no distinct idea of Mr. Malam's plan, for he observes the shutting off the gas may be effected in *various ways*, that is to say, "by valves or sealing the pipes with water." If the reader examines the figures representing Mr. Malam's gas-meters, he will find there is not a valve in either, and also that there are no pipes to be sealed with water.

Under such circumstances it cannot but be astonishing to find on Mr. Malam's submitting his meter to the Society of Arts, in March 1819, that Mr. Clegg came forward to dispute the priority of invention. It would not become me to enter into detail on the proceedings which took place before the Society on this occasion; let it suffice to say that after a committee there, composed of some of the most eminent chemists and engineers in this or any other country, had for eight hours patiently investigated the business, they formed a resolution, stating Mr. Malam's gas-meter to be new, ingenious, superior to other gas-meters, and likely to be of great benefit to the Public, and awarded him their gold medal for his invention. But in consequence of some opposition made when this resolution was brought before the Society, the subject was re-committed, and underwent another eight hours' ordeal, from whence it was sent again to the Society with the same resolution and the same reward:—and on the 28th April, 1819, the Society voted Mr. Malam their gold Isis medal for his invention.

Before entering upon the description of Mr. Malam's gas-meters, I am to observe that many months before he was employed by the Gas-light Company, he suggested to me the idea of making a gas-meter on the principle of Archimedes' screw: indeed, he made a small one on that plan in the beginning of the year 1816, having the L-shaped pipe of supply and receiving-chamber; but which was not brought into action till a much later period, and, when it was so, it was found to answer the purpose of a gas-measurer to admiration.

Description of Mr. Malam's Gas-Meter.

Plate XIV. *Fig.* 4, is a section through the axis, and *Fig.* 3 a section across the axis. A A A A, *Fig.* 4, is the outer case of this meter, within which the interior cylinder B B B B, with the chamber C C attached thereto, revolves upon the pivots *a b*—the former pivot (*a*) being attached to the inverted pipe D, which brings the gas into the chamber C C, from whence it is conveyed by the openings *a b c d*, *Fig.* 3, into the inner cylinder A B C D, in rotation, as each of the said openings rises above the level of the water expressed by the dotted line in *Fig.* 3, and that marked *c*, *Fig.* 4.

To each side of the outer case is attached a vessel, of the breadth of the meter, which rises nearly from the bottom to the height of the water-line in the interior. These vessels are for the purpose of introducing the necessary quantity of water into the meter, there being an opening into the outer case within them, which will by them, of course, be known;—for, as soon as the water rises above the height with which the meter is intended to work, it will run over the tops of these vessels. The openings at the top are secured by small brass plugs, which screw into them:—they are kept closed when the meter is in action. Whenever it may be desired to empty the water from the meter, the introduction of a small syphon through the opening to the bottom of the vessel, the plug *g* being removed will accomplish it.

In front of this meter is a small vessel of semicircular shape, rising rather more above the centre of the meter than the water in the interior. It is filled with water to form a joint, and through it is brought the pivot *b* (*Fig.* 4), on which, as an axis, is fixed a small pinion, or a crank, which, acting upon the necessary wheel-work, points out the number of revolutions made by the meter, or expresses by pointers, on a plate for the purpose, the number of cubic feet of gas that has passed through it.

This meter being unencumbered with stuffing-boxes, and revolving upon small pivots, is very little impeded by friction—and the water, rising above the centre, so effectually seals it as to preclude the possibility of a loss of gas.

The inverted pipe D conveys the gas into the chamber C C, *Fig.* 4, and thence by the opening *a b c d*, *Fig.* 3, into the chambers ABCD, the pressure of which between the surface of the water and the divisional partitions, causes a rotary motion; and, therefore, it follows that in one revolution every part of the interior cylinder must be filled with gas. The capacity of that being known, the quantity in cubic feet, or any other measure, is known also.

E is the exit-pipe which conveys the gas to the burners when the meter is used for ascertaining the quantity of gas consumed in a house or other building, *&c.*; or for conveying it to the gas-holder when it is constructed on a large scale for ascertaining the quantity of gas generated.

On referring to *Fig.* 3, which shews the divisional arrangement of the meter, the entrances to and exits from the inner cylinder, we shall see its action more clearly. Supposing the gas to be turned on, and the stop-cock opened which conveys it from the outer case when the opening *a* is just above the water. The opening *d* being at the same time above the water, that part of the chamber D which is above the water, will be first filled with gas, and the meter will be put in motion towards the left hand till such time as the opening of exit from that chamber 4 rises above the water, when the gas which it contains will be allowed to escape into the outer case. But before the opening of exit 4 rises above the water, the opening of entrance *d*, into the chamber D, will have sunk beneath the water, and consequently as the gas escapes from that chamber into the outer case, its place will be occupied by the water entering into it at *d*, as well as by the centre, which allows a communication of water between all the chambers equal to its level.

The opening of exit 4 having risen above the level of the water, the chamber D, as we have already observed, is gradually filled therewith; but before it is so, the chamber A will have been filled with gas, and the chamber B also nearly ready to discharge itself; for, almost as soon as the opening of exit from the chamber D has risen above the water, the chamber A will, by the opening *a*, be nearly half filled with gas, and the opening *b* to the chamber B, will be ready to rise above the water also. The motion of the interior cylinder being uniform, the exit 1 will next allow the chamber A to commence emptying, which will not be entirely accomplished till that chamber has sunk beneath the water at the left hand side of the meter—the gas at the time entering at *b* into the chamber B till that is filled, and the exit 2 opened by its rising above the water:—before that takes place, the chamber C commences filling, and does so gradually by the opening *c* till the exit 3 is opened, and, when that is the case, the chamber D will be in the same situation as when the opening of entrance *a* was just rising above the water, as has already been described. Having described the action of this meter through one entire revolution, it would be but a repetition of the same thing to go further into detail, and it would be entirely useless to do so; for, if the reader strike a circle upon a card, with the radius of that circle which forms a section of the outer case of the meter, *Fig.* 3, and copy the section of the interior cylinder A B C D of the same figure, connecting the two centres together by a small pin, to represent the pivot on which it works, he will have a simple model of the gas-meter. Let him then fasten a silk thread across this model, at the height shewn by the dotted line, which will represent the height of the water therein:—then, if he moves the inner circle gradually from right to left, he cannot fail to understand its action.

It may not be improper to remark, that such part of the space between the concentric circles formed by the interior cylinder and the external case will, of course, when the meter is in action, be occupied by gas above the level of the water; and therefore the motion of the inner cylinder will have a velocity in proportion to the diameter of the exit-pipe, or the orifice supplying the burners. Thus, for instance, if a meter of sufficient capacity to supply ten lights be used to supply one light, it will, in the latter case, make but one revolution on its axis, whilst it would have made ten in the former.

The meter as above described, on being tried, was found to answer every purpose that was required; it was much more compact and simple than any which had before been attempted, and, in short, it was as great an improvement upon the patent gas-meter as could well be expected. But, notwithstanding its advantages, the inventor was desirous of making one to occupy even less room than it did; and as he could not decrease the diameter of the interior cylinder, he adopted the following method, which completely answered his purpose, and upon this plan he has made several gas-meters, some of which have now (April 1819) been in action nearly two years, and all of them have been perfectly accurate in their performance.

Description of Mr. Malam's improved Gas-meter.

Instead of there being a chamber C C, as described in *Fig.* 4, attached to the interior cylinder, for the purpose of receiving the inverted pipe D, the chamber in this improved meter is at the centre, see *Fig.* 1. By this contrivance the meter, of which *Fig.* 2 is a section, will be one third less from A A than one of the same capacity made on his first plan, *Fig.* 4. These two sections, being of meters which, in one revolution, allow equal quantities of gas to pass through them, and they are laid down from the same scale.

The outer case A A A A,—the inner cylinder B B B B,—the entrance-pipe D,—the exit-pipe E,—the water-line *c*, *&c.*, *Fig.* 2, being the same as already described at pages 322, 323, 324, and 325, preceding, a repetition of their uses, *&c.*, here would be unnecessary. I shall, therefore, turn to *Fig.* 1. E F is a section of the chamber into which the inverted pipe D conveys the gas. A B C D are the chambers into which this meter are divided, and are a range of gas-holders acting with a rotary motion instead of a vertical one. These gas-holders receive the gas by the openings *a b c d*, and discharge themselves into the outer case by the openings in the rim of the interior cylinder 1, 2, 3, and 4.

Now, supposing the opening *a* to be just at the top of the water, and the stop-cocks which allow the gas to enter into, and to discharge itself from, the meter to be opened; the opening *d* being above the water, will allow that part of the chamber D, which is unoccupied by water, to be filled with gas; the expansion of which, between the surface of the water and the divisional partition R, will cause the internal cylinder to move on its axis towards the left, which motion will bring the opening *a* above the water; and, as that rises, the chamber A will be emptied of water, and the space which the water occupied will be filled with gas. Whilst this is doing, and prior to the opening *b* rising above the water, the opening of exit 4 will have allowed the gas to escape, from the chamber D, into the outer case. The gas will, at this time, be exerting itself through the opening *a*, between the surface of the water and the divisional partition S, till the opening 1 is unsealed. The chambers B and C undergo the like operations, till the opening *a* is in the position first described, and, when it is so, the interior cylinder will have made one entire revolution.

I would here, also, as on a former occasion, recommend the reader to project a circle upon a card, with the radius of that circle which forms a section of the outer case of the meter, ***Figure*** 1, and copy the section of the interior cylinder A B C D of the same figure, connecting the two centres together by a small pin to represent the pivot on which it works. Let him fasten a silk thread across this model, at the height shewn by the dotted line, which will represent the height of the water. If he then moves the interior circle gradually towards the left, it will make the description given more intelligible.

It would be very natural to conceive that when a gas-meter, such as I have described, was brought forward, and proved to act uniformly (as this has been for so long a time) it would be adopted by the manufacturers of coal-gas, if not for the purpose of ascertaining the quantity of gas consumed in the houses of their different customers, at least for shewing them the quantity of gas generated,—a thing of very considerable importance, on which the existence of an establishment very materially depends, and which may be sought for, in vain, by calculations made on the rise of the gas-holder in a specific time. For, whoever may have been at all conversant in making such calculations, must be aware what very imperfect data he has for doing so. Indeed, if the heights of the gas-holders be correctly taken at the beginning and end of each charge, there may be a probability of coming at something near the truth; but, unless he attends to this himself, fabricated statements may be made to him, and, consequently, the results of all his calculations will be erroneous.

To come at the exact quantity of gas generated during twenty-four hours, appears somewhat difficult, when we consider that, though in the summer months he may have two or three charges, according as the retorts may be worked, to calculate upon, yet, in the winter months, when thrice the quantity of gas is generally made, he will never have more than one charge to calculate upon in one day; for the valves will be open into the street-mains more than sixteen hours out of the twenty-four. When such is the case, what means can he have for knowing what the retorts are doing? He cannot be aware of the exact quantity of gas going out from the gas-holder; and, consequently, by no rule can he ascertain what is going into it. The only means he would have would be that of working into gas-holders so connected that the one into which the retorts were working should always be shut off from supplying the street-lights whilst it was filling: but in such case the trouble would be very considerable, and the additional expenses of valves and connexions, setting aside gas-holders, ten times as much as would erect a meter for performing what was required, and for doing so without any trouble beyond that of examining the dial at stated times.

If we reflect upon the uses of this meter, we cannot fail to observe, amongst others, that it would be a constant check upon the stoker, and we must be aware, that in such case only a very material advantage is gained: for, from idleness or inattention, he may possibly neglect his fires, or not charge his retorts properly during the night. In the former case, the heat of the retorts will be so much decreased as to fail in extracting the gas from the coal in a proper time, which can only be remedied by firing them so high as to endanger the retort, and very considerably to injure the fire-work: but this he will do prior to the hour when the heat of the retorts may be likely to be inspected by the principal stoker, or other person, whose office it may be to examine them. With such a check, then, as the meter, constantly upon him, he would be compelled to be attentive to the performance of his duty. Instead of the retort being worked at so low a heat as to leave a great quantity of gas unextracted from the coal, when it was drawn, such a circumstance would never happen; for, as the meter had registered, during the day, the quantity of gas generated from a given quantity of coal, in a certain time, so would it also during the night. Of course it would be necessary that the dial, on which such quantity was shewn, should not be accessible to any person, save the principals of the concern, or to him who kept the diary of carbonizing.

In large works, where the street-mains are very extensive, and the lights numerous, it not unfrequently happens that burners, particularly in the streets, are left open during the day, allowing atmospheric air to pass into the different ramifications of pipe, whilst the valve, through which the supply of gas is given, being shut, takes off the pressure of the gas-holder from them. From such circumstance, a very considerable evil arises; that is to say, when the valve is opened, the atmospheric air is driven by the pressure from the works towards the ends of the mains; and, till the whole of that is extracted, all the lights near such situations will not burn for an hour or two after the opening of the valve, save with a pale blue flame yielding hardly any light.

To prevent such from being the case, recourse is sometimes had to a method which altogether prevents it from being known what quantity of gas is generated. I here allude to having an inch, or, perhaps, a two or three-inch-main, constantly open to the street-mains, by which the pressure from the gas-holders overcomes the action of the atmospheric pressure, and prevents air from entering into them. But, with such contrivance, where will any customer find a difficulty in obtaining gas whenever he may be inclined to use it? The quantity of gas passing through this pipe of supply, differing according to circumstances, is as much against any calculation for ascertaining the quantity of gas generated as if the main valve was open also; therefore we must have recourse to some method different from calculation for ascertaining it. Under all the circumstances of the case, is it not surprising that, save at the King's Mint, and one or two places in the country, no such thing as the gas-meter has been used for that purpose. In the larger establishments, where, of course, the gas-meter would, in proportion, be more useful, it has not been introduced: nay, even those who appear to have first seen its utility in theory have failed to bring it into practice.

Before speaking of the value of this invention when applied for ascertaining the quantity of gas consumed in houses where gas is used, I have to point out another of its uses which would be a great saving of expense to the manufacturer who purifies his gas by the means of lime, either in solution or as a semi-fluid. By its being put up near the purifying vessel, it may be made to work the agitators,—a method far more certain than trusting to manual performance. It is of very considerable importance that the agitators should never remain at rest; but, when the manufacturer has to trust to a labourer's constantly turning the winch (which, in the night-time, particularly, he may neglect to do for an hour or two without much chance of detection) he cannot be certain that the lime has continually been kept from settling to the bottom of the vessel; for, should the person who is put to work the agitators, fall asleep, or, from idleness, let them stand, the gas will soon have but little lime to act upon, and will, therefore, in consequence, pass into the gas-holder in a very impure state. But, if a meter were applied for the purpose, such could not hapden; for, whenever gas was passing through the purifying vessel, it would from thence pass through the meter also in its way to the gas-holder, giving it a constant rotary motion, which might be communicated to the axis of the pinion driving the wheel, on the axis of which the agitators are fixed.

If the gas-meter is used for driving the agitators, it may, at the same time, be employed for measuring and registering the number of cubic feet of purified gas which pass into the gas-holder. It is clear that, if the meter be used as a moving power, the gas will be therein compressed in proportion with the resistance it meets with. But in this case, the purifying vessel is worked with a mixture, the density of which is nearly equal at all times. If, therefore, the meter be fitted with proper wheel-work for shewing the number of its revolutions, the manufacturer has only to ascertain, by a series of experiments, what number of revolutions the meter makes for conveying a specific quantity of gas into the gas-holder. Having taken their mean, let him construct tables shewing the number of cubic feet equal to the number of revolutions from one to as high a number as his establishment may require. Then, by examining the dial of his meter, and finding the number of revolutions made, if with that number he enters his tables he will find, by inspection, the number of cubic feet sought for.

Rule

For ascertaining the power, *&c.* of the gas-meter, if applied for the purpose of working machinery.

"The whole *momentum* or quantity of force of a moving body, is the result of its quantity of matter, multiplied by the velocity with which it is moved, and upon this principle it is easy to compute the power of any mechanical engine."

Having ascertained the pressure at which your meter is to work, and the number of revolutions it will make in any specific time, to find what weight it would raise to a given height in the same time.

For the sake of example let us proceed to find the power of the meter, of which *Figs.* 1 and 2 are sections. It makes two revolutions in a minute, and is worked at an inch and a half pressure.

The diameter of the interior cylinder is	16 ins.
The diameter of the chamber of supply is	6
The breadth of the interior cylinder is	8

Bisect *B e* at *f* and *g* respectively. The distance from *f* to *g* will be the diameter of that circle, which, if made a pully, and attached to the side of the meter, would support a weight equal to the area of the chamber *B e*. *B e* in inches

multiplied by the weight of water pressing upon each square inch: or by the pen thus:
B B being 16 ins. ÷ 2 = 8 ins. the radius of the circle. *e e* being 6 ins. ÷ 2 = 3 ins. the radius of circle forming the chamber of supply.
Then 8 — 3 = 5 the distance from B to *e*:—one half of which 2½ ins. is the distance from B to *f*, or from *e* to *f*—if it be doubled and added to the diameter of the chamber of supply, it will give the diameter *f g* = 11 ins.

To find the circumference of that circle, say

As 7 : 22 : : 11 : 34,57142 inches.

therefore it follows that to such height (viz.:—34,57142 inches) the weight would be raised every revolution.

To find what the weight raised to the height as above stated by one revolution of the gas-meter would be.

Multiply the breadth B B 8 ins. by the depth of the chamber B *e* 5 ins., and that product again by the weight of 1½ cubic inches of water, thus:

8 × 5 = 40 the area of B *e* B *e*.

one cubic inch of water weighs 9,26 drams avoirdupois, consequently 9,26
and 4,63

13,89 = to pressure on every square inch.

Then 13,89 × 40 ÷ 16 = 34,725 oz.* avoirdupois, and this weight will be raised 69,14284 inches in a minute.

Having ascertained the power of this meter, should we be desirous of knowing what proportion it bears to that of a man, we are to recollect, that, a man turning a horizontal windlass by a handle or winch should not have above 30lbs. weight acting against him if he is to work ten hours a day, and raise the weight at the rate of three feet and a half in a second.

From the above data he will raise 30 lbs. 210 feet high in a minute and 12600 feet high in an hour:—or, he will raise 6300 lbs. 1 foot high in a minute and sixty times that weight one foot high in an hour.

But, when machinery is driven by a perpetually moving power, it will appear that whatever power would raise a weight of 30 lbs. 210 feet high every minute during the whole twenty-four hours, would perform as much work as 2,4 men could do in the same time; for, it has been already stated that one man could not work longer than ten hours a day with such resistance, therefore such machine would in power be equal to 2,4 men.

Under these circumstances a man cannot be

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* Or 2,17 lbs. avoirdupois, nearly.

said to raise a weight of 30 lbs. more than 87,5 feet high in a minute; or, 2625 lbs. one foot high in the same time.

To compare the power of the meter with that of a man, there being given

2,17 lbs. avoirdupois the weight raised
5,762 feet high in a minute by the meter,
and
30 lbs. avoirdupois the weight raised
87,5 feet high in a minute by one man:—
say by the double rule of three

	lbs.	Feet.	Meter.
If	2,17 ———	5,762 ———	1
	30,00 ———	87,5	

here the blank falling under the third term, multiply the first two terms together for a divisor, and the last three for a dividend; the quotient arising from them will show the number of such meters it would require to raise 30 lbs. 87½ feet high in a minute.

Thus 5,762 × 2,17 = 12,50354 the divisor
and 87,5 × 30 × 1 = 2625 the dividend.

Then 2625 ÷ 12,50354 = 209,9 the number of meters of the above dimensions working at the pressure and velocity as already stated that it would require to perform the work of one man.

Before quitting this subject, I shall give an example of the mode of ascertaining the dimensions of a gas meter for a large establishment, capable of measuring the quantity of gas generated and driving the agitators of the purifying vessel.

Let us suppose, that, in an establishment where 907,200 cubic feet of gas is generated during the week, that it were proposed to put up a meter for the purpose of measuring and registering the quantity of purified gas produced, previous to its being allowed to enter into the gas-holder; and, at the same time, to work the agitators, the following data being given to find its breadth and power:

The pressure between the hydraulic main and the purifying vessel, 14 inches.

The depth of purifying mixture, through which the gas has to rise in the lime-vessel, 11 inches.

The pressure at which the gas-holder is worked, 1½ inch.

The diameter of the interior cylinder of the meter proposed to be put up, 7 feet.

The diameter of the inner chamber, 2 feet; and the meter to make two revolutions in a minute.

First, find the number of cubic feet of gas generated during the time the meter is making one revolution (*viz.*, half a minute) by dividing the quantity of gas generated in a week by the number of half minutes there are in a week: thus:—there being 20,160 half minutes in a week, divide 907,200 by that number, and the quotient, 45, is the quantity produced in half a minute; therefore, as that quantity is produced in the time the meter is making one revolution, it follows that such (45 cubic feet) must be the capacity of the meter.

Then, for the breadth of the meter,—first, find the area contained between the two concentric circles forming the chamber and the interior cylinder, thus:

for the inner chamber ,7854 × 2 × 2 = 3,1416 feet,
for the interior cylinder ,7854 × 7 × 7 = 38,4846 feet,

then, 38,4846 − 3,1416 = 35,3380 feet, the area between the two concentric circles already mentioned. By which, if we divide the capacity of the meter, we shall for a quotient, have its breadth: thus,

45 ÷ 35,3380 = 1,27 feet; or, in round numbers, say 15 inches.

Next, to find the diameter of the pulley, which, if attached to the side of the meter, would support a weight equal to the area of the chamber, multiplied by the weight of water pressing upon each square inch.

The radius of the interior cylinder is 42 inches,
,, chamber of supply is 12 ,,
Difference . . 30
to which add,
The diameter of the chamber of supply 24
the sum 54 inches
is the diameter of the pulley wanted.

To find its Circumference.

Say, as 7 : 22 : : 54 : 169,71428 inches, therefore it follows that to such height (*viz.*, 169,71428 inches) the weight would be raised every revolution of the meter.

To find what the Weight would be.

We have already found, that the difference between the radii of the inner cylinder and chamber of supply is 30 inches, and that the breadth of the meter is 15 inches; the pressure at which it is worked being an inch and a half, or (as was found at page 337), 13,89 drams, avoirdupois, on every square inch.

Therefore, $30 \times 15 \times 13,89 \div 16 = 390,65625$ oz. avoirdupois, and such weight would be raised 339,42856 inches in a minute.

To compare the power of the meter with that of a man, there being given

390,65625 oz. avoirdupois, the weight raised 339,42856 inches high in one minute by the meter,

and

30 lbs. avoirdupois, the weight raised 1050 inches high in one minute by one man,

Say, by the Double Rule of Three,

	lbs.	Feet.	Meter.
If	24,416	28,2857	1
	30,	87,5	

Here, the blank falling under the third term, multiply the first two terms together for a divisor, and the last three for a dividend; the quotient arising from them will shew the number of such meters it would require to raise 30 lbs. 87½ feet high in a minute:

Thus 24,416 × 28,2857 = 690,6236512, the divisor, and 87,5 × 30 × 1 = 2625 the dividend.

Then, 2625 ÷ 690,6236512 = 3,8 the number of meters of the above dimensions, working at the pressure and velocity, as already stated, that it would require to perform the work of one man.

The diameter of this meter has been stated to be seven feet; it would, therefore, follow, that its breadth must be about fifteen inches, to allow forty-five cubic feet of gas to pass through it during one revolution; but, perhaps, the best proportion between the diameter and breadth would be, the former to the latter as five to two, and in smaller meters as two to one.

There is but one more remark to make on the subject of the meter, when used as a moving power; it is, that a meter, such as has just been described, of sufficient strength to last seven years, might be constructed and fixed up at a cost not much exceeding 30*l.*; and this meter would perform the work which employs two labourers, whose wages could not be less than eighteen shillings, each, per week; or together at the rate of 93*l.* 12*s.*, *per annum*.

The interest of 30*l.*—the expense of putting up a meter, being, at 5 *per cent.*, 1*l.* 10*s.*; we have for that sum as much work performed as by manual labour we should have to pay 93*l.* 12*s.* for; consequently, there arises a saving of 92*l.* 2*s.* *per annum*; or of 644*l.* 14*s.* in seven years, the time which the meter has been estimated to last.

I come now to speak of the meter when applied for the purpose of measuring and registering the quantity of gas consumed in the different houses where gas-lights are used. In doing so, I hope to make it appear that the adoption thereof would be equally beneficial to the manufacturer and to the consumer of gas. The former, as I have already stated, by charging for light according to the diameter of flame and time of burning, cannot make a charge to his customers that is uniformly correct. That such mode is most fallacious, experience must point out to him; for, though he may estimate,—nay, prove, his burners to consume a certain quantity of gas in a given time, when properly adjusted, and, on delivering them out, make his charge accordingly; yet they will no sooner be out of his hands, but the person using them may, if he chooses, allow a much greater quantity of gas to pass through them: and it will be well if the manufacturer, at the year's end, finds his rental in reality much more than two-thirds of what he may have estimated the gas produced in that time to be worth. As I have already spoken somewhat at large upon the disadvantages which the usual mode of charging for light is subject to, in the beginning of this Chapter, I shall make such further observations upon it as are necessary, and then endeavour to prove that the evils resulting therefrom would be entirely removed by the application of the gas-meter.

It has been stated, but without much shew of reason to support it, that, unless there be some contrivance appended to this meter for preventing the gas from passing through it, in the event of leakage in the outer case, or water being drawn off by the consumer,—it will not register correctly, and that frauds might be practised without fear of detection. Further, that in many cases the water is liable to such a degree of evaporation as to reduce it so low as to allow the gas to pass through the meter without being registered.

In replying to the latter, I am to observe that, as far as relates to my own experience only, I can speak to the fact. A small gas-meter, of Mr. Malam's construction, put up in my office on the 7th of December, 1817, has not to this day, the 1st of May, 1819, had any fresh supply of water, and yet it performs admirably, and the water remains at the proper level. Another meter, precisely on the same construction, put up at some distance from the works, several months prior to the one just mentioned, has acted under the like circumstances to the present time.

With respect to frauds being practised, I consider the idea too futile to require a serious refutation. It must be considered that if a hole were made in the outer case of the meter, the thing would be observed by the collector when he made his call; for, on that occasion, a part of his duty would be to inspect it. The party making such hole would find some difficulty in stopping it up again, so as to be gas-tight, and, was water attempted to be introduced, it is rather doubtful whether he would be able to procure that tightness which would be requisite. In short, I am firmly of opinion that, were such practice attempted, it would certainly be detected. The attempting to make good the place by solder, would fail, and it would be well, were such attempted, if it were done without accident.

But, as, I believe, it is very generally established that on all lines of mains, however distant from the manufactory, there are found condensations, those who use the gas-meter need not be alarmed as to any deficiency of water therein. The pipe bringing the gas into it, should the water accumulate to too great a height, which is more probable than the contrary, will carry it off by means of a syphon thereto attached for the purpose. Supposing the gas-meter to be very generally adopted, it might be made with the outer case of cast-iron; then such ideas as would obtrude themselves, had it been made of tin, must entirely vanish.

However, Mr. Malam, to guard against such procedure, contemplated (from the time of his taking out a caveat for the gas-meter in April, 1817) a mode for preventing it. He proposed a float of cork should be made so as to surround the upright part of the introducing pipe. Upon this float were fixed two or more upright wires, having at their top a plate with an inverted blunted cone at its centre, to fit into the supplying pipe, which was formed like a cup at the top, for receiving it, and furnished interiorly with a coating of tallow. It is clear, that, with such contrivance, if the water were removed the float would sink, so as to allow the cone to fall into the cup and thus shut off the passage of the gas; but, if the water remained at its proper level, it would be kept at such a height above the supplying pipe as would allow a sufficient gas-way. With this species of safety-valve, Mr. Malam constructed a meter so long ago as September, 1817, which was put up at the Gas-Light and Coke Company's works, Brick-lane, Old-street, London.

For the sake of giving a nominal value to the gas produced, I shall suppose every thousand feet of it to be worth fifteen shillings: consequently, a burner charged at 4*l.* a-year, should consume but about 5,333 cubic feet of gas in that time. The burner had been proved by the manufacturer to consume such quantity in an hour as was in proportion to that number of cubic feet in a year; but then the flame had been adjusted to a certain height and the pressure uniform. When fixed to the fittings in any house, both these very material data would be lost; for, the pressure on different parts of the street-mains varies in almost every street, and with every level; whilst the turning on of the stop-cock to its full bore allows a flame of thrice the length that it ought to be; it therefore follows that much more gas passes through the burner than is necessary for yielding the best light, which is obtained from a flame about three inches high.

Should the quantity of gas passing through a 4*l.* burner in a year (nine times out of ten) be stated at 7,000 cubic feet, instead of 5,000, it would not be very far from the truth; but, in such case, the burner ought to be charged five guineas a-year instead of four pounds; or otherwise the value of the gas is reduced from fifteen shillings per thousand cubic feet, to about eleven shillings.

Did the consumer of gas obtain a better light from this greater proportion of gas used, there might be some plea in favour of his using it; but he must be aware, should he try the experiment, that the intensity of light does not increase in proportion to the length of flame, but to the complete combustion of the body yielding it. A more striking example can hardly be given than that of observing a common tallow candle when first snuffed, and just before the light from it becomes so dim as to require its being snuffed. In the first instance, the flame is bright, but low; in the latter, it is lengthened, but red, dull, and smoky, yielding very little light. The same thing holds good with respect to gas-lights. A four-pound burner, when properly adjusted, has, by experiment, been proved to yield as much light as six mould candles of six to the pound; but, if it be allowed to burn with a flame of six or eight inches in length, it will not, in intensity of light, be equal to more than three or four such candles.

To remedy these evils the gas-meter is well calculated; for, with the regulator (which will be described hereafter) the flame, let the pressure be what it may from the street-mains, will never be in length more than about three inches. Therefore, supposing the manufacturer to contract with his customer for supplying him with gas by measure, at the rate of fifteen shillings per thousand cubic feet consumed, he will find that he obtains a larger rental from the same means with which he had supplied light in the ordinary way, and the consumer will have a better light at less expense. By using the meter in all places, the manufacturer will have no occasion for a valve to shut off the supply to the street-mains—therefore upon them will constantly remain the pressure of the gas-holder—nor need he encumber his works with smaller mains to answer that end, for, he may rest assured, when his customer is aware that he is to pay for the gas which the meter will point out as consumed upon his premises, and no more, that he will not make use of such light but when it is absolutely necessary; he will be careful not only as to the time, but the mode of burning it, consequently the manufacturer will be able to supply more lights, and to increase his rental proportionally.

Wherever the meter may be adopted, it will in a short time convince the consumer of gas that for every light, which by the usual mode of charging he had been accustomed to pay at the rate of four pounds a year, he would be supplied with a sufficient quantity of light at ten or fifteen per cent. less expense. He would be able to use the gas whenever he chose to do so, for as the pressure of the gas-holder would be constantly upon the mains, he would at all times be able to obtain it. This, alone, would be a very great convenience to the consumer, who, under the existing circumstances, is not allowed the use of a gas-light, save from sun-set to the hour such light is contracted for; therefore, to have so complete a command of it, at less expense, must be a desirable object.

If the consumer is at all acquainted with machinery, he need but barely look at the meter to be sure of its uniform action—it is so simple in its construction as to preclude all chance of its getting out of order—and its portability is such that where a tradesman may have hardly any room to spare in his shop, he could scarely fail to find enough for it to stand in: for, a meter of sufficient capacity to supply from four to six 4*l.* burners, might be placed in a recess of a foot square and six inches deep. In most cases it might be put up in a conspicuous place, for if neatly finished, it would be an ornament to either a shop or a parlour, as to it might be given the appearance of a table-clock: and, owing to its acting in water, which so securely forms a joint as to prevent any escape of gas, nothing offensive could arise from the use of it.

In whatever I have said of this meter, I have been influenced by a desire of promoting the advantages equally of the manufacturer and the consumer of gas, and I hope I need not add more to induce both to adopt it—the benefits to each would be mutual, and the accommodation to the latter much greater than the present mode of supplying him with gas can allow. All that would be required to be done, were it used, would be for the collector to observe when he made his collection, what number of cubic feet of gas had been consumed since his last call, and to charge and give receipts for the amount thereof. The dial being under his lock and sealed, he should, when payment was made, note in his book the position of the hands, and from thence commence his new account.

STATEMENT,

Shewing in what Particulars the Gas-Meter, of Mr. John Malam's Invention, differs from Mr. Samuel Clegg's Patent Gas-Meter.

Mr. Clegg's patent Gas-Meter.	**Mr. Malam's Gas-Meter.**
The axis is a hollow cylinder, differing in diameter according to the number of cubic feet of gas intended to pass through it in a given time (for a house where from four to six lights are used, it would require to be, at least, one inch and a quarter in diameter). The gas enters	The axis on which it revolves is a small wire of about one-eighth of an inch in diameter, when used for shewing the quantity of gas consumed in houses; and, when the meter is intended to register the quantity of gas consumed by any number of lights, from two to twenty,

Mr. Clegg's patent Gas-Meter (*continued*).	Mr. Malam's Gas-Meter (*continued*).
at one end of the same, and, being conveyed from thence, by means of hollow arms, into the divisional chambers, it is discharged from them, and returns, by a similar contrivance, to the opposite end of the axis to which it entered, and is from thence conveyed to the burners.	it need not be increased. The gas does not enter into the meter through the axis, but by a fixed pipe, somewhat in the shape of the Roman letter L, the horizontal part of which is immersed in water, which rises to within about an inch and a half of the top of that part which is perpendicular. It is enclosed by a chamber which has an opening to each of the divisional partitions, and these empty themselves into the outer case in succession.
The gas is prevented from communicating between two adjoining chambers by means of scrolls forming either mercurial or hydraulic joints, or by valves, on which very little dependence can ever be placed.	The gas is prevented from communicating between two adjoining chambers by means of an hydraulic joint which can never fail in its performance.
Owing to the axis of this meter being of considerable bulk, and its being absolutely	The axis of this meter being very small, and stuffing-boxes not necessary, the

Mr. Clegg's patent Gas-Meter (*continued*).	Mr. Malam's Gas-Meter (*continued*).
necessary (to prevent an escape of gas) that it should work in stuffing-boxes, the action of it is much encumbered by friction.	action of it is very little impeded by friction.
The water in the outer case of this meter does not rise more than about one-third of its diameter; and, if it were filled above its centre, it would not act.	The water in the outer case of this meter, as well as in the interior cylinder rises considerably above the centre, by which means it shuts off all gas communication between the respective divisional chambers; and, if it were not filled with water above the centre, the meter would not perform.
The dimensions of this meter, when of sufficient capacity for supplying four lights, are, The diameter, 30 inches, And breadth.. 8 „	The dimensions of this meter, when of sufficient capacity for supplying four lights, are, The diameter, 12 inches, And breadth.. 6 „
A meter made on the plan, and of the dimensions, just stated, could not be got up for less than five or six pounds	A meter made on the plan, and of the dimensions, just stated, might be got up for about three pounds, leaving the manufacturer a handsome profit.

MR. CLEGG'S PATENT GAS-METER (*continued*).	MR. MALAM'S GAS-METER (*continued*).
This meter, owing to the great complexity of its construction, is constantly liable to be out of repair; and, having so far failed from the end that the inventor had in view, he has laid it on one side and adopted another, which is similar in construction to the one for which Mr. Malam took out his caveat on the 10th of April, 1817.	This meter, owing to its very simple construction, is not liable to be out of repair; it has been upwards of two years in action without once requiring being meddled with; and, if the simplicity of any piece of mechanism enhances its value, Mr. Malam, as the original inventor of this meter, is entitled to very considerable credit.

CHAPTER XVIII.

On the Regulator.

THE unfair manner in which many of the customers of gas-light companies burn their gas led the managers of such concerns to adopt measures for preventing it. The instrument for answering such purpose was originally called "*The Governor,*" but it is now more generally known by the term "Regulator."

The first instrument of that kind which appears to have been offered to the notice of the Public is described in Nos. 176 and 177 of the second series of the *Repertory of Arts* for January and February 1817. This governor was invented by Mr. Samuel Clegg, and for it he obtained a patent under date 9th December, 1816. If the reader consults the description abovementioned, he will understand its properties, and perceive that its action will be to keep the pressure constantly equable. It will effect the regulation in an equal degree when the inequalities of pressure are occasioned by an increased consumption as when they are increased by an increased supply; for the operation of it is to adapt the orifice through which the gas passes to the quantity required to pass, so as to keep the pressure under which the gas shall issue nearly equal. On examining the figure and consulting the description, the reader will easily perceive that Mr. Clegg's patent governor could not fail of answering the purpose intended. The only objections which could be stated against it were the expense of construction and the room required for it to stand in. Indeed, no one would hesitate to pronounce the thing more likely to answer than other governors which have since been offered to the Public by that gentleman. In attempting simplicity and compactness, some of the best properties of the governor have been lost, and those which have supplied its place cannot be considered in all cases effective, nor much to be depended upon.

Upon a large scale there can be little doubt of these governors answering the end in view; but the smaller ones, such as have fallen beneath my notice, no reasonable person would expect much service from. By the reader's referring to the thirtieth volume of the second series of the *Repertory of Arts*, No. 176, *Plate* III. *Figure* 14, and attending to the following observations, he will understand the construction of Mr. Clegg's altered governor. It consists of a gas-holder, somewhat similar to that shewn by the part marked G: it had an air-vessel round the bottom, so constructed as to allow it to work at the pressure required. To the height which the air-vessel was carried it was cylindrical, but above that it presented the frustum of a cone, the diameter of the top being about an inch and a half less than the bottom: and a tin-case as H If we suppose the case to be about one foot deep and six inches diameter, the gas-holder will be about five inches deep and as many in diameter at the bottom. At the distance of about three inches from the bottom of this external case is an inner bottom, upon the centre of which is supported a pipe R, of the same height as the gas-holder. Upon the top of this pipe is soldered a small brass-wheel having a hole drilled through its centre for receiving a brass wire of about one-eighth of an inch in diameter, the lower part formed into a cone, the base of which is three-eighths of an inch and height about three inches, and the bottom of the pipe is brass-bushed, so as to leave a conical aperture with a base of about three-eighths of an inch in diameter. The wire just mentioned is brought through this aperture and the central hole at the top of the pipe, and screwed to the centre of the top of the gas-holder, so that when the gas-holder is down in the tank, the conical orifice at the bottom of the pipe is nearly open; but as the gas-holder is lifted up the cone is drawn up with it, gradually shutting off the passage till at its greatest rise it is entirely closed. Above the inner bottom is a pipe of three quarters of an inch in diameter, similar to the pipe B, which is connected to the upright pipe R, above the conical orifice. This is the pipe of exit. Another pipe of the same diameter placed below the inner bottom brings the gas into the governor. If we suppose the governor to be connected to the service-pipe, and with the fittings leading to the burners, preparatory to bringing it into action, it will be necessary to remove the lid at the top and pour water into the case or tank till it rises to within an inch of the top of the upright pipe R. This being done, the top and bottom of the governor are to be put on and made gas-tight with a luting of bees-wax and tallow, and when this is effected it is fit for action. The gas-cocks attached between it and the burners being gradually opened, allow the gas to pass through it and escape at the orifices where it is consumed. It is evident that under such an arrangement, if the pressure from the street-mains be increased, the gas will flow with more rapidity into the gasholder of this governor: this greater impetus raises the gasholder in the tank, and consequently draws up the cone with it, by this means lessening the aperture of supply so that the pressure is retained nearly equal, and the flame of the burners supplied though the governor remains at one uniform height.

On the contrary, if the consumer were inclined to burn his gas at too great a height, the governor would prevent it; for, if it were constructed so as to work with such a pressure as was sufficient for supplying the lights required, and no more, he would be compelled to turn the cocks supplying his burners to their full bore, to enable him to obtain a light about three inches high; nor would he be able to obtain a higher flame let the pressure at the works be increased as it might, which is evident from what has been already stated.

Mr. Clegg's practice, whilst in the employment of "the Chartered Gas-light and Coke Company," was to make his governor with a cone, the base of which was three-eighths of an inch in diameter, for supplying four or five lights, and half an inch for supplying ten lights. The length of the cone was from two and a half to three inches. His pipe of supply and exit-pipe in each case being three quarters of an inch in diameter.

The objections against this governor are the following, that is to say: The cone being of small diameter and great length, requires the gas-holder to rise considerably before the action of shutting off is sufficiently effected. The gas-holder being but small, any sudden pressure is apt to blow the water from beneath it, nor could the governor constructed on this plan for the use of private houses be made to sustain more than a few inches pressure. The wire connecting the cone with the gas-holder being fixed to the centre of the top of the latter and to the cone, passes through a hole at the top of the upright pipe—if, therefore, it becomes corroded it is apt to stick, and render the governor useless. And as the cone itself is subject to the same, it sometimes closes up the orifice altogether, and entirely shuts off the passage of the gas. These things, when the governor was used by the Chartered Gas-light and Coke Company, produced inconveniences and brought the governor into disrepute.

Under such circumstances the case stood when Mr. Malam introduced his gas-meter in April 1817. To remedy the inconveniences he seems to have contemplated the lessening of friction, the more delicate action of the governor, and the prevention of the water being blown out of the tank by any highly-increased and sudden pressure. His regulators, instead of being cylinders and deep, like Mr. Clegg's governors, are parallelopipedal and shallow, serving as pedestals for his gas-meters when used therewith. GHIK, *Plate* XIV. *Figure* 1, is a longitudinal section of the outer case of Mr. Malam's regulator, of such length as is equal to the diameter of the meter with which it is used. LMNO is a similar section of the gas-holder (constructed so as to act at a certain pressure) which acts upon the pivot shewn at M. P is an upright pipe which rises nearly as high as the top of the gas-holder when that is in a horizontal position. Immediately over the centre of this pipe in the top of the gas-holder is a small hook, to which is hung the wire attached to the cone so as to act freely in all directions. The wire for supporting the cone is formed into two links, the lowermost of which is connected to a hook rising from its apex. Thus, as the top of the pipe is entirely open, there can be no apprehension of the wire being there bound, or so obstructed as to prevent the cone from acting. The vertical pipe Q is that by which the gas escapes towards the burners. The manner in which the gas is brought into this regulator will be better understood by consulting the transverse section at *Figure* 2. AAFG of that figure is a transverse section of the outer case, of such breadth as is equal to the breadth of the meter with which it is used. LMNO is a similar section of the gas-holder which acts upon the pivots shewn at L and M. The upright pipe P, with the wire and cone, have been already described when speaking of the longitudinal section (*Figure* 1.) S, *Figure* 2, represents the pipe which conveys the gas from the meter to the regulator by means of the pipe R, or from the service-pipe when used without a meter. A pipe similar to that shewn at S is also attached to the upright pipe Q (*Figure* 1) for conveying the gas from the regulator towards the burner. At the bottom of the regulator, immediately beneath the pipes P and Q, are soldered two screwed brass rings of about two inches diameter, upon which, when the regulator is in action, are screwed two brass caps having a short piece of pipe brazed to the centre of each (which is cut out for the purpose) with a cock for drawing off any condensations which may descend in the pipes. The pipe marked T, *Figure* 1, is soldered upon the top of the outer case of the regulator over a hole made therein. This pipe is open at the top. It is for the purpose of allowing the regulator to sustain a greater pressure than could be effected were the top entirely closed.

On examining the sections of this regulator the reader will perceive the difference of arrangement between it and the governor. If we begin with the gas-holder, the area of the base of the latter is much greater than that of the former, and as the length is considerable, and that acting as a lever upon the fulcrum at M, any change of pressure is immediately felt and checked: for there cannot possibly be that friction in its action which was before noticed, and, owing to the difference of application, if that were possible, it would be more easily overcome.

In constructing a regulator on Mr. Malam's principle for acting with his gas-meter when four lights are to be supplied, the gas-holder would be about ten inches long, five inches wide, and three and a half inches deep. The area of the base would be fifty superficial inches; in the former case a governor for such number of lights had to work with a gas-holder, the area of the base of which was not more than about twenty superficial inches. As several of the more prominent alterations have already been noticed, they will not be further dwelt upon: however, the difference of shape in the cone must be conceived considerably for the better. Mr. Clegg's governor was furnished with a long taper cone, which required a very considerable rise in the gas-holder before the action was felt. Its base was only about three-eighths or half an inch in diameter when the entrance and exit-pipes were three quarters. Mr. Malam's regulator had a short blunted cone of the same diameter of base as the supplying and discharging tubes. This cone was not more than an inch in length, consequently a very small rise of the gas-holder was sufficient to bring it sensibly into action. Again, the governor was not calculated for sustaining much pressure, whereas the regulator might be constructed so as to sustain a a very great one; for if the pipe T were carried two or three feet high, instead of about six inches, as shewn in the Figure, it would sustain a greater pressure than ever happens in the gas-light manufactory. In short, for simplicity of construction, and uniformity of action, there is no regulator that has fallen beneath my notice equal to Mr. Malam's.

CHAPTER XIX.

On Tests.

IN the Chapter "On Purification" it was stated to be necessary, occasionally, to take tests for ascertaining whether the purifying process effectually deprived the gas generated of the sulphuretted hydrogen gas, and carbonic acid gas, which are evolved with it. That this should be done frequently, appears requisite; for it is highly necessary that the manufacturer should supply his customers with such gas only as is fit for use, and either of those, just mentioned, are far from being so. Their ill effects have been already noticed, therefore do not require to be further spoken of in this place. I shall now proceed to mention such tests as may be employed for detecting them.

1*st Test.*

Mix three grains of sugar of lead with two ounces of distilled water, in a wide-mouthed bottle, by shaking the mixture well together, and it will have a milky appearance. Then, having fitted a stop-cock to a large sized bladder, let it be filled with gas from the main whence it is wished to be tried, which can easily be effected by screwing the cock attached to the bladder upon a small piece of tubing fixed thereon for the purpose. It will be necessary to have a small bend which can be screwed to the cock after the bladder is filled with gas. Let this bend be introduced into the test, the cock opened, and the gas pressed out, which will bubble up through the mixture. If the gas is freed from the sulphuretted hydrogen, the test will remain white and milky; but, if it is charged with sulphuretted hydrogen, it will become dark and cloudy. This is a delicate test for discovering minute portions of sulphuretted hydrogen gas, with which it forms a black precipitate.

2d Test.

Into a wide-necked bottle put an ounce of distilled water, and then impregnate it with the gas, which it is desired should be tried, by blowing it through the water, by means of a bladder, as described in the foregoing test. If it contains sulphuretted hydrogen gas, it will produce a fœtid odour, resembling the smell of rotten eggs.

Should a single drop of nitrate of silver, superacetate of lead, or muriate of bismuth, be dropped into water impregnated with sulphuretted hydrogen gas, in the manner already described, it will instantly be rendered black.

3d *Test.*

Tincture of litmus may be employed for detecting either carbonic acid gas, or sulphuretted hydrogen gas. The natural colour of this tincture is a dark blue, inclining to purple. The action of either of the above gases upon the tincture of litmus produces a redness. If barytic water be mixed with the tincture thus coloured by carbonic acid gas, it immediately becomes turbid, and a soluble precipitate falls down with effervescence in pure dilute muriatic or nitric acid. If the change of colour had been effected by sulphuretted hydrogen gas, no precipitate is formed. By this criterion, the action of carbonic acid gas, upon litmus, from that of sulphuretted hydrogen gas, may be distinguished.

4*th Test.*

If an ounce of distilled water be tinged slightly blue by tincture of litmus, and then impregnated with the gas desired to be tried, if carbonic acid gas be present, it will speedily produce the reddening effect.

5*th Test.*

Into an ounce of distilled water, impregnated with gas, let fall twenty or thirty drops of sulphuric acid. If carbonic acid gas be present, many minute air bubbles will be rapidly disengaged.

6th Test.

Impregnate distilled water with the gas to be tried, in a wide-mouthed bottle, and then let it be poured upon a plate, or into a small evaporating basin. Hold close to the surface a slip of paper, wetted with a solution of nitrate of silver. If sulphuretted hydrogen gas be present, it will escape from the fluid and cause the paper to be blackened.

Were it necessary, many more tests might be added; but these already mentioned are amply sufficient for general purposes. Should the reader, however, be desirous of pursuing his inquiries relative thereto, still further, he will be furnished with the necessary instructions by consulting Parkes's *Chemical Catechism*, or Mr. Accum's work on chemical re-agents.

CHAPTER XX.

On the Chemical Constitution of Coal-Gas—Remarks on the Methods of obtaining it, and cursory Observations on its Usefulness when employed for generating Artificial Light, and for other purposes.

WHEN we consider the qualities of coal-gas, and the various productions obtainable from coal by distillation, we are led to conclude that pit-coal contains solid hydrogen, carbon, and oxygen. In the process of distillation of pit-coal we find, that when the heat to which it is exposed has reached a certain degree of intensity, part of the carbon is united to part of the oxygen, producing carbonic acid. This product, by means of a further supply of caloric, is formed into carbonic acid gas. Whilst this is performing, part of the hydrogen of the coal is attracted by distinct portions of carbon and caloric, which forms the carburetted hydrogen gas. The qualities of this gas differ with the circumstances of heat under which it is produced, as well as from the material employed for its production. During the distillatory process is also produced olefiant gas, carbonic oxide, and sulphuretted hydrogen; but the quantities of these vary with the qualities of the coal which may be submitted to distillation.

We are not to consider that pit-coal is the only substance which affords carburetted hydrogen gas. It may be procured in various ways; for it is found ready formed on the surface of stagnant waters, and in marshes. In hot weather we may observe large bubbles thereof rise through the former, and should we be desirous of collecting it, we may do so by adopting the following method:—Fill a wide-necked bottle with the water, and cause it to be therein inverted, with a large funnel in its neck; then, by stirring the mud directly under the funnel, the bubbles of air will rise from the mud beneath it and enter into the bottle. This gas is, for distinction, called the carburetted hydrogen of marshes. It contains, in the purest state which we can collect it, about twenty per cent. of nitrogen.

When any kind of vegetable matter is submitted to such a heat as is necessary to decompose it, it gives out carburetted hydrogen gas, and the proportion thereof obtained is greater when such process is carried on in close vessels. Charcoal wetted with water, and submitted to the action of heat in a crucible or earthern retort, will produce gas which consists partly of carbonic acid and partly of carburetted hydrogen. This gas is also procured by causing steam to pass through an iron tube, which, by being conveyed through the fire, is kept red hot,—by allowing spirit of wine to trickle through red hot tubes, or by distilling camphor in them. In short, carburetted hydrogen gas is obtained by distilling in close vessels either oil, wood, bones, wax or tallow, or from any animal or vegetable body, be it what it may. There is a curious variety of carburetted hydrogen gas obtainable from ether or alcohol, which, when brought into contact with chlorine gas, generates an oil that is heavier than water, whitish and semi-transparent, which if kept becomes yellow and limpid. It has a fragrant smell, a sweetish taste, and is partly soluble in water, to which its peculiar smell is imparted. This gas has been by some termed oily carburetted hydrogen; by others, olefiant gas. It is composed of carburetted hydrogen, supersaturated with carbon. In the distillation of most kinds of coal a portion of this species of gas always comes over with the common carburetted hydrogen; and, it must be evident, the coals yielding the greatest quantity thereof will always best answer the gas-light manufacturer's purpose.

Whenever carburetted hydrogen gas is obtained from coal by the process of distillation in close vessels, its nature varies with the circumstances under which distillation is carried on, with the qualities of the coals used, and with the various stages of the process. In the first stage of the process it is heavier than in the last, but even then it is lighter than atmospheric air. It holds in solution a portion of oil; for we find when gas, produced during the first part of the distillatory process, is confined for some time in the gas-holder over water, it becomes lighter, from many of the oily particles subsiding, and, consequently, when submitted to combustion, does not require so much oxygen for saturation as if it had been burnt immediately after it was generated. We may state the average specific gravity of carburetted hydrogen gas, from that of the heaviest and lightest which is obtained in the process, at ,8.

It may not in this place be improper again to observe, that both the quantity and quality of carburetted hydrogen gas, obtainable from coals of the like species, depend very much upon the mode employed for distillation, and the temperature at which such process is carried on. By disposing of the coal in thin strata to the action of the fire, and making the conducting pipes to the hydraulic main of greater diameter than has hitherto been usually adopted, a greater proportion of gas is obtained in less time than it can be when cylindrical vessels are used, which necessarily require the process of distillation to be considerably extended. And this greater quantity of gas, so obtained, arises principally from decomposition being more readily accomplished, and from the tar and oil, produced during the evolution of the gas in its rising state, being brought in contact with the bottom or sides of the distillatory vessel, then red-hot; thus causing these products to be decomposed, they form carburetted hydrogen gas and olefiant gas, consequently increasing the quantities of these gases from the same quantity of coal, if differently managed.

We know, from the results of many experiments made for the purpose of ascertaining what quantity of gas could be obtained from a given quantity of coal-tar, that one pound thereof yields about ten cubic feet of carburetted hydrogen gas, which abounds with olefiant gas. The number of cubic feet of gas obtainable from one pound of coal-tar is the average quantity deduced from the distillation of about four tons of coal-tar in vessels of a syphon-shape, lying horizontally; the tar was allowed to enter the distillatory vessel near the mouth-piece of the upper leg, and to trickle over a continued red-hot surface till decomposition was effected.

With respect to the distillation of coal-tar for the purpose of generating gas, the greatest nicety, as to the heat at which the retorts should be kept, is requisite. In the course of my experience I generally found that such heat as is required for distilling pit-coal was not sufficient for obtaining very favourable results from the use of coal-tar. But, perhaps, there has not been enough done to enable any one to speak satisfactorily on the advantages obtained by the manufacturer from converting his coal-tar into gas. The retorts on which my experiments were made were not found to answer on any bearing: they were expensive, could not be kept in action more than a few days together, and their interior, particularly about the bend, became so choaked up as to render them very soon unserviceable. I am of opinion, however, that if the tar could be received into the retorts upon a clean surface, instead of first coming in contact with the retort itself, the syphon-shaped retort would answer the purpose admirably, and it might be advisable to try the experiment upon one retort in any establishment where from a ton to a ton and a half of coal-tar is daily produced. In a former part of this work I have had occasion to state that fire-stone, Welch-lumps, and fire-clay, are not so great absorbents of heat as iron. On this principle it is evident that the heat of such bodies is thrown out with more force, and therefore if we suppose that towards the mouth of the upper leg of the retort a piece of Welch tile of about thirty inches in length were introduced, so as to allow the tar to drop upon it from the feed-pipe near its superior end, it would be almost, if not altogether, decomposed before it had passed over its surface; but if it should not, it would then have a length of ten feet of red-hot iron to come in contact with before it reached the exit-pipe at the bottom of the mouth of the lower leg, which could hardly fail of converting the small quantity of tar escaping from the first process into a gaseous state.

But returning to the subject of obtaining gas from pit-coal, I am to observe that when the manufacturer's chief object is to obtain the greatest quantity thereof in the least time, it is evident he must not use cylindrical retorts. These of the dimensions now in use are capable of carbonizing two bushels, or 168 pounds, of coal in eight hours, and from that quantity 555 cubic feet of gas are produced, or about 3⅓ cubic feet to every pound of coal carbonized; but, supposing the layer of coals in them does not exceed four inches in depth, the same retort will carbonize about one bushel in five hours, and this quantity of coal yields 2,772 cubic feet of gas, and at the same ratio per pound as in the former instance. By spreading the coal in a thinner surface to the action of the heat, as in the elliptical retort, a bushel and a half, or 126 pounds, of coal are carbonized in four hours, and produce 625 cubic feet of gas, or nearly five cubic feet for every pound of coals thus carbonized. We are, therefore, certainly to consider that these retorts, or any other description which will allow the coal to be exposed in thin strata, are very superior to cylindrical ones. On the proper heating of the retorts, and due management with respect to disposing of the coal for undergoing the distillatory process, more depends than the gas-light manufacturer generally supposes. From these circumstances not only the quantity but the quality of the gas, is materially affected. For we find from experience that when coal is distilled at a low red heat, scarcely visible by day-light, the gas is not sufficiently extricated from it, and that which is obtained, when submitted to combustion, produces but a very feeble light:—if the temperature be increased to a dull redness, we have more gas, and that of a better quality, but still short in every respect of what it ought to be. Indeed, if we are desirous of working the retorts to advantage, they should always be kept at a bright cherry redness, visible by day-light. Gas thus produced is increased in quantity and improved in quality. Here we must stop, and not by any mistaken notion increase the temperature to a higher degree; for, if we bring it to a white heat, the retort is in danger of melting, and the gas given out, being chiefly a mixture of carbonic oxide and hydrogen gas, yields a bluish flame of little illuminating power. Some of the species of Newcastle coal abound with pyrites, or sulphuret of iron; these, when distilled, produce a considerable portion of sulphuretted hydrogen, which increases the illuminating power of the coal-gas; but such gas requires great attention in its purification; for, should it pass to the burner without that process having been performed with the greatest nicety, it produces a suffocating odour where it is burnt, most easily observed in low and confined rooms.

If coal-gas be burnt in a vessel of oxygen gas, over lime-water, in the pneumatic trough, its constituent parts may be ascertained; these are found to be water and carbonic acid. When it is mixed in the proportion of one part of gas with nine of atmospheric air, it will explode with a force equal to gunpowder.

It has been already noticed that carburreted hydrogen gas is produced from various substances as well as from pit-coal. "Messrs. Sobolewsky "and Horrer, of St. Petersburgh, have employed "wood for the purpose. The pyroligneous acid "obtained in this operation, when freed from the "empyreumatic oil with which it is mixed, be"comes acetous acid, and is applicable to all the "uses of vinegar. A cubic cord of wood, equal "to 2,133 French metres, (a metre being rather "more than an English yard) yields 255 Paris "pounds of charcoal, and seventy buckets of acid. "The latter gives thirty pounds of tar; after the "extraction of it, fifty buckets of good vinegar

" remain. The same quantity of wood furnishes
" 50,000 cubic feet of gas, sufficient for the supply
" of 4,000 lamps for five hours*."

In the first number of the Quarterly Journal of Science and the Arts is a paper by Mr. Brande, on the application of coal gas to the purposes of illumination, in which he observes, that " besides
" the different varieties of coal and coal-tar, an
" useful gas may be procured from a variety of
" other substances; and in the laboratory of the
" Royal Institution we often feed the retort with
" waste paper, sawdust, pieces of wood, &c., and
" consume the gas for a variety of purposes,
" where oil was formerly employed.

" The following are the results of some experi-
" ments upon these subjects, compared with the
" produce from coal:—

" 1. The retort was charged with four pounds
" of coal. The quantity of gas amounted, after
" having passed the purifiers, to twenty cubic
" feet. The coke remaining in the retort weighed
" 2lbs. 8,7oz.

" The heating power of the gas flame was
" compared with that of a wax candle, by ascer-
" taining the time required by each to raise two
" ounces of water, in a thin copper vessel, from
" 55° to 212°. The flames were made as similar in
" dimensions as possible, and so placed that their

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* *Repository of Arts*, Vol. II. No. 36, page 341.

" points just touched the bottom of the vessel. " The heating power of the candle being assumed " as = 1, that of the coal-gas flame was = 1,5.

" 2. Four pounds of the dried wood of the " common willow yielded sixteen cubical feet of " gas, and fourteen ounces of charcoal remained " in the retort. The gas burned with a very pale " blue flame, and was unfit for the purpose of " illumination, and contained no olefiant gas.

" 3. Four pounds of the wood of the mountain " ash afforded fifteen and a half cubical feet of " gas, and thirteen ounces and a half of charcoal. " The flame was very pale and blue.

" 4. Four pounds of white birch wood gave " fourteen cubical feet of gas, and twelve ounces " of charcoal. The flame similar to 2 and 3.

" 5. Four pounds of hazel wood yielded thirteen " cubical feet and a half of gas, and twelve " and a half ounces of charcoal. Its heating " power was = 1,2. It burned with a better " flame than 2, 3, and 4, but the intensity was not " sufficient for any useful purpose of illumination.

" 6. Four pounds of writing paper gave eighteen " cubical feet of gas, and the remaining charcoal, " which beautifully retained the form and texture " of the paper, weighed eleven ounces and a " half. The heating power of the gas was = 1,6. " It burned with a flame nearly approaching in " illuminating power to that of coal-gas.

" These experiments prove that the gas from

" woods is not fit for the purposes of illumination, " although, as evolved during the production of " charcoal, it may conveniently be consumed in " the laboratory as a source of heat."

In a former part of this work a rule was given for ascertaining the quantity of light afforded by a gas-burner, and comparing it with that of a tallow candle. By proceeding as there directed, it will be found that an Argand burner, consuming $5\frac{5}{9}$ cubic feet of gas in an hour, yields a light equal to six mould candles of six to the pound. A pound of such candles, if lighted and burnt out one after another, would last 54 hours; consequently, if they were all lighted at once, they would be burnt out in nine hours; therefore, if we multiply the number of cubic feet of gas consumed in one hour, for affording an equal light to that emitted by six mould candles of six to the pound, by such number of hours as the candles would last if all lighted together, we shall have the number of cubic feet of gas equal in illuminating power to a pound of such candles:—

Thus, $5\frac{5}{9} \times 9 = 50$, the number of cubic feet of gas which is equal in illuminating power to a pound of mould candles of six to the pound.

Hence, if it be desired to know the number of cubic feet of gas required to be generated for supplying light equal to a given number of pounds of mould candles of six to the pound, should the number of pounds of candles be multplied by 50, the product will express the number of cubic feet of gas required for producing light equal in effect.

At page 376 preceding, it was stated, that, according to the most approved mode of operation, five cubic feet of gas are generated from one pound of Wallsend coal:—it follows, then, from what has been just stated, that ten pounds of such coal produce as much gas as is equivalent in illuminating power to a pound of mould candles of six to the pound.

Hence, if the weight of coal for furnishing gas-light, equal to the light afforded by a given number of pounds of such candles, is wanted to be known, we have only to multiply the pounds of candles by 10, and the product shews the number of pounds of coal. As the chaldron of Newcastle coals may in practice be generally estimated to weigh 27 cwt., or 3,024 pounds,—

If we divide the pounds of coal last found by 3,024, we find the chaldrons; by 84, the bushels; and by 21, the pecks necessary to be submitted to the distillatory process.

By proceeding in this manner, the reader cannot be at a loss to ascertain the quantity of gas required for furnishing a certain proportion of light, nor will he have any difficulty in finding what quantity of coal must be distilled for the purpose. Should he be furnished with a small apparatus for generating gas, I should recommend that he make experiments for himself, on the light afforded by different sized burners, compared with candles of various sizes, according to the instructions already furnished, which will, I should apprehend, be more satisfactory to him than a whole volume of tables for shewing such things by inspection, especially when the tables are constructed by another.

With respect to the superiority of light afforded from carburetted hydrogen gas, it is to be observed that it has a decided advantage over other lights; for, it has been ascertained that there is considerably less carbonic acid produced by its flame than by the flame of oil, tallow, or wax. Dr. Henry states, that " One hundred cubic " inches of carburetted hydrogen gas require, " for burning, two hundred and twenty cubic " inches of oxygen, and produce one hundred " cubic inches of carbonic acid. One hundred " cubic inches of the same gas, obtained from " wax, require, for burning, two hundred and " eighty cubic inches of oxygen, and produce " one hundred and thirty-seven cubic inches of " carbonic acid. One hundred cubic inches of " the same gas, procured from lamp-oil, require " one hundred and ninety cubic inches of oxygen " for burning, and produce one hundred and " twenty-four cubic inches of carbonic acid."

Can any proof be required more decisive than the above in favour of the use of gas-light? But, to produce such light, it is necessary that the gas should be well purified; for, if it is not deprived of the sulphuretted hydrogen, it emits sparks, and produces a portion of sulphureous acid, by the union of the oxygen of the air with the sulphur dissolved during the process of combustion.

Although coal-gas, if allowed to escape without being burnt, emits a disagreeable odour, yet this circumstance argues nothing against the use of it; for we are well aware that, if a candle be blown out, during the time the wick may remain ignited, it produces a smell equally disagreeable. But gas is not intended to be wasted in such manner, and it is now established, most satisfactorily, that, during its combustion, it is void of all smell whatever. It may be considered that the smell of the gas is a fortunate circumstance rather than otherwise; for, from thence, whenever there may be a leak in the pipes, it is easily detected; whereas, if the gas were void of smell, leaks might happen, and, in some cases, the most serious accidents occur, from the explosive nature of the gas when mixed with atmospheric air, should a light be brought in contact with the explosive mixture.

Coal-gas possesses an advantage over all other artificial lights, inasmuch as it may be applied in any direction, and thus throw the strongest portion of light to where it is most wanted,—a thing very difficult to effect when lamps or candles are used. By turning the cock which supplies the burner, a brilliant flame can be produced instantaneously; and that, again, in as short a time, lowered to such a degree as barely to be perceived. In either case, it will remain for any length of time without variation in height or intensity, provided the supply of gas be continued, and the pressure remain uniformly the same.

Perhaps it would not be improper here to suggest that the powerful strength and uniformity of the gas-flame, and the practicability of giving it any shape, makes it exceedingly applicable for use in the different light-houses. We know that, if a metal box were made of sufficient dimensions for allowing a figure or letter of large size to be painted on one of its sides, that provided holes of the thirtieth of an inch in diameter were drilled therein so as to allow the gas, when ignited, to present that letter or figure in flame, it might be distinguished at such a distance as to warn ships from approaching near it. We will suppose that this box is supported upon the top of an upright pipe which is kept in its position by a carriage for the purpose; the bottom being made gas-tight by an hydraulic joint. If, then, there be a wheel placed upon this pipe, which allows another to act into it, over the axis of which a weight is suspended, with the aid of a fly to regulate the motion, the distinguishing figure would, in a specific time (say five minutes), be presented towards every point of the compass. Were there then an alphabetical list of the light-houses published, noticing the figure or letter by which each was distinguished, no person could mistake one for another. This mode of lighting might be carried into effect at one-half the expense of that at present adopted, under an arrangement so simple, that any one acquainted with the gas-light machinery would do it with the greatest ease imaginable.

But, to contrast this strength of light with the opposite extreme, we are able, by the use of gas, to lower the flame to the height of one-sixteenth of an inch without fear of its going out. When a gas-burner is so adjusted, the flame is of a nature affording very little light; still it can, in a moment, be increased to any degree of intensity by merely turning the supplying cock. Under such circumstances, it would be very advantageously used in the chambers of the sick and of the studious.

The gas-light is well adapted for splendid illuminations, from the facility with which it can be conveyed in any direction, and from the diversity of shape in which its flame can be exhibited. To speak of its use in the interior of houses would be a waste of time; for the experiments proving its benefits when so employed, have now in every respect been most satisfactory.

If we compare the flame of a gas-light with that afforded by a candle, or a lamp, its superiority is at once established; and, taking the gas-lights on a larger scale, as in a manufactory, and comparing their effect with that of candles, makes the disparity between the two appear more striking. The most obvious application of gas-lights, consists in lighting streets, shops, and houses: in each it is safe, economical, and superior, to other modes of illumination. But there are other uses to which they might advantageously be put, such as the supplying of light-houses, the lighting of barracks, arsenals, and dock-yards.

As to gas-lights ever being introduced on board of ships of war, there can be little hesitation in observing that the thing appears totally impracticable: for, although there might not be much difficulty in carrying on the distillatory process, no one who is aware of the motion of a ship at sea would conceive much hope of constructing a gas-holder to act there with uniformity. It must be evident, that either the pitching or rolling of a ship would prevent the use of a tank; and, were it possible to construct the gas-holders without one, the motion of the ship would give such a motion to the balance-weights as would force out the gas with a very unequal pressure, and, consequently, produce a very unsteady light, and such a one as must fail of being useful. In short, with respect to its application on board of vessels of war, or merchantmen, we must despair, unless we can first devise some means for keeping a ship always on an even keel.

As to the use of gas-light in shops, counting-houses, and public offices, it must be allowed a superiority over candles or lamps. It yields a pure white light nearly equal to day-light, and at the same time produces such a degree of warmth as almost to render a fire, in the place where it is burnt, useless. From my own experience I am enabled to state that two Argand burners, each consuming about five cubic feet of gas in an hour, so sufficiently heat a room of about ten feet square, as to render a fire there unnecessary even in the depth of winter. Indeed, every one who has used gas-lights must be aware of their heating quality beyond that of candles or lamps. This arises from their flame condensing more air than the flames of candles, *&c.*: the consequence arising therefrom, is, the production of a greater proportion of heat; in short, a gas-light flame may be so enlarged as to heat apartments of the largest dimensions. Mr. Dalton, in the first volume of his *System of Chemistry*, page 76, has given a rule for ascertaining the comparative quantity of heat given out by the burning of different inflammable gases, and other substances capable of yielding flame, which I here introduce to the reader's notice, and strongly recommend for simplicity, ease, and accuracy:

" Take a bladder of any size, (let us suppose, " for the sake of illustration, the bladder to hold " or to be equal in capacity to 30,000 grains of " water,) and, having furnished it with a stop-" cock and a small jet-pipe, fill it with the com-" bustible gas, the heating power of which is to " be tried. Take also a tinned iron vessel, with " a concave bottom, of the same capacity; pour " into it as much water as will make the vessel " and water, together, equal to the above-stated " bulk of water in the bladder, that is to say, " 30,000 grains. This being done, set fire to the " gas at the orifice of the pipe, and bring the " point of the flame under the bottom of the " tinned vessel, and suffer it to burn there, by " squeezing the bladder, till the whole of the gas " is consumed. The increase of temperature of " the water in the tinned vessel, being carefully " noticed before and after the experiment, gives " very accurately the heating power of the given " bulk of the inflammable gas.

“ It was thus proved:

“ Olefiant gas raises an equal volume of “ water	14 deg.
“ Carburetted hydrogen, or coal-gas	10
“ Carbonic oxide	4
“ Hydrogen	5
“ Spermaceti oil, 10 grains burnt in a “ lamp, raised 30,000 grains of water	5
“ Tallow	5
“ Wax	5,75
“ Oil of turpentine	3
“ Spirit of wine	2

The flame of the gas light is well adapted for use in such of the processes of the arts as require a moderate degree of heat; and, where much nicety is required, it possesses advantages not to be obtained from flaming fuel of any description. No species of fuel can be managed like it; for, when fuel is used, if there be a deficiency of air the combustion is imperfect,—there is no flame produced,—and the only product is an aqueous and sooty vapour. On the contrary, too great a supply of air frequently causes these vapours to burst out with an intensity of flame which is more violent than required. There is a difficulty in managing one, that can hardly be overcome, whilst the other is effected with the greatest possible ease.

I am here to observe, that to ascertain the great power of a gas flame, we must not content ourselves with experiments upon a small scale, for it cannot be determined by a small-sized light which burns quietly. In such case the air acts but superficially upon the flame, and that is of too small dimensions to produce much effect. But, let the dimensions of the flame be enlarged, and at the same time cause the light to be agitated with a current of air, and its heating power will be found most wonderfully augmented, and particularly adapted for heating large quantities of matter with rapidity, and to a high degree, where the application of solid fuel for the purpose may be inconvenient or impracticable.

CHAPTER XXI.

On the Coke, Tar, Ammoniacal Liquor, &c. produced from Coal during the process of Distillation.

COKE—is the carbonaceous base of the coal which remains in the retort after the evaporable products have been expelled therefrom during the process of carbonization. The qualities of coke vary with the kinds of coal used, and the process adopted for extracting the gaseous and other products. Coals of the first class, as heretofore described, yield no product of coke that is useful, nor is that produced from those of the third class fit for any beneficial purpose, let either be operated upon in any way whatever;—but coals of the second class, when the distillatory process is carried on for eight hours, by means of cylindrical retorts, such as have already been described, produce an excellent coke, in many cases nearly of sufficient strength for metallurgical operations. When coals of this class are submitted to the distillatory process in thin strata, the coke produced is light, and well adapted for parlour fires or for culinary purposes; it lights easily, and burns with a cheerfulness almost equal to coal. In manufacturing coal-gas, the operator will always find from coals of the second class an increase of coke, by measure, on the coals carbonized, though the weight must necessarily be diminished. The coke is always drawn from the retort in large pieces, whether the coal used be large or small; indeed, if the coal be but free from foreign matter, the small is as good as the large for the purpose of generating gas.

The heat afforded by coke is more intense than that afforded from coal, and it is more uniform: that it should be so is very easily accounted for; we know that when coal is submitted to the process of combustion, a considerable portion of it is changed from a solid to a state of elastic fluidity, necessarily carrying off part of the caloric, without producing heat; whilst coke, having no demand of this kind, allows its heating power to remain unimpaired.

Coke has, however, one inconvenience—that is, the producing a greater proportion of ashes than coal. These are apt to choke up the bottom of the grate, which frequently requires clearing, to allow the necessary draught for causing combustion to be perfect.

When the heating powers of coal and coke are compared, it will be found, that for heating equal quantities of water to equal temperatures, in vessels of like magnitude, where 80 pounds of coal would be required, the same might be performed by 30 pounds of coke; consequently the proportions will be as 3 to 8. The foregoing statement is drawn from several experiments, of which it is the mean, which were performed after the following simple manner:—Equal quantities of water were completely evaporated under equal surfaces and circumstances, with coal and coke, and the quantities of fuel used in each case carefully noticed; from whence the relative effect of each was ascertained, as far as regarded their respective powers of producing heat. When coke is used for domestic purposes, it is found to be about two-thirds as durable as coal; or, to speak in other words, two chaldrons of coal are equal in durability to about three of coke, when used in the same fire-place.

Coke may be advantageously used for burning lime. It has been ascertained by the Earl of Dundonald, that a given quantity of lime-stone is burnt by a quantity of coke in one third of the time that it would be by using the coal from which the coke was made. We may account for this by considering that coke is deprived of the tar and moisture, which, when coal is used, must necessarily be thrown out, and impede the rapid ignition of the lime-stone. The sooner that is wholly effected, the better will the lime be burnt.

It will by coke be done in less time than by coal, and at less expense also. In using coke for this purpose, the kiln will hold nearly a third more lime at once, so that in every case coke is to be used for burning lime in preference to coal.

It may also be used for burning bricks and baking plaster-stone. An account of its advantages, when adopted for such purposes, is given by Mr. Davis, in the 33d Volume of the *Philosophical Magazine*, from whence the following account is extracted:—" The coke obtained in " the gas process is so valuable, that it appears " inexplicable that men should not avail them- " selves of this mode of procuring light, to the " almost total exclusion of all other methods now " in use. I have lately employed coke for the " burning of bricks. My bricks are burnt in " clamps, made of bricks themselves. The place " for the fuel or fire-place is perpendicular, about " three feet high. The flues are formed by ga- " thering or arching the bricks over, so as to " leave a space between each of a brick's breadth; " and, as the whole of the coal, if this fuel be " employed, must, on account of the construction " of the pile, be put in at once, the charge of " the bricks is not, and never can be, burnt pro- " perly throughout; and the interference of the " Legislature, with regard to the measurement " of the clamp, is a sufficient inducement for the

" manufacturer to allow no more space for coal " than he can possibly spare.

" If coke be applied instead of coal, the arches " or empty spaces in the clamp or pile, as well " as the strata of the fuel, may be considerably " smaller: the heat produced in this case is more " uniform and more intense, and a saving of thirty " per cent. at least is gained.

" In the baking my own plaster-stone I also " employ coke. The calcination of the stone " for manure I perform in a common reverbera- " tory-furnace, and the men who conduct the " process (who are otherwise averse to every " thing new) are much pleased with the steadi- " ness of the fire, and little attendance which the " process requires, when coke is used instead " of coal."

As to the quantity of coke obtainable from a given quantity of coal it varies with circumstances: if we speak of Newcastle coals, it may be stated at from twenty-five to fifty per cent. by measure on the coals carbonized, as has already been noticed in the chapters " On the Retorts," and " On Carbonization."

Coal Tar—is an another product obtainable from coal during the distillatory process; it is so called from its resemblance to common tar, not only in appearance but many of its qualities. The quantity produced from a chaldron of coals has already been noticed at page 194 preceding. The production of tar from coal has been effected at different periods both in this and other countries, but without any return of profit worthy of notice. In the year 1781, the Earl of Dundonald invented a mode of distilling coal for the purpose, and at the same time to form coke: but it was not till the gas-light scheme was established that the process was carried on advantageously, the former operators neglecting to collect the carburetted hydrogen evolved, which certainly is the most valuable of the products obtained from coal. Coal-tar, however, in its crude state, is not fit for using upon cordage: it is impregnated with a considerable portion of ammoniacal matter, which is destructive thereto. It may be deprived of the ammonia, and other foreign substances, by evaporation in open vessels, and thus rendered of such a consistence as to make it more fit for use.

Should coal-tar be distilled in close vessels, it yields an essential oil that is known by the name of oil of tar. This process requires to be carried on with a very moderate heat, as the tar is very apt to boil up and endanger the safety of the still. During the former part of the process the product is chiefly an ammoniacal fluid, mixed with a considerable portion of oil, but, as it advances, the ammoniacal liquor lessens in quantity, whilst that of oil increases, till at the last the product is principally oil. These two products, though received into the same vessel, do not mix, and therefore may easily be separated by cocks fixed at proper heights in the receiving vessel for the drawing off of each. This oil possesses the quality of inferior oil of turpentine: it may be used for making varnishes, and for coarse out-door work. The tar itself, in its unprepared state, forms a good coat for fencing, and for protecting out-door iron-work. Coal-tar distilled as abovementioned forms a species of pitch, and, if it has been evaporated in an open vessel, preparatory to being put into the still, it is nearly equal to that in common use. This pitch, by an additional fusion, is formed into a species of asphaltum.

From the results of experiments made on the distillation of about fifty tons of prepared tar in close vessels, I have ascertained that one gallon thereof, wine measure, which weighs 9½ pounds avoirdupois, produces

6,84 pounds of pitch
1,26 quarts of oil of tar
and 0,46 pints of spirits of tar.

On the subject of coal-tar, pitch, and oil of tar, I am to notice that, although they have not yet found a market, they are to be considered as very effectual substitutes, in many cases, for tar, pitch, and oil of turpentine, and will doubtless be so acknowledged if once they are allowed a fair and unprejudiced trial.

Ammoniacal Liquor.—This product has been manufactured into muriate of ammonia, and some species of salts, but there has not yet been found a sufficient demand for the quantity so manufactured. The quantity of this liquor obtained from a chaldron of coals has been stated at page 194 of this work; it is chiefly composed of sulphate and carbonate of ammonia.

CHAPTER XXII.

On the Tendency of the Gas-light Scheme towards promoting the Coasting Trade. Where Gas-light is most economically used. Its Safety.—Remarks on arranging a Station.—Recapitulation of the Process for generating Gas.—Mr. Onthett's Apparatus.—Mr. Malam's Retorts.—Conclusion.

IT will not be necessary here to take into consideration the slowness with which new, and frequently useful, inventions are adopted by the Public; for in such respect the gas-light scheme is most decidedly an exception. It has already been noticed with what avidity gas-light has almost every where been called for: still the system is spreading daily in every direction.

If a nursery for seamen is worthy of attention, the gas-light system promises fair for forming it, as such it may be recommended to notice: for we know that coasting vessels supply ten times as many seamen to the Navy in time of war as are furnished from the Greenland ships. The greater consumption of coals in the manufacture of carburetted hydrogen gas will call for more hands in the coasting trade than are employed in the fisheries; and every one, knowing any thing of the alertness and discipline on board our ships of war, will allow that there are no better seamen in the naval service than such as have served their apprenticeship to the sea in colliers and coasting vessels. But the adoption of gas-light even on the most extended scale is not likely totally to supersede the use of tallow or of oil; for there are cases where such must be used in preference, at least till such time as means are adopted for making the light afforded by gas a transferable one.

Gas-light cannot be manufactured with economy on a small scale, such for instance as where but three or four lights are wanted: it is in the large way where the profits arising are most perceptible. In manufactories, and for lighting streets, it is most advantageously employed; but, in the latter case, were only the parish lamps lighted, it would not be attended with much profit. To make it answer the manufacturer's views he ought also to light shops, and the interior of private houses, from the same range of main-pipe as supplies the street lights.

The price of coals can make but little difference in the price of the gas; for where coals are plentiful it follows that they will be cheap, so will also the coke; but where coals are dear the coke will also fetch a higher price, and find a more ready market.

In adverting to the safety of this species of light it may be observed that, under proper management, and with a due degree of caution, accidents will hardly ever happen: indeed the apparatus is such as cannot be put out of order but by wilful design. That carburetted hydrogen gas, when mixed with a certain proportion of atmospheric air, possesses an explosive quality no one will attempt to deny: yet, if we consider the portion thereof necessary for causing an explosion, it cannot be expected except in a close and confined place. A room fifteen feet square and nine feet high, if entirely closed, would require five cubic feet of gas to escape in an hour for nearly forty-eight hours together, so as to form an explosive mixture. But in rooms having a fire-place, and doors or windows not fitting very tight, were there an escape of gas, from the stop-cock to a burner being left open, or from leaks, it would require a considerable time to elapse before a sufficient quantity of gas was allowed to escape so as to make an explosion, on the introducing a light, certain. I should state, as a matter of opinion, that, under such circumstances, an explosion could not happen. This has been most satisfactorily proved by several years' experience, and therefore does not require to be further dwelt upon.

In order to give the reader, who is totally unacquainted with the nature of gas-light apparatus, an idea of the process, I shall briefly recapitulate what has been already stated in the respective chapters of this work which treat on the machinery: but before I do so it may not be amiss to point out the relative situation of the different apparatus. If we suppose the boundary lines of the manufactory such as to form a square, it would be adviseable to have the entrance about midway of one of the sides. At one side of the gateway there might be erected a house for the officer superintending the works, and at the other another of similar appearance, fitted up for the different offices. The retort-house should stand with one of its ends near the entrance, and the chimney should be placed at the other. A sufficient space should be left to allow a team to pass entirely round the retort-house, to prevent the necessity of turning in the yard, which, when confined, is attended with inconvenience. It would be well to have a range of buildings on each side of the retort-house running parallel thereto, and contiguous to the boundary lines: that on one side being fitted up so as to allow the lower part to form stores for castings, and heavy stores, and the upper for work-shops for the mechanics and for small stores. The other building might be divided so as to form stores for coal and coke in the lower part, and above for other products. Beyond the retort-house might be placed the condenser, tar-vessel, purifier, and gas-meter, in a line parallel to its end; between these and the side opposite to that of entry, might be occupied by the gas-holders. An arrangement like this would present an uniformity of appearance, and a saving of room, which does not always appear to be considered by the manufacturer. However, the arrangement of the apparatus will vary with local circumstances, and therefore no general rule can be given for the purpose. It will be obvious, notwithstanding, that it will be well to place the gas-holders at as great a distance from the retort-house as the premises will allow.

Supposing the works to be complete, and the retorts heated to a bright cherry redness, preparatory to being charged; the lid is then removed from the mouth-piece, and a portion of luting, made of clay or Windsor loam, put round the edge of it. The coal is next introduced into the retort, after which the lid is put on and secured by means of the cross-piece, so as to form a gas-tight joint. The distillatory process now commences, and the gas is carried up the pipe connected to the mouth-piece (with the tar and ammoniacal fluid in a gaseous state) over the H pipe, into the hydraulic main, till the whole of the evaporable products are extracted from that charge, when the lid is removed and reluted, the charge drawn, and another introduced as before.

This process goes on continually till the retort is destroyed. The gas, tar, and ammonia, having descended into the hydraulic main, they are conveyed away from it, by means of cast-iron pipes, towards the condenser, and, having passed through that vessel, the tar and ammoniacal liquor enter into the tar-cistern, whilst the gas passes into the purifier, where it undergoes a process for depriving it of the sulphuretted hydrogen gas and carbonic acid gas evolved with it. It then passes through the gas-meter, in order that the quantity made may be registered, on its way to the gas-holder, and, entering that, it is stored up till wanted for use. As the action of each part of the apparatus has been already described, the reader by referring to the respective chapters, after reading what has just been recapitulated, can hardly fail of fully understanding the subject.

In order that I may fulfil my promise of speaking of the inventions of ingenious men, I am here to observe, that since the Chapters on the Retorts, Condenser, and Purifier were printed, I have been favoured by Mr. Onthett with a sight of the various drawings of gas apparatus for which he has obtained a patent. Of his gas-holder I have already spoken; I am now briefly to notice the other parts of his apparatus. His retorts are so modified as to be likely to possess durability and usefulness. I should have no hesitation in declaring them capable of carbonizing at a considerably less per centage than those most generally used, and of producing from 15 to 16,000 cubic feet of gas from one chaldrom of coals, if worked at thè four hours' process.

In speaking of Mr. Onthett's retorts, it is to be understood that he has not adopted new shapes for the retorts themselves, but to each kind, whether circular, square, or elliptical, he has made such additions as he considered would tend to shorten the process of carbonization, lessen the labour of drawing and charging, increase the durability of the distillatory vessel, and produce a greater proportion of gas. When the cylindrical retorts are used with his modification, they are exteriorly similar in appearance to those in common use, and are of the same dimensions. Inside of each are introduced three cast-iron pipes, which come close up to the mouth-piece, and proceed to within a few inches of the farther end. Under this arrangement the gas will escape from these tubes at the farther end, and pass between their exterior and the interior of the surrounding cylinder towards the mouth-piece, whence it escapes towards the hydraulic main. The volatile products being thus submitted to the heat of a large surface of red-hot iron, are more effectually converted into a gaseous state than by the ordinary method, and hence the greater proportion of gas to a chaldron may be accounted for. With a trivial variation, Mr. Onthett adopts the square and elliptical retorts for performing a similar operation, and his plans promise fairly for answering the end he has in view. In all the different kinds of retort he introduces the charge in boxes, for effecting which he has a moveable frame which traverses in front of the retorts, and being brought in contact with any one wanted to be drawn, the catches upon the frame clip over an end of the box, and it is drawn entirely out upon the frame. Another motion turns the box over and allows the coke to fall out of it. It is then re-charged, and again introduced into the retort, in order that the coals it contains may be submitted to the distillatory process. The boxes being thus continually heated, do not suffer from the contraction and expansion which would follow from their being allowed to become quite cold, and are, therefore, more likely to increase in durability. By this mode of operation the labour is much decreased, and the benefits which arise from it are many, and of great importance to the manufacturer.

Mr. Onthett does not use the H pipe; instead thereof the connecting-pipe from the retort proceeds upwards to the height of about five feet, where it has a socket for receiving another pipe, of a syphon shape, one end of which is jointed into that socket, the other descends into the hydraulic main. At the bend part of this syphon-shaped pipe is a flanch, upon which a cap is jointed, which can be removed when the pipe is choked up, and an iron rod pushed down on either side to clear the passage. This kind of conducting-pipe is used under all the modifications of Mr. Onthett's plan. It is about three inches diameter inside, and therefore not so liable to stop up as when smaller pipes are used for the purpose.

Mr. Onthett's condensing vessel is somewhat similar in construction to that invented by Mr. Malam, heretofore described. It is a square vessel, cast in pieces, so as to require but little trouble in connecting it together. The gas enters near one of its corners, and passing in a spiral direction through square pipes, of about two inches wide by twelve inches high, is discharged at the centre. Between these pipes water is continually running in a contrary direction; thus the pipes are kept constantly cool, and condensation is well effected.

His purifying vessel is circular-shaped, and not very deep. The gas enters at the centre, through a conical-shaped casting: another casting of the same shape descends from the top, so as to clip over the former, having an opening on one side for allowing the gas to pass to the purifying mixture. On one side of this opening is a divisional plate, descending nearly to the bottom of the vessel: hence, the gas, after entering, must pass entirely round the outer cone before it can escape; the opening of exit being at that side of the plate just mentioned, which is opposite to the opening of entry. The interior of the top of this purifier is an inclined plane. The top is not fixed, as in the ordinary vessel, but suspended from a beam laying across the centre at a sufficient height above it to allow the top to be raised, so that it will admit the vessel to be cleaned out whenever it may be necessary. For removing the top, the wheel which is used when the vessel is in action, is put into gear with another for performing that office, and thus it is effected with a facility hardly to be conceived. To prevent an escape of gas from the top of this purifier, Mr. Onthett attaches thereto a rim of plate-iron, nearly of the same depth as the outer vessel, which, of course, when the vessel is in action, is lowered so deep into the purifying mixture as to form an hydraulic joint. The supplying vessel to this purifier is so constructed as to allow the purifying mixture to enter with any required velocity. Thus, the charge can be introduced all at one time, or it may be continually entering: in the latter case, it is evident that there must be some contrivance for taking the impure lime away, which Mr. Onthett has also effected.

In addition to these improvements in gas-light apparatus, which are so well worthy the attention of the manufacturer, Mr. Onthett has also constructed a valve, which, for safety of operation, cannot be excelled. He had, from a very just mode of reasoning, conceived that in the use of the single hydraulic valve there was much probability of the water being blown out of the cup when shut or opened, and that therefore it would soon be rendered less effective than intended: for, when the cup is lifted to a distance from the surface of the water, less than the pressure at which the gas-holder is worked, the water is forced out of the lower cup. If the reader refers to *Plate* X. *Figure* 2, the description of Mr. Onthett's hydro-pneumatic valve will be made more easy. Its outward appearance is very similar to that figure; it has, however, only a single cup. The gas enters into the valve, and is discharged from thence, in the same way as was described when speaking of Mr. Malam's double hydraulic valve, of which the figure alluded to is a section. Below the centre of the interior of the upper cup, is a plate which is lowered down upon the top of the inferior cup, by means of a screw which effects a gas-tight joint. The action of another screw then lowers the cup, and thus the valve is secured, both pneumatically and hydraulically. The pneumatic sealing of the valve being first effected, the passage of the gas is stopped, and thus the hydraulic sealing of it can be accomplished without any danger of displacing the water. When it is to be opened, the cup is first lifted, and afterwards the plate raised. It is evident that this contrivance answers the desired end, without leading the manufacturer into needless expense, or occupying so much room as many of the valves now in use. This valve is well adapted for use in the manufactory, and may be relied upon as trust-worthy in any other situation.

Having led the reader through the different stages of the process for generating and distributing gas, and, I hope, fulfilled my promise made in the Introduction; I am now to notice, that, since writing the Chapter on Retorts, the value of Mr. Malam's have been stamped at the Peter-street gas-works, by a trial on fifty: the result of which has induced the managers of the concern to order a sufficient number for generating the gas wanted for use at that station. Thus, it appears probable that Mr. Malam's mode will supersede others which have been adopted to answer a similar end, that of submitting the coal in thin strata to the distillatory process. The performance of his retorts, even on an extended scale of operation, has more than verified my former statement: they are decidedly superior to any other at present used. That it has taken so long a time to bring them forward is not very surprising, if we consider the immense sums which have been expended in experiments by the Chartered Gas-Light and Coke Company,—many of which have tended to no useful purpose. From dear-bought experience, the directors of that company have learnt the fallacy of many pretensions, and thence things of real merit are received with a caution that can hardly be blamed. In this case, however, if they had reasoned from analogy, they need not have taken two years to consider whether the elliptical retorts were likely to answer. They had, at a great expense, proved the advantages resulting from pursuing the mode of distillation effected by similar means, as far as related to the generation of gas, and thence might have drawn a proper conclusion.

To conclude;—I am to observe that, although much has been already done towards promoting the progress of this new science, still there is much remaining unaccomplished: a wide field is yet open for improvement, into which, it is to be hoped, men of science will deign to enter; and, by their exertions, dispel those clouds with which empiricism has veiled it.

THE END.

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