"The Builder" Student's Series.

GAS AND GAS FITTINGS.

A HANDBOOK OF INFORMATION RELATING TO COAL-GAS, WATER-GAS, POWER-GAS, AND ACETYLENE.

FOR THE USE OF ARCHITECTS, BUILDERS, AND GAS CONSUMERS.

BY

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With Seventy-three Illustrations.

LONDON:
WHITTAKER & CO., 2, WHITE HART STREET, PATERNOSTER SQUARE, E.C.
AND
66, FIFTH AVENUE, NEW YORK.

1902.

LONDON:
PRINTED BY LOVE AND MALCOMSON, LIMITED,
GREAT QUEEN STREET W.C.

PREFACE.

Architects and builders long familiar with the perennial newspaper statement that gas manufacture as an industry is in a retrogressive condition, and is doomed to speedy extinction through the competition of electricity, must credit the expiring industry with an extraordinary degree of vitality when they take into consideration the provisions they are called upon to make in all classes of buildings for the introduction of gas.

Palatial modern hotels illuminated throughout, regardless of cost, with electric light, have to be provided with gas services larger and more extensive than those employed before the advent of electricity; for where hundreds of cubic feet of gas were formerly used for illumination, thousands are now consumed for heating purposes. In large city restaurants gas-fittings have to be provided to supply numerous grillers, ovens, and water-heaters, and in both city and suburban shops and residences the incandescent gas-light is everywhere in demand. In model dwellings and workmen's cottages gas is extensively used in conjunction with the *penny-in-the-slot meter;* and in casual wards, asylums, and other public institutions, the use of gas is rapidly extending for the heating of halls, cooking appliances, and drying chambers. In the workshop thousands of small gas-engines are now used for driving lathes and circular saws, and the use of gas for heating muffle furnaces, and other appliances employed in the minor arts and crafts, is daily becoming more common.

The most recent authoritative account of the present condition of the gas industry is that contained in a Paper communicated to the Institution of Civil Engineers by Mr. H. E. Jones in April, 1901. Referring to the Board of Trade returns relating to gas supply in the United Kingdom, Mr. Jones points out that "the volume of trade has increased by 21¾ per cent. in the past four years; and if this figure is not particularly striking as a simple ratio, it must be remembered that it is calculated upon a basis already so large, as compared with any analogous industry, that the increase shown, whether considered in money value or in volume of production, is far in excess of what has accrued to any competitive system."

It is evident, therefore, that those who undertake the erection of buildings must continue to make themselves familiar with the requirements of gas consumers, and should be sufficiently acquainted with the properties of the various descriptions of gas commonly used for lighting or heating to enable them to make provision in any type of building for a satisfactory gas supply, and when consulted by their clients to show that they possess a knowledge of the conditions necessary for the satisfactory application of gas for all ordinary industrial or domestic purposes.

Fifteen years ago all public gas supplies in this country consisted of coal-gas alone, but in London and most other large towns, as well as in many towns of minor importance, a mixture of coal-gas and carburetted water-gas is now supplied. This mixture differs from coal-gas in specific gravity and composition, requires a different proportion of air for its combustion, and should be supplied to the burner under a different pressure. In many large factories a low grade non-luminous gas known as "power-gas" or "fuel-gas" is largely used for driving machinery, and this also requires a higher pressure and less air for its combustion than either coal-gas or water-gas.

Within the last six years the use of acetylene, as an illuminant and fuel, has become fashionable in country mansions, churches, and villages which possess no public gas supply, and architects and builders are frequently consulted as to its applicability for various purposes, and are liable to be called upon to make provision for its introduction into widely different classes of buildings.

In the present volume the methods employed for the manufacture of coal-gas, water-gas, power-gas, and acetylene are described in general outline, while the properties of the different gases, and the conditions under which they are consumed with greatest advantage, are discussed in greater detail. Reference is made to the new business methods adopted by many gas companies, and the offer of some of the companies to supply and fix all internal gas-fittings. A brief description is given of the work of the Local Authorities in making provision for the constant testing of the gas supplied to consumers, and in affording facilities for the impartial testing of consumers' meters, while the laws of this country relating to the use of acetylene, and the storage of calcium carbide, are enumerated in the concluding chapter.

The author is indebted to Messrs. H. O. Carr, A. M. I. M. E., and R. P. Harris, for most of the illustrations, and takes this opportunity to also thank those gas-works' managers and technical chemists who have supplied him with information upon various subjects. He is also indebted to the "Journal of Gas Lighting" and the "Gas World" for information obtained from those journals.

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GAS AND GAS FITTINGS.

CHAPTER I.

INTRODUCTION.

THE gas industry was founded by the Scotch engineer, William Murdoch, in the last decade of the eighteenth century. Prior to that period no gasworks of any description existed in any part of the world, although it had long been known that inflammable gas could be obtained from coal and certain other substances by distillation, and could be led through a pipe and ignited at its open end.

Claims of priority of discovery of the fact that gas obtained by the distillation of coal could be used for lighting purposes have been made for certain Continental experimentalists, but the fact that Murdoch was the first to establish gas manufacture as an industry, and the first to erect gasworks for lighting purposes on a comparatively large scale, is beyond dispute.

During the nineteenth century the industry rapidly developed into one of foremost importance. Gas-producing plant was erected in every civilised country, and gas securities took rank with those of water and railway undertakings. The introduction of electricity and of cheap oil caused fluctuations in the value of gas shares, but did not cause any diminution in the world's rate of gas production. Not only is the consumption of gas at the present time greater than at any previous period, but extensions of existing plant are in course of erection in numberless districts. At the close of the century 1,614 separate gas undertakings were in existence in the United Kingdom alone, and these collectively manufactured gas at the rate of 156,665,269,000 cubic feet per annum.

In the early part of the nineteenth century all the gas undertakings were controlled by private owners or by companies, but throughout the last half century Local Authorities have evinced an increasing desire to obtain control of the works supplying gas to their respective districts. In spite of the fact that gas properties have become so valuable that high prices have always to be paid for them, we find on reference to the "'Gas World' Year Book" for the year 1901, that 265 gas undertakings in the United Kingdom are already in the hands of the Local Authorities, and included in this list of localities supplied with municipal gas are the towns of Aberdeen, Belfast, Birkenhead, Birmingham, Blackburn, Edinburgh, Leeds, Leicester, Nottingham, and Manchester.

At first gas was manufactured exclusively from coal, and was used almost solely for lighting purposes, but as time progressed and the art of gas-making was more closely studied by chemists and engineers, it was found that inflammable gas could be economically manufactured from a number of other materials, and that illumination was but one of a great number of purposes for which gas was eminently suited. Certain kinds of sawdust and timber yield very good gas, and even sewage has its advocates as a gas-making material. In certain parts of the world, notably in the United States, America, vast subterranean accumulations of so-called "natural gas" have been discovered, and these have been tapped and distributed in the neighbouring towns as a substitute for coal-gas. An accumulation of inflammable gas has recently been discovered in this country, at Heathfield in Sussex, and the gas has been employed for lighting the local railway station by the incandescent gas-light system. The gas confined in these subterranean chambers is, of course, all consumed sooner or later, as the formation of gas, if still proceeding, proceeds at a very slow rate. Sometimes, however, the quantity of natural gas discovered is very large, and is sufficient to supply a town for many years. In the neighbourhood of coalfields natural gas had been discovered long before Murdoch was born, but no successful attempt had been made to utilise it for lighting purposes. During the last five years acetylene gas, produced from calcium carbide, has also been extensively used, but at the present time the only formidablé competitors of coal-gas are water-gas and the diluted form of water-gas commonly termed "power-gas," "fuel-gas" or "producer-gas."

By blowing steam through strongly-heated coke or other form of carbon a non-luminous gas can be manufactured which possesses about half the heating value of coal-gas, and which can be produced in many localities at much less than half the cost. If illuminating gas be required, the non-luminous gas can be mixed with oil-gas or enriched in some other manner, and thus be made to resemble coal-gas in illuminating power. Carburetted water-gas, as the mixture of oil-gas and water-gas is termed, is, however, inferior in some respects to coal-gas of equal illuminating power. The difference between the two varieties of gas will be explained in a succeeding chapter.

It is obvious that the solution of the question as to whether coal-gas, water-gas, or carburetted water-gas is the most suitable for the supply of a specific district is dependent upon the local prices of gas-coal, coke, and oil, and upon the purposes for which the main proportion of the gas is required. In some districts cheap gas of a low illuminating value is the most suitable; but in districts in which good gas-coal is abundant and cheap, coal-gas of comparatively high illuminating value remains the most economical supply.

As coke is one of the residuals obtained from the distillation of coal, it frequently happens that a mixture of coal-gas and carburetted water-gas may be economically supplied. As a matter of fact, carburetted water-gas *per se* is very largely used in America, while in London, north of the Thames, and in many other British towns, a mixture of coal-gas with carburetted water-gas is used. In factories where the gas is used for driving engines cheap non-luminous fuel-gas is largely used, the consumption of Mond gas at the works of Brunner, Mond & Co., in

Cheshire, for example, being about a million cubic feet *per hour.*

The manufacture of gas of different composition, specific gravity, illuminating power, and calorific value in different localities has rendered it necessary for a purchaser of gas appliances to take into consideration the district in which the appliances are to be fitted, if they are to be used under the most favourable conditions. The satisfactory use of gas is, moreover, made difficult by fluctuations in the pressure of the gas supplied. In London the tests made by the gas examiners appointed by the London County Council show that the pressure in the street mains varies from about 1·4 in. to 3·8 in. of water, and in buildings the pressure sometimes fluctuates to a yet greater extent owing to defects in the fitting of the local-service pipes, and the height to which the pipes are carried. The pressure in buildings in London seldom exceeds 3½ in., but it often falls to 1 in., and at the latter pressure many gas appliances fail to work in a satisfactory manner. Gas governors may be used to reduce the pressure to any desired point, but are useless when trouble is caused by insufficient pressure. An "atmospheric" gas fire which will burn satisfactorily with coal-gas supplied at 1¼ in. pressure will not burn so well with a mixture of coal-gas and water-gas of the same illuminating power supplied at the same pressure, because water-gas, whether plain or carburetted, has a higher specific gravity than coal-gas, and having a different composition, requires a different proportion of air for its combustion. This fact is recognised by some of the gas-fire makers, who supply a special fitting for use with water-gas mixtures.

Where gas is supplied of uniform composition and at a uniform pressure appliances can readily be devised to consume the gas in a satisfactory manner, whatever may be its composition or the pressure (above 1½ in.), at which it is delivered from the mains; but in London north of the Thames, and in certain other localities, much trouble has been caused by frequent fluctuations in both composition and pressure.

For the incandescent gas-light system non-luminous gas is as serviceable as illuminating gas, provided it possesses the same heating power, and recent experiments by Dr. Strache appear to prove that water-gas, having only one-half the heating value of coal-gas and quite devoid of illuminating power, may be as efficient for lighting purposes by this system as the coal-gas. If illuminating gas is to be used for incandescent gas lighting, it must be mixed before reaching the point of ignition with sufficient air to cause it to burn with a non-luminous flame; otherwise the mantle will become coated with soot and cease to emit light. In view of the statement of Mr. George Livesey, Chairman of the South Metropolitan Gas Company, that 50 per cent. of the gas sold by that company is used for purposes other than lighting, and of the fact that throughout the country the ratio of gas used for heating to that used for lighting (other than incandescent lighting) is already large and is increasing at a rapid rate, it is apparent that the commercial value of gas is now dependent upon its calorific value rather than upon its illuminating power. In practical gas manufacture it is found that the higher the illuminating power of the gas the greater is its heating power; but no inflexible law simultaneously controls the two factors, and it is possible to produce two gaseous mixtures, the one giving a non-luminous flame and the other a flame having a certain illuminating power, of which the non-luminous flame shall be capable of yielding more light with the incandescent mantle than the illuminating gas. It has, moreover, been found that the increase in heating power of a so-called "high quality" gas is often very far from proportionate to the increase in the cost of manufacture; and in Styria the town of Pettau has been brilliantly lighted with non-luminous water-gas and incandescent mantles in preference to employing the more costly coal-gas. The water-gas is made and purified by the "Strache" process, the fuel employed being a low-quality brown coal.

During the last fifteen years the number of purposes to which gas has been applied has increased to a remarkable extent, and has, of course, been accompanied by a corresponding increase in the variety of gas appliances manufactured. The penny-in-the-slot prepayment meter has also been introduced within that period, and has proved so popular that there are already about 800,000 of them in use in the United Kingdom alone. Since the introduction of the slot meter the use of the ring burner for boiling water has become general in all large towns, even in the workman's tenement or cottage, and prepayment gas fires have become extensively employed for hotel bedrooms.

These facts sufficiently indicate the importance to all gas consumers, and especially to students of building construction, of a knowledge of what is being done at our great gas factories, of the facilities which exist for using gas for domestic purposes and in the various arts and crafts, and of the concessions which are now being granted by many gas companies, under the spur of competition, and in recognition of the more extensive requirements of gas consumers of the present day. In the present volume these matters are discussed, and a description is given of modern burners and various appliances for the use of gas, while the concluding chapters are devoted to acetylene gas and the apparatus employed for its generation and consumption.

Much has yet to be discovered before the highest possible efficiency in light, heat, or power can be obtained from inflammable gas, but a large number of the complaints which from time to time are made against the public gas supply are due to ignorance, and result either from misuse of the gas or from its avoidable deterioration after manufacture. Sometimes the gas manufacturer is at fault; but more frequently the consumer, who consumes the gas in unsuitable burners, or the architect who approved the internal fittings of the building and the contractor who supplied them, are really responsible for the fact that the gas fails to perform its legitimate duties. The causes which lead to many of these complaints, and the precautions which must be observed in order to obtain satisfactory results from the gas, are discussed in subsequent chapters.

CHAPTER II.

MANUFACTURE OF COAL GAS.

MURDOCH made his earliest experiments with gas as an illuminant in 1792 at Redruth, in Cornwall, and subsequently at Old Cumnock, in Ayrshire, the place of his birth. But it was after his removal to the works of Boulton, Watt & Co., at Soho, near Birmingham, in 1798, that his most important work in gas-lighting was carried out. At the Soho works he collaborated more or less with James Watt, of steam-engine fame, and was allowed to erect a gas-making plant, which satisfactorily supplied a portion of the works of this celebrated firm with the new illuminant.

The early history of the gas industry is replete with interest and not devoid of humour, for many of the sensational claims made for gas by a popular lecturer and company promoter of the period named Winsor, and by other enthusiasts less cautious than the industrious Murdoch, appear very ludicrous in the light of present knowledge regarding the properties of coal-gas. It is interesting to observe that before inflammable gas was successfully employed for lighting purposes, efforts had been made to use it as a source of power. In 1801 Philipe Lebon, a French experimenter, in amending his patent of 1799, claimed the use of motive power obtained by the explosion of inflammable gas mixed with air; and in this country, as early as the year 1791, John Barber obtained a patent for "a method of using inflammable air for the purposes of procuring motion and facilitating metallurgical operations," which consisted partly in successively exploding mixtures of air and coal-gas. It is, however, necessary to here confine our attention to the study of the gas industry as it exists at the present time, and those desirous of tracing its development during the nineteenth century will find the subject exhaustively treated in King's "Treatise on Coal-Gas."

Although inflammable gas may be manufactured from so many different carbonaceous substances, coal is still more extensively employed than any other material for the purpose of gas manufacture.

Coal.—The coals most largely employed in this country for gas manufacture are the bituminous coals of Durham and the neighbouring counties. The cannel coals of Scotland, Wales, and Northumberland yield the largest volume of gas, and the gas is of the best quality. At one time it was the common practice to mix a certain proportion of cannel with the bituminous coal in order to produce a gas of higher illuminating power than could be obtained from the bituminous coal alone, but about ten or twelve years ago the quantity of available cannel coal became so small, and its price so high, that it ceased to be used to any large extent in the southern counties of England, and the carburetted water-gas which was then introduced as a substitute for gas from cannel coal is now being used not merely as an enriching agent, but to a certain extent in many districts as a substitute for ordinary coal-gas itself. Anthracite and the various classes of steam coal are not used for coal-gas manufacture, because they yield very little gas, and are valuable for steam-raising purposes.

The quality and quantity of the gas yielded even by coals of the same class vary considerably, but as an indication of the results commonly obtained it may be said that ordinary bituminous coal should yield not less than 10,000 cubic feet of 15-candle gas per ton, while cannel should yield not less than 11,000 cubic feet of 28 or 30-candle gas.

Coke.—The average yield of coke from ordinary gas-coal is 1,360 lbs. per ton. The coke should be of good quality and not yield more than about 4 per cent. of ash when burnt, although it not infrequently amounts to 8 or even 10 per cent. The average yield of coke from cannel coal is somewhat less, and, owing to the large quantity of ash it yields, the coke has no commercial value.

Retorts.—To obtain coal-gas from coal the coal is placed in cylindrical chambers called "retorts," from which air is excluded, and which are heated to redness in a

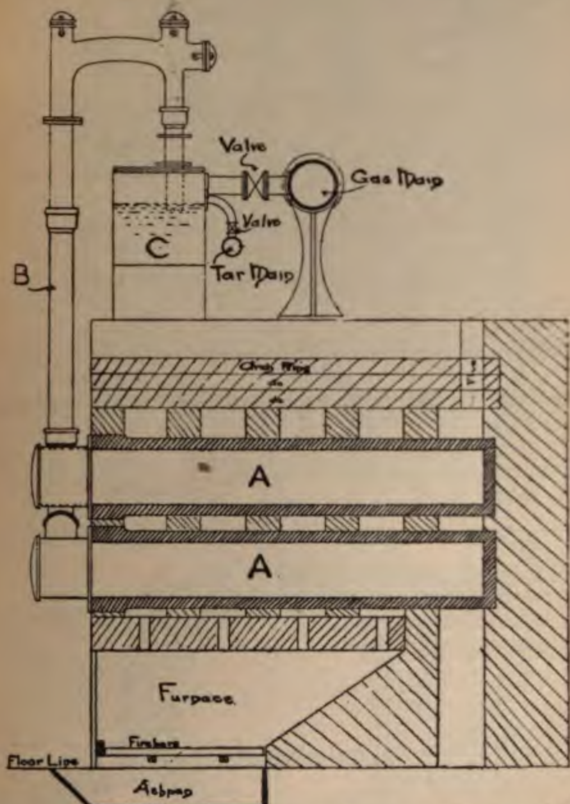


Fig. 1.—Single Retorts; showing (A) Retorts, (B) Ascension Pipe, (C) Hydraulic Main.

furnace. At first the retorts were made of cast-iron and were placed in a vertical position, but they are now almost

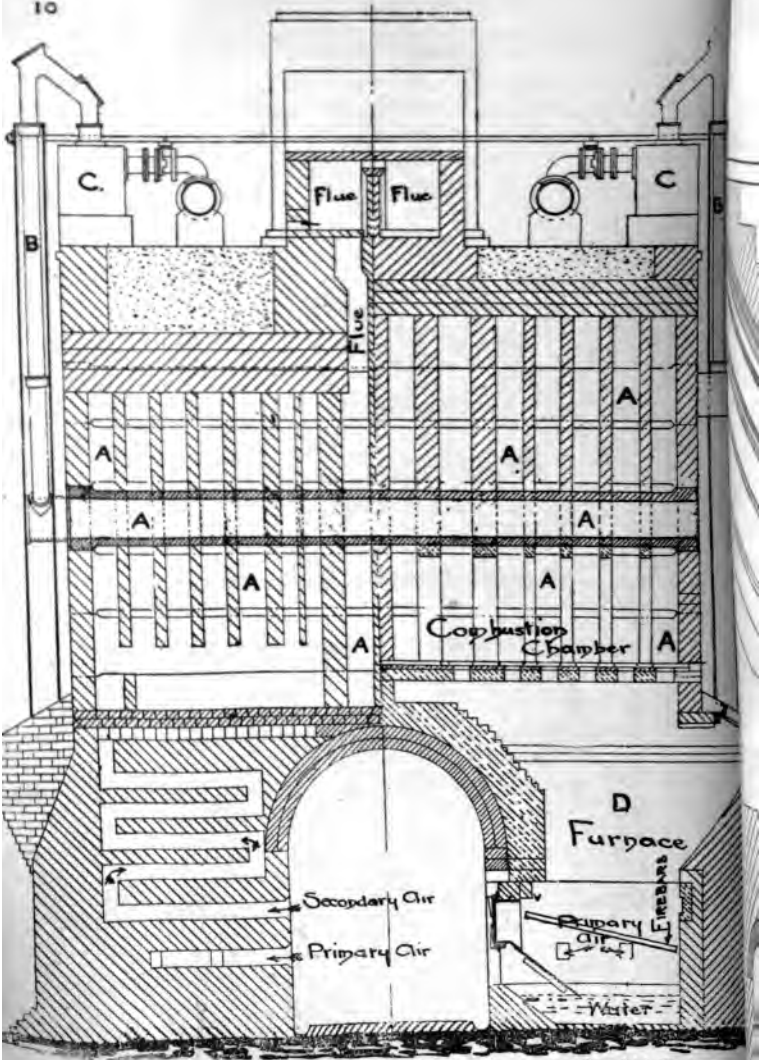


Fig. 2.—"Through" Retorts in Regenerative Setting; showing (A) Retorts, (B) Ascension Pipes, (C) Hydraulic Main, (D) Generator.

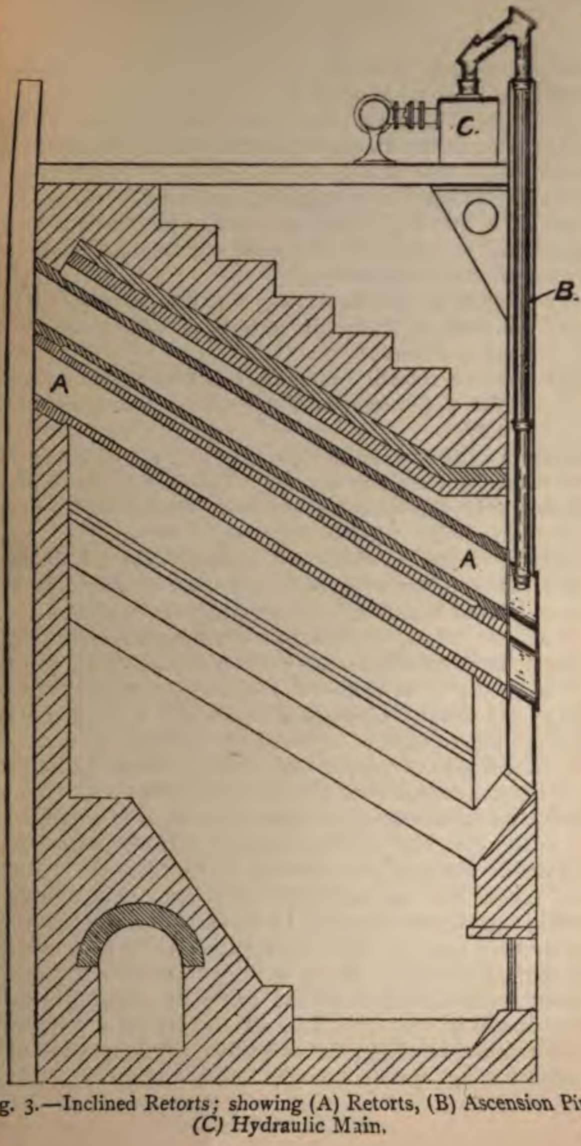


Fig. 3.—Inclined Retorts; showing (A) Retorts, (B) Ascension Pipe, (C) Hydraulic Main.

universally made of fireclay and fitted either in a horizontal position or inclined at an angle of 30 to 33 deg.

The retorts may be round, oval, or ∩-shaped in cross section, the latter shape being the most common. The internal diameter of the retort is usually about 21 in. 15 in. The length of a "single" retort is 10 ft., while the length of a "through" retort, having a mouthpiece at both ends, is 20 ft. The retorts now commonly used may divided into three classes—

(1) Singles, or retorts having only one mouthpiece;
(2) Doubles, or "through" retorts, having a mouthpiece at both ends;
(3) Inclined retorts, in which the coal is introduced the upper end and the coke withdrawn from the lower.

Retorts with one mouthpiece only (fig. 1) are now seldom used except in small gasworks. The coal is introduced one end only, the opposite end being closed with a fireclay back. In large works, "through" retorts (fig. 2) usually employed. These are double the length of the called "single" retorts, and are usually made in pieces, jointed together. A mouthpiece is provided at end of the retort, and coal is simultaneously introduced through each mouthpiece. Each mouthpiece is provided with a gas-tight lid or door. Inclined retorts or "slopers" (fig. 3) are usually ∩-shaped and either 15 ft. or 20 ft. length. The angle of inclination is about 32 deg. The coal is fed into the upper end of the retort and distributes itself by gravitation over the inclined floor; and when the distillation is completed the coke is allowed to slip out from the lower end, the coke being stirred, if necessary, with a long rake. Inclined retorts may be charged and "drawn" with much less expenditure of labour than horizontal retorts, and when the coal to be carbonised is of uniform quality they may be used with success. When, however, the coal to be used varies greatly in quality and specific gravity, trouble is often caused by the coal failing to spread itself properly over the floor of the retort, and imperfect carbonisation, resulting in excessive agglomeration of the pieces of coke and a low yield of gas, occurs. To break the force of the stream of coal as it is shot into the inclined retort, baffle plates have in some cases been adopted, and other devices have been proposed to make inclined retorts a greater practical success. Many gas engineers are now using them in great number without baffle plates and with good results, while others claim that for ordinary working conditions the horizontal retorts remain the better form.

Retort Settings.—The retorts are set in brickwork having joints made with fireclay mortar. A number of retorts are grouped together over one furnace, and form a "bed." The number set in one bed varies in different works from three to twelve, but seven or nine laid in three tiers is the number most commonly adopted. The retorts are supported by the front walls of the bed, and by a number of walls erected within the setting. A number of beds built side by side in one block form a "bench" of retorts.

Heating the Retorts.—The retorts may be heated by direct firing from beneath, but this method of heating is rapidly being superseded by the so-called regenerative system. By the regenerative system the retorts are more uniformly heated and their life is prolonged, while a higher heat efficiency is obtained from the fuel consumed. The regenerative system consists essentially in the conversion of the solid fuel into inflammable gas, the combustion of this inflammable gas in the chamber or furnace in which the retorts are fitted, and the utilisation of the heat of the products of this combustion as they leave the furnace for heating the air (called the secondary air) admitted to the furnace for the purposes of combustion. The generator in which the solid fuel is converted into gaseous fuel is usually situated beneath the charging floor of the retort-house. It is filled with coke heated to incandescence, and a carefully regulated current of air (termed the primary air) is allowed to pass up through it. In some cases the current of primary air is heated by the waste heat of the furnace before it is admitted to the generator. The carbon of the coke combines with the oxygen of the air to form the inflammable gas, carbon monoxide. This carbon monoxide together with the nitrogen of the air admitted passes from the upper part of the generator into the overhead furnace in which the retorts are located. Here the carbon mono meeting with hot secondary air burns to carbon dio with the evolution of heat, which maintains the retort the required temperature.

The inflammable gas from the generator should co about 30 per cent. of carbon monoxide; the remainde the gas is mainly atmospheric nitrogen which will burn, and which acts solely as a diluent which abs heat from the flame of the carbon monoxide. A s proportion of carbon dioxide is also always present in generator gas owing to the imperfect control of the rea between the oxygen and the heated coke; and s quantities of hydrogen and methane are usually pre owing to the decomposition in the generator of a ce quantity of steam from the ashpans beneath the gener The products of combustion which escape from the fur flues to the main flue and thence to the shaft w terminates above the roof of the retort-house, sh consist almost wholly of nitrogen and carbon dio The channels which admit the secondary air to furnaces are formed in close proximity to the furnace fl so that the escaping products of combustion serve to the incoming air before they escape into the atmosp Sometimes the blue flame produced by carbon mono when it burns to carbon dioxide may be seen at the to the shaft of the retort-house. The presence of this fl shows that the current of secondary air admitted to furnaces is not being properly regulated, and that the w of the heat obtainable from the generator gas is not b utilised in the furnaces.

Ashpans.—A pan containing water is placed u the furnace bars of each generator. The heat from incandescent fuel and from the falling cinders vaporis certain quantity of the water, and the steam passing through the furnace bars tends to keep them cool an retard the rate at which they wear away.

Charging and Drawing.—When the retorts charged by hand the coal is either introduced with aid of the shovel, or is placed in a long semi-circular sc having a capacity of about 1½ cwt. of coal. Three raise the scoop and thrust it into the retort, the man having charge of the handle at the back of the scoop turns the scoop round and then withdraws it. A second scoop-charge is immediately added through the same mouthpiece. If "through" retorts are employed, another gang of men simultaneously charge the opposite end of the retort, for the scoops extend only to one-half the length of the retort. Consequently the charge taken by each "through" retort is about 6 cwt., or 3 cwt. per mouthpiece. Immediately the charging is completed the mouthpieces are closed. After the coal has been in the retort for four, five, or six hours, as the case may be, the mouthpieces are again opened, and the residue in the form of coke is withdrawn by means of a long-handled rake. The red-hot coke is cooled with the aid of water, or is taken in its hot condition to feed the generators. The charging and drawing is now commonly performed by machinery, instead of by manual labour.

Retort Carbon.—Some of the hydrocarbons evolved from the coal under the influence of heat are decomposed before they can escape from the retort, and a hard, dense deposit of carbon, known as "retort carbon" or "scurf," accumulates on the sides of the retorts. The deposit forms less rapidly when there is a slight vacuum in the retorts instead of a slight pressure. By the use of an "exhauster" the gas pressure in the retorts can be maintained approximately at atmospheric pressure, but the variations in the rate at which the gas is expelled from the coal render fluctuations unavoidable. When the deposit has attained a thickness of one or two inches it must be removed, as it lessens the capacity of the retort and diminishes its heat conductivity. It is usually removed with the aid of chisel bars.

Clinker.—"Clinker" is produced by the partial fusing of the mineral matter left as ash from the fuel upon the heated fire-bricks, a kind of slag being formed. This clinker is extensively used for "rockwork" in ferneries and for garden purposes. The fire-brick rubbish, together with the clinker, is sometimes pulverised and mixed with sand or sharp grit and used in concrete.

Ascension-pipes.—The gas and vapour expelled from the coal in the retorts passes up a vertical pipe, called an ascension-pipe, which rises from each mouthpiece to a short distance above the retort stack. The ascension-pipes usually have an internal diameter of about 5 in.

Bridge-pipes and Dip-pipes.—The upper end of each ascension-pipe is joined to a short bridge-pipe which extends horizontally back towards the retorts. The other end of each bridge-pipe is connected to a short dip-pipe which extends vertically downwards into the hydraulic main, where it terminates in an open end dipping just below the surface of the liquid in the main.

Hydraulic Main and Foul Main.—The hydraulic main is a pipe not less than 18 ins. in diameter. It may be ∩-shaped, square, oblong, or round in cross section, and is preferably constructed of mild steel plates. The hydraulic main is frequently supported on standards placed on top of the retort bench. All the dip-pipes along one side of the bed dip into the same main, being sealed by the liquid, which is maintained at a constant level in the main. The gas as it enters the hydraulic main is laden with tarry matter in the form of fine spray, which gives it the appearance of a brown vapour, but the greater portion of the tar condenses out before the gas leaves the main. The tar sinks to the bottom of the main and is covered with an aqueous ammoniacal liquid, which also is condensed from the gas coming from the retorts. Frequently a second large main called the "foul main," which runs the whole length of the retort-house, is provided at the back of the hydraulic main, and the gas leaving the hydraulic main passes into the foul main.

CHAPTER III.

PURIFICATION OF COAL-GAS.

Condensers.—The temperature of the gas as it leaves the main is usually about 130 deg. Fahr., or as it leaves the foul main about 125 deg. Fahr., and in order to cool it to atmospheric temperature the gas is led from the foul main through the condensers. These may be vertical or nearly horizontal (fig. 4) pipes. They are exposed to the open air, and if of the horizontal form, may be cooled in hot weather by being sprinkled with water. The condensers in use vary greatly in size and form, but are all provided with means for drawing off the tar and ammoniacal liquor which condênses in them. No attempt is made to cool the gas below the atmospheric temperature.

Exhausters.—The gas leaving the condensers usually passes next to an exhauster. The exhauster is a description of pump which draws the gas (through the hydraulic main and condensers) from the retorts and prevents the gas from accumulating under pressure in them; while the gas, as it passes through the exhauster, is so compressed that it issues from the outlet at a pressure sufficient to enable it to force its way through the washing and purifying apparatus and station meter, and to lift the bell of the gasholder.

Washers and Scrubbers.—After removing the condensable matter from the gas by passing it through the condensers, the gas as it leaves the exhauster is led to the washers and scrubbers, where it is washed and scrubbed in order to remove, as far as practicable, all the soluble impurities, The term "washer" is usually applied to a rect tank in which the gas bubbles through the liquid agent, while the term "scrubber" is applied to the tower in which the gas filters through a bed of having its surfaces maintained in a moist conditior term "washer-scrubber" is applied to an appar which both washing and scrubbing are effected. Tl terms are, however, sometimes used indiscriminate

In the washers the gas is washed in the amr liquor obtained from the hydraulic main and conder this liquor may be made to retain a further quantit impurities remaining in the gas. To this liquor added the weakest liquor from the scrubbers. The used in many works are rectangular tanks fitted number of perforated trays immersed in the amr liquid. The volume of gas is broken by being a through perforated tubes and by contact with the tr rises in small bubbles through the liquor. In the the remaining portion of tar is extracted from hence the washers are sometimes termed "tar ext In other cases a specially constructed "tar extra put in action before the washers. From the wasl gas passes to the scrubbers, where with the aid ammoniacal liquor, and finally of clean water, the a still remaining in the gas, together with a quantity soluble impurities, is removed.

The scrubber towers (fig. 5) are usually filled w or with wooden grids, through which water is all trickle. The gas flowing upwards meets the de water and parts with its ammonia. In more scrubbing appliances circular brushes or a series forated discs attached to a central shaft are made tc at a slow speed and cause the water to come into contact with the gas. The object of all wash scrubbing devices is to remove the ammonia fron with the use of as little water as possible, for the the quantity of ammonia in the "gas liquor" obta greater is its value for the purpose of manut sulphate of ammonia.

Purifiers.—After leaving the scrubbers the

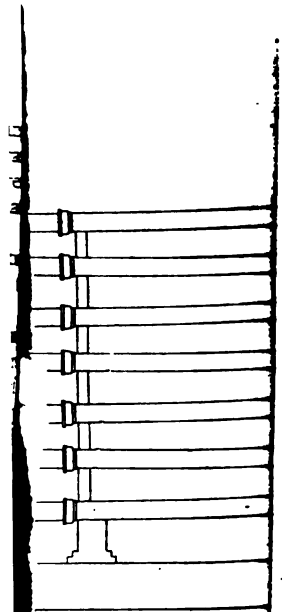


Fig. 4.—Ho

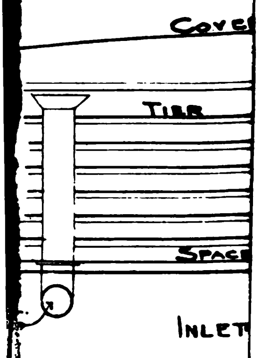


Fig. 6.—Sectio

contains a certain quantity of sulphuretted hydrogen, carbon dioxide, and carbon bisulphide, which should be removed.

The carbon dioxide (commonly called carbonic acid) is abstracted by passing the gas through slaked lime, carbonate of lime being formed (fig. 6). The sulphuretted hydrogen may also be removed by slaked lime, but the sulphur in the lime compound produced cannot readily be recovered, and the compound itself possesses such an obnoxious odour that its production in large quantity in any residential neighbourhood is liable to be resented. The sulphuretted hydrogen is therefore now usually removed by passing it through hydrated oxide of iron to which sawdust has been added to render the oxide more porous. The sulphide of iron produced is decomposed when allowed contact with air into oxide of iron and free sulphur, and before being permanently put out of action the oxide is several times turned out of the purifiers and exposed to the atmosphere for revivification. The free sulphur can be employed without difficulty for the manufacture of sulphuric acid, and is therefore a residual of considerable value. The "spent oxide," as it is called, has also the advantage of emitting a less objectionable odour than lime which has been saturated with sulphuretted hydrogen.

The carbon bisulphide has no affinity for slaked lime, but slaked lime which has been saturated with sulphuretted hydrogen readily abstracts it from the gas. The carbon bisulphide is therefore removed by passing it through lime which has been "sulphided" on the works.

The scheme usually adopted for the dry purification is the following:—The gas from the scrubbers enters a set of purifiers containing slaked lime spread in layers upon wooden grids. The carbon dioxide and the sulphuretted hydrogen are at first both abstracted by the lime, a mixture of carbonate of lime and hydroxyhydrosulphide of lime being formed. But carbon dioxide is able to decompose hydroxyhydrosulphide of lime [CaOHSH], driving out the sulphuretted hydrogen and itself combining with the lime to form carbonate of lime. When, therefore, the gas containing both carbon dioxide and sulphuretted hydrogen does not meet with sufficient free slaked lime to readily satisfy all the carbon dioxide, the carbon dioxide begins to attack that portion of the lime which has been combining with the sulphuretted hydrogen, and turning out the sulphuretted hydrogen, sends that impurity forward again with the gas, and itself combines with the lime. The carbon dioxide is therefore retained in the first set of lime purifiers, while the gas still containing sulphuretted hydrogen, but not carbon dioxide, passes forward to a second set of lime purifiers. Here the sulphuretted hydrogen is able to combine with the lime undisturbed by the presence of carbon dioxide. When the second set of purifiers is sufficiently charged with sulphuretted hydrogen these purifiers are employed to purify the gas from carbon bisulphide, while the sulphuretted hydrogen which still continues to come forward is removed by passing the gas through a third set of purifiers containing hydrated oxide of iron. In some cases, after the sulphide purifiers have been prepared, the purifiers containing oxide of iron are brought into action between the carbonic acid purifiers and the "sulphide" vessels, so that the gas passes first through the lime purifiers, which remove the carbon dioxide, then through the oxide of iron purifiers, which remove the sulphuretted hydrogen, next through the sulphide purifiers, which remove the bisulphide of carbon, and finally, through another oxide of iron purifier, termed "the check box," which removes the small quantity of sulphuretted hydrogen which is evolved from the sulphide purifiers.

System of connecting Purifiers.—To enable the gas to be sent in any necessary order of rotation through the purifiers, and to enable any purifier to be disconnected from the other purifiers in a set without putting the whole set out of action, by-pass pipes have to be provided as shown in fig. 6a. The illustration shows the connections for a set of three lime purifiers, Nos. 1, 2, and 3, and it will be seen that ... the arrangement of pipes and valves there figured ...le to send the gas in the order of rotation Nos. 1, ... 3, 1, 2, or to cut off No. 2 for recharging, and ...as to be purified by passage through No. 1 ...y number of purifiers may be placed in a ...gas may be passed through any number of

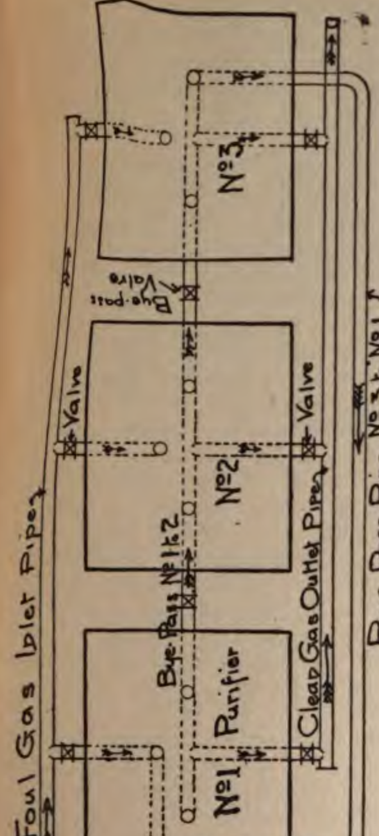


Fig 6a.—System of connecting Pipes for a set of Purifiers.

sets, but provision must always be made for continuous purification.

Many years ago "milk of lime" was used for gas purification, and the waste product acquired great notoriety under the name of "Blue Billy" on account of its horrible odour. Owing partly to the difficulty of disposing of the waste material, the liquid paste has long been superseded by the comparatively dry hydrate of lime, which when "spent" has a somewhat less foul odour, and can be reburnt on the works and used again for purification, or, after long exposure to the air, can be carted away for agricultural purposes without attracting undue attention by its perfume.

Many gas manufacturers do not purify the gas so thoroughly as it has to be purified in London. In many cases no attempt is made to remove the carbon bisulphide, but by Act of Parliament all gas supplied to consumers must be free from sulphuretted hydrogen, and consequently this impurity is, as a rule, removed as completely as possible. The carbon dioxide is also usually more or less completely removed, because it prejudicially affects the illuminating power of the gas. One per cent. of carbon dioxide in the gas reduces its illuminating power about 4 per cent.

Mixing Air with the Gas.—When consumers of gas make the discovery that air is being deliberately added to the gas passing into the purifiers, they in many cases imagine that the air is being added to serve as an adulterant. Now the presence of 1 per cent. of air in the purified gas diminishes its illuminating power by about 6 per cent., 4 per cent. of air reduces the illuminating power 25 per cent., and 45 per cent. of air causes the gas to burn with a non-luminous flame. It is evident, therefore, that air cannot in practice be used as an adulterant, for its presence in any appreciable quantity would be at once apparent even to the untrained eye when the gas was used as an illuminant.

The fact is that a quantity of air not exceeding 3 per cent. of the gas purified is in some works let into the purifiers to oxidise the sulphur compounds of lime or iron which are formed there, but the atmospheric oxygen is all abstracted by the material in the purifiers before the gas passes from them. The atmospheric nitrogen passes forward with the gas, but is too small in quantity to exert much influence. Usually the proportion of air admitted is limited to a maximum of 1½ per cent.

In oxide of iron purifiers the oxygen of the air attacks the sulphide of iron formed by the action of the sulphuretted hydrogen on the iron oxide, and re-converts it into oxide of iron, while the sulphur displaced by the oxygen is found in a free state mixed with the oxide. The admission of air makes it possible to use the oxide for a longer period before it is necessary to turn it out and expose it to the atmosphere for more complete revivification. In fact, the oxide need not be revivified in the open air until some 25 per cent. of its weight consists of free sulphur. The use of air in the purifiers also diminishes the odour emitted by the spent material when first exposed to the open air.

In lime purifiers air is often admitted when an alternative scheme to that described is adopted for purification from sulphur compounds. About $1\frac{1}{2}$ per cent. of air is admitted to partially sulphided lime purifiers, the oxygen oxidises the sulphur compounds of lime, and free sulphur often amounting to 10 per cent. is found in the spent lime. Spent lime from purifiers to which air has been admitted creates less nuisance than spent lime from sulphide purifiers from which air has been excluded.

Other schemes and other substances have been adopted for gas purification, but lime and hydrated oxide of iron used in a manner more or less approximating to the system here delineated are employed more extensively than any other materials.

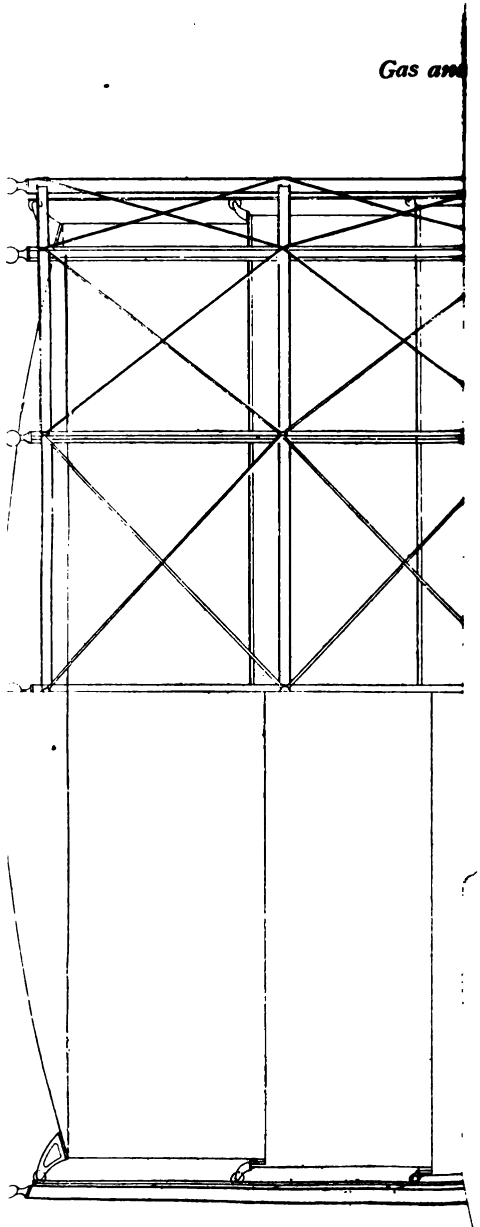
CHAPTER IV.

STATION METERS, GASHOLDERS, STATION GOVERNORS, DISTRIBUTION

Station Meters.—The gas leaving the purifiers usuall passes next to the "station" or "works" meter (fig. 7), i order that the total quantity of gas made may be ascertaine and recorded. The meter case is usually rectangular fo large meters and cylindrical for those of smaller capacit Sometimes a separate meter is provided for each reto house. The station meter is always one of the variet known as "wet" meters, in which a drum revolves in chamber partly filled with water. The drum has three o four internal compartments of equal capacity.

The meter is filled with water to a level a little highe than the axle on which the drum revolves. The gas enterin one of the chambers causes it to slowly revolve. As the chamber becomes filled with gas its inlet passes beneath the water level, and the inlet to the next chamber at the same time rises above the water level, and allows gas to enter and continue the revolving motion of the drum. The capacity of the chambers of the drum is dependent on the level of the water; when the water level is too low the gas capacity of each chamber is increased, and the meter registers a smaller quantity of gas than has in reality passed through it, and when the water level is too high the gas capacity of each chamber is decreased and the meter indicates a larger consumption than the correct amount. It is necessary therefore to maintain the water at a constant level, and this is accomplished by supplying the meter with a small but continuous stream of water, and a siphon overflow which prevents the water from rising above the proper water line.

Gas an



Gasholders.—From the station meter the gas passes into the gasholder (fig. 8). The gasholder is often called a "gasometer" by those not connected with gas undertakings, but the term has long been discarded by gas engineers. The gasholder still remains a gasometer, inasmuch as it is possible to estimate roughly the quantity of gas in the gasholder by counting the number of riveted plates (of known dimensions) in a vertical line above the water level in the tank. From the height of the holder above the water, and from its diameter, it is easy to calculate the contents of the holder; but the introduction of the station meter has rendered the use of the gasholder as a meter unnecessary. The gasholder consists of a cylindrical bell which is free to rise and fall in a tank containing water. It is maintained in equilibrium by suitable supports, and has its lower end, which is open, always immersed beneath the surface of the water. The holder may be single or telescopic, the bell which contains the gas being technically known as a "lift." A telescopic holder may have several lifts, but the dome of the top lift serves for all the other lifts, which are merely telescopic cylinders. In a telescopic holder the lower edge of the smaller upper lift is turned outwards and upwards to form an annular trough or "cup," which is filled with water and which receives the turned-over upper edge of the large cylinder. A gas-tight seal is produced, and when the inner cylinder is filled with gas and continues to rise, its cup is caught by the turned-over edge of the lower and outer cylinder, which is then drawn up out of the water tank without breaking the water seal in the cup. The pressure on the gas within the holder may be as great as 12 in. of water, but varies with the weight of the holder.

The largest gasholder in the world is that erected by Mr. Livesey, at the East Greenwich works of the South Metropolitan Company. This holder has six lifts, is 300 ft. in diameter, rises when filled to a height of 180 ft., and has a capacity of 12 million cubic feet. The two topmost lifts ascend above the top of the framing.

The gasholder tank is usually a circular excavation walled with concrete, brick, or stone; a circular or conical mound termed the "dumpling" or "cone," being commonly left in the centre of the tank. Modern gasholder tanks are sometimes constructed in steel and built above ground. Leakages in such tanks are more readily stopped than in those of brick or concrete. Steel tanks are, in some cases, cheaper than brick or concrete tanks, and are said to be almost as durable, but the selection of a material for tank construction must be governed by the relative prices of steel, brick, and cement.

Station Governor.—After leaving the gasholder the gas passes to the station governor (fig. 9), which enables the pressure of gas passing forward to be reduced and regulated to any desired point. The governor most commonly employed consists of a cast-iron* water tank, through the bottom of which the gas from the gasholder is conducted up by a pipe which terminates in an open end just above the surface of the water. Within the tank is a floating bell which covers the gas inlet and outlet pipes, and from the crown of which a conical or parabolic valve with its apex upwards is

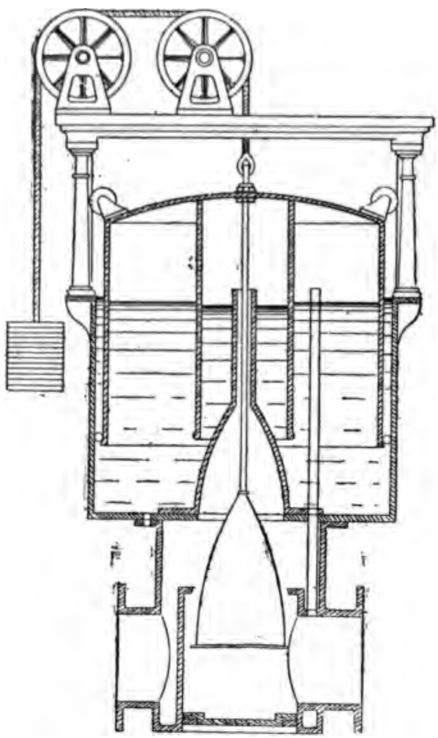


Fig. 9.—Station Governor.

Diameter of Pipe 1 *in.*

Length of pipe in yards	10	20	30	50
Cubic feet of gas delivered under initial pressure of 1 in.	675	476	389	301
Cubic feet of gas delivered under initial pressure of 1·2 in....	738	522	427	329

Diameter of Pipe 36 *in.*

Length of pipe in yards	1,000	5,000	10,000
Cubic feet of gas delivered under initial pressure of 1 in. ...	530,000	234,000	166,000
Cubic feet of gas delivered under initial pressure of 2 in. ...	741,300	332,300	234,000

In practice, however, the actual discharge is considerably less than the theoretical quantity, especially in the case of small pipes. The smaller the pipe the greater the friction per unit of gas delivered. Hurst gives a table based on actual experiments showing the gas (sp. gr. not quoted) discharged through small service pipes of various lengths, from which the following are taken :—

Diameter of Pipe 1 *in.*

Length of pipe in yards..............................	10	20	30	50
Cubic feet of gas delivered under initial pressure of 1 in.	337	233	190	148
Cubic feet of gas delivered under initial pressure of $1\frac{1}{4}$ in.	368	260	212	164

It will be seen that the discharge of gas obtained at the burners from small service pipes is only about one-half the volume that should, according to Pole's formula, pass through the pipes if perfectly straight and horizontal.

Even for larger pipes the volumes of gas discharged quoted by Hurst are much smaller than those given by Newbigging, as will be seen from the following comparative figures :—

Diameter of Pipe 12 *in.*

Length of pipe in yards	500	1,000
Cubic feet of gas delivered under initial pressure of 1 in. (Hurst)	33,255	23,515
Cubic feet of gas delivered under initial pressure of 1 in. (Newbigging)	47,433	33,631
Cubic feet of gas delivered under initial pressure of 2 in. (Hurst)	47,030	33,255
Cubic feet of gas delivered under initial pressure of 2 in. (Newbigging)	67,262	47,433

In practice it is better to adopt the figures quoted by Hurst, for the introduction of angles and curves in the pipes, and the accumulation in them of liquid or solid matter, tends to diminish their delivering capacity. The smaller the pipes the greater their liability to become blocked with naphthalene, tarry matter, rust, or water. The present tendency in gas supply is to distribute it at a considerably greater pressure than 1 in. The delivering capacities of the pipes vary approximately directly as the square root of the pressure and inversely as the square root of the length. If the pressure is increased four times the volume of gas delivered is doubled. If the length of pipe is increased four times the quantity of gas delivered is halved.

Main-service Pipes.—The main-service pipes should be of wrought iron, unless the employment of this material be prohibited by the corrosive action of the soil. Cast-iron pipes are often used, but are apt to have leaky joints, and lead pipes are apt to become distorted owing to subsidence of the ground in which they are buried. The diameter of service-pipe required is dependent upon the description number of the appliances to be supplied. It is usual me that each burner requires 5 cubic feet of gas per hour, but as most consumers use a large proportion of the gas consumed for purposes other than lighting, this rule is now of little service. Domestic gas fires commonly consume over 30 cubic feet per hour, ring burners from 12 to 15 cubic feet, while cookers and water heaters use an indefinite quantity but require a comparatively large volume for a short period. The capacity of the pipes required should not be calculated upon the average hourly consumption, but upon the consumption when every gas-consuming appliance in the building is in use at the same moment, and at the lowest pressure permitted by Act of Parliament. As a rule, the gas manufacturer provides and fits the main service-pipe and meter; and, owing to the comparatively heavy cost of pipes of large diameter, frequently supplies a pipe barely large enough for the duty required from it when the gas is first connected to the building, and as additional fires and stoves are usually introduced from time to time after the service-pipe has been laid, it frequently happens that the pipe is not sufficiently large for the work it is expected to perform. The consumer obtains a very low efficiency in light or heat per unit of gas consumed, and naturally concludes that the manufacturer is supplying "bad gas," and regards it as an additional injury that just at the time he most urgently needs an ample supply (as on a cold, foggy day) his gas flames assume their worst appearance, owing to the fact that his neighbours are simultaneously drawing upon the supply as largely as possible. The fact that the gas bill is a little less heavy does not in any way compensate for the fact that the gas fails to perform its legitimate duties.

CHAPTER V.

WATER-GAS; CARBURETTED WATER-GAS; PRODUCER-GAS.

WATER-GAS is produced by passing steam through incandescent coke. The oxygen of the water vapour unites with the carbon of the coke to form the inflammable gas, carbon monoxide, while the hydrogen of the water vapour is left in an uncombined condition. Water-gas therefore consists essentially of a mixture of the two inflammable gases, carbon monoxide and hydrogen; it contains other gases in small quantities, but the whole of these should never amount to 10 per cent. of the total volume of the gas.

Water-gas has no odour, and burns with a non-luminous flame, while its heating power is about one-half that of coal-gas. It is sometimes called "blue water-gas" to distinguish it from carburetted water-gas which burns with a bright luminous flame instead of with the blue non-luminous flame of plain water-gas. Water-gas is more poisonous than coal-gas because it contains a larger proportion of carbon monoxide, the most poisonous constituent present in appreciable quantity in coal-gas. To diminish the danger attendant upon the use of a poisonous gas devoid of odour, the water-gas when used alone is usually impregnated with mercaptan or carbyalmine, very small quantities of which will give a penetrating odour to large volumes of the gas.

Carburetted Water-Gas is a mixture of water-gas with oil-gas. The water-gas is passed through the heated chamber in which the oil is decomposed, and the mixture of water-gas and oil-gas is then passed through a superheater to make the gas more permanent. Carburetted water-gas has an odour quite as penetrating as that of coal-gas, and burns with a luminous flame. Its heating and lighting value varies with the proportion of oil-gas it contains, but compared with coal-gas of equal illuminating power the heating value of carburetted water-gas is about 10 per cent. less than that of coal-gas.

Producer-Gas, sometimes called "fuel-gas," or "power-gas," is produced by passing a current of air, or of air and steam, through incandescent coke or other carbonaceous matter. About one-half of the total volume of the gas is non-combustible nitrogen, while the other half consists mainly of carbon monoxide and hydrogen. The gas has so low a combustible power that in some cases, where the nitrogen exceeds 60 per cent., it is necessary to use the gas in a hot condition as it comes from the producer to prevent the gas from becoming incombustible. Some of the better class producer-gases, such as Mond gas, can be used whether hot or cold, but they are all of very low heating value. In most cases the producer-gas has a heating value of about one-half that of water-gas, or one-fourth that of ordinary coal-gas. Producer-gas is largely used for industrial purposes, because it can be made very cheaply and from almost any description of carbonaceous matter. Dowson gas, Siemens gas, Wilson gas, and Mond gas must all be classed as producer-gases. A great number of producers have been devised both in this country and abroad, but the gases produced always consist mainly of a mixture of carbon monoxide and hydrogen largely diluted with atmospheric nitrogen.

Water-Gas Manufacture.

"European" Process.—Water-gas is made by heating a bed of coke to incandescence with the aid of a blast of air, then cutting off the air and sending a current of steam through the heated coke. The products of combustion obtained when the coke is subjected to the air blast are not allowed to mix with the gas produced by the action of the steam on the coke. Producer-gas is the term given to the products of combustion obtained when the air is in use, and in the "European" process the producer-gas formed can be used for heating the oil for carburetting the water-gas or for other purposes. The producer-gas contains sufficient carbon-monoxide to render it, while hot, capable of combustion with the evolution of heat. While the steam is passing through the coke, the coke is rapidly cooling down, and it soon becomes necessary to stop the flow of steam and again raise the temperature of the coke with the aid of the air-blast. By the old method of working the European process the "blow" was in operation for nearly ten minutes, and the

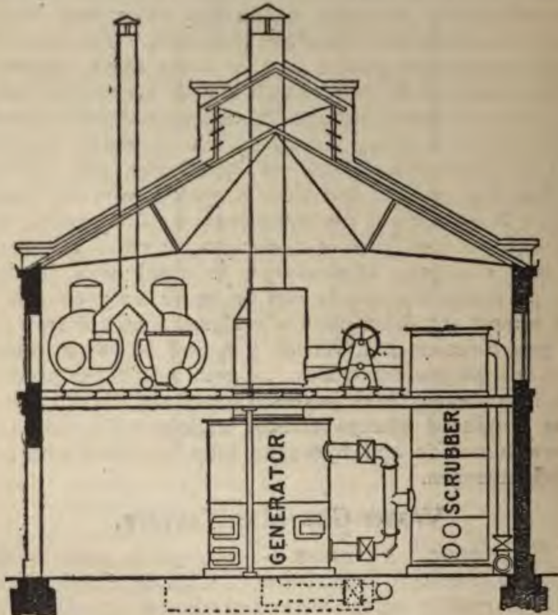


Fig. 10.—Dellwik-Fleischer Water-Gas Plant. Section.

steam for four or five minutes, but it has since been found possible to shorten the time of the blow considerably.

"Dellwik-Fleischer" Process.—In 1896 Mr. Carl Dellwik introduced the method of making water-gas, which, in an improved form, is now known as the "Dellwik-Fleischer" process. In this process the coke is heated to the temperature necessary for the manufacture of water-gas in a much shorter time than by the older process. The bed of coke is made less deep and is maintained at a constant level, and a more powerful air blast is used to ensure the presence of an excess of air. The result is that carbon dioxide instead of carbon monoxide is formed in the producer. Also by passing the steam alternately first from the bottom upwards and then from the top downwards through the heated coke the temperature throughout the

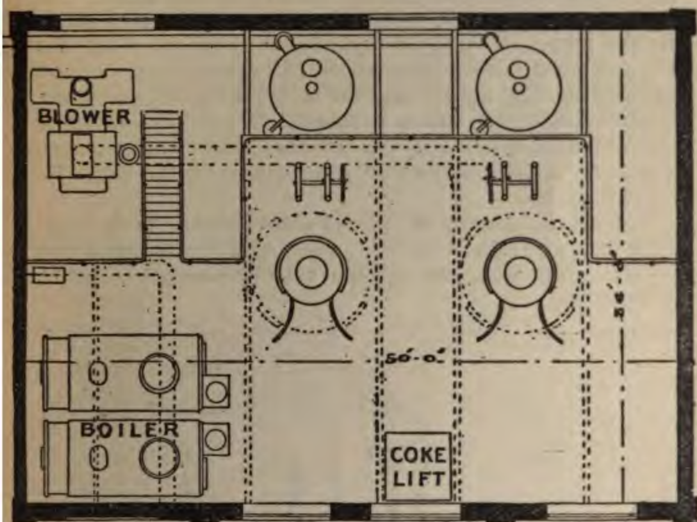


Fig. 11.—Dellwik-Fleischer Water-Gas Plant. Plan.

bed is equalised, and the brick lining of the generator is not worn away more rapidly at one point than at another. Carbon monoxide is first produced as in the older "European" process, but owing to the larger ratio of air to coke in the Dellwik producer this carbon monoxide is immediately oxidised to carbon dioxide. Now, 1 lb. of carbon when burned to carbon monoxide evolves 4,350 British thermal units, while the same quantity of carbon when burned to carbon dioxide evolves 14,500 B.T.U. The coke in the producer is therefore raised to the necessary temperature more quickly when carbon dioxide is formed within the producer than when the producer-gas consists of carbon monoxide. Working on this system the time occupied by the "blow" has been reduced to less than two minutes, and the time during which water-gas is made has been prolonged to ten minutes, and over 70,000 cubic feet of water-gas can be made per ton of coke in place of the 34,000 cubic feet made by the "European" process.

On the other hand, owing to carbon dioxide instead of carbon monoxide being formed, the producer-gas from the Dellwik plant is not combustible, and cannot, therefore, be used for heating the oil used for carburetting the gas when an illuminating gas has to be manufactured. The value of the combustible producer-gas does not, however, approach that of the additional yield of water-gas obtained with the Dellwik plant.

The specific gravity of Dellwik water-gas has been found by Professor Lewes to be 0·5365, and the composition of the gases obtained by the two processes to be as follows :—

—	"European" Process.		"Dellwik-Fleischer" Process.	
	Inflammable Producer-Gas.	Water-Gas.	Non-flammable Producer-Gas.	Water-Gas.
Hydrogen	2·88	51·54	—	51·76
Carbon monoxide	29·33	39·98	1·40	38·58
Carbon dioxide	4·15	5·61	18·25	4·73
Oxygen	—	—	1·20	0·81
Nitrogen	63·64	2·87	79·05	4·12
	100·00	100·00	100·00	100·00

The following analysis of Dellwik water-gas, showing he small quantities of hydrocarbons commonly present, has been published by Professor Lunge :—

	Dellwik Water-gas.
Hydrogen	50·80
Methane	·82
Ethylene	·05
Carbon monoxide	39·65
Carbon dioxide	4·65
Oxygen	·20
Nitrogen	3·83
	100·00

The drawings, pp. 40, 41 (figs. 10 and 11) show a Dellwik-Fleischer water-gas plant in vertical section and plan. The gas-producing capacity of plant of the dimensions here shown is 40,000 cubic feet per hour.

Lewes Carbonization Process.— During the ordinary process of manufacturing gas from coal, some of the rich illuminating hydrocarbons which are present in the gas evolved from the coal, are decomposed during the passage of the gas along the heated retort into gases of less illuminating value. Other illuminating hydrocarbons are also lost in the formation of tar. Professor Lewes has suggested that much of this loss might be prevented by passing a rapid stream of water-gas through the retorts at the same time that the coal is being distilled. It was thought that the stream of water-gas would carry the coal-gas out of the retorts before the richer hydrocarbons had been so largely decomposed by contact with heated surfaces, and that the mixture of coal-gas and water-gas thus produced would have a higher illuminating value than if coal-gas were merely diluted with water-gas in a gasholder.

During the summer months of the years 1900 and 1901, a number of experiments on a large scale were carried out at the Crystal Palace District Gasworks by Professor Lewes and Mr. Sydney Y. Shoubridge on the lines indicated, and it was found that as much as 40 per cent. of non-luminous water-gas could be passed through the retorts without reducing the illuminating power of the mixed gas by more than about 10 per cent. The coal-gas alone had an illuminating power of 16·55 candles, and this was reduced to 14·85 candles when 40·1 per cent. of water-gas was passed through the retorts. After making allowance for the reduction in illuminating power it is calculated that a saving of over two shillings per ton of coal carbonized may be effected by the adoption of this method of carbonization.

Carburetted Water-Gas Manufacture.—The apparatus most commonly used in this country for the manufacture of carburetted water-gas, is a modification of the Lowe plant so extensively used in the United States. The plant consists of three main parts, the generator, the carburettor, and the superheater (fig. 12); and as the gas is made by an intermittent system, the sets are usually erected in duplicate.

In the generator, plain water-gas is made in the manner previously described. The carburettor is a chamber of about the same height as the generator, say, 18 ft. in height, and 10 ft. in diameter, and is packed with small fire-bricks arranged in chequer form. The hot producer-gas from the generator is led into the upper part of the carburettor, where it meets with a blast of air and is partially consumed, the heat evolved by the combustion serving to heat the bricks in the carburettor. The products of combustion, together with the gas not yet consumed, pass into the superheater, which is a chamber about 6 ft. higher than the carburettor and is likewise packed with bricks. In the superheater the gases meet with another blast of air, the combustion is completed, and the temperature of the bricks is thereby raised. The products of combustion escape into the open air through a shaft. The generator, carburettor, and superheater having been raised to the required temperature, the supply of air is cut off and steam is admitted to the generator. Water-gas is immediately produced and passes to the carburettor: here it meets with heated oil which is being pumped in at the top of the carburettor, and which is dispersed in the form of spray. In the carburettor the oil is converted into gas, and mixes with the water-gas, which carries it forward to the superheater. The mixture of oil-gas and water-gas ing the carburettor is not of a permanent character, the hydrocarbons being liable to partially condense and to rate from the water-gas as the temperature of the

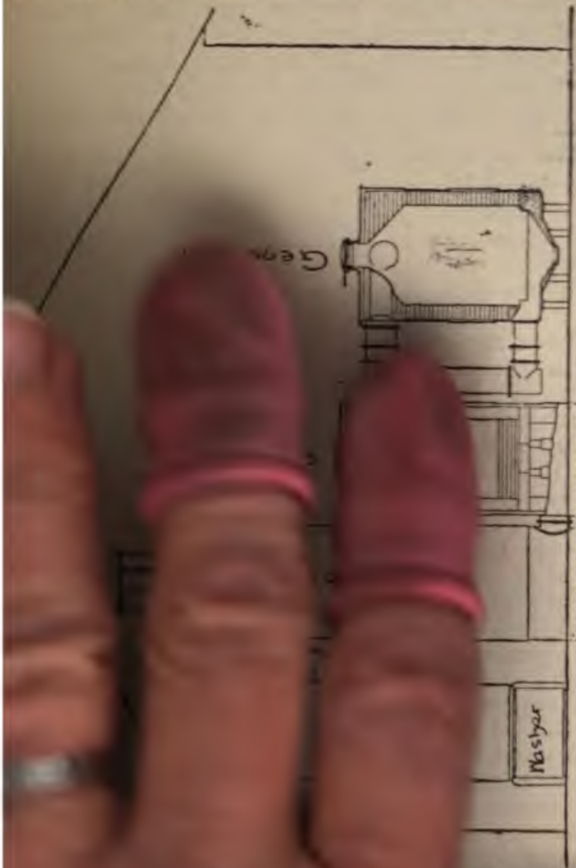


Fig. 12.—Lowe Carburetted Water-Gas Plant.

[illegible] through the [illegible] decom[illegible] stable under ordinary atmospheric conditions than coal-gas. The gas is subsequently purified by a series of operations very similar to those employed for the purification of coal-gas, but as the gas contains very little ammonia or bisulphide of carbon it does not urgently require purifying from these impurities. The tar obtained in the manufacture of carburetted water-gas frequently contains 50 to 60 per cent. of water, or more, and this must be removed before the tar can be distilled.

According to Butterfield, the composition of carburetted wâter-gas of 26 c.-p. (sp. gr. 0·62) made by this process is approximately:—

Hydrogen	34·0 per cent.
Methane	15·0 „
Hydrocarbons absorbable by fuming sulphuric acid	12·5 „
Carbon monoxide	33·0 „
Nitrogen	0·5 to 5·0 „

The oil commonly used for carburetted water-gas manufacture is that known as "solar distillate," having a specific gravity of about 0·870, and a flashing point of about 170 deg. Fahr., but other oils varying considerably in composition, gravity, and flashing point have been successfully employed for this purpose. In practice about 45 lbs. of coke and 3¼ gallons of oil are used for every 1,000 cubic feet of 22-candle gas produced.

Carburetted water-gas has been used in America since about 1878, its popularity there being due to the abundance and cheapness of petroleum. The first plant used in this country was erected in London in 1891. By the end of the year 1900 carburetted water-gas plant had been erected in the United Kingdom by eighty-one companies or Local Authorities, the total gas-producing capacity of the plant being 134,570,000 cubic feet per day.

From time to time objections have been raised to the public supply of carburetted water-gas, and in 1899 a Departmental Committee was appointed to inquire into the use of water-gas and other gases containing a large proportion of carbon monoxide. After hearing many experts, the Committee recommended that when water-gas is supplied a maximum limit for carbon monoxide should be fixed; that where such limit is fixed, some person should be appointed to test for carbon monoxide; and that, before any kind of water-gas is distributed in any place, due notice should be required to be given.

So far as the supply of illuminating gas is concerned, the recommendations of this Committee have apparently been completely ignored by Parliament and the Government Departments up to the present time, while the desirability of introducing a statutory calorific standard has not yet been discussed by Local Authorities or by Parliament, although Professor Lewes in his Report to the Birkenhead Corporation (1897), and Dr. Harold Colman, of the Birmingham Gasworks, have both shown that carburetted water-gas has a lower heating value than coal-gas of equal illuminating power. The answer to the question as to whether the use of carburetted water-gas should be allowed, should depend mainly upon the relative prices to be charged for coal-gas and carburetted water-gas, and the terms of the contract made. If a standard price has been fixed for 16-candle coal-gas, an article of somewhat less value is being obtained if 16-candle carburetted water-gas is being supplied, and, therefore, the standard price should be slightly lowered.

In the year 1901, an important step in the right direction was made by the introduction into the Mond Gas Company's Act, which permits the distribution of non-luminous gas in certain districts for heating and power purposes, of clauses relating to the heating power of the gas, and also to the proportion of carbon monoxide in the gas. The proportion of carbon monoxide is to be limited to 14 per cent., and the minimum heating value of the gas is to be 125 British thermal units, and provision is made for the appointment of impartial examiners to test the quality of the gas, at testing places provided and maintained at the expense of the Gas Company.

CHAPTER VI.

PRODUCER-GAS MANUFACTURE, MOND GAS, OIL-GAS, AIR-GAS, ENRICHMENT WITH LIGHT OILS.

Producer-Gas Manufacture.—The description of producer-gas obtained by blowing air through heated coke has already been described as a by-product in the old process of water-gas manufacture. Instead of separately making a high-class water-gas and a low-class producer-gas by alternately blowing air and steam through the heated fuel, a higher class producer-gas, consisting of a mixture of water-gas and the producer-gas previously described, may be made by passing a regulated mixture of steam and air through the fuel, the heat evolved by the combustion of the carbon with the atmospheric oxygen being made to balance the heat absorbed during the decomposition of the steam. An excess of air has to be used to compensate for loss of heat through unavoidable causes. A large number of generators or producers have been invented to manufacture gas of this description, and the gas produced is usually known by the name of the inventor of the plant—*e.g.*, Mond gas, Siemens gas, Dowson gas.

In some producers anthracite or a more bituminous fuel is used instead of coke, as, for instance, in the Mond producer, in which cheap coal slack is employed; and the hydrocarbon gases evolved from the fuel enrich the producer-gas to a certain extent, and increase its value. The tar may be recovered by cooling and washing the gas, or may be destroyed by passing the gas through a sufficient thickness of heated coke.

The following table shows approximately the composition and relative heating values of natural gas and of the gases most commonly used in this country for lighting, heating, and motive power; but it must be remembered that in every case the composition of the gas is variable:—

	London Coal-Gas.	Natural Gas of U.S.A.	Water-Gas.	Mond Gas.	Dowson Gas.	Siemens Gas.
Hydrogen	52·85	20·62	49·17	24·8	18·76	8·6
Methane	33·88	73·28	·31	2·3	0·31	2·4
Unsaturated Hydrocarbons	3·97	4·30	nil	nil	0·31	nil
Carbon monoxide	5·34	1·00	43·75	13·2	25·07	24·4
Carbon dioxide	nil	0·80	2·71	12·9	6·37	5·2
Nitrogen	3·96	nil	4·06	46·8	48·98	59·4
	100·00	100·00	100·00	100·0	100·00	100·0
Gross Calorific value, B.T.U. per cubic foot	624	890	304	155	150	135

The difference between the heating value of coal-gas and carburetted water-gas of similar illuminating power is shown by the following figures published by Dr. Colman:—

	Coal-Gas.	Carburetted Water-Gas.	
Illuminating power	17·31	17·46	candles.
Heating value (gross)	158·9	142·5	calories per cubic ft.
,, ,, (net)	145·7	132·9	

To convert the calories into British thermal units multiply by 4 (or, more correctly, 3·968).

The table (see p. 50) given by Bryan Donkin in his book on "Gas Engines" is interesting as showing the variations in the composition of the coal-gas supplied in different localities. The analysis of London gas supplied by the Gas Light and Coke Company needs revision, as the carbon monoxide now commonly amounts to 9 or even 12 per cent., owing to the addition of large proportions of carburetted water-gas.

Chemical Composition of Coal-gas in Various Cities and Towns in Percentage by Volume.

(Donkin's "Gas, Oil, and Air Engines."

Constituents in Gas. Percentage by volume.	London Gas Light and Coke Co.	London Society of Arts Trial, 1888.	Manchester.	Kilmarnock Trial. Professor Kennedy.	Gas Motoren Fabrik, Col gne (Slaby).	Bonn (Clerk).	Dresden (Schöttler).	Hanover (Schöttler).	Hoboken, New York (Brookes and Steward).	Paris (Peclet).	Paris (Witz).
Heavy Hydrocarbons	4·41	3·77	6·46	5·55	3·50	4·75	3·00	3·17	6·60	5·80	5·50
Marsh-Gas, CH_4	37·54	37·34	34·90	42·80	34·40	43·12	33·40	37·55	37·30	33·10	32·30
Hydrogen, H.	47·99	50·44	45·58	43·60	56·90	39·80	48·70	46·27	39·50	50·10	52·80
Carbonic Oxide, CO	3·75	3·56	6·64	4·30	5·20	4·66	8·00	11·19	4·30	6·30	5·60
Carbonic Acid, CO_2	—	0·51	3·67 H_2S		—	3·02	1·50	0·81	2·70 and impurities.	1·50	—
Oxygen, O	0·26	—	0·29	1·05	—	—	1·40	—	1·40	0·50	—
Nitrogen, N	5·95	3·98	2·46	2·70	—	4·65	4·00	1·01	8·20	2·70	3·80
Totals	10 ·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Producers.—In the older forms of producer the fuel usually rested on firebars through which the air supply entered. In order to make the draught sufficiently powerful to carry the producer-gas forward an overhead cooling tube was provided. The gas ascended to this tube, and after being cooled was allowed to descend, the weight of the cold descending gas being sufficient to create a "pull" on the hot gas ascending through the fuel, and to thus increase the current of air drawn through the firebars. In these "open" producers the rate of manufacture is slow owing to the slow speed of the air draught, and the small quantity of steam permissible. Better results are obtained by closing the ashpit and admitting regulated currents of air and steam under pressure. The air and steam are supplied together. A jet of steam is blown into a tube, and owing to the force of its impulsion draws air into the tube with it, and the steam and air pass together into the producer. The size of the jet is adjustable, so that the proportion of air to steam can be varied as required. By using a hollow jet of steam instead of the so-called "solid" jet formerly used, a given quantity of steam can be made to draw in a larger volume of air.

Mond Gas.—Hitherto producer-gas has in this country been manufactured on the works on which it is to be used, and is usually consumed while hot. The promoters of the Mond scheme propose to supply a large area in Staffordshire, including several important towns, with Mond gas for power purposes. It is proposed to distribute the gas in steel mains under an initial pressure of 7 lbs. per sq. in. in order to limit the size of the mains required. The difference between this pressure and that of 1 in. to 4 in. of water under which coal-gas is commonly supplied is shown in the following table :—

Weight of a column of water in lbs. per square inch. (*Water at maximum density at* 3·9 *deg. C*).

$\frac{1}{10}$th in.	water	=	0·00361	lbs. per sq. in.
1 in.	„	=	0·0361	„
27·7 in.	„	=	1·0	„
194 in.	„	=	7·0	„
554 in.		=	20·0	„

According to Sir F. Bramwell, the gas is to be sent out under an initial pressure of about 7 lbs. per sq. in. from the distributing stations, and at the point of delivery to the consumers is to be reduced to about 2 lbs. The maximum price is to be 3d. per 1,000 cubic feet, when not less than four million cubic feet per quarter are used, and 4d. per 1,000 cubic feet for smaller quantities.

Mond gas is a producer-gas made with the aid of an unusually large quantity of steam, about 2½ tons of steam being blown into the fuel for every ton of coal slack consumed. A large quantity of ammonia is present in the gas produced, and this is recovered and subsequently converted into sulphate of ammonia, the sale of which is expected to almost cover the cost of the coal slack.

Oil - Gas. — Instead of being used for the manufacture of carburetted water-gas, oil may be directly decomposed into a gas very rich in illuminating hydrocarbons. The oil-gas may be used without admixture with other gas, or may be used for enriching gas of poorer quality.

Pintsch's System and Pope's System.—The oil-gas produced by these systems is extensively used for lighting railway carriages, lighthouses, and buoys. Even after compression it has an illuminating power of about 7½ candles per cubic foot when consumed in the ordinary railway carriage-lamps. A gallon of oil, such as Russian Solar Distillate or Scotch gas oil, yields about 82 cubic feet of 50-candle gas. The gas is stored for use in steel cylinders under a pressure of about ten atmospheres (150 lbs. per square inch). When subjected to this compression, about 1 gallon of tarry liquid, known as "hydrocarbon," condenses from every 1,000 cubic feet of gas compressed, and the illuminating power of the gas is reduced from 50 to about 38 candles per 5 cubic feet rate.

The oil-gas is manufactured by vaporising and decomposing the oil in specially-constructed retorts heated to a cherry red heat. It is now a common practice to mix about 20 per cent. of acetylene with the oil-gas before compression, the illuminating power of this mixture being double that of the plain oil-gas.

Peebles Process.—By this process, the invention of Messrs. Young & Bell, oil or tar is converted into gas and coke, the gas being washed with oil or tar, which is itself subsequently decomposed into gas and coke. One ton of tar from Durham coal is said to yield 15,000 cubic feet of 25-candle gas and 15 cwt. of good quality coke; and one ton of Scotch gas oil to yield about 22,000 cubic feet of 90-candle gas, the illuminating power being calculated from the enriching value of the gas when mixed with low quality gas. About 5½ cwt. of hard graphitic coke is obtained per ton of oil.

Oil-gas is so rich in heavy hydrocarbons that it burns with a very smoky flame in burners which are suitable for coal-gas, and has therefore to be consumed in burners with very small orifices, such as the No. 0 or No. 00 Bray burner, and at the rate of about 1 cubic foot per hour. Professor Lewes gives the following as the composition of oil-gas as made by the Pintsch and Young systems respectively:—

Composition of Oil-Gas.

	Pintsch Gas.	Young Gas.
Unsaturated hydrocarbons	35·65	43·83
Saturated hydrocarbons	45·37	36·30
Hydrogen	12·44	16·85
Carbon dioxide	0·74	0·63
Carbon monoxide	0·60	0·00
Oxygen	2·00	1·14
Nitrogen	3·00	1·25
	100·00	100·00

Air-Gas.—In America, illuminating gas is often made by passing air at ordinary temperatures over light petroleum spirit. This is, however, a crude and wasteful method of using the oil, and many accidents have occurred owing to an explosive mixture of air and petroleum vapour having been formed in some part of the apparatus.

The Kitson Light.—This light is produced by heating a large mantle to incandescence by means of an oil flame rendered non-luminous by causing the oil vapour to draw in by its injecting action the necessary volume of air just before it enters the burner. The mantle is similar to that used by the Welsbach incandescent gas light, but is larger. The oil is placed in a cylinder, and air is then pumped into the cylinder. The pressure of air in the cylinder (about 50 lbs. per square inch) forces the oil up a pipe of very small bore, and injects it into the lamp, where it passes through a tube located a short distance above the mantle and where, heated by the waste combustion products, it is vaporised. The compressed air is not used for combustion of the oil. The apparatus is compact, and has the advantage of not requiring any distributing pipes. It is, therefore, useful for lighting works not supplied with gas, or for works of a temporary nature where a powerful light is required without incurring the expense of laying gas service-pipes. The hissing noise made by the lamp makes it unsuitable for most indoor work. The illuminating power of the light is about 1,000 candles, and the cost of the oil used amounts to about 1d. per hour.

Enrichment of Gas with Light Oils.—Instead of decomposing heavy oil into a rich gas and using it to enrich low quality gas, the gas may be passed over liquid light oil or brought in contact with oil which has been vaporised but not decomposed, with the aid of steam. These light oils are mostly distillates from American petroleum, and are sold under fancy names. *Carburine* has a boiling point of about 70 deg. C. and a specific gravity of about 0·68. *Gasolin* has a boiling point of about 40 deg. C. and a specific gravity of about 0·65. *Petroleum Spirit* a boiling point of about 95 deg. C., and a specific gravity of about 0·70. Commercial 90 *per cent. benzol* contains, according to Butterfield, about 70 per cent. benzene and 25 per cent. toluene, and has boiling point between 82 and 112 deg. C., while its specific gravity varies from 0·882 and 0·885.

The process of enriching gas with oil vapour is termed "carburetting." In Germany benzol is largely used for carburetting plain water-gas. The gas may be carburetted with light oils at atmospheric temperatures, but in this country it is usual to vaporise the oil by steam heat. In

London, all gas supplied north of the Thames is required by Act of Parliament to have an illuminating power of not less than 16 candles when consumed in a standard argand-burner at a rate of 5 cubic ft. per hour. The gas from the coal used in London has an illuminating power of 14 to 15 candles, and it is therefore necessary to raise it to about 16½ candles by carburetting it with light oil or by mixing it with rich carburetted water-gas. Mr. H. Leicester Greville has found that 1 gallon of petroleum spirit vaporised in a Price carburettor is capable of enriching 10,286 cubic ft. of coal-gas from 16 to 17 candle-power.

CHAPTER VII.

BY-PRODUCTS AND THEIR USES.

THE residuals obtained in the manufacture and purification of coal-gas, and the articles of commerce made therefrom, are too numerous to be even enumerated here. The manufacture of coal tar products is of itself an industry of the first importance. The aniline colours, creosote, carbolic acid, pitch, coke, sulphate of ammonia, and nitro-benzene are among the products derived directly or indirectly from coal.

At the Beckton Gasworks, London, which are the most extensive in the world, tar distillation is carried on and many by-products are manufactured, but in most cases the tar is sold by the gas manufacturer to the manufacturer of chemicals or dyes. The principal products other than gas commonly sent out from a gasworks are coke, tar, sulphate of ammonia, spent oxide, and spent lime.

Coke.—Gas coke should consist almost wholly of carbon. It should not contain more than 5 per cent. of water, nor yield more than 8 per cent. of ash. The amount of sulphur should not exceed 1 per cent. The statement that gas coke contains much more sulphur than household coal is, generally speaking, altogether erroneous. The coke as it leaves the retort is in pieces of too large a size to be convenient for domestic use, but it can now be obtained from the works broken to convenient size, and consequently finds a more ready sale for domestic purposes.

Tar.—About 10 gals. of tar are commonly obtained per ton of coal carbonised. The tar from Durham coal has usually a specific gravity of about 1·200. Butterfield gives the following as the results of an assay of a typical London coal tar:—

	Per cent. by weight.	Remarks.
Specific gravity at 15·5 deg. C. = 1·192.		
Aqueous ammoniacal liquor	3·53	
Light oils (distilling over below 170 C.)........................	1·99	Lighter than water. Include benzol, which is used for the manufacture of aniline.
Middle oils (distilling over between 170 and 270 C.)	18·46	Include napthalene and carbolic acid.
Anthracene oils (distilling over above 270 C.)................	12·20	From which alizarin is manufactured.
Pitch (medium)	59·20	Used for paving, roofing, varnishes, patent fuel, &c
Loss on distillation	4·62	
	100·00	

Tar Concrete and Tar Pavement.—Tar concrete is made of broken stones or shingle thoroughly mixed with tar, about twelve gallons of tar being used for every cubic yard of concrete. The tar should be heated and the solid matter dried before the two are mixed. Breeze, furnace cinders, broken clinker, and other materials are also often employed for mixing with the tar. For tar pavement, Newbigging recommends the following treatment:—The solid ingredients are divided into three grades—1. Coarse material which will not pass through a sieve having bars $\frac{3}{4}$ in. apart; 1. Riddlings which will pass this screen, but will not pass through a $\frac{3}{8}$ in. sieve; and 3. Fine material which passes through both sieves. The three grades are made hot and mixed with hot tar in the following proportions:—

1. Coarse material	1 part tar 9 parts solid	or 24 gals. tar to 1 ton solid.
2. Riddlings	1 part tar 7 parts solid	or 30 gals. tar to 1 ton solid.
3. Fine material	1 part tar 6 parts solid	or 36 gals. tar to 1 ton solid.

The footpath having been curbed, the upper edge of the kerb standing 3 in. above the solid bottom of the path, the coarse mixture is laid down 2 in. thick; then the medium mixture is laid $\frac{5}{8}$ in. thick; and, finally, on top of this the finest material is laid about $\frac{3}{8}$ in. thick. Each layer is rolled with a 10 cwt. roller before being covered with the succeeding layer. The surface of the pavement may be sprinkled with powdered Derbyshire spar or granite to improve its appearance.

Tar for making pavement should, according to O'Connor, be heated until converted into pitch that will harden on cooling; but if overheated the tar will lose its tenacity, and produce a pavement which will disintegrate rapidly. The tar should be heated in open boilers, at about 194 deg. Fahr., for from four to twelve hours.

Tar as a Paint for Iron.—Coal-tar contains substances of an acid nature, and these should be removed before the tar is used as a preservative paint for iron. When tar is distilled a neutral, solid, resinous pitch is obtained as a residue, and this pitch, when dissolved in benzene or petroleum, makes a better paint for iron than raw cold-tar. It should be applied while hot. Coal-tar or coal-tar pitch should not be used on iron exposed to the direct heat of the sun's rays, for tar paints so heated are liable to soften and run. Tar paints are valuable for painting pipes to be laid under ground and for sheet-iron flues. Tar is also suitable for protecting iron rivets and nuts. In its raw condition it always contains more or less water mixed with it, and this should be carefully removed before it is used as a paint.

Spent Oxide.—Spent oxide of iron, when discarded for further use in the purifiers, should contain not less than 50 per cent. of free sulphur. In large works this is sometimes converted into sulphuric acid to be used on the works for the manufacture of sulphate of ammonia, but the spent oxide produced in smaller works is usually sold to sulphuric acid manufacturers.

Gas Lime.—The lime used for gas purification should be flare lime, and as pure as possible. A good building lime would not be suitable for gas purification, for the power of "setting," indicative of a good building lime, is a feature to be avoided in lime required for gas purifiers, and the impurities which often increase the value of the lime for building purposes always depreciate its value as a purifier. When the lime in the purifiers has become "spent" it is thrown out and exposed to the atmosphere for as long a period as possible, unless it is to be re-burnt to quicklime on the works. Exposure to the air causes oxidation of some of the unstable constituents, and diminishes the intensity of the odour evolved by the lime.

In large towns the gas manufacturer usually has to pay for the removal of the spent lime, but in country towns the farmers buy it for a small sum for agricultural purposes. Gas lime improves soils of a certain class, and checks certain plant diseases, but it should never be used until it has been exposed to the air for a long period. Dr. Voelker has found the composition of gas lime, which has been exposed to the atmosphere for a sufficiently long period to render it a safe manure, to be as follows:—

Composition of Gas Lime (dried at 212° F.).

Water of combination and a little organic matter .. .. per cent.	7·24
Oxides of iron and alumina, with traces of phosphoric acid	2·49
Sulphate of lime	4·64
Sulphite of lime	15·19
Carbonate of lime	49·40
Caustic lime	18·23
Magnesia and alkalies	2·53
Insoluble silicious matter	·28
	100·00

Sulphate of Ammonia.—The ammoniacal liquor from the hydraulic main, condensers, washers, and scrubbers is collected in a well or tank, and subsequently used for the manufacture of sulphate of ammonia. The sulphate is principally used for agricultural purposes as a nitrogenous manure.

When the ammoniacal liquor is boiled, the carbonate and sulphide of ammonia it contains are decomposed and free ammonia is liberated. The ammonia, together with steam and other gases, passes to a vessel termed the "saturator," which contains diluted sulphuric acid, and in which solid sulphate of ammonia in the form of minute crystals is precipitated as the acid becomes saturated with ammonia. The sulphate is fished out with a perforated ladle and placed on a draining table. A small proportion of the ammonia in the ammoniacal liquor is present as chloride, sulphate, and other compounds of ammonia which are not decomposed when the liquor is boiled; the residual liquor remaining after the "free ammonia" has been removed by boiling is therefore heated with lime, which causes the "fixed" ammonia to be liberated, and renders it available for conversion into sulphate of ammonia.

A sample of ammoniacal gas liquor (sp. gr. 1·0207 at 22 deg. C.) examined by S. Dyson had the following composition:—

		Grammes per Litre.
Ammonium	sulphide	3·03
,,	carbonate	39·16
,,	chloride	14·23
,,	thio-cyanate	1·80
,,	sulphate	0·19
,,	thio-sulphate	2·80
,,	ferro-cyanide	0·41

Prussian Blue.—Compounds of hydrocyanic acid (prussic acid) are present in small quanties in the unpurified coal gas as it leaves the retorts. These compounds are termed cyanides (ammonium cyanide and sulphocyanide), and several processes have been devised to recover the cyanogen in the form of sodium or potassium ferrocyanide for subsequent conversion into the cyanide of iron ($Fe_7 Cy_{18}$) known as Prussian blue. The manufacture of Prussian blue is, however, carried on at very few gasworks in this country, and very few details relating to the method of manufacture, and the economy effected, have yet been published; and it is said that the Prussian blue obtained is not so pure as that manufactured from other sources. Prussian blue is always present in more or less quantity in oxide of iron which has been used for purifying the gas from sulphuretted hydrogen.

Bisulphide of Carbon.—Liquid carbon bisulphide has been recovered on a comparatively large scale by H. Leicester Greville from the spent lime discharged from the purifiers used for removing this impurity from the gas. The liquid bisulphide may be obtained by simple distillation of the spent lime with water. It was found that the lime would yield about 1½ per cent. by weight of liquid bisulphide, and that the residue left in the boiler contained 50 per cent. of free lime, and could be again used for purification purposes. It was proposed to use the liquid bisulphide for dissolving the free sulphur from the spent oxide of iron produced on the works, the sulphur and bisulphide of carbon to be subsequently separated by distillation, and the oxide of iron, after removal of the sulphur, to be again used for gas purification. The scheme has not, however, been adopted, as it has been found more economical to burn the sulphur contained in the spent oxide into gaseous sulphur dioxide, and to subsequently convert it into sulphuric acid.

CHAPTER VIII.

CONSUMER'S METER AND SERVICE PIPES.

Consumer's Meter—The consumer's meter may be of either the "wet" or "dry" description, but the "dry" meter is now almost universally employed. Fig. 13 shows a wet meter in section, and fig. 14 a dry meter. The wet meter is constructed on the same principle as the station meter previously described.

The dry meter has a case of tinned iron divided into compartments by a central partition, and two or more movable diaphragms having flexible leather sides. The gas enters and leaves the compartments alternately through suitable slide valves. The pressure of the gas on the surfaces of the diaphragms causes alternate inflation and collapse of the bellows-like chambers, and, consequently, alternate variations in the area of the inner and outer compartments, and the movements of the diaphragms bring into operation the lever and cranks which actuate the wheelwork of the indicators.

Meters are classed according to the number of "lights" which they are intended to supply, each light being supposed to consume 6 cubic feet of gas per hour. Thus a 10-light meter should be provided when the consumption is likely to approach 60 cubic feet per hour, and a 50-light meter when a supply of 300 cubic feet per hour is required. This nominal capacity of the meter does not represent the largest quantity of gas which can be passed through the meter under ordinary pressures, but the meter should not be required to perform more than its nominal duty The *prepayment meter*, also called the *coin meter* or the *slot* *meter*, is an ordinary meter having attached to it a box with a slot in it. When a penny, or any other coin for which the meter is provided, is dropped through the slot a certain quantity of gas is allowed to pass to the burners, and when the pennyworth of gas is nearly consumed, the volume of gas passing gradually diminishes until the flow altogether ceases unless another penny is dropped through the slot.

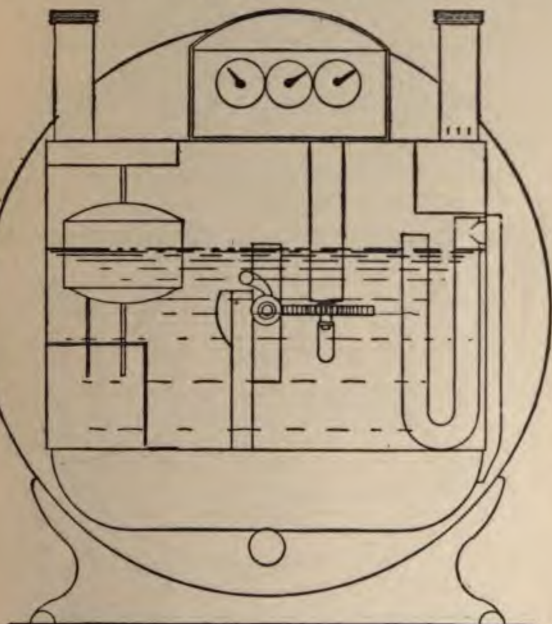


Fig. 13.—A Wet Meter in Section.

The price charged for the gas is greater than when bought by means of an ordinary meter, because the extra cost of the meter has to be considered, and the price is usually calculated to include the rental of supply pipes, brackets and burners which are provided without additional charge. From 20 to 25 cubic feet of gas are commonly allowed for one penny, but the quantity varies in different districts. A common practice is to add 10d. per 1,000 cubic feet to the price charged for gas sold by ordinary meter.

The prepayment meter first came into use about ten years ago, but it at once became very popular, especially in cottages and workmen's tenements, and there are now about 500,000 of them in use in the United Kingdom alone.

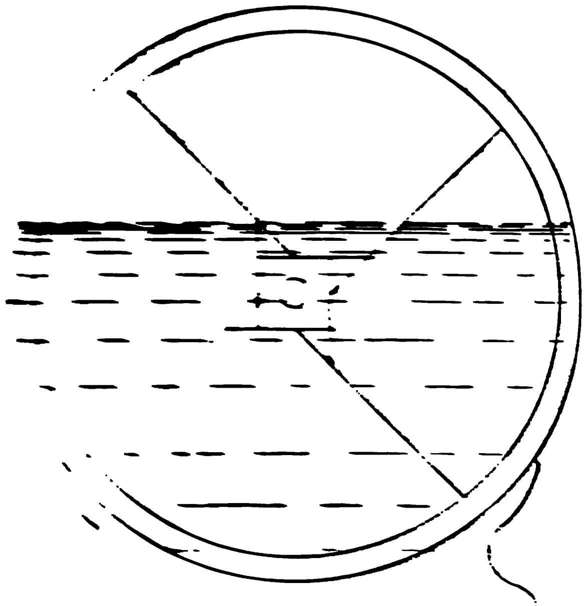


Fig. [illegible].—Wet Meter in Section.

A meter is termed "slow" when it registers less than the actual volume of gas passed through it, and "fast" when the registered consumption is larger than the amount actually passed through it. A meter which registers correctly at the ordinary pressure of gas would register "slow" if the gas were measured under a higher pressure. By the

"Sale of Gas Act" of 1859 a meter is passed as correct when it registers not more than 2 per cent. fast or 3 per cent. slow, the slow registration being in favour of the consumer.

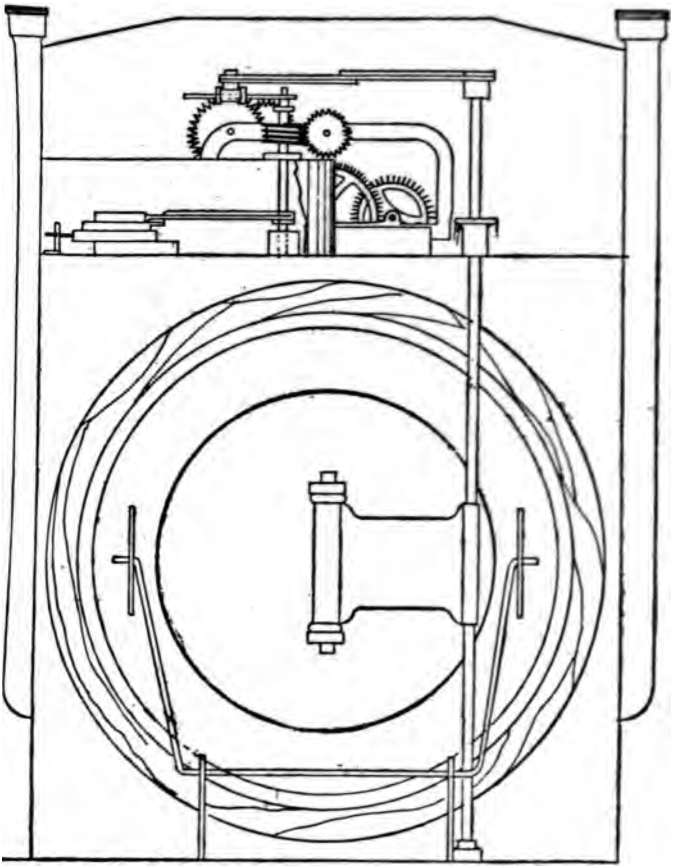


Fig. 14.—A Dry Meter.

In most large towns one or more meter testing offices are provided and maintained by the Local Authority, which also employs competent and impartial inspectors to test any meter which may be sent to the office for the low fees quoted in the Sale of Gas Act.

The following circular, issued from the Guildhall, London, will serve as an example of the facilities commonly afforded to gas consumers for verifying the registration of gas-meters. The privilege of having a meter, or any number of meters, tested at this low rate of charge is not confined to the inhabitants of the City of London, but is open to every one. The circular runs thus :—

"The attention of the inhabitants of the City is called to the facilities for testing gas-meters :—

I. The Testing Office provided by the Corporation is situate at the City Green-yard, Lower Whitecross-street. Office hours 9 to 5.

II. A gas consumer desiring to have his meter tested should first give twenty-four hours' notice thereof to the gas company. If at the expiration of that time the company have not taken the necessary steps to examine and test such meter, the consumer may do so, the party in the wrong paying certain charges.

III. The charge for testing a 2, 3, or 5-light meter is sixpence, and for larger meters as follows :—

Dry Meters.			Wet Meters.		
Lights.	s.	d.	Lights.	s.	d.
10	1	0	10	1	0
20	1	0	20	1	0
30	1	0	30	2	0
50	2	0	50	2	0
60	2	0	60	3	0
80	3	0	80	4	0
100	3	0	100	5	0
150	5	0	150	8	0
200	7	0	200	10	0

IV. Three days are by the Act allowed for testing, but as a rule a meter can be received back the same day.

V. The consumer can, under special circumstances, have his meter tested on his own premises, but extra cost is thereby incurred.

CHAPTER IX.

GAS PRESSURE AND GAS GOVERNORS, PRESSURE AND CONSUMPTION GAUGES.

When gas is required for the purpose of producing an illuminating flame it should be supplied at the point of ignition under very low pressure (say 0·5 in. of water), but when required for incandescent burners, or other burners in which air is admitted to produce a non-luminous flame, the gas should be supplied to the point at which it is injected into the mixing tube of the burner under a higher pressure (say 1½ in.). It is commonly stated that "atmospheric" gas fires are most efficient when supplied with gas under a pressure of about ¾ in., but although this may be true when coal-gas is used in nicely adjusted gas fires having clean burners and tested under favourable conditions in a room free from draughts, it is a statement which is likely to mislead the ordinary consumer.

In practice the burners are seldom perfectly clean, but are more or less covered with dust deposited from the atmosphere or dropped upon them from the overhead fire-clay or asbestos fuel; consequently the gas ceases to issue in sufficent volume, becomes mixed with too large a proportion of air, and "flashes back" when ignited, or burns with a short, noisy, green flame. Non-luminous flames, produced by admitting air before the point of ignition, have also a greater tendency to "flash back" under the influence of air draughts, caused by opening windows or doors, when the gas is supplied under a pressure of less than 1 in. than with gas under a higher pressure. Also the common practice of mixing carburetted water-gas with the coal-gas, and thereby increasing the specific gravity of the gas, necessitates the use of gas under a higher pressure than $\frac{3}{4}$ in. The main disadvantage attendant on the use of gas under high pressure is the hissing noise produced in the burner.

Initial or House Gas Governors.—The pressure of the gas as it leaves the consumer's meter varies considerably during every twenty-four hours in most districts, and to prevent it exceeding a certain limit at the points of ignition a governor is often affixed on the service-pipe close to the outlet of the meter. The object of the governor is to prevent wasteful consumption of gas, and to maintain a uniform pressure at the burners irrespective of the changes in the pressure under which the gas is supplied to the meter. When the pressure of the gas entering the meter is too low, or the meter itself is too small, governors are quite useless.

Governors should always be fitted in a level position, and in places where they can readily be inspected. By turning a screw or manipulating small weights the governors can be so adjusted that the pressure at the outlet will be maintained at any desired point lower than the pressure at the inlet. It is usual to recommend that the pressure be reduced to 1 in. when the usual number of lights are in use, but if incandescent burners or other appliances fitted with "atmospheric" burners are to be supplied in addition to burners for luminous flames, it is better to allow a pressure of $1\frac{1}{2}$ in. at the governor outlet, and for the luminous flames to use governor burners, or Bray burners fitted with the "economisers" to be described in the next chapter.

The governor usually consists of a small chamber through which the gas flows, the inlet being partially closed by a small cone which automatically rises and reduces the size of the inlet orifice when the pressure increases, and which descends as the pressure decreases and thereby increases the size of the orifice through which gas can pass. In some governors the upper part of the chamber consists of a flexible leather diaphragm, which expands in an upward direction when the pressure increases and draws up the conical or semi-spherical plug which is connected to the diaphragm by a central spindle, and which controls the gas inlet orifice. The gas pressure required to raise the diaphragm and top plate is regulated by removable weights, or by turning a screw which regulates a spring pressing upon the flexible diaphragm. To obtain greater regularity of action the governor sometimes consists of two of these expansible chambers arranged side by side, and forms what is termed a "double dry governor."

In Peebles's "mercurial" governor (fig. 15) a small gas bell floats in a cup containing mercury, the rise of the bell when the pressure increases causing a reduction in the size of the inlet orifice, and the gas pressure required to raise the bell being dependent upon the weight placed upon it.

FIG. 15.—Peebles's Mercurial House Governor.

One of these governors is sometimes attached to every appliance which consumes a large volume of gas, such as a fire or stove, as in such cases the saving effected by carefully governing the supply may be considerable.

Occasionally trouble is caused by the valve of a governor becoming jambed against the sides of the chamber in which it is located, and refusing to pass the required volume of gas. In such cases the valve can readily be released, but instances have occurred in which the consumer has been too ignorant to detect the cause of the trouble and has at once concluded that the gas company has been distributing gas under deficient pressure or of inferior quality.

Governor Burners.—Instead of, or in addition to, placing an initial governor at the outlet of the meter, the burners used may each be provided with a small governor, situated either in the body of the burner or immediately beneath it.

In Peebles's needle burner (fig. 16) the chamber beneath the steatite burner tip contains a perforated conical float of white metal, and as the gas pressure increases the float rises and reduces the size of the orifice through which the gas escapes to the burner tip. The needle is an upright central metal rod which passes up inside the float and prevents it becoming tilted out of its proper position. The greater the pressure the smaller becomes the outlet orifice, while a decrease of pressure is accompanied by a descent of the float and consequent enlargement of the outlet orifice.

Fig. 16.—Peebles's Needle Governor Burner.

A great variety of burner governors are manufactured, but most of them depend upon the movements of a float which automatically reduces the size of the gas inlet or outlet orifice as the gas pressure increases, and enlarges it as the pressure decreases. They are mostly effective while maintained in good working order, but all require occasional inspection, as the accumulation of a little dirt within them, or the corrosion of the metal, is liable to put them out of action. Sometimes in float governors the float becomes jambed against the sides of the chamber containing it, and needs to be released by tapping the burner, or by unscrewing the base of the chamber and shaking it free.

Pressure increases with the Elevation.—The specific gravity of coal-gas being much lower than that of air, the gas pressure increases as the height of the supply-pipe above ground level increases, and decreases when the pipe is carried in a downward direction. A gasworks is usually situated on the lowest level in the district to be supplied, because a higher pressure is required to distribute gas downhill than uphill. The pressure on the top floor of a building is greater than in the basement, if no governor be employed. The increase in pressure is equal to about $\frac{1}{10}$ in. of water for every 10 ft. of elevation, and in lofty buildings a governor may with advantage be provided on the service-pipe at every elevation of 30 ft.

Pressure Gauges.—The simplest pressure gauge is a glass U-tube filled to about half its height with water, one end of the tube being open to the air and the other open to the air until connected to the gas supply-pipe. When both ends of the tube are open to the atmosphere the column of water is at the same height in both limbs; but when one limb is connected to the gas supply the pressure of the gas causes the water level to be depressed in one limb and to rise in the other. The height of the water level in the one limb above that in the other limb is measured in inches, and represents the pressure of the gas in inches of water. For convenience the water in the tube may be tinted with cochineal or soluble indigo, a scale graduated in tenths of an inch may be attached to the tube, and a stopcock and nipple may be fitted to the end of each limb; but these additions merely render the apparatus more convenient to use, and do not affect the accuracy of the readings.

Mercury Gauges.—For pressures higher than the maximum of 4 in. or 5 in. under which coal-gas is usually supplied, the U-tube may be charged with mercury instead of water, mercury being 13·4 times the weight of water. Mercury gauges are sold having a scale on which the figures represent the pressure in inches of water, and the necessity of multiplying the readings by 13·4 in order to convert them into inches of water is thereby obviated.

High-pressure Gauges.—For measuring pressures of many pounds to the square inch, spring gauges in a circular metal case, similar to those used for steam boilers, are employed.

Service-pipe Cleansers.—Supply pipes and service pipes exposed to low temperatures sometimes become blocked with naphthalene or other matter deposited from the gas. To remove the obstruction the pipe is usually "blown out" with the aid of a force pump known as a "service cleanser," the removal being sometimes facilitated by introducing into the pipe a solvent, such as benzol, naphtha, or petroleum.

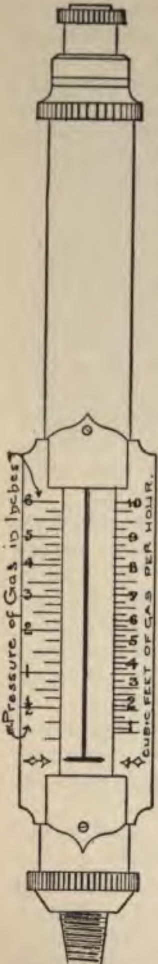


Fig. 17.—Consumption and Pressure Indicator.

Consumption and Pressure Indicator.—Indicators are manufactured which show at a glance the approximate hourly rate of gas consumption of any ordinary gas-burner, and which may also be used as pressure-gauges. The consumption readings of the indicator vary with the specific gravity of the gas, and consequently an indicator adjusted to give correct readings with rich Scotch gas would not indicate correctly the consumption of burners tested with London coal-gas. The indicator must be adjusted by the manufacturer to suit the quality of the gas supplied in the district in which it is to be used.

To ascertain the rate of consumption of any burner the indicator (fig. 17) is attached to the gas supply pipe, and the burner is screwed into the top of the indicator. The gas entering the bottom of the indicator passes through a glass tube, within which is a floating disc which rises to a height dependent upon the rate of flow of gas to the burner. On one side of the metal case containing the glass tube is a scale of cubic feet per hour, the consumption of the burner under examination being indicated by the position of the floating disc, which rises until opposite that figure on the scale which indicates the consumption. As the height to which the disc is raised is dependent upon the specific gravity of the gas, it follows that the instrument registers inaccurately when used with gases of widely different specific gravity, but for obtaining an approximate estimation of the consumption of different burners in districts supplied with gas of uniform specific gravity the apparatus is very useful.

To use the instrument as a pressure

gauge a cap provided with the instrument is screwed on the top in place of a burner, and reference is made to another scale engraved on the opposite side of the metal case. The float rises as before, and the point at which the disc remains at a constant height indicates on the scale the pressure in inches of water of the gas under examination. Variations in the specific gravity of the gas do not affect the accuracy of the pressure indications.

Testing the Gas Fittings.—Gas supply pipes and fittings to be used with gas under ordinary pressures of less than 4 in. of water should always be tested under a pressure of 10 in. or 12 in. before being approved as gas-tight. A force pump and mercury or water pressure-gauge with connecting pieces form the whole of the apparatus required for testing; gas or air being forced into the pipes until the required pressure is obtained, and observation being made as to whether the pressure remains constant for a long period or gradually decreases. A leak-detector of this description is made by Harrison & Sheard, and quite recently a detector known as the "Wizard," in which benzoline is provided to render the air inflammable, and thus facilitate detection of the point of leakage, has been introduced by Falk, Stadelmann & Co.

CHAPTER X.

LUMINOUS FLAT FLAMES.

To obtain the highest lighting efficiency from a luminous flame the pressure under which the gas escapes at the point of ignition must be very low. The luminosity of the flame is due to the presence of minute particles of solid carbon liberated by the decomposition of certain hydrocarbons under the influence of heat. The greater the temperature to which the carbon particles are heated the greater is the intensity of the light emitted.

When gas issues under high pressure from the burner, less light is emitted from the flame than when the gas is burned under low pressure, because rapid currents of air are induced in the neighbourhood of the flame, which consequently becomes cooled and over ærated, and becomes less highly charged with the solid carbon particles.

The gas should issue from the burner in such a manner that the flame is capable of supplying itself with that proportion of air required to effect complete combustion of the gas without cooling the flame by undue dilution. If the flame is of such shape or dimensions that it cannot attract to itself sufficient air to completely oxidise all the carbon particles liberated, the flame becomes smoky and emits less light than when the gas is consumed under favourable conditions. A poor quality gas requires less air than a rich gas, and the apertures in a burner to consume the former should be larger than those in a burner for rich gas. A pressure of 0·5 in. at the inlet of the burner is sufficient in most cases.

Flat flame burners may be divided into three classes :—

(1) Batswing, (2) union-jet or fishtail, (3) slit union burners.

The burner tip should always be made of some material which is not a conductor of heat, the materials most extensively used being steatite and enamel.

Fig. 18 (a).—Batswing burner.

Fig. 18 (b).—Union-jet burner.

Fig. 18 (c).—Slit-union burner.

Batswing Burners.—The batswing burner (fig. 18a) yields a flame (fig. 19a) having a shape somewhat resembling that of a bat's wing. It is specially adapted for rich gas, such as that obtained from cannel coal, of from eighteen t· thirty-candle power.

The richer the gas the more narrow must be the slit in the burner, and the smaller the rate of consumption.

Union-jet or Fishtail Burner.—Bray's union-jet burner (fig. 18b) is an enamel burner cased in brass. The gas issues from two channels drilled in the enamel at an angle somewhat greater than 45 deg., the size of the orifices being dependent upon the quality of the gas to be consumed.

Fig. 19 (a).—Batswing flame.

The burners range in size from No. 00000 to No. 9, the latter having the largest orifices. The inclination of the two channels in the enamel also varies according to the quality of the gas to be consumed, so that the angle at which the two jets of gas impinge against each other may be such as will give a suitable spread to the flame when supplied with gas under low pressure. The fishtail burner derives its name from the shape of the flame it gives (fig. 19b).

The flame being of less breadth than the batswing flame is less liable to crack the glass shades commonly used with flat flames. The light efficiency obtained when these burners are used with gas under the full pressure at which it is usually supplied to the consumer (say, 2 in.) is very low. The gas pressure ought to be reduced to abont 0·5 in. before passing to the burner, but, as a matter of fact, the majority of gas consumers use Bray burners without a

Fig. 19 (b).—Union-jet or fish-tail flame.

governor of any description, the sole regulation of the gas consumption being that produced by turning the gas-cock until the flame appears to be emitting the maximum quantity of light.

Slit Union Burners.—The slit union burner (fig. 18c), is a combination of the union-jet and batswing burner. It somewhat resembles the batswing burner in appearance, but has a recessed top, and produces a flame wider ...

base than the batswing, and less ragged at its upper edges (fig. 19c). These burners are often employed for street lamps.

The flame photographs reproduced in figs. 19a, 19b, and 19c were obtained from the No. 5 burners shown in fig. 18 when supplied with 15-candle gas under a pressure of 1 inch.

Fig. 19 (c).—Flame from slit-union burner.

Bray Burners with Economisers. — The gas "economiser" is merely a small expansion chamber of brass, fitted internally with a muslin screen and terminating at top with a slit burner. These economisers slip over the ordinary Bray union-jet burners, and have the effect of materially increasing the illuminating power of the flame without affecting the rate of gas consumption. They are particularly effective when used in places not provided with governors, and supplied with gas under the usual pressure of $1\frac{1}{2}$ to $2\frac{1}{2}$ in. Bray's "Codac" economisers may be bought retail for a 1d. each, or 7d. per dozen, and although like all slit burners they gradually become blocked with carbonaceous deposit, their price is so small that they may be replaced by new ones every two or three months without appreciably affecting the annual cost of maintenance of a lighting installation. The Bray burners most extensively used are Nos. 4 and 5, commonly consuming 8 and 10 cubic feet per hour respectively under the ordinary gas pressure of $1\frac{1}{2}$ to 2 in. These may with advantage be replaced with No. 2 burners capped with No. 7 Codac economisers. When the economisers are discarded for

Fig. 20 (a).

Fig. 20 (b).

Fig. 20 showing Bray burner (a) without and (b) with economiser.

new ones, it is not necessary also to renew the No. 2 burners.

Bray's adjustable burners are constructed on similar lines, but the upper portion of the burner is made to screw on to the lower portion instead of to slip over it.

The following tables show the lighting power and rate of gas consumption obtained with a No. 2 and No. 3 Bray burner (patent enamel regulator) respectively when tested under different gas pressures with and without the economiser, the gas-cock in every case being turned fully open without regard to the appearance of the flame. The

Fig. 21a.—Without economiser.

quality of the gas tested in a standard Argand burner was 15½ candles per 5 cubic feet per hour rate :—

No. 2 Bray Burner without Economiser.

Pressure of gas supply. Inches.	Gas Consumption. Cubic feet per hour.	Iluminating power. Candles.	Candles per cubic foot per hour. Candles.
1·75	5·6	1·4	0·25
1·00	4·1	1·7	0·41
0·50	2·5	1·2	0·48

No. 2 Bray Burner with No. 7 Codac Economiser.

1·75	5·6	16·6	2·96
1·00	4·1	9·6	2·34
0·50	2·5	4·8	1·92

Fig. 21(b).—With economiser.

No. 3 Bray Burner without Economiser.

Pressure of gas supply. Inches.	Gas Consumption. Cubic feet per hour.	Illuminating power. Candles.	Candles per cubic foot per hour. Candles.
1·75	6·75	4·0	0·59
1·00	4·70	3·8	0·80
0.50	3·00	3·0	1·00

No. 3 Bray Burner with No. 7 Codac Economiser.

Pressure of gas supply. Inches.	Gas Consumption. Cubic feet per hour.	Illuminating power. Candles.	Candles per cubic foot per hour. Candles.
1·75	6·75	18·0	2·66
1·00	4·70	11·4	2·42
0·50	3·00	6·6	2·20

A No. 2 union-jet Bray burner (a) without and (b) with the No. 7 Codac economiser is shown in fig. 20. The relative sizes of the flames obtained from this burner (a) without and (b) with the economiser respectively are shown in fig. 21. In each case the rate of gas consumption was 5·6 cubic ft. per hour, and the pressure under which the gas was supplied to the burner was 1¾ inches. The illuminating power of the flame without the economiser was 1·4 candles, but this was increased to 16·6 candles when the burner was capped with the economiser.

It will be observed that the lower the pressure the better the result when no economiser was used, but that when the burner was capped with the economiser the results improved as the pressure increased. The gas issuing from the economiser is under less pressure than when it issues from the orifices of the burner below it, and in every case the economiser increased the light efficiency of the gas. The light efficiency obtained when the Bray burners were used without an economiser would probably have been higher had the flow of gas to the burners been adjusted by turning the gas-cock until the flame appeared to be giving the maximum amount of light. Professor Lewes gives the following table of comparative duties of flat flame burners of different sizes tested with 16-candle gas, but the pressure of the gas is not stated, and the flames were probably always adjusted by turning the gas-cock until the brightest flame was obtained.

		Candles per cubic foot per hour.
Flat-flame burner (without Economiser)	No. 0	0·59
Ditto	1	0·85
Ditto	2	1·22
Ditto	3	1·63
Ditto	4	1·74
Ditto	5	1·87
Ditto	6	2·15
Ditto	7	2·44

Sugg's "Winsor" Burner is a flat-flame burner, provided at the bottom of the burner chamber with a screw regulator, by means of which the gas consumption can be reduced to suit the gas pressure. Every variation in pressure necessitates a re-adjustment of the regulator, and these burners are therefore intended to be used where a governor is placed at the outlet of the meter.

Sugg's "Christiania" Burner is another flat flame burner provided with a self-acting governor with a screw on top of the gas chamber to regulate the consumption to any desired point.

Iron Burners.—Flat-flame burners constructed of iron are still used for flames exposed to the open air, as for stalls and the outside fronts of shops. They will stand rough usage from rain and wind better than the finer grade steatite or enamel burners, but the yield of light from them per unit of gas consumed is very low, and they also have the disadvantage of being liable to become blocked with rust.

CHAPTER XI.

ARGAND, REGENERATIVE, AND VENTILATING BURNERS. THE ALBO-CARBON LIGHT.

Argand Burners.—The Argand gas-burner is a modification of the Argand burner for oil-lamps invented by Argand about a hundred years ago, and many of the earliest Argand gas-burners were, in fact, merely Argand oil-burners altered to gas-burners. A perforated top was fitted in the position previously occupied by the wick, and the gas was admitted through the oil-inlet. Those primitive burners have, however, long been superseded by improved forms invented by Mr. William Sugg.

The City of London Gas Act of 1868 stipulated that "The gas referees shall prescribe the burner for testing the illuminating power of the gas, and it shall be such as shall be the most suitable for obtaining from the gas the greatest amount of light, and shall be practicable for use by the consumer." This proviso still remains in force, and the burner selected by the referees is "Sugg's London Argand No. 1." The Argand burners commonly used by gas consumers differ slightly in their dimensions from the standard Argand, but a description of the latter burner will serve to illustrate the principles upon which all Argand burners are constructed.

Sugg's London Argand No. 1 is shown in sectional elevation in Fig. 22. The burner consists of an annular hollow steatite ring (D) pierced with twenty-four holes for the passage of the gas, and connected with a metal body having three small supply tubes (A) and terminating

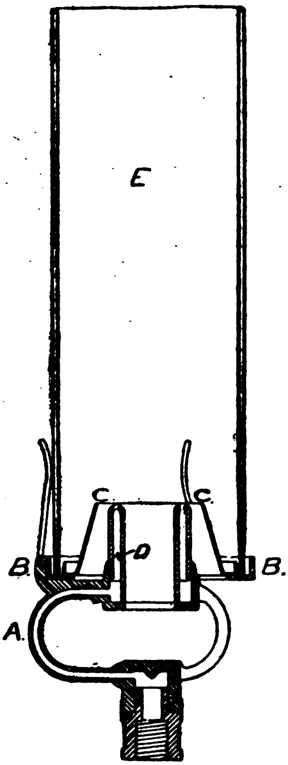


Fig. 22.—Sugg's London Argand.

in the socket which is screwed upon the gas supply pipe. Above the supply tubes is a gallery (B) which carries a glass chimney (E) 6 in. in height and 1⅞ in. in internal

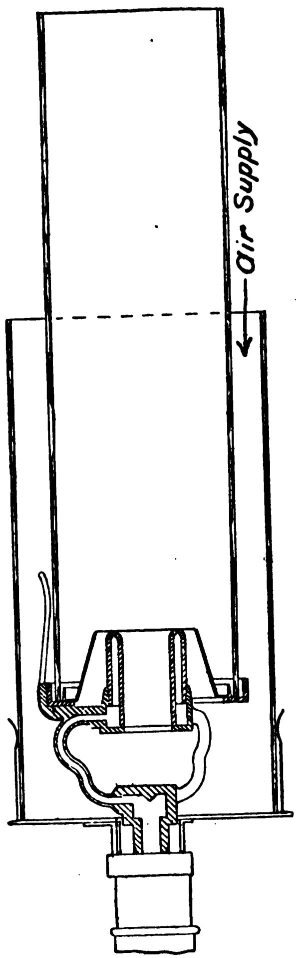


Fig. 23.—Regenerative Argand Burner.

the products of combustion escaping from the flame. The burners are placed at a considerable height above the floor, and most of the light emitted from them is thrown in a downward direction.

Burners for Illuminating and Ventilating.—The regenerative lamp is often made to assist in the ventilation of a room (fig. 24). A perforated metal case is placed around the upper part of the lamp, and has its upper end sunk into the space between the ceiling and the overhead floor. The waste products of combustion passing from the lamp into the flue create an up-draught, and increase the rate of flow of air through the room. The flue is carried in a horizontal direction between the ceiling and the floor overhead into a brick chimney, or into the open air. It is usually constructed of sheet iron, and must be carefully encased in non-conducting fireproof material. The initial cost of ventilating regenerative lamps of good quality is somwhat heavy, and lamps of this description have the disadvantage of requiring occasional cleaning by a skilled workman.

For simultaneously lighting and ventilating large halls and theatres gas lamps of the "sun" or "sunlight" class are still extensively used. Strode's sunlight (fig. 25) may be regarded as a typical example of lamps of this kind. It consists of a number of flat-flame burners horizontally inclined and arranged in rings near the mouth of a ventilating shaft. The illuminating value per unit of gas consumed obtained from these burners is rather low, owing to the cooling effect of the upward current of air and the distance of the flame above the floor, but the general lighting effect is good, and where economy is not of the first importance they are often preferred to more economical burners. They are very simple in construction, and any of the burners which may become unfit for use may readily be replaced by new ones at very small cost.

Different persons have different notions as to what constitutes effective lighting, but Professor Lewes, in the Cantor Lectures delivered in 1896, refers to some experiments made in that year by Major Scott Moncrieff on the suitability of various burners for illuminating the interior

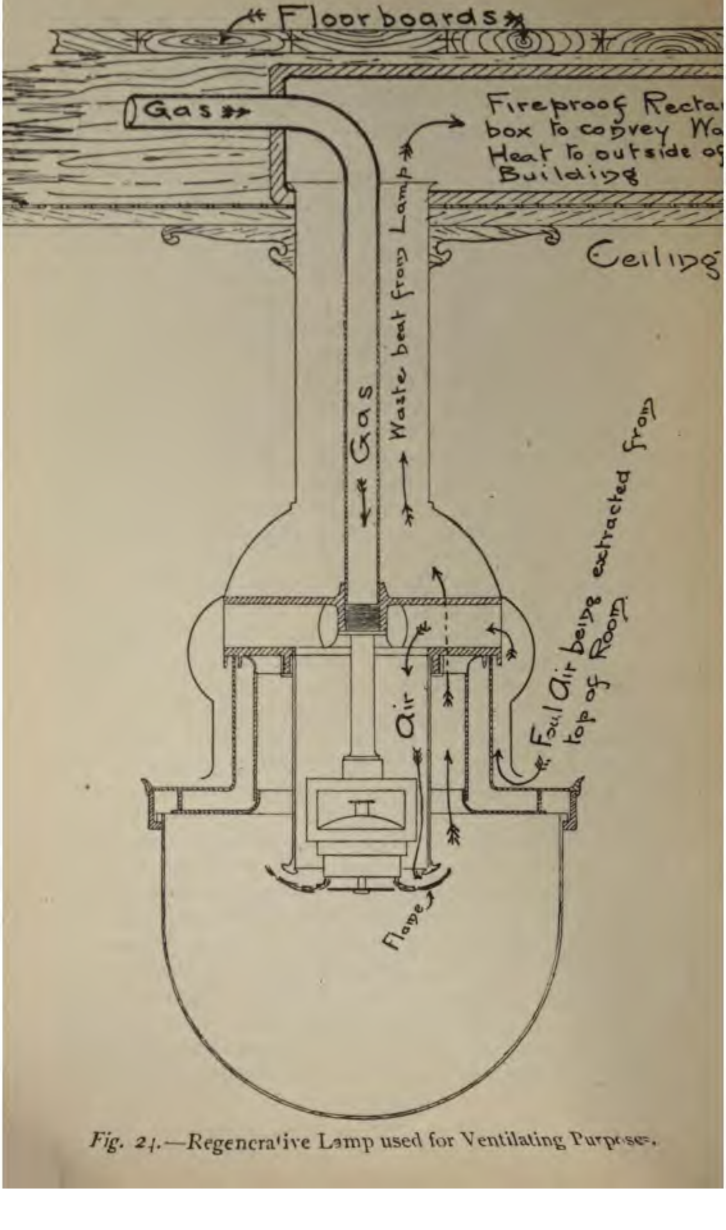


Fig. 24.—Regenerative Lamp used for Ventilating Purposes.

of barracks and buildings of a similar character, and the deductions made by Major Scott Moncrieff from the results of his experiments may serve as a guide in estimating the amount of illumination required in other circumstances.

The barrack-room in which the experiments were conducted was 40 ft. long by 20 ft. wide, and the source of

Fig. 25.—Strode's Sunlight Ventilating Burner.

light was fixed 8 ft. above the floor. The illumination on a horizontal plane 2 ft. above the floor was then determined by means of a specially-constructed photometer. The height of 2 ft. was selected as representing the lowest level at which it would be necessary to be able to read printed matter.

egenerative

3. For reading-rooms, sergeants' messes, and other accessory buildings, the incandescent light is the best illuminant.

4. For places where the light source is some height above the floor, as in gymnasia, lecture-halls, and churches, regenerative lamps give very satisfactory results.

Ventilating by Gas Flames.—When gas is required solely for ventilating purposes, it is immaterial whether a luminous or a non-luminous "atmospheric" flame be employed. Chemical laboratories, for example, are sometimes ventilated by shafts in which gas burners are provided to produce a strong upward current, and in such cases luminous and non-luminous flames are of equal value. Mr. Thomas Fletcher found that with a vertical flue 6 in. in diameter and 12 ft. in height a gas flame had the ventilating values indicated in the following table :—

Gas consumed per hour. Cubic feet.	Speed of air current per minute.	Total air exhausted per hour.	Air exhausted per cubic foot of gas consumed.	Temperature at outlet of flue. Normal 62° F.
1	205	2,460	2,460	82° F.
2	245	2,940	1,470	92° F.
4	325	3,900	975	110° F.
8	415	4,983	622	137° F.

The most economical speed of air current for a flue of these dimensions is, therefore, that of 200 ft. per minute, obtained by consuming gas at the rate of one cubic foot per hour. Mr. Fletcher concluded from his experiments that for each circular foot of section in a ventilating flue the consumption of gas should not be allowed to exceed 5 cubic feet per hour.

The Albo-Carbon Light.—Albo-Carbon is recrystallised naphthalene, one of the distillates obtained from coal tar. It is solid at atmospheric temperatures, but melts when heated to 174 deg. Fahr., a temperature considerably below the boiling point of water. In the albo-carbon lighting

The following table shows the practical results yielded by the different burners :—

Illumination of a Barrack-room, 40 ft. by 20 ft., at a height of 2 ft. above the floor.

Description of burner.	Total gas consumption per hour, cubic feet.	Illumination.
Two Bray burners	16	Whole room insufficiently lighted, nowhere possible to read small print 6 ft. below gaslamp.
Two flat-flame burners fitted with caps	11·4	About one-quarter the working space illuminated.
Two Stott-Thorpe reflex lights	18	Eight-tenths of working level efficiently lighted.
Two Sugg's workshop lights...	16	About one-quarter the working space efficiently lighted.
Siemens' regenerative............	11	Whole room well illuminated.
Diemel regenerative	9	Two-thirds working space efficiently lighted.
Two Schulke lamps..	10	Practically whole working space illuminated.
Welsbach incandescent, with glazed conical reflector ...	4·3	Whole room brilliantly lighted

The following conclusions were drawn from the results of the investigation :—

1. The present illumination of the barrack-rooms by means of No. 5 Bray burners is wasteful of gas and inefficient as regards illumination.

2. The Bray burner may be retained if used with caps and grouped as in the "Stott-Thorpe" arrangement. This may in some cases be extravagant in gas, but the illumination is good, and the arrangement is not easily damaged, and ventilation is assisted.

3. For reading-rooms, sergeants' messes, and other accessory buildings, the incandescent light is the best illuminant.

4. For places where the light source is some height above the floor, as in gymnasia, lecture-halls, and churches, regenerative lamps give very satisfactory results.

Ventilating by Gas Flames.—When gas is required solely for ventilating purposes, it is immaterial whether a luminous or a non-luminous "atmospheric" flame be employed. Chemical laboratories, for example, are sometimes ventilated by shafts in which gas burners are provided to produce a strong upward current, and in such cases luminous and non-luminous flames are of equal value. Mr. Thomas Fletcher found that with a vertical flue 6 in. in diameter and 12 ft. in height a gas flame had the ventilating values indicated in the following table :—

Gas consumed per hour. Cubic feet.	Speed of air current per minute.	Total air exhausted per hour.	Air exhausted per cubic foot of gas consumed.	Temperature at outlet of flue. Normal 62° F.
1	205	2,460	2,460	82° F.
2	245	2,940	1,470	92° F.
4	325	3,900	975	110° F.
8	415	4,983	622	137° F.

The most economical speed of air current for a flue of these dimensions is, therefore, that of 200 ft. per minute, obtained by consuming gas at the rate of one cubic foot per hour. Mr. Fletcher concluded from his experiments that for each circular foot of section in a ventilating flue the consumption of gas should not be allowed to exceed 5 cubic feet per hour.

The Albo-Carbon Light.—Albo-Carbon is recrystallised naphthalene, one of the distillates obtained from coal tar. It is solid at atmospheric temperatures, but melts when heated to 174 deg. Fahr., a temperature considerably below the boiling point of water. In the albo-carbon lighting system the naphthalene is melted by the waste heat of the gas flame, and is used for enriching the gas as it passes to the burner. Lumps of albo-carbon are placed in a spherical metal reservoir fitted with a gas-tight screw cap. The gas enters the reservoir and passes through it to the burner. The flame raises the temperature of a copper conductor, which is located a short distance above it, and which is connected to the reservoir in such a manner that heat is rapidly conducted from the copper to the reservoir. In a few minutes the temperature of the reservoir rises above the melting point of the albo-carbon, and the gas flowing through the reservoir mixes with the naphthalene vapour, and its illuminating power is thereby increased. The burners used are flat-flame burners with very small orifices, such as are used for consuming oil gas, and, according to Butterfield, a light of 25 candles is obtained with a gas consumption of 4¾ cubic feet per hour, and a consumption of 0·02 lb. of albo-carbon per hour. One albo-carbon reservoir may serve to supply a number of burners arranged in a cluster around it. A bright, steady flame is obtained, but the flame is more liable to smoke than the ordinary coal-gas flame, and more rapidly blackens the ceiling above it. The albo-carbon light is more economical than that obtained from flat coal-gas flames, but the trouble of periodically refilling the reservoir often prohibits its adoption, and of late years it has been largely superseded by the incandescent gaslight.

CHAPTER XII.

INCANDESCENT GAS LIGHTING.

Energy Lost in Generating Light.—In all artificial methods of generating light, other than phosphorescent light, more energy is expended in producing heat than in producing light. The large proportion of energy so wasted is indicated in the following table quoted by Professor Lewes in the Cantor Lectures of 1896.

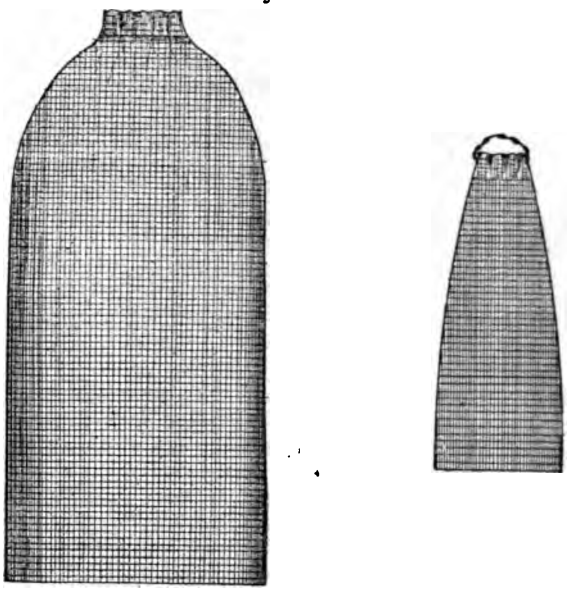
Percentage of energy transformed into :	Heat.		Light.
Candles	98	...	2
Oil lamps	98	...	2
Coal gas :—			
Flat flame and argand	98	...	2
Regenerative	93	...	6
Incandescent	88	...	12
Electric light :—			
Geissler tubes	97	...	3
Arc	90	...	10
Incandescent	95	...	5
Magnesium light	85	...	15
Sunlight	70	...	30
Glowworms, fireflies, and luminous beetles	1	...	99

Welsbach System of Lighting.—The foregoing table shows that a marked advance over all the earlier methods of generating light from gas has been made by the discovery of the Welsbach system of lighting. This system consists in heating to brilliant incandescence certain substances in a finely divided condition by means of a non-luminous gas flame. The luminosity of an ordinary luminous flame is due to the presence within it of solid advanced to account for it, but none are entirely satisfactory. Mr. Swinton has proved that the same generation of light does not occur if the mantle be heated in a vacuum tube, and it may therefore be assumed that one of the constituents of the atmosphere, probably the oxygen, exerts an important influence upon one or both constituents of the mantle when the thoria and ceria are mixed or combined in the required proportions. Dr. Bunte has suggested that the generation of light is due to intense local temperature produced on the surface of the mantle by combination of the hydrogen of the gas with atmospheric oxygen, brought about by the catalytic action of the ceria. He found by experiment that in the absence of ceria, chemical combination between hydrogen and oxygen, mixed in the proportion of 2 to 1, did not occur below a temperature of 1,200 deg. Fahr., whereas in the presence of ceria the combination took place at a temperature of 600 deg. Fahr. Thoria was found to have no influence upon the temperature at which chemical action occurred.

So far as is known, ceria will not act so efficiently as an excitant upon any other material as upon thoria, and although other materials may be used as excitants for thoria, none are so efficient as ceria.

Many cases are known in which two substances will not enter into chemical combination unless a third body be present, which, however, itself undergoes no permanent chemical change, and the influence exerted by this third body is spoken of as "catalytic action." The cause of catalytic action is not yet known, and the term is scarcely more lucid than the fatuous phrase, "Nature abhors a vacuum," used by ancient philosophers to explain the water-raising power of the common pump.

Pink "Sunlight" Mantles.—Other oxides than those of thorium and cerium have the power, when mixed in certain combinations, of emitting light when used in the form of mantles for gas flames. The pink "Sunlight" mantle, which emits a golden-yellow light, consists of the oxides of aluminium and chromium; zirconia may also be added, but merely acts as a neutral constituent without affecting the lighting efficiency of the mantle. Mantles of ure alumina or of pure chromic oxide have little or no ight emitting power, but when the two oxides are combined n certain proportions the mantle of mixed oxides gives a light efficiency of about eleven candles per cubic foot of gas consumed per hour. The chromium, however, appears to gradually volatilise under the high temperature of the flame, and in the course of a few weeks the light emitted by the mantle diminishes materially.



) Cotton Hood for Incandescent Mantle Manufac ure.

(*b*) Mantle Produced after Burning off the Cotton and subsequent trimming.

Fig. 26.

Manufacture of Mantles.—To manufacture a mantle r incandescent gas lighting, a network hood (fig. 26*a*) of otton or other vegetable fibre is soaked in a strong soluon of the nitrates of thoria and ceria mixed in the most uitable proportions. The mantle is then passed throu a small wringer, dried, stretched into suitable shape on a wooden or glass mould, and then, with the aid of a gas flame, the cotton is ignited. The hood while burning shrinks considerably, and a fragile mantle of oxides is obtained; the conversion of the nitrates into oxides is usually completed by heating the mantle over a blast flame, which also has the effect of strengthening the mantle. Finally, the mantle is trimmed (fig. 26*b*) with a knife around its lower edge to remove the ragged ends of the filaments, and is then "collodionised."

The object of dipping the mantle into a solution of collodion, or some substance of a similar flexible nature, is to render it less liable to breakage when handled and during transport; and as soon as the mantle is placed upon the burner and a flame applied to it, the collodion burns away and leaves the fragile network of oxides.

Collodion Mantles.—Instead of making mantles by soaking cotton fabrics in solutions of the salts, they are now extensively manufactured by mixing the salts into a paste with collodion solution, then squeezing the paste into threads by passing it under pressure through capillary tubes, and finally weaving the dried thread into a network hood similar in shape to that made from cotton fabric.

When the collodion is burnt off, the network of oxides forming the mantle may be distinguished from the mantle made by the use of a cotton hood by examination under the microscope. The threads from the collodion mantles appear like loose bundles of rods, while the threads from mantles made with cotton, after the cotton has been burnt off, have a fluted and more compact appearance.

Shape of Incandescent Mantle.—In this country mantles of the Welsbach shape are at present universally used, but in America the De Lery tassels, arranged in a circle around a rose burner (fig. 27), are also somewhat extensively employed. These tassels are, we believe, similar in composition to the Welsbach mantles, although they do not give so great an illuminating power per unit of gas consumed, but their effect is more pleasing to the eye, owing to the absence of the irritating glare common to mantles of the Welsbach shape.

Attempts have also been made to adapt incandescing bodies to non-luminous flat flames. Fahnehjelm, of Stockholm, introduced (in 1885) a comb consisting of a number of thin magnesia rods, set in a fireclay back, having an iron frame. This comb (fig. 28) was suspended over the non-luminous flame. If water-gas were used the gas was consumed in a small Bray burner, but the comb was never very successful, owing to the volatility of the magnesia.

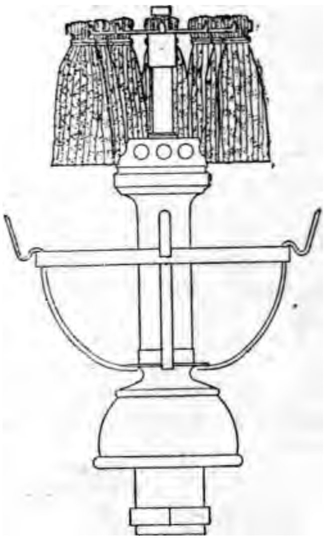


Fig. 27.—De Lery Burner and Tassels.

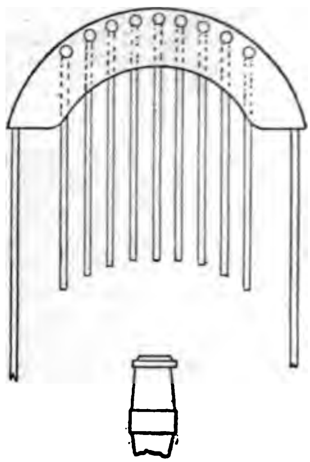


Fig. 28.—Fahnehjelm Comb for Incandescent-Lighting.

The "fringe" or "plume" subsequently invented by De Mare was a somewhat similar device, but was more successful, owing to its being composed of non-volatile rare earths having a greater light-emitting power and to the division of the material into finer rods or threads. The use of these rare earths, however, ... country held to be an infringement of a W...

Value of Different Gases for Incandescent Lighting.—It is often stated that the value of gas for incandescent lighting is directly proportionate to its calorific power, and Mr. Foulis has published the following figures, which appear to support that statement, since the calorific value of plain coal-gas increases with the illuminating power :—

Illuminating Power. Flat flame, corrected to 5 cubic feet per hour. Candles.	Illuminating Power. Incandescent burner, corrected to 5 cubic feet per hour. Candles.
23·1	117·3
17·9	90·3
16·2	87·9
14·6	84·4
13·5	81·9

Dr. Bunte and Dr. Strache have, on the other hand, shown that as high an efficiency for incandescent lighting may be obtained from gases of much lower calorific value, as from coal-gas. Dr. Bunte experimented with coal-gas alone and then with coal-gas mixed with certain other gases, and found that the addition of 20 per cent. of water-gas to the coal-gas does not diminish its efficiency for incandescent lighting, although it materially reduces its illuminating power for flat-flame lighting, and necessarily reduces its calorific value. The following are some of the results obtained by Dr. Bunte :—

	Slit burner. 5¼ cubic feet per hour. Hefner candles.	Welsbach incandescent burner. 3·53 cubic feet per hour. Hefner candles.
Coal-gas	15·0	70·0
Coal-gas, with 20 per cent. water-gas	3·1	73·5
Coal-gas, with 20 per cent. carbon monoxide	2·8	59·5
Coal-gas, with 20 per cent. hydrogen	7·3	70·0
Coal-gas, with 20 per cent. marsh gas	12·5	61·6
Coal-gas, with 25 per cent. ethylene	40·0	95·2
Coal gas, carburetted with benzol	25·0	75·6

The Hefner-Alteneck amyl-acetate lamp is extensively used in Germany as a standard of light, and a Hefner candle is equivalent to 0·877 of an English standard candle.

Dr. Strache has devised a number of incandescent burners for consuming plain water-gas, which is of about one-half the calorific value of coal-gas. The water-gas flame being non-luminous, it is not necessary to mix air with the gas before the point of ignition, and Dr. Strache finds that the plain water-gas is quite as efficient for incandescent lighting as coal-gas. In fact, it will be seen from the following figures published by him that he claims a considerably higher efficiency for water-gas than for coal-gas:—

Incandescent light.	Consumption per 1,000 candle hours.	Heat developed per 1,000 candle hours.	Oxygen consumed per 1,000 candle hours.
	Cubic feet.	Calories.	Cubic feet.
Water-gas	52·4	3,710	24·6
Coal-gas	84·5	11,970	103·1

Dr. Strache claims for incandescent lighting with plain water-gas that a very white light of great brilliancy is obtained, and that, compared with incandescent lighting with coal-gas, it has the advantage of emitting less heat per unit of light, that less atmospheric oxygen is consumed and less carbon dioxide produced, and that as air is not mixed with the gas before the point of ignition, the flame can never "flash back." Also that, owing to the absence of hydrocarbons in the gas, the flame never smokes, and carbon is never deposited upon the mantle.

It is evident, therefore, that the value of gas for incandescent lighting as used at the present time is not solely dependent upon its calorific power, but that the flame temperature per unit of area must also be taken into consideration. Water-gas when consumed in an argand burner at the rate of 5 cubic feet per hour gives a flame

1 in. in height whereas coal-gas consumed at the same rate gives a flame from 2½ in. to 3 in. in height. Hence a given area of water-gas flame may be of a higher temperature than a similar area of coal-gas flame, although the total heat of the coal-gas flame per unit of gas consumed is twice as great as that of the water-gas flame.

Possibly a method may presently be discovered of causing the coal-gas to burn with a shorter flame (as it does in high-pressure systems), and a higher value for incandescent lighting be obtained from it.

In a paper read at the Engineering Congress at Glasgow, in 1901, Professor Lewes ascribed the high lighting efficiency of water-gas to the fact that it does not require admixture with air before the point of ignition, that the inner cone of flame formed in coal-gas burners is therefore absent, and that, consequently, there is "little or no difference in the temperature of the outer zones of the flames in which the mantle is heated." It is possible that this may be the correct explanation, but extensive experimental investigation is yet required into the relationship between light and heat in the Welsbach system of lighting, and if it be found that the intensity of the light increases directly as the temperature of the flame it may be possible to devise a better method of using coal-gas than that at present in vogue.

CHAPTER XIII.

INCANDESCENT GAS BURNERS. SELF-LIGHTERS.

Burners with Chimneys.—In this country all public gas supplies consist of illuminating gas, and in order to produce a non-luminous flame which will not deposit soot upon the mantles, the gas is consumed in "atmospheric" burners of the Bunsen type. The gas under pressure is made to issue in one or more fine jets in an upward direction into a vertical tube having holes formed in its sides near the base. The gas in its uprush draws air also into the tube through the side holes, and a mixture of air and gas flows to the head of the burner, and when ignited burns with a non-luminous flame. The efficiency of the flame so obtained depends upon the proportion of gas to air in the mixture, and the completeness of the mixing operation.

In the earlier forms of Welsbach burners the proportion of air drawn into the tube was not sufficient to produce a non-luminous flame of the required shape unless a chimney were used with the burner to create an up-draught, and thus bring a strong current of air in contact with the surface of the mantle and flame. When the glass chimney supplied with burners of this description (fig. 29) is removed from the burner, the gas cannot obtain sufficient air for complete combustion until it has escaped through the network of the mantle, and a large proportion of the heat which should be utilised in bringing the mantle to an incandescent condition is lost.

The proportion of air required for combustion of the gas varies with the richness of the gas in illuminating hydrocarbons, and consequently the length of the glass chimney should be varied in accordance with the quality of the gas to be consumed. An 8-in. chimney is of sufficient length for use with London 16-candle gas, while for 14-candle gas a 6-in. chimney would be suitable, but with the 20-candle to 26-candle gas supplied in some parts of the North of England and Scotland a 10-in. or 12-in. chimney is required.

Fig. 29.—Welsbach "C" Burner, with Chimney.

Effect of Dust or Dirt on the Burners.—In the course of a few weeks a considerable quantity of dust from the mantle, or from other sources, accumulates on the wire gauze of the burner, and on the gas nozzle near the air holes. The presence of this dust often reduces the light emitted by the mantle by fully 50 per cent. To remove the dust, first take off the glass chimney, then lift the head of the burner off the Bunsen tube without removing the mantle from the head. Blow gently up the tube of the part removed in order to blow the dust off the gauze, and then unscrew the Bunsen tube from the nozzle from which the gas issues, and remove the dust from the nozzle also. Then replace the parts in their original positions and relight the burner. The dust can be more readily blown from the gauze by first removing the mantle, but it is difficult to perform the latter operation without breaking the mantle. Whenever a new mantle has to be placed on the burner, the latter should first be freed from dust.*

* The influence exerted by dust in the Kern chimneyless burner is equally prejudicial, the intensity of the light emitted being greatly diminished by its presence.

Deposition of Soot upon Mantles.—The deposition of patches of soot upon incandescent mantles is caused by imperfect combustion of the gas. Imperfect combustion is usually due to the burner being in a dirty condition, and consequently producing a flame having more or less luminosity. Even a very feebly luminous flame will speedily produce a deposit of carbon upon the mantle. By-pass burners, in which a small luminous flame is used to ignite the main flame without necessitating the use of a match, are often rejected on account of their liability to blacken the mantles and to be extinguished by draughts. The small by-pass flame is often of sufficient size to come in contact with the mantle and to leave a black patch upon it. When burners without governors are used it is often impossible to avoid altogether this blackening, because the by-pass must pass sufficient gas to prevent the flame being extinguished when the pressure falls to its lowest point, and even when adjusted to the smallest dimensions under the lowest pressure the flame becomes sufficiently elongated when the pressure increases to its maximum point to come in contact with the mantle and blacken it. Another objection to many by-pass burners is, that a slight but distinctly perceptible odour is often emitted from them owing to the fact that the gas issuing from the by-pass does not undergo combustion. A useful by-pass device which gives two completely non-luminous flames situated on the sides of the socket which receives the rod used to support the mantle, and which are not easily extinguished, has recently been invented by Mr. A. Clarke. It is a marked improvement upon burners having a luminous by-pass jet, but has not yet come into general use.

Chimneyless Incandescent Burners.—In 1898 the Welsbach Company placed upon the market a new burner for incandescent gas lighting which did not require a glass chimney. This burner is known as the "Welsbach-Kern" burner, and has attained great popularity. Bandsept had introduced a chimneyless burner a few years earlier, which was largely used for public lighting, but was not so serviceable for domestic lighting as are the small sizes of the Kern burner. The use of burners without c made possible by effecting a thorough mixing of the gas and air in the most efficient proportions before the mixture reaches the point of ignition. The light efficiency per unit of gas consumed obtained from the mantles when these Kern burners are used is found to be considerably greater than that obtained from the older forms of chimney burners; but owing to the hissing noise emitted by the chimneyless burners many consumers still prefer the less noisy chimney-burners. It is stated that the production of a hissing noise is an indication that an excessive volume of gas is being consumed, and that the gas cock should be adjusted until the noise is no longer observable; but in practice this procedure is often found to produce an immediate diminution in the intensity of the light emitted.

The effect of slightly increasing or decreasing the proportion of air to gas in the mixture issuing from the burner is shown in the following table published by Professor Lewes, who made a series of experiments with a chimneyless burner. The gas supply was maintained at a constant rate under a pressure of 1½ in., and the air supply was regulated as required. The gas used for the experiments was 16-candle London gas:—

Condition of flame.	Rate of flow.		Ratio.		Candle-power per cubic ft. of gas.	Temperature of mantle 1 in. above burner-head.
	Gas. c. ft.	Air. c. ft.	Gas.	Air.		
Under aërated	4·5	10·0	1	2·2	14·4	1880 C
Best aërated	4·5	12·75	1	2·75	20·0	1915 C
Over aërated	4·5	15·25	1	3·4	17·7	1905 C

It was found by experiment that 1 volume of the gas required 5½ volumes of air for complete combustion, and it is therefore evident that the best results are obtained with 16-candle gas when half the total quantity of air required for combustion is mixed with the gas before the point of ignition.

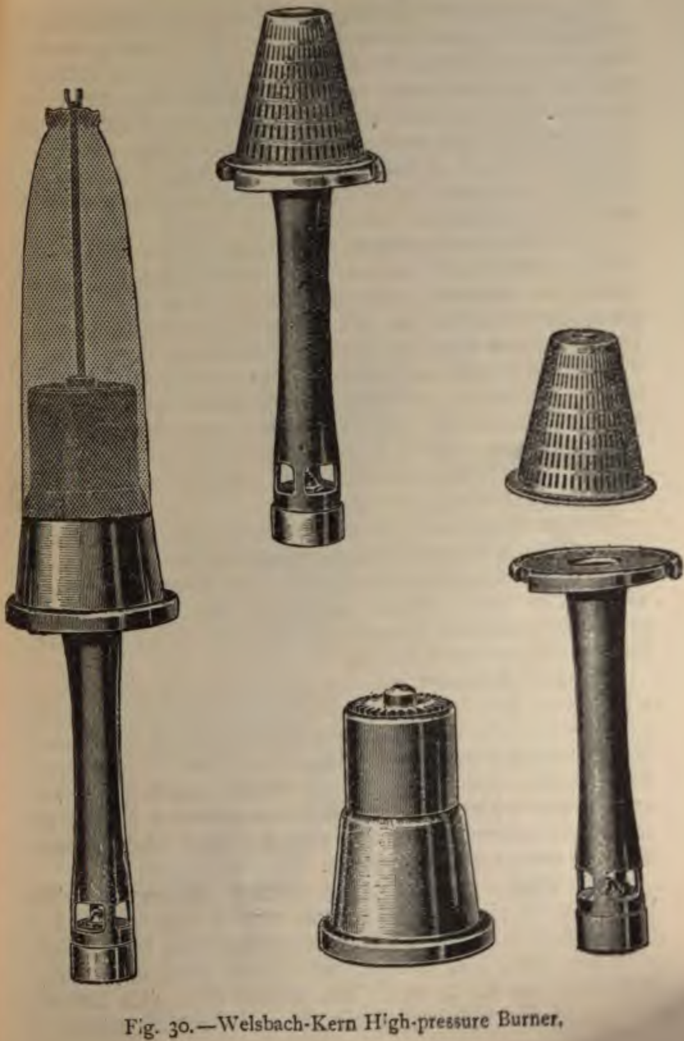


Fig. 30.—Welsbach-Kern High-pressure Burner.

High-pressure Burners.—By increasing the pressure of the gas supplied to the burner and increasing the consumption, it is found that a higher illuminating value per unit of gas consumed can be obtained than with low-pressure gas, and for street lighting with lamps of high candle-power high pressure burners are being extensively adopted. Most of the high-power burners can be used without chimneys, but require a glass guard to protect the mantle from wind and the gaslighter's torch.

The Welsbach-Kern High-pressure Burner.—This burner closely resembles the Kern burner used with gas under ordinary pressures, and can readily be taken to pieces for cleaning (fig. 30). The burner is intended to be used with gas supplied under a pressure of 8 in. to 10 in., and is said to give a light of 30 to 35 candles per cubic foot of gas consumed per hour, as compared with a light of 20 to 25 candles per cubic foot obtained with the ordinary Kern burners. With a consumption of 10 cubic feet of gas per hour the high-pressure Kern burner is said to yield a light of 350-candle power.

At present gas is commonly supplied under a pressure of less than 3 in., and for high-pressure systems it is necessary to use compressing apparatus to raise the pressure to 10 in. or 12 in. When calculating the cost of a high-pressure system of lighting the cost of the compressing apparatus must be included.

There is, however, no reason why the gas companies should not be called upon to increase the pressure of the public supply to 10 in., since with the aid of inexpensive governors the consumer can readily reduce the pressure to any desired point; and it has been repeatedly demonstrated that by the use of suitable mains and fittings gas can be distributed under this comparatively high pressure without undue loss by leakage.

The Self-Intensifying Kern Burner. — The Welsbach Company claim that results almost equal to those obtained with high-pressure gas can be obtained with gas under low pressure when consumed in the Self-intensifying Kern burner. This burner (fig. 31) is intended for use in the lighting of streets or industrial works. It

Fig. 31.—Self-intensifying Kern Burner, with "Shadowless" lantern.

is a Kern burner so modified that with the comparatively large gas consumption of 10 cubic feet per hour the head of the burner is sufficiently small to fit into a No. 4 high-pressure Kern mantle, a slight alteration being made in the internal construction of the burner head. In the upper part of the lantern in which the burner is placed is a metal chimney, from the lower end of which is suspended a glass chimney. The glass chimney surrounds the mantle, and the so-called "self-intensification" is due to the draught produced by the elongated chimney thus formed. It is claimed that a light of 300 candles is obtained with a consumption of about 10 cubic feet of gas per hour

Compressing Apparatus.—To raise the pressure of the gas supplied to the burner to the 10 or 12 in. required for high pressure gas lighting many devices have been adopted. In the Scott-Snell lamp the waste heat from the burner is employed to actuate a novel compressing apparatus which is located a short distance above the mantle; and in other systems, motors actuated by water supplied from the street mains are used. In the latter case the cost of the water must be taken into consideration when estimating the cost of the light, and it is usually found with all high-pressure systems that the mantles have a shorter life than when used with gas supplied under low pressure.

Anti-Vibration Devices.—When incandescent gas lights were first used for street lighting it was found that the number of mantles broken by vibration and shock caused by the passage of heavy vehicles over the roads was so great as to almost prohibit their employment in the main thoroughfares. A number of anti-vibration devices were, however, soon invented and placed on the market, and some of these are now extensively used. They are mostly of simple construction and depend upon the interposition of some description of spring between the burner and the gas supply pipe to which it is attached. Those which depend upon the elasticity of india-rubber should be avoided, since this material perishes with comparative rapidity, and is affected by changes in the temperature of the atmosphere.

Advantage of Incandescent Lights over Luminous Flames—The principal objections to the use of gas are:—(1) The heat generated is out of proportion to the light obtained; (2) The flames are usually more or less smoky, especially in draughty situations, and quickly blacken the walls and ceilings; and (3) The withdrawal of oxygen from the air and the formation of carbon dioxide by combustion of the gas is prejudicial to health. The luminous flames most commonly used are flat flames or argand flames burning not less than 5 cubic feet per hour, and having an illuminating power of about fifteen candles. When these are replaced by incandescent burners, it is usual to introduce a burner giving a light of sixty candles for a gas consumption of 3·5 cubic feet per hour for every 15-candle flame previously in use. Consequently, a better light is obtained, the gas consumption is reduced 30 per cent., less heat is generated, and, owing to the use of a non-luminous flame as well as to the reduction in the temperature of the air and products of combustion rising from the burner, the ceilings are less rapidly blackened.

On the other hand, the mantles for which the high retail charge of 7½d. is at present made in this country require renewing periodically, and in some households are a constant source of trouble.

Until mantles less fragile than those at present manufactured are introduced the incandescent system cannot be regarded as altogether satisfactory, but great progress has been made since 1886, when Welsbach's earliest mantles were placed on the market, and there is every reason to believe that other improvements equally important may be made within the present decade.

Avoid Powerful Lights of Small Area.—The use of points or surfaces of small area from which light of great intensity is emitted should be avoided as much as possible in all systems of lighting. A 60-candle power light emitted from an area of 1 in. is more irritating to the eyes, and less serviceable for illuminating purposes, than a light of the same total value emitted from an area of, say, 6 in. Two No. 1 Welsbach-Kern burners fitted in suitable positions with good diffusive shades will effectively illuminate a dwelling-room of moderate size (say, 22 × 15 × 10 ft.), although each burner consumes only 1·5 cubic feet of gas per hour, and has an illuminating power of probably only twenty-five candles; whereas a single burner having an illuminating power of seventy candles, and used without a shade, will be found to brilliantly illuminate one portion of the room while another part is left in comparative darkness. The fact that the two small burners have a total illuminating power of only fifty candles for a consumption of 3 cubic feet, while the larger burner gives a light of 70 candles with the same rate of gas consumption, does not necessarily prove that it is better to use the single burner instead of the two small burners

The electric arc light has a high illuminating power, but no one would select it for the illumination of dwelling-rooms, since it possesses in a marked degree the feature which it is most desirable to avoid—*i.e.*, it emits an intense light from a very small light-emitting surface.

Self-Lighters.—When a stream of coal-gas is allowed to come in contact with freshly-prepared platinum black, or spongy palladium in the presence of air, the coal-gas becomes ignited. Many attempts have been made to utilise this property of platinum and palladium to enable gas to be lighted in daily practice without the aid of a flame. To present a large surface of the platinum black to the gas it has been incorporated with, or deposited upon, pumice, asbestos, meerschaum, and other substances of a like nature, and nodules of the composition thus prepared have been attached to suitable supports and suspended over the burner. In some cases when the "self-lighter" has been used with incandescent mantles, a portion of the mantle itself has been coated with the sensitive platinum. These devices often work well for a time, but have not hitherto been reliable. They frequently refuse to ignite the gas after they have been in use for a short time, and even when they work satisfactorily in the summer months they usually fail in frosty weather.

CHAPTER XIV.

SHADES, CHIMNEYS, REFLECTORS, AND GUARDS.

Flat-Flame Shades and Globes.—Shades are usually placed around gas-flames to produce greater diffusion of the light, to prevent the irritation caused by exposure of the eyes to direct rays of light from the naked flames, and to give a more pleasing appearance to the apartment illuminated.

All shades offer a certain obstruction to the passage of light, but the proportion of light obstructed varies according to the shape of the shade and the material of which it is constructed.

Mr. W. King found that when No. 3 fish-tail burners were employed, globes of different descriptions obstructed the passage of light in the proportions shown in the following table:—

	Loss of Light.
Clear glass globe	10·57 per cent.
Ground ,, ,,	29·48 ,,
Smooth opal ,,	52·83 ,,
Ground ,, ,,	55·85 ,,
Ground opal with painted figures	73·98 ,,

The obstruction exerted by glasses of different descriptions and thicknesses is shown in the following table of results, obtained by Mr. F. H. Storer and published in *Silliman's American Journal of Science and Arts.* He placed sheets of the various glasses at a distance of 3 ft.

from the Argand burner in which the gas was consumed, and determined the loss of light in each case :—

Description of Glass.	Thickness of Glass.	Loss of Light.
Thick English plate	1/3 in.	6·15 per cent.
Crystal plate	1/4 ,,	8·61 ,,
English crown	1/8 ,,	13·08 ,,
Double English window glass	1/8 ,,	9·39 ,,
Double German	1/8 ,,	13·00 ,,
Single German	1/16 ,,	4·27 ,,
Double German ground	1/8 ,,	62·34 ,,
Single German	1/16 ,,	65·75 ,,
Berkshire (Mass.)	1/16 ,,	62·74 ,,
Berkshire enamelled*	1/16 ,,	51·23 ,,
Orange coloured window glass	1/16 ,,	34·48 ,,
Purple ,, ,, ,,	1/8 ,,	85·11 ,,
Ruby ,, ,, ,,	1/16 ,,	89·62 ,,
Green ,, ,, ,,	1/16 ,,	81·91 ,,
A porcelain transparency	1/16 ,,	97·68 ,,

* Ground only on portions of its surface.

Mr. Storer thought that the percentage of light obstructed remained the same whatever the distance between the illuminant and the glass screen ; but in the year 1881, the late Mr. Hartley contributed a series of papers on "Observations on Glass as an Obstructor and Reflector of Artificial Light," to the *Journal of Gas Lighting*, in which he gave the results of a long series of experiments he had conducted with both Argand and flat flames to ascertain the influence of different kinds of globes upon the light obtained in a horizontal and in a downward direction, and he found that the greater the distance between the flame and the glass, the greater was the proportion of light obstructed. Hartley's papers are worthy of careful study by manufacturers of gas shades, and the general conclusions he drew from the results of his experiments, and enumerated in the following order, may serve as a useful guide in the selection of shades for different purposes :—

Horizontal Lighting : Sheet Glass.

1. That ordinary sheet glass, apart from thickness, varies in its obstructive power to the passage of light. That the *percentage loss increases* with the distance of the

glass from the flame, and *increases* also as the *light grows stronger*.

2. That ground sheet glass, apart from thickness, also varies in obstructive power. That the *percentage loss increases* with the distance of the glass from the flame, and *decreases* as the *light grows stronger*. That the percentage loss depends on which side, clear or ground, is presented to the flame.

3. That with flashed opal the losses follow the same law as ground glass for distance from, and for power of light.

4. That with clear glass as an *obstructor* of light in front of the flame, and clear glass behind the flame as a *reflector* of light, the reflected light reduces the *loss* to a degree dependent on the distance of each glass from the flame.

Globes.

5. That a clear glass globe obstructs light from an *Argand* flame, but increases the sensible light from a *flat* flame.

6. That globes of ground glass obstruct less light than sheets of ground glass. That the percentage loss *diminishes* as the light grows *stronger*; and is, for an average light, from 18 to 20 per cent.

7. That opal globes obstruct an amount of light equal to 33 to 65 per cent.

Overhead Lighting.

8. *That the amount of light yielded by a flame in an angular direction is much less than it yields in a horizontal direction.*

9. That glass globes with elevated or overhead Argand flames *reduce* the power of the light—clear globes about 3 per cent.; ground globes, about 21 per cent.; and albatrine globes, about 23 per cent.

10. That glass globes with flat flame burners, at a certain elevation and within a certain radius, *increase* the power of the light—clear globes, about 6 per cent.; ground globes, about 9 per cent.; albatrine globes, about 23 per cent.; and German opal globes, about 21 per cent.

11. That reflectors greatly increase the power of the light, within a radius dependent on the shape and size of

the reflector ; the range in the experiments being from 52 to 92 per cent.

12. That screens at the base of an Argand flame cause a reduction in the power of the light, whatever be the size and form of the reflector.

It is especially noteworthy that when the shades are used on overhead burners, as is usual in practice, the loss of light occasioned by their employment is not nearly so great as that indicated by the early experiments of King and Storer, who measured only the light obstructed in a horizontal direction.

The shape of the shades is a matter of considerable importance. Globes with narrow openings at top and bottom were at one time almost universally used, but are now

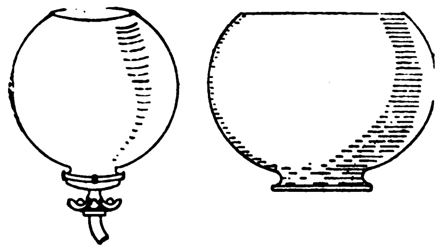


Fig. 32.—Flat-flame Shades of Bad Shape.

recognised as the worst form of shades for flat flames that could be devised. The contracted openings cause the globe to act as a chimney, the heated air and products of combustion escaping through the small opening at the top of the globe cause a strong draught of cold air to be drawn through the narrow opening at the bottom and brought in contact with the flame, with the result that the flame is constantly flickering, and, owing to the cooling action of the current of air, emits less light.

In some cases the shade is made with a more open top, while the narrow opening at the bottom is retained. Such shades are less objectionable than those with a narrow top, but still cause flickering of the flame, and are not so good as those with an opening 4 in. or 5 in. in diameter at both top and bottom. Two of the old forms of shade are shown in fig. 32, while more modern shapes, with large

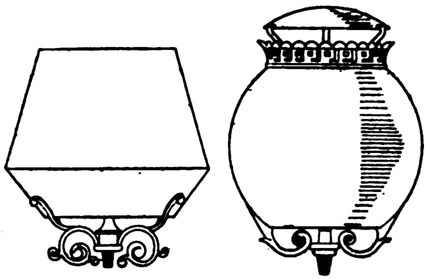


Fig. 33.—Flat-flame Shades of Good Shape.

openings at top and bottom, are shown in fig. 33. The term "shades of good shape," applied to the shades depicted in fig. 33, applies only to the openings at top and bottom. The lower portions of the shades reflect the light in an upward direction, and unless these lower portions are constructed of clear glass an appreciable proportion of the light emitted from the flame is lost.

Holophane Shades.—A new type of shade, designed by Psarondatri and Blondel, has been placed on the

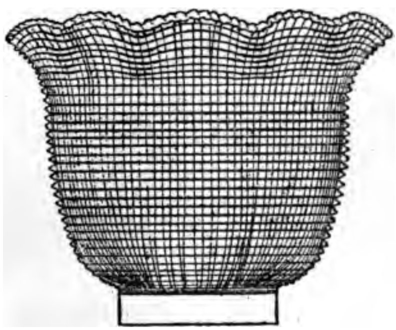


Fig. 34.—Holophane Shade.

market under the name of the "Holophane" globe or shade. (Fig. 34.)

draughts and dust to a greater extent than when chimneys of ordinary shape are used. Glass screens are manufactured in a variety of patterns to surround the lower part of the bulb, and the bulb has then a very pleasing appearance. These "Jena" bulbs are not, of course, intended to be used with the chimneyless burners.

Chimneys.—Chimneys are required with Argand burners and with certain descriptions of incandescent burners, because the flames from these burners would otherwise be of long, irregular shape and would be too unsteady for lighting purposes. The gas issuing from the burner-head under low pressure does not induce sufficient air to flow towards it to cause oxidation to proceed with the required speed, and the flame becomes elongated owing to the greater distance it has to travel before meeting with the volume of air necessary for complete combustion. Immediately a chimney is placed upon the burner an upward current of air comes in contact with the flame, and causes combustion to take place more readily, with the result that the flame becomes shorter and more rigid. The proportion of light obstructed by glass chimneys varies with their thickness and colour. Chimneys made of glass rods have the advantage of causing better diffusion of the light than plain glass chimneys, but this is counterbalanced by their greater liability to break and the greater difficulty experienced in cleaning them.

Mica chimneys are extensively used for incandescent burners, and have the advantage of being practically unbreakable, but they obstruct a considerable proportion of the light. Chimneys made of mica of inferior quality are liable to become ragged and unsightly and to obstruct fully 25 per cent. of the light emitted from the mantle or flame, but a mica chimney of good quality will remain in good condition for an indefinite period, and should not obstruct more than 15 per cent. of the light.

Reflectors.—The object of reflectors is to obstruct the passage of light thrown in those directions in which it is not required, and to send it into the field to be illuminated. Mirrors and polished metals are excellent reflectors but bad diffusers of light and are not agreeable for indoor illumination, although most valuable when the light has to be concentrated into one strong beam, as in searchlights.

Reflectors made of opal or thin porcelain have a much

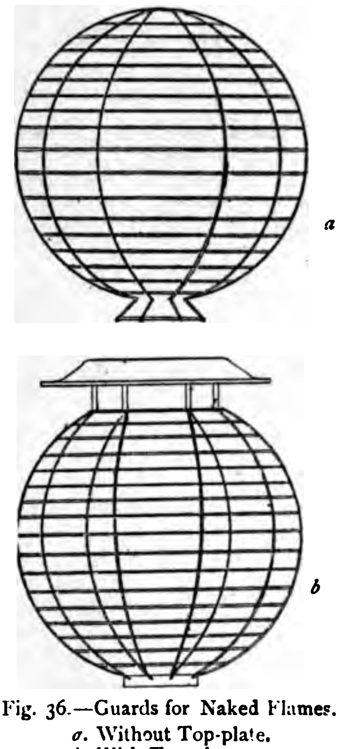


Fig. 36.—Guards for Naked Flames.
a. Without Top-plate.
b. With Top-plate.

more pleasing effect for indoor use, and may increase the light thrown in any particular direction by fully 60 per cent. The angles of inclination of the sides of reflectors were at one time very frequently made too acute, a portion of the light from one side of the reflector being thrown upon the opposite side, instead of upon the object to be illuminated, but the advantage gained by inclining the sides at more obtuse angles is now generally recognised.

The most agreeable form of light is that obtained entirely from diffused reflected light, the sources of light being entirely concealed from sight. This method of lighting is extravagant, but where the ceiling is white and the walls are covered with paint or paper of a light tint the cost need not be prohibitive.

Guards for Naked Flames.—In many cases where naked flames are in use the risk of fire may be materially reduced by the employment of wire guards (fig. 36). When the flames are less than 3 ft. from the ceiling the wire guards should be provided with covers of sheet metal (fig. 36 *b*).

CHAPTER XV.

GAS FIRES.

Luminous and Non-Luminous Fires.—Gas fires may be divided into two classes—(1) those fitted with "atmospheric" burners, in which air is allowed to mix with the gas before the point of ignition; and (2) those fitted with burners to which air is not admitted before the point of ignition, and which therefore produce luminous flames. The heat produced per cubic foot of gas consumed is precisely the same in the two classes of fires, provided that the gas be consumed under suitable conditions, but the admixture of air before the point of ignition not only renders the flame non-luminous, but makes it much shorter, and the heat of combustion is therefore concentrated in a smaller area than in a luminous flame.

Radiated and Convected Heat.—Radiant heat is that form of heat which is transmitted from one body to another without materially raising the temperature of the atmosphere through which it passes. Convected heat is heat conveyed by particles of heated air or other similar medium. Rooms heated by convected heat alone (*i.e.*, by hot air, steam, or water pipes) are never so comfortable as those heated by the radiant heat from an open coal or coke fire. The temperature may be raised more economically by convected heat than by radiant heat, but the inhalation of heated air is prejudicial to health, and the walls of rooms heated by convected heat remain at a comparatively low temperature, and absorb heat from the human body. In rooms well heated by radiant heat the atmosphere remains comparatively cool, while the walls and furniture are raised to a temperature sufficiently high to prevent them abstracting heat from the body and producing a sensation of chill. Warming by radiant heat alone is, ducts of combustion are conducted through suitable tubes or chambers to utilise as much heat as possible before allowing them to escape into the flue, reflecting stoves form very efficient heating agents. They are less liable to get out of order and are more readily repaired than fires with "atmospheric" burners. As the flames never come in contact with any cool surface, they do not, as a rule, evolve any disagreeable odour or poisonous incomplete products of combustion, but they should, nevertheless, be connected to a flue. The temperature of the combustion products as they enter the flue should always be sufficiently high to feel hot to the hand. If cooled to atmospheric temperature, water would be condensed in the stove, and the remaining combustion products, being heavier than air, would probably fail to rise to the top of the flue.

CHAPTER XVI.

COOKERS, WATER HEATERS, GEYSERS, AND GREENHOUSE BOILERS.

Cookers.—Gas-cooking appliances are now universally used in all towns provided with a public gas supply, and vary in size from the small griller used in workmen's tenements in conjunction with the penny-in-the-slot meter to the imposing "cookers," over 6 ft. in height and in width, used in many hospitals, hotels, and business premises where meals have to be provided for several hundred persons. For a long period an unreasonable prejudice existed amongst the general public against the use of gas for cooking, but this has gradually been overcome, and gas is now recognised as a more perfect cooking agent than coal. The fact that gas-cooking appliances have been introduced into a great number of hospitals and asylums has satisfied the general consumer that the use of gas for cooking will not result in his untimely decease, and the number of cooking-stoves lent out on hire by gas companies has increased rapidly during the past few years, the total number of cookers in use in the United Kingdom being now over 800,000.

A glance through the catalogues issued by the principal firms of gas stove manufacturers will show that cookers are now made to meet almost every conceivable requirement, but space cannot be devoted to a detailed description of these in the present volume. The ovens should be provided with a jacket or case filled with slag wool or other suitable non-conducting material to economise the heat as much as possible, and the interior of the oven should be enamelled to render cleaning less troublesome.

The Odour emitted from Gas Stoves.—When a gas flame comes in contact with, or in very close proximity to, a cold surface, the flame becomes cooled and emits a disagreeable odour, owing to the fact that incomplete combustion of the gas then occurs. With many stoves and fires this odour is perceptible for the first few moments after lighting, but is no longer emitted when the stove becomes hot. A similar odour is emitted when the flame flashes back and burns within the mixing tube, owing to the occurrence of incomplete combustion caused by the cooling action of the metal tube and the limited volume of air admitted to the flame. When a cold sheet of metal, such as the bottom of a kettle filled with cold water, is lowered into a flame the odour is at once perceptible, and continues to be emitted until the metal becomes sufficiently hot to allow the flame to rise again to the temperature necessary for complete combustion.

A frequent cause of unpleasant odours from cookers is the accumulation of dirt or grease upon them. Unless a cooker is kept scrupulously clean, it is certain to emit a disagreeable odour immediately the fatty matter becomes strongly heated, and in many cases the odour is distributed over the building by the down-draught from a defective flue. Gasfitters frequently assure their employers that a flue for a cooker is quite unnecessary, but it is a foolish practice to use any appliance consuming a large volume of gas without providing means for the removal of the combustion products.

Position of Flue.—The flue should, where possible, be carried from the stove into an existing chimney having a good natural up-draught. If the flue be carried through a side wall of a room which also contains a chimney, the up-draught of the chimney is apt to produce a "pull" on the wall orifice and draw air, together with the ascending products of combustion, down the stove flue instead of allowing the combustion products to escape. A flue of this description is worse than useless. With an efficient flue and a clean cooking range, with flames not too close to cold surfaces, a gas cooker is as free from smell as a coal fire.

Water Heaters and Geysers.—When coal gas is consumed under the best conditions carbon dioxide is formed, and as this gas is not a supporter of animal life, it should be conducted from the room by an efficient flue. When a coal-gas flame is cooled by contact with a cold surface, an intensely poisonous gas, termed carbon monoxide, is formed, owing to the fact that complete oxidation of the carbon in the decomposing hydrocarbons is not effected. Carbon dioxide, the product of complete combustion, will not support animal life, but it does not possess the poisoning activity exerted by carbon monoxide. Carbon monoxide has no odour, but when incomplete combustion of the gas occurs other products are simultaneously formed which emit a very penetrating odour and give warning that the poisonous carbon monoxide is being generated. The "smoke" from a coal fire contains both carbon monoxide and carbon dioxide, together with a number of objectionable compounds which are not present in the products of combustion from the purified coal-gas supplied in our towns, but if the visible "smuts" were not present in coal smoke, there is little doubt that a grate would soon be placed on the market with the assurance that coal might be consumed in it with perfect safety in a room not provided with a chimney. Some water heaters are used in bathrooms without any flue, and do not evolve any perceptible odour; while others always produce a disagreeable smell, and have upon several occasions been the cause of death to persons exposed to their influence. In the former cases complete combustion of the gas is effected, while in the latter the combustion is not complete. The fact that bath water heaters are often used in small rooms without exerting any *apparent* prejudicial influence does not necessarily prove that the combustion products are harmless even when complete combustion occurs, and as it is known that carbon dioxide is not a supporter of animal life, it is a wise precaution to always provide means for its withdrawal in such small rooms as bathrooms of average size.

taking place when the main gas burners are lighted. These water heaters are not intended to actually boil the water, but merely to rapidly raise it to a scalding hot temperature. The rate of gas consumption is necessarily high, but as a large volume of water is heated in a few minutes, it is not usually necessary to keep the gas burning for a long period. With the "Gulf Stream" water heater the consumption is 70 cubic feet per hour, but hot water will be delivered from it in two minutes after the time of lighting and will continue to be delivered as long as the gas is kept burning. The rate of water flow and the rate of gas consumption are simultaneously regulated by manipulating the handle.

In some cases baths are heated by gas burners placed beneath them, the water being made hot while the bath is being filled. This arrangement is apt to damage the bath and is much inferior to a good geyser.

Boilers.—For heating water to a boiling condition with the aid of gas, boilers are made in all sizes in copper or galvanised iron. They are sometimes fitted with cross tubes around which the flames and hot products of combustion pass, and then form, in fact, a description of multitubular boiler; and although when first lighted they may evolve the disagreeable odour due to incomplete combustion, the odour ceases to be emitted as the temperature of the tubes increases. With a good boiler 10 gallons of cold water may be boiled in half an hour with a consumption of 25 cubic feet of gas.

Greenhouse Boilers.—Gas is not an economical agent for heating large greenhouses, but it is exceedingly useful for maintaining a uniform temperature of any required degree, and for small greenhouses its cost is not as a rule prohibitive. The products of combustion must not be allowed to accumulate in the greenhouse, as they exert a prejudicial influence upon plant life. The sulphur compounds, which appear to be the most injurious, may, however, be eliminated to a considerable extent by the use of condensing stoves, and these are often used in greenhouses without a flue.

In order to heat a greenhouse uniformly it is necessary to use hot water or steam circulating pipes. A cast-ir apparatus suitable for heating water pipes known as Arden Hill's "Acme" Greenhouse Boiler, is shown partly in section in fig. 42. It is equally adapted for the heating of conservatories, workshops, or halls. The cross tubes are heated by the ascending current of hot combustion products,

Fig. 42.—Greenhouse Boiler heated by Gas.

and a higher heating efficiency is obtained than when an ordinary boiler is employed.

In every description of gas heating apparatus the burners and the heated metal must be kept scrupulously clean, and the flames should not be allowed to come in contact with a cold surface.

CHAPTER XVII.

GAS-ENGINES. GAS-HEATED INDUSTRIAL APPLIANCES.

Gas-Engines.—Gas-engines are now extensively used in all large towns for driving circular saws, lathes, drills, and all the tools to be found in carpenters', engineers', or smiths' workshops which are capable of being worked by mechanical power. For these purposes engines of low horse-power are used, while the larger engines are principally employed for driving dynamos for the generation of electricity.

The practical utility of the gas-engine may be said to date from the year 1876, when the Otto engine was introduced into this country, but for a long period after this date it was thought to be impossible to construct gas-engines of high horse-power. Within the last ten years it has, however, been discovered that by improving the design of the cylinder liner, the piston, and the valves, so that they may all be efficiently water cooled, engines of almost any power may be constructed. Quite recently the American Westinghouse Company have constructed an engine of 1,500 B.H.P. (brake horse-power) for use with the natural gas found in the United States, and it is believed that it will be possible to make them of fully double this power.

In this country the greatest number of engines are used with ordinary town (illuminating) gas, and are of low power. Many of the gas companies allow a considerable discount when a large quantity of gas is used for power purposes, and the small ground space occupied by gas-engines as compared with steam-engines is a factor of considerable importance in large towns. According to Mr. Bryan Donkin the number of gas-engines in use in the United Kingdom at the commencement of the year 1897 was 25,700, of which 4,600 were working in London, and the engines varied in size from half-man power to 100 h.-p. Of these 50 per cent. were estimated to be below 5 nominal horse-power, and 25 per cent. between 5 and 10 h.-p., the remaining 25 per cent. being larger sizes. A considerable increase has, however, occurred since 1897 both in the number of gas-engines employed and in the sizes in which they are constructed. The use of cheap power gas, such as Mond gas, Dowson gas, or water gas, is rapidly extending, with the result that even large steam engines of several hundred horse-power are gradually being rejected in favour of engines driven by gas. Messrs. Brunner, Mond, & Co., for example, have gas-engines of 500 and 650 h.-p. respectively working in connexion with their electrolytic plant in Cheshire, and several municipal authorities are using gas-engines of over 100 h.-p. for the generation of electric light.

The cost per brake horse-power of running a gas-engine varies with the price of the gas, the heating power of the gas, the description of gas-engine employed, and the size of the engine; but the following table may serve to convey an approximate idea of the working cost of one of 10-h.p., taking town coal gas at 3s., water gas at 4d., and Mond gas at 3d. per 1,000 cubic feet :—

	Heating value of gas, B.T.U. per c.-ft.	Gas consumed per b.h.p. per hour. C.-ft.	Cost per b.h.p. per hour. Pence.
Town gas	624	20	0·72
Water gas	304	40	0·16
Mond gas	155	80	0·24

Water gas can be manufactured by the Dellwik process at a cost of about 3½d. per 1,000 cubic feet delivered in the gasholder. The water gas plant does not occupy much ground space, and where not less than 500,000 cubic feet are consumed per day the gas can be manufactured and consumed on the works, in lieu of town gas, with great economy; but water gas cannot be distributed over large areas at so low a cost as 3½d. or 4d. per 1,000 cubic feet.

Mond gas has only about one-half the heating value of water gas, but can be manufactured at a cheaper rate. Parliament has recently sanctioned the formation of a company to undertake the supply of Mond gas, or other similar fuel gas, to a number of towns in Staffordshire at a maximum price of 3d. per thousand cubic feet to consumers taking not less than 16 million cubic feet per annum, and 4d. per 1,000 cubic feet to those consuming less than this quantity. The company may refuse to supply any consumer requiring less than 4 million cubic feet per annum. Whether Mond gas is as suitable for distribution for power purposes as water gas is a matter of dispute, but should the operations of the Mond Company prove a financial success there is little doubt that the use of steam as the motive power for stationary engines of less than 100 h.p. will soon be almost completely abandoned in this country.

Steam versus Gas.—Although, even with the best modern gas-engines, from 70 to 75 per cent. of the heat developed by combustion of the gas is lost, the proportion of heat wasted by the employment of steam-engines is yet greater. Bryan Donkin gives the following table of heat efficiencies, *heat efficiency* being the ratio of heat turned into work to the total heat received by the engine :—

Percentage Proportion of Heat Converted into Work.

Agent employed to Work Engine.	Engine of 100 h.-p.	Engine of 50 h.-p.	Engine of 10 h.-p.
Steam ...	12·5	8·3	4·0
Lighting gas...	25·5	23·1	21·2
Water gas ...	23·5	18.7	13·3
Dowson gas *	23·5	18·7	13·3

The proportion of heat converted into work by a 100-h.p. gas-engine is therefore about double that converted by

* Dowson gas closely resembles Mond gas in composition and heating power.

a steam-engine of the same power, and with engines of lower power the relative economy of the gas-engine is yet greater.

Gas for Electric Lighting.—Gas-engines of from 6-h.p. to 14-h.p. are extensively used for driving dynamos for private electric-lighting installations; while gas-engines of over 100-h.p. are used for municipal electric-lighting stations, a cheap fuel-gas being in the latter cases manufactured on the works. Gas-engines of high power driven by town gas are more costly than steam-engines, but when cheap power gas can be obtained as a fuel steam is the more expensive. Town gas as at present supplied is of too costly a quality for economical use as a fuel, and there is little doubt that in the immediate future the gas consumers in every part of the country will demand the supply of a cheaper lower grade gas which may be economically used in place of coal for fuel purposes, and that provision will be made for the daily testing of the heating power of the gas by official gas examiners appointed by the Board of Trade or by the Local Authorities.

In view of the fact that gas is in many cases the most suitable agent for generating electricity, it has been proposed that electricity shall in general practice be supplied from the same works as gas, and the gas companies of Walker and Wallsend and of St. Albans have already obtained powers from Parliament which enable them to supply electricity in addition to gas.

Gas Engines for Tramcars.—Gas has been successfully applied for driving tramcars at Blackpool, Dessau, and elsewhere, the cost of traction being less with gas than with horses. The gas is compressed under a pressure of about 90 lb. per square inch in cylinders which are placed beneath the platforms of the cars, and a compressing station is provided at one end of the line to enable the cylinders to be recharged at the end of each journey.

The Otto Cycle.—The mechanism of gas-engines constructed by different firms varies considerably in design, but most of the engines at present in use work upon what is known as the "Otto" cycle. Each cycle is completed in two revolutions, during which only one impulse is given to the piston. The following are the four operations comprised in each complete cycle:—

First revolution	1. The outstroke of the piston draws in air and gas. 2. The instroke compresses this charge.
Second revolution	3. The ignition is effected, causing explosion and expansion. 4. The products of combustion are driven out by the instroke of the piston.

In England the ignition of the explosive mixture of gas and air is usually effected by means of a Bunsen flame, but on the Continent an electric spark is commonly employed.

Gas for Industrial Appliances.—Gas is already employed as a fuel in a great number of industries, and when a supply of cheap gas is substituted for the existing costly supply, it will be yet more widely adopted. Mr. Thomas Fletcher, the pioneer in the work of adapting gas to industrial requirements, has already successfully intro-

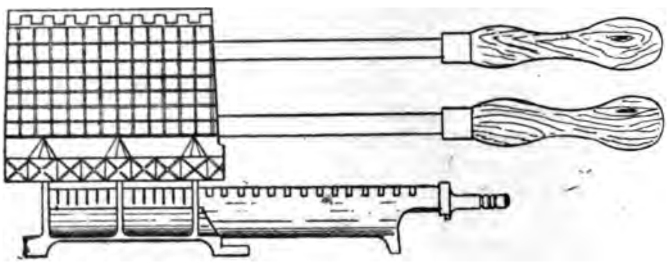


Fig. 43.—Heater for Soldering-irons.

duced gas furnaces for enamelling, for hardening and tempering steel used for cycles, for glass-working, for gold-refining, and a host of other purposes. He has also adapted gas to many appliances of comparatively minor importance, such as blowpipes, soldering-irons, and drying ovens. A large number of ovens heated by gas for japanning

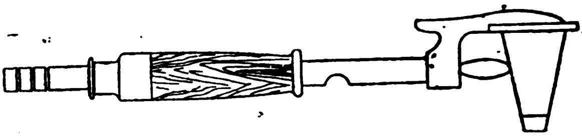


Fig. 44.—Self-heating Soldering-iron for Leaded Window Makers.

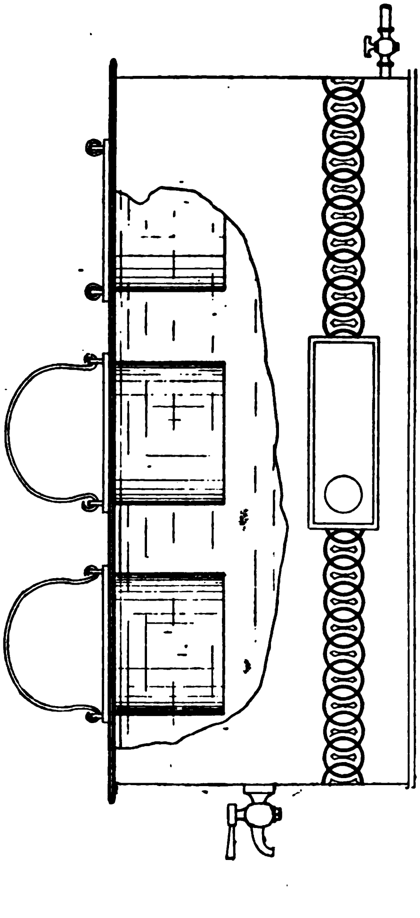


Fig. 45.—Glue-pot Stove.

work are now in operation in all parts of the country, and especially in the districts devoted to the manufacture of bicycles, the ease with which the temperature of these ovens can be adjusted to suit the description of varnish to be dried being a factor greatly in their favour. There is practically no limit to the uses to which gas can be applied, but among the gas appliances already largely used in connexion with building may be mentioned gas-heated lacquering tables, blowpipes for brazing, heaters for soldering-irons (fig. 43), self-heating soldering-irons for leaded window makers (fig. 44), and glue-pot stoves (fig. 45), which can be made to maintain any number of glue-pots at the required temperature at very small cost.

Gas for Lead Burning.—It was at one time believed that the fusion of the edges of lead sheets in cisterns and acid chambers could only be performed by the aid of hydrogen, but it has since been found possible to perform the work equally well with coal-gas. The blow-pipe jet must be small, and a comparatively high pressure must be obtained with the aid of a small foot-blower. When coal-gas cannot be conducted by a pipe to the field of operations, cylinders containing compressed coal-gas may be employed.

CHAPTER XVIII.

GAS LEAKAGES—EXPLOSIVE MIXTURES OF GAS AND AIR—DETECTION OF SMALL PROPORTIONS OF INFLAMMABLE GAS OR VAPOUR IN AIR—DETERMINATION OF THE HEATING POWER OF GAS.

When a strong odour of gas is perceptible in the atmosphere of a room or building, all lights should be immediately extinguished, all windows should be opened, and unless the leakage of gas is occurring at some point where the cause of leakage is obvious, and where it can readily be stopped, as, for example, when a cock has been accidentally turned on, the gas should then be turned off at the meter.

After shutting off the gas at the meter, and when the odour of gas is no longer perceptible, an inspection should be made of all the pipes and cocks in the neighbourhood of the leakage, and if no defect can be detected the consumer should then seek the aid of the officers of the gas company, or send for an experienced gasfitter.

Cheap brass pendants, constructed of thin brazed tube, instead of thick drawn brass tube, should be avoided. They have a dangerous habit of splitting longitudinally. A long but hardly perceptible crack suddenly occurs in the tube and allows the gas to escape in large volume. Also the cheap ball-and-socket connexions are frequently defective and allow gas to escape, particularly when the pendant becomes slightly tilted from the vertical position.

Explosions have sometimes been caused by the accumulation of gas in the space enclosed between the floorboards of a room and the ceiling of the room beneath. Gas confined in this space often fails to be detected until it is present in sufficient volume to form an explosive mixture, especially when the greater part of the floor is covered with carpet or linoleum; and when a naked light is taken near a crack between the boards, or a board is removed for examination of the pipes and a match is ignited to illuminate the space, a disastrous explosion occurs.

To ascertain whether any leakage is occurring in any part of a building, all the cocks to the burners should be closed, while the meter tap is left full on. Most meters have a dial situated above the ordinary recording indices which has a pointer which will make a complete revolution for every 2, 5, or 10 cubic feet (varying with the size of the meter) which pass through the meter. If a record be made of the position of this pointer when all the burner cocks are closed, and if, during a period of fifteen minutes, it be found that the pointer remains quite stationary, the consumer may be satisfied that the fittings are gas-tight.

Explosions have occurred through two or more small gas jets being left burning in a room exposed to draught from a window. One of the jets has been extinguished by the draught, and sufficient gas has accumulated in the room, in spite of the open window, to form an explosive mixture, which has then been ignited by the jet not extinguished by the draught.

Leakages have occasionally occurred from sliding pendants provided with water seals, owing to neglect of the precaution to periodically add water to compensate for that lost by evaporation. This danger may be avoided by using glycerine, instead of water, in the water reservoir, as glycerine does not evaporate, and will, therefore, act as a permanent seal. If the use of glycerine be considered too costly, the rate of evaporation may be retarded by pouring a layer of lubricating or other suitable oil on the surface of the water until the layer is about ½ in. in depth.

Explosive Mixtures of Gas and Air.—The most important experiments which have been made to ascertain the proportions of air required to form explosive mixtures with different gases are those carried out in 1895 and 1896 by Dr. Frank Clowes, the Chemist to the London County Council. Some of the results of his investigation are shown in the following table, and it will be noticed that the explosive limits vary widely with different gases, the danger of the formation of an explosive mixture being, for example, greater with acetylene than with coal-gas :—

Explosive Limits of Mixtures of Gas and Air. —A mixture of—

Coal gas and air will not explode if it contain less than 5 per cent. or more than 28 per cent. of coal gas.

Water gas and air will not explode if it contain less than 5 per cent. or more than 55 per cent. of water gas.

Hydrogen and air will not explode if it contain less than 5 per cent. or more than 72 per cent. of hydrogen.

Carbon monoxide and air will not explode if it contain less than 13 per cent. or more than 75 per cent. of carbon monoxide.

Acetylene and air will not explode if it contain less than 3 per cent. or more than 82 per cent. of acetylene.

Methane (fire-damp) and air will not explode if it contain less than 5 per cent. or more than 13 per cent. of methane.

Detection and Estimation of Small Quantities of Inflammable Gas or Vapour in Air.—Coal-gas cannot always be detected by its odour. By passing through certain soils it may be deprived of its characteristic odour, and may accumulate in its odourless condition in an enclosed space in sufficient quantity to form an explosive mixture. It has been suggested that the mysterious explosions which have upon several occasions occurred in culverts containing electric lighting cables may have been due to leakages from neighbouring gas mains, the gas being deprived of its odour before reaching the culverts by passage through the interposing soil. When an electric wire becomes overheated gas is sometimes generated by the decomposition of the insulating material with which the wire is covered, and forms with air an explosive mixture which is ignited by an electric spark.

It has long been known to miners that when the atmosphere in a mine contains inflammable gas, but in too small a quantity to form an inflammable or explosive mixture, and a lighted candle is exposed in this atmosphere, a pale flame, or "cap," may be seen surmounting the candle flame.

When a Davy safety lamp is taken into an atmosphere of this description the presence of inflammable gas in the air is indicated by the presence of a pale flame filling the gauze chamber and eventually causing extinction of the lamp flame, or if the quantity of inflammable gas be insufficient to produce a mixture which burns within the gauze chamber it may yet be present in sufficient quantity to cause the oil flame to "spire" or become elongated and smoky. If the wick of the lamp be turned down until the oil flame has become almost non-luminous, the presence of as small a proportion as 3 per cent. of fire-damp in the atmosphere may be detected by the presence of a pale flame cap over the oil flame.

In 1881 MM. Mallard and Le Chatelier recognising that the employment of a luminous flame reduced to very small dimensions in the attempt to render it non-luminous is less useful for this test than a larger flame which is naturally non-luminous, proposed the use of a hydrogen flame in place of the oil flame. The process of generating hydrogen proposed was, however, too cumbersome for practical use, and trouble was experienced in regulating the size of the flame; and it was not until about the year 1890, when Dr. Clowes applied small cylinders of compressed hydrogen to this purpose, that the hydrogen flame test became of practical utility. Dr. Clowes has invented a lamp, consisting of a combination of the Davy safety lamp, with a cylinder of compressed hydrogen. The cylinders had to be manufactured of sufficient strength and capacity to safely carry an ample supply of gas for testing purposes without materially affecting the weight or portability of the lamp. All difficulties, have, however, been overcome, and the lamp is now extensively employed in coal mines.

By means of the hydrogen flame used in this lamp very small proportions of fire-damp or of coal-gas can be detected and quantitatively estimated, the length of the flame-cap increasing with the proportion of inflammable gas present; while if the inflammable gas be present in dangerous quantity the flame is at once extinguished without igniting the explosive mixture in which it is exposed. The lamp may therefore be carried into an inflammable atmosphere without danger.

Disastrous explosions have occurred in the empty tanks of steamships used for the transport of petroleum owing to an explosive mixture of air and petroleum vapour having been formed within the tank and ignited by red-hot rivets or by lights taken into the tanks by workmen employed on repairs. Dr. Boverton Redwood, co-operating with Dr. Clowes, has adapted the hydrogen flame test for testing the atmosphere of the tanks of petroleum steamships, and after a steamship has discharged its cargo of oil it is now usual to test the tank atmosphere before any person is allowed to enter the tank.

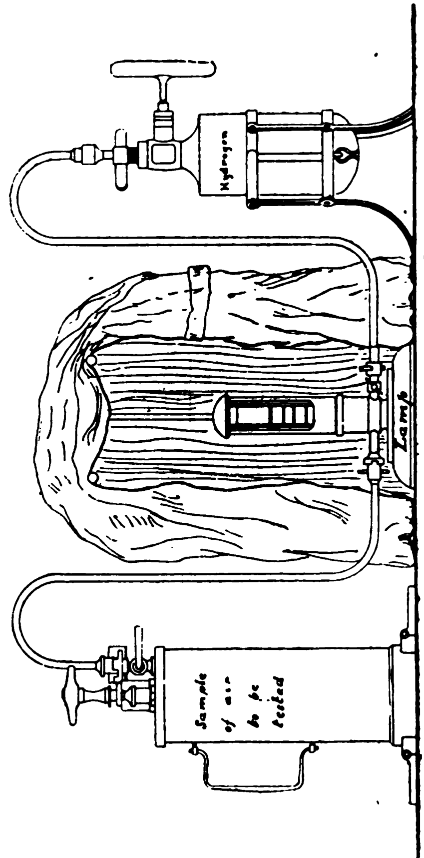


Fig. 46.—Apparatus for Detecting Inflammable Gas in Air.

The testing apparatus devised by Dr. Redwood is shown in fig. 46.

The sample of air to be tested is collected under compression in a small metal cylinder by means of a pump. When being tested the air is led through a pipe to the base of the lamp, and flows around the hydrogen flame as it rises to the top of the lamp and escapes into the outer air. A series of wire baffles, through which the sample of air to be tested must pass, is provided in the lower part of the lamp, so that should the air sample be explosive the flame cannot flash back into the metal reservoir. The hydrogen supply for the lamp is obtained from a cylinder of the compressed gas of any convenient size. Behind the lamp is an upright metal rod with horizontal arms to support a black cloth, which is provided to enable the examiner to screen off external light and to observe the height of the non-luminous hydrogen flame, and (if the air tested contain inflammable gas) the height of the flame-cap, through the glass front of the lamp.

The standard height to which the hydrogen flame should be adjusted is 0·4 in., and Dr. Redwood finds that a distinct cap is visible when the proportion of petroleum vapour amounts to one-ninth of the quantity which will make the mixture inflammable, or one-eighteenth of the quantity which renders it explosive, and considers that if the interior of the tank or other confined space be ventilated until a sample of the atmosphere within it is found to give no flame cap with this apparatus an ample margin of safety will be provided.

It has not yet been found possible to distinguish a flame-cap caused by the presence of fire-damp from a flame-cap caused by the presence of petroleum vapour. Further information relating to the detection and estimation of small quantities of inflammable gas or vapour in air may be obtained by reference to the book on this subject written by Drs. Clowes and Boverton Redwood, but from the brief outline which has been given of the method now commonly used for testing the atmosphere of coal mines and oil tanks it may be seen that the hydrogen flame-cap test may be applied to any atmosphere suspected of containing inflammable gas or vapour in dangerous quantity. Dr. Clowes states that with his lamp a visible flame-cap is obtained when as small a proportion as 0·1 per cent. of coal gas or of fire-damp is present in the atmosphere.

A number of instances will occur to the mind of the architect and engineer in which reliable information on this subject would be most valuable. Paints containing benzene or other light oils sometimes impregnate the atmosphere of the structures (such as the holds of ships) in which they are used with a dangerous proportion of inflammable vapour, and the lamp may also be used for testing the atmosphere of vaults, sewers, and subways.

The Heating Power Test.—Reference has already been made to the great difference in the relative heating values of coal gas, water gas, and Mond gas. The determination of the calorific power of a gas is an extremely simple process, and

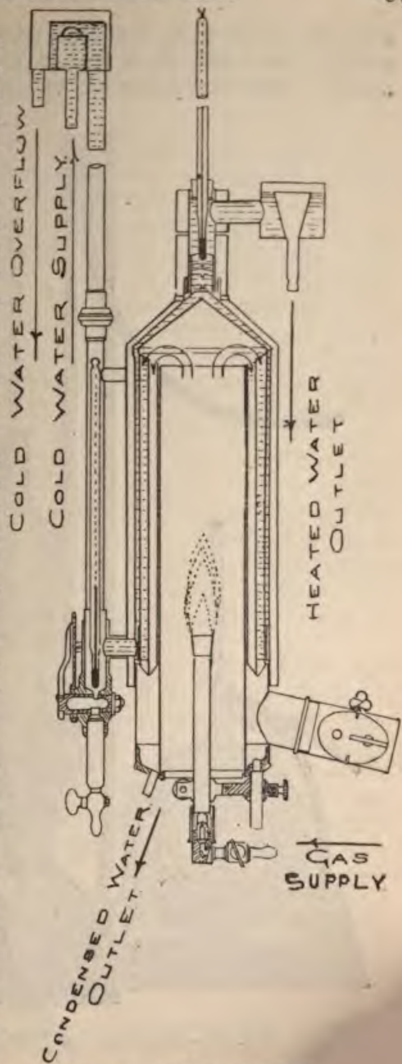


Fig. 47.—Junker's Calorime

may be made with sufficient accuracy for all practical purposes in a very short time by means of Junker's calorimeter. The heat generated by combustion of the gas is

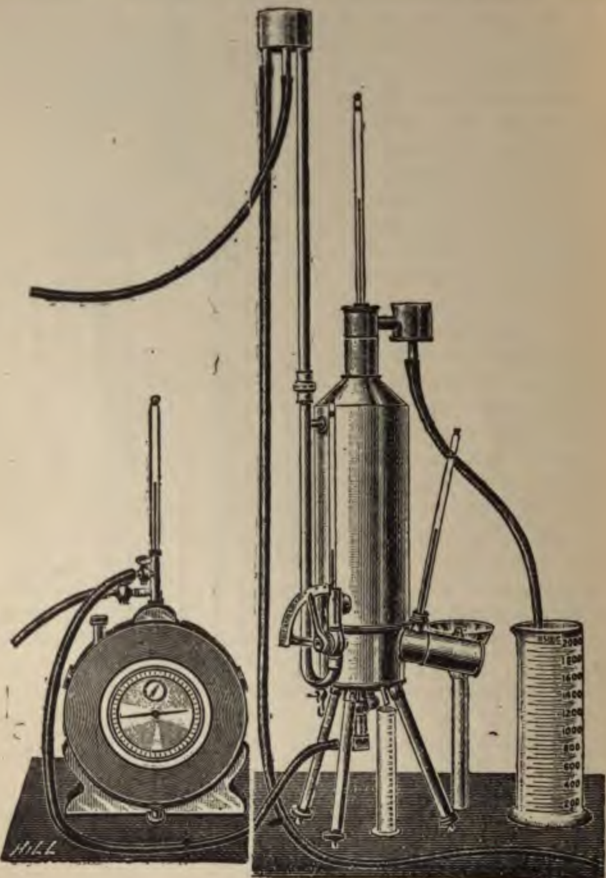


Fig. 48.—Apparatus for Heating Power Test.

transmitted to a current of water flowing at a constant rate, and observations are made of :—

1. The quantity of gas burned.
2. The quantity of water heated.
3. The increase in the temperature of the water heated.

The calorimeter is shown in section in fig. 47, and the complete apparatus required for testing is shown in fig. 48.

The gas to be tested is led through the meter to an atmospheric burner which forms part of the calorimeter. The gas is consumed at about the rate of 6 cubic feet per hour if coal-gas is being tested, but at a greater rate if the gas is fuel-gas of low heating power. The burner is surrounded by a vertical double-walled cylinder, and the hot products of combustion escape through a number of copper tubes passing down between the walls of the cylinder. The hot products pass down through the tubes while the flowing water ascends outside the tubes. The tubes terminate in a common chamber in the bottom of the cylinder, and the uncondensable gases escape through the throttle at atmospheric temperature. The water flows through the calorimeter at a constant rate owing to the fact that the inlet device is provided with an overflow, and water is supplied to the instrument at a greater rate than it is allowed to flow through it.

The rate of flow is regulated until it is found that the temperature of the water flowing out of the calorimeter is between ten and twenty degrees C. higher than the temperature at the inlet. When the test is commenced the volume of water heated is carefully measured in a graduated cylinder of two litres capacity, and a reading of the gas meter is made. During the test readings of the thermometers at the inlet and outlet are made at short intervals and recorded.

The gross heating value of the gas in calories is found by the following equation :—

$$\frac{\text{Number of litres heated} \times \text{by increase in temperature of water.}}{\text{Cubic feet of gas consumed.}}$$

The hydrogen contained in the gas is converted int[illegible] which condenses in the calorimeter, and gives up i[illegible] heat to the circulating water. When gas is used as a fuel in practice the water formed escapes as steam and is not utilised. The latent heat is, therefore, usually deducted from the gross heating value, and the resultant figure is termed the "net" calorific value. The water condensed from the products of combustion is collected in a cubic centimeter measuring cylinder, and for every c.c. collected a deduction of 0·6 calorie is made. If 53 c.c. of condensed water were obtained from 2·0 cubic feet of gas, a deduction of 15·9 calories should be made from the gross heating value, thus :—

$$\frac{0{\cdot}6 \times 53}{2} = 15{\cdot}9 \text{ calories}$$

The heating value of a gas is usually expressed in calories or British Thermal Units. A *calorie* is the amount of heat required to raise the temperature of one litre or one kilogramme of water one degree C., and a *British Thermal Unit* is the amount of heat required to raise 1 lb. of water one degree F. To convert calories into B.T.U. multiply the calories by 4 (or more correctly by 3·968).

CHAPTER XIX.

OFFICIAL GAS EXAMINERS AND THEIR WORK—HOW GAS IS TESTED FOR ILLUMINATING POWER AND PURITY.

Official Gas Examiners.—Competition in the supply of illuminating gas is no longer permitted in any part of the United Kingdom because the nuisance created by the incessant tearing up of the public roads by rival companies was found to be intolerable. The operations of one gas company in each district in addition to those of the water company, the electricity supply company, the telegraph authorities, the tramway and railway engineers, and the road repairers, already cause too frequent disorganisation of the traffic in many of the main thoroughfares. The country is therefore divided into districts, each of which is served with illuminating gas by only one company or local authority. Quite recently power has been given to the Mond Gas Co. to distribute cheap low grade gas for heating and power purposes in certain Staffordshire districts already supplied with illuminating gas, but this is a departure from the policy adopted by Parliament during the last half century.

The operations of each gas company are conducted under powers and conditions specified in certain Acts of Parliament, each company having its own special Act or Acts relating to the laying of pipes, the opening of streets, and the standard price, illuminating power, and purity of the gas to be supplied. Many of the smaller companies are controlled by the Gas Works Clause Act of 1871, which stipulates that a place for testing the gas, and the necessary apparatus, shall be provided and maintained by the gas company, and that the official gas examiner appointed by the Local Authority shall have access to such testing place within certain specified hours. Where no such gas examiner is appointed by the Local Authority, two Justices may, upon the application of not less than five consumers, appoint a competent and impartial examiner to test the illuminating power and purity of the gas. The standard illuminating power of the gas supplied from small works in England is usually 14 or 15 candles, and the gas is required to be purified from sulphuretted hydrogen only.

In large towns a more elaborate system of testing is commonly adopted, and a more rigorous purification of the gas is required. In London there are twenty testing stations well distributed over the area under the jurisdiction of the London County Council, in which the gas is tested every day for purity and illuminating power by examiners appointed by the Council. Within the City boundaries three additional testing stations are provided, in which the gas is similarly tested by examiners appointed by the Corporation of London. The County Council and the Corporation, moreover, each retain the services of an eminent chemist to act as superintending gas examiner and to advise on all matters relating to the public gas supply. The situation and number of the testing stations to be maintained by the gas companies, and the methods of testing to be adopted by the examiners, are prescribed by three gas referees appointed by the Board of Trade. A chief gas examiner who acts as arbitrator when a gas company appeals against the report of any of the gas examiners, and whose decision is final, is also appointed by the Board of Trade. The present chief gas examiner is Lord Rayleigh, F.R.S., and all the gas referees are also Fellows of the Royal Society. The Act stipulates that one at least of the referees shall have "practical knowledge and experience in the manufacture and supply of gas," but owing no doubt to the able manner in which the scientific men have carried out the duties of the office no practical gas engineer has been appointed as a referee for many years.

At present the Acts of Parliament which control the operations of the Metropolitan gas companies regulate only the pressure, the illuminating power, and the purity of the gas from sulphuretted hydrogen, other sulphur compounds, and ammonia; but in view of the increasing use of materials other than coal for the manufacture of gas, it appears probable that Parliament will presently be requested by the Local Authorities, on behalf of the consumers, to fix a minimum standard for heating power, and a maximum standard for the proportion of carbon monoxide, and that the gas examiners will be called upon to include determinations of these in their daily tests. Already a Home Office Committee has recommended that wherever water-gas is mixed with coal-gas for public supply, a limit for carbon monoxide be fixed, and the London County Council has granted a sum of money for the purpose of making a series of estimations of the proportion of this poisonous constituent in the gas supplied in different parts of the metropolis.

In the Mond Gas Company's Act of 1901, which relates only to gas for heating and power purposes, standards have been fixed for heating value and for carbon monoxide, and provision has been made for the gas to be tested by gas examiners appointed by the Local Authorities.

Illuminating Power.—It is beyond the scope of the present volume to discuss in detail the various methods of measuring the intensity of the light emitted from gas flames and other light sources. For detailed information, reference should be made to Dibdin's "Practical Photometry," or Butterfield's "Chemistry of Gas Manufacture"; but a brief general outline may be given of the official methods of testing.

The illuminating power of gas in this country is expressed in "candles," a standard candle being the light emitted by a sperm candle (six to the pound) when consuming sperm at a rate of 120 grains per hour. The intensity of the light thrown upon an object by a light-emitting surface varies inversely as the square of the distance of the object from that light-emitting surface. Thus a flame which will throw a light of 16 candle power upon an object 1 ft. distant, will throw a light of any 4-candle power upon an object 2 ft. distant.

The Bar Photometer.—In the old method of gas testing (fig. 19) which is still employed in many districts, the measurement of light is made by burning two standard candles (A) at one end of a graduated horizontal bar (C) while the Argand burner (B), in which the gas is tested when burning at a rate of 5 cubic feet per hour, is fitted at the opposite end of the bar. The distance between the centre of the gas flame and the candle flames is exactly 60 in., and plumb lines are fitted at each end of the bar to enable the photometrist to see that the flames are vertical and the correct distance apart. A greased paper disc, having a circular spot in the centre which is left ungreased, is fitted in the disc-holder (D), which is mounted on wheels and can be moved along the bar either towards the gas flame or towards the candles. The greased and ungreased portions of the disc have a different degree of translucency, and if the light thrown upon one side of the disc be more powerful than that thrown upon the opposite side, one side of the disc is at once seen to be illuminated to a greater degree than the other side. When the gas is being tested the disc is moved towards the candles or towards the gas flame until the disc is seen to be equally illuminated upon both sides, and it is then known that the disc is receiving an equal amount of light from the two candles as from the gas flame.

To enable the examiner to observe both sides of the disc at the same moment, two inclined mirrors, one on each side of the disc, are provided at the back of the disc-holder; and to prevent any error arising through one side of the disc becoming discoloured, Dibdin has introduced a disc-holder in which the disc, together with the two mirrors, is supported on a pivot, so that when a certain number of observations have been made with the disc in one position, the disc and mirrors may be rotated, and an equal number of observations made with the positions reversed.

Attached to the disc-holder is a pointer which moves in front of the graduated scale on the bar as the disc is moved, and on the bar is graduated to indicate candles (thus obviating the necessity of measuring the relative distances of the gas flame and the candles from the disc) the candle-power of the gas flame may be obtained by observing the

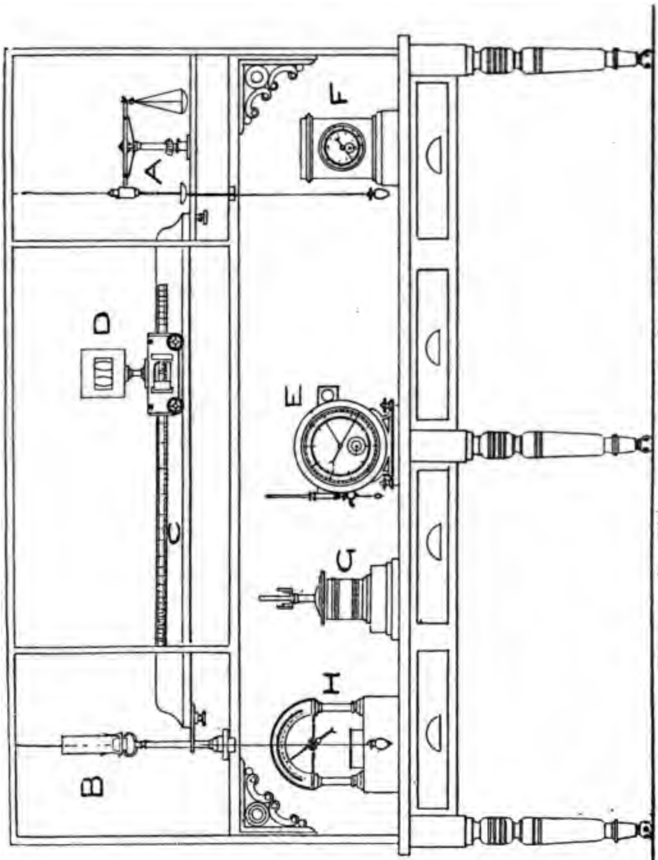


Fig. 49—Bar Photometer with Standard Candles.

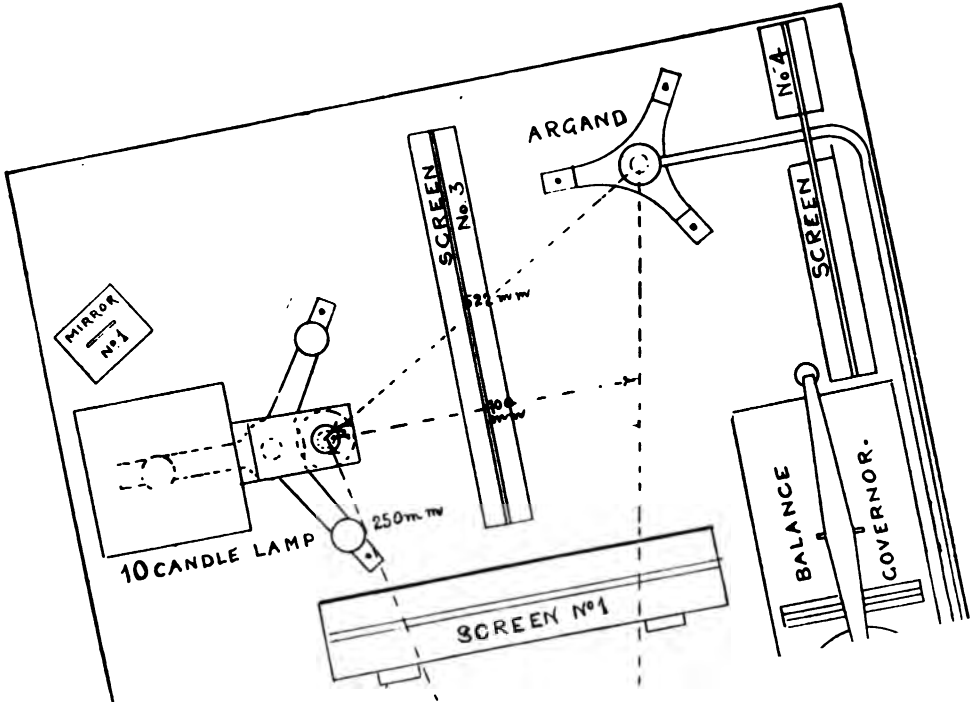
figure on the scale indicated by the pointer, and multiplying this figure by two, because two candles are used as the source of comparison. Thus, if the pointer be opposite the this intensity of light is then recorded, and a calculation is made to ascertain the proportional intensity of light which would be obtained with a rate of consumption of exactly 5 cubic feet per hour.

Instead of a greased disc being used to ascertain when the intensity of the light thrown by the gas flame and by the pentane flame upon a given spot is identical, a piece of white unglazed paper clamped in the photoped is used, and the gas flame is adjusted until the photoped paper is seen to be uniformly illuminated. The distances of the 10 c.-p. lamp and the gas flame are so fixed that when the gas flame has an illuminating power of sixteen candles the intensity of the light thrown upon the photoped from the two sources shall be equal.

The photometer is used in a dark room, and suitable black screens are provided to prevent extraneous light interfering with the light thrown upon the photoped. Screen No. 1 (fig. 51) has orifices which allow the light from the burners to pass to the photoped without interference. The mirrors are provided merely to facilitate adjustment of the pentane flame and to throw light upon the gas-regulating tap.

Pressure.—The pressure under which the gas is supplied is ascertained by means of a water-gauge. From time to time tests are made in the street lanterns by the gas examiners, the burner and governor being removed and the pressure-gauge screwed in its place. One-tenth of an inch is deducted from the observed pressure in order to allow for the difference in height between the gas lamp and the gas main. The minimum pressure permitted in London between midnight and sunset is equal to a column of six-tenths of an inch of water, and between sunset and midnight to a 1-in. column of water.

Sulphuretted Hydrogen.—The gas is required to be completely purified from sulphuretted hydrogen, the company being liable to a heavy penalty for every day on which this impurity is detected in the gas distributed to consumers. The test for sulphuretted hydrogen consists in allowing 10 cubic feet of gas to flow at a rate of about 0·6 cubic feet per hour through an apparatus in which are suspended slips of white bibulous paper impregnated with



MIRROR No. 1
SCREEN No. 3
522 mm
400 mm
ARGAND
No. 4
SCREEN
250 mm
10 CANDLE LAMP
SCREEN No. 1
BALANCE
GOVERNOR.

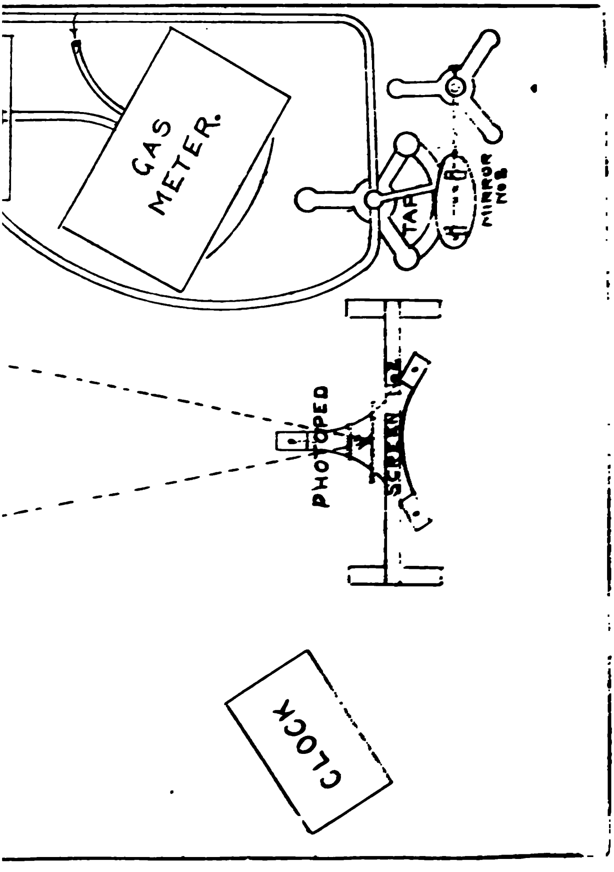


Fig. [illegible]. Table [illegible] with Pentane Standard Lamps as used in London Testing Stations.

acetate of lead. The presence of even a minute proportion of sulphuretted hydrogen in the gas causes a brown or black stain to appear on each of the slips.

Sulphur Compounds other than Sulphuretted Hydrogen.—In London the gas must not contain more than 17 grains of sulphur per 100 cubic feet of gas between April 1 and September 30 in each year, nor more than 22 grains in other months. To estimate the quantity of sulphur 10 cubic feet of the gas to be tested are burned in a small Bunsen burner at a slow rate in an atmosphere impregnated with ammonia evolved from lumps of ammonium sesqui-carbonate. The products of combustion are led into a condensing-cylinder where the water vapour produced by combustion of the hydrogen and hydrocarbons in the gas is condensed; and the condensed water holds the sulphur compounds, which are oxidised during combustion, and which enter into combination with the ammonia, in solution. When 10 cubic ft. of gas have been consumed the gas is automatically shut off, and the quantity of sulphur in the condensed liquid is subsequently estimated by chemical analysis.

Ammonia.—The proportion of ammonia in the gas must not, in London, exceed 4 grains per 100 cubic ft. of gas. The quantity of ammonia present is found by allowing 10 cubic ft. of the gas to pass at a slow rate through a glass cylinder containing glass beads, moistened with 50 septems of dilute sulphuric acid of a known strength. The acid combines with the ammonia present in the gas to form sulphate of ammonia, and by estimating the quantity of uncombined acid remaining in the cylinder after 10 cubic ft. of gas have passed through it, the quantity of acid neutralised by the ammonia, and consequently the quantity of ammonia present in the gas, is obtained.

More detailed information relating to the chemical examination of gas cannot be given in the present volume, but the "Notification of the Gas Referees," containing the official instructions given to the London gas examiners with regard to the tests for illuminating power, purity, and pressure, may be obtained from Messrs. Eyre & Spottiswoode.

CHAPTER XX.

THE RELATIONSHIP BETWEEN THE GAS VENDOR AND THE GAS CONSUMER.—RECENT CONCESSIONS.—HOW TO READ THE METER.—HOW TO ASCERTAIN THE RATE OF CONSUMPTION OF ANY GAS-CONSUMING APPLIANCE.

DURING the last ten or fifteen years a remarkable change has occurred in many districts in the attitude of the gas manufacturer to the gas consumer.

Formerly a gas company considered its work satisfactorily completed when gas had been carried to the consumer's meter. If, after the gas had passed the meter, the consumer through ignorance consumed the gas in wasteful burners, it was not to the interest of the gas company to teach him how to obtain more light or heat with a smaller consumption of gas. That was the opinion at one time commonly expressed by officers of gas companies.

With the passing of the nineteenth century, however, a radical change was witnessed in the business methods adopted by many gas companies and gas-producing Local Authorities. The gas vendor of the present day realises that it is to the interest of the shareholder as well as of the consumer to aid the consumer to obtain the highest possible efficiency in light, heat, or power, as the case may be, from every cubic foot of gas consumed. The introduction of leaky supply pipes and wasteful burners into a consumer's premises by an incompetent local ironmonger, whose opinion as to the value of a burner is more or less dependent upon his rate of commission, is no longer viewed with equanimity by the gas manufacturer.

Managers of gas undertakings now vie with one another in devising new schemes for popularising the use of gas both for domestic and industrial purposes; but each company has its own rules as to the extent to which it will assist consumers in obtaining an efficient gas supply at small initial cost, and as to the class and variety of gas-consuming appliances which it will let out on hire or lend to consumers without charge. The following list of concessions which have already been granted by one or more companies or gas-producing Local Authorities shows that some gasworks managers have already recognised the necessity of adopting modern business methods, and will indicate to the consumer the kind of assistance he may be able to obtain from the gas vendor.

1. **Gas Supply Pipes.**—Many gas companies will provide and fix all gas pipes of any size and for any purpose at cost price, while a few will supply and fix the pipes free of charge. As most gas companies keep a large staff of competent fitters constantly employed upon this class of work, it is usually a good policy to have the fittings put in by the gas company's men.

2. **Flat Flame Burners for Lighting Purposes.**—In some cases these are supplied free of charge, and in others at cost price.

3. **Incandescent Gas Burners.**—These are in some cases supplied by the gas company at a lower price than that charged by shopkeepers, and in several cases the gas company undertake to maintain incandescent burners in good condition, and renew all mantles and chimneys whenever necessary at a nominal charge.

4. **Gas Fires, Stoves, and Cookers.**—These are let out on hire by most gas companies at a small charge. The rental for a fire for a dwelling-room of ordinary size is usually from 1s. 6d. to 2s. 6d. per quarter, and for a domestic cooker of moderate size from 2s. to 3s. per quarter. A few gas companies will lend these appliances to consumers without charge.

5. **Ring Burners.**—Small ring burners, suitable for boiling a kettle of water, are in many cases lent to consumers free of charge.

6. **Gas Engines.**—At High Wycombe these may be obtained on the hire-purchase system, or on the continuous hire system. Few, if any, other gas companies have, however, yet undertaken to supply these on any terms whatever.

7. **Periodical Inspection of Fittings.**—Some companies now undertake without charge to keep and maintain all ordinary fittings in a clean and efficient condition. Inspection is made either upon receipt of request or by periodical visits. In most places the officers of the gas company will examine a consumer's fittings upon special request without charge.

8. **Prepayment Meters.**—Most gas companies will connect a house to the gas main and provide and fix a prepayment meter and all the required pipes and burners without initial charge. The gas is obtained by dropping a penny into the slot of a box attached to the meter. The quantity of gas obtained for each penny dropped into the box is adjusted to cover the cost of the meter and fittings, and is usually supplied at a rate of between 5d. and 10d. per 1,000 cubic feet above the amount charged for gas supplied by ordinary meter. Prepayment meters to supply gas in larger quantities, for coins of greater value, are also supplied.

All this "free-of-charge" business must, of course, be paid for eventually in the price paid for the gas, but by minimising the danger attendant upon the use of gas by periodical inspection of the fittings by competent officers of the gas company, by showing the consumer how to obtain the greatest efficiency from the gas with a minimum pollution of the atmosphere, and by assisting him to obtain appliances at low cost which he would otherwise reject, there is little doubt that real progress has been made since the time when the internal gas fittings of buildings were left to men who sometimes were incompetent fitters, and frequently were quite ignorant of the most elementary laws relating to the combustion of gas.

Reading the Meter.—The reading of the dials on an ordinary gas-meter is an extremely simple process; but many consumers neglect to watch the meter because the interpretation of the indications is thought to require special knowledge.

To ascertain the rate of consumption per day, per month, or per quarter, as the case may be, it is necessary to make a record of the position of the pointers on the dials at the commencement of the period and also at the end of the period, and to subtract one figure from the other. In fig. 52, for example, the positions of the pointers are shown at the commencement of a week at A, and their positions at the end of the week at B.

The dial with only two figures upon it which is seen above the four main dials is not taken into account when the meter is read by the gas inspector. The pointer of the dial with the superscription "1 thousand" makes a complete revolution for every 1,000 cubic ft. which pass the meter, and as the dial is divided into ten equal parts, the pointer moves from one numeral to the next in succession during the passage of 100 cubic ft.

The pointer of the dial superscribed "10 thousand" makes a complete revolution for every 10,000 cubic ft. which pass the meter, and consequently the movement of the pointer from one numeral on this dial to the next indicates the passage of 1,000 cubic ft.

The pointer of the dial superscribed "100 thousand" makes a complete revolution for every 100,000 cubic ft. which pass the meter, and consequently the movement of the pointer from one numeral to the next represents a consumption of 10,000 cubic ft.

The pointer of the dial superscribed "1 million" makes a complete revolution for every million cubic ft. which pass the meter, and consequently the movement of the pointer on this dial from one numeral to the next indicates the passage of 100,000 cubic ft.

In fig. 52 the positions of the pointers when 273,800 cubic feet have passed the meter since the pointers were all at zero are sho[illegible] [illegible]sitions of the pointers, say, one wee[illegible] The consumption indicated at B is 274,900. The refore inone week 1,100 cubic feet (274,900—273,800) of gas have been consumed.

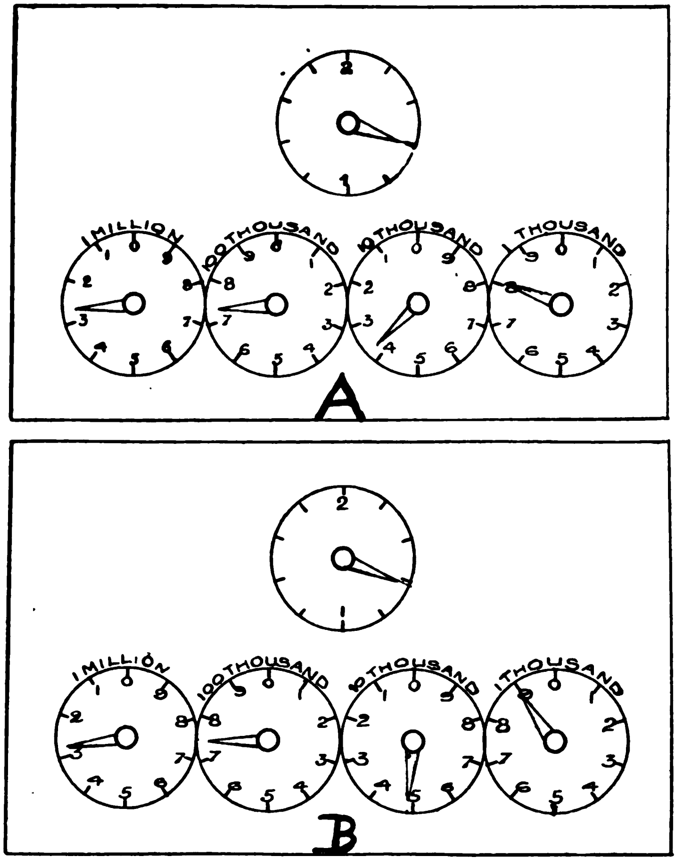


Fig. 52.—Index on Consumer's Meter showing a consumption of 273,800 cubic feet at A, and of 274,900 feet at B.

Testing the Rate of Consumption of any Gas-consuming Appliance.—The dial situated above the four main dials (fig. 52) on the meter affords a means of ascertaining the rate of consumption of any particular appliance and of the soundness of all the gas fittings within a building. The pointer of this dial makes one complete revolution for every two cubic feet of gas which pass the meter, and as there are ten equal subdivisions on the dial, the movement of the pointer from one subdivision to the next indicates the passage of a fifth part of one cubic foot of gas. Larger meters have a dial divided into cubic feet, and the pointer makes a complete revolution for every five or ten cubic feet of gas which pass the meter.

When all the burner cocks are shut off and the main cock on the meter outlet is turned full on, the pointer on this dial will remain quite stationary if the pipes and fittings are gas-tight, but will change its position if a leakage of gas is occurring at any point.

Having ascertained that all the fittings are gas-tight by observing that the pointer remains quite stationary for a period of, say, fifteen minutes, the gas appliance to be tested should be put in action while all other burners are still kept shut off. The number of revolutions made in a fixed period, say ten minutes, should be noted, and the consumption per hour then be calculated.

If in ten minutes the pointer makes one complete revolution the consumption per hour is 12 cubic ft.; and if it makes two and a half revolutions in this period the rate of consumption is 30 cubic ft. per hour. In this manner the rate of consumption of any burner or cooker or other appliance may readily be ascertained.

In addition to testing the rate of consumption of the different appliances in use it is a good practice to keep a record of the gas consumed from quarter to quarter, and if the consumption suddenly increases largely without apparent cause beyond the quantity consumed in the corresponding quarter of the previous year, to send the meter to be tested at one of the public meter-testing stations.

CHAPTER XXI.

THE PROPERTIES AND MANUFACTURE OF CALCIUM CARBIDE.

Properties of Calcium Carbide.—Calcium carbide is a dense solid compound of calcium and carbon. Its chemical formula is CaC_2, which indicates that it consists, when pure, of 62·5 per cent. by weight of calcium combined with 37·5 per cent. of carbon. It is neither explosive nor inflammable, and may be strongly heated in an open fire or in a gas flame without undergoing any change. When exposed to the atmosphere, calcium carbide, like a lump of quicklime, slowly changes into a bulky powder. This change of condition is due to the water vapour in the air. The hydrogen of the water vapour enters into chemical union with the carbon of the carbide to form the inflammable gas acetylene, which continues to escape into the air so long as any undecomposed carbide remains exposed to its influence; at the same time the oxygen of the water vapour combines with the calcium of the carbide to form calcium oxide, or quicklime, which in turn combines with a further quantity of atmospheric water vapour to form calcium hydrate or slaked lime.

When liquid water is poured upon calcium carbide, or the carbide is dropped into water, the same reactions occur as when the carbide is exposed to the atmosphere, but they take place at such a rapid rate that the decomposing carbide becomes more or less strongly heated, and acetylene gas is evolved in a brisk stream.

Absolutely pure calcium carbide will yield 5·82 cubic feet of acetylene per pound of carbide decomposed, but with commercial carbide of good quality the average yield of acetylene does not exceed 5 cubic feet per pound, and with inferior carbide or with generators of an inferior type the yield often falls considerably below this volume.

Moissan has shown that pure calcium carbide is white and transparent, but the carbide of commerce is neither pure, transparent, nor white. Commercial calcium carbide is usually in the form of dense semi-crystalline masses of bluish-grey or grey-black colour, but when freshly fractured is often found to have a reddish hue and to exhibit iridescent surfaces. It has a semi-metallic appearance and resembles granite in hardness. Its density is 2·22. The difference in the physical condition of different samples of commercial carbide is caused by variations in its rate of cooling from the fused state in which it is formed in the furnace, and also by variations in the nature and quantity of the impurities present. Comparatively large crystals are formed when the carbide cools slowly, and small crystals when it cools rapidly. The colours are mainly due to the presence of iron as an impurity in the raw materials employed. Black particles of carbon which have not united with calcium to form carbide are also usually present. No reliable indication regarding the purity of commercial carbide is afforded either by its colour or by the size of its crystals.

The Electric Arc.—If a wire through which a strong electric current is passing be severed, and the severed ends remain within a short distance of one another, the current will leap across the space by which they are separated, and its passage will be accompanied by the evolution of light. If a rod or pencil of carbon be attached to each of the ends formed by severing the wire, and the tips of the two pencils be brought in contact and then drawn a short distance apart a dazzling light will be at once emitted. The evolution of light is due partly to the ends of the carbon pencils becoming incandescent, partly to the electric arc which is produced as the electric current leaps from one carbon pencil to the other, and partly to small particles of carbon which flow with the current from one pencil towards the other, and which becom[illegible] descence in the arc. The end of the positive carbon emits a more brilliant light than the end of the negative carbon, and after a short period it becomes slightly flattened and has a small hollow or "crater" formed in it. It is from this crater that the whitest and most intense light is emitted.

Fig. 53.—The Electric Arc.

The appearance of the electric arc and carbon pencils is shown in fig. 53, which is reproduced from a photograph for which the writer is indebted to Professor Vivian B. Lewes, and it will be seen that while the positive pole becomes flattened, the negative pole becomes more pointed.

When the ends of the carbons are too close together a hissing noise is produced, and if they are a little too far apart a roaring noise is emitted and the evolution of light is apt to suddenly cease, owing to the failure of the current to effect a junction between the two carbons. When the carbons are a suitable distance apart the combustion of the carbons and the passage of the current should proceed silently, and be accompanied by the evolution of a brilliant and steady light. The value of the electric arc for the manufacture of calcium carbide is, however, not due to the evolution of light nor to any influence peculiar to electricity, but merely to the fact that the temperature of the arc is much higher than that obtainable by any other known means.

Electric Furnaces.—The temperature of the electric arc has been found by experiment to be 3,500 deg. C., and by enclosing it in a chamber having infusible non-conducting walls the useful appliance known as an electric furnace is constructed. Electric furnaces have been employed for scientific research work for a long period, but it is only within the last quarter of a century that they have become of great industrial value. Lewes divides electric furnaces into two classes:—

1. Those in which the substance to be heated is placed in the path of the electric arc, or is made to form one or both poles for the formation of the arc, and

2. Those in which the heat is generated by offering resistance to the flow of current, as when a piece of thin platinum wire is heated to incandescence by making it the link between two copper wires of greater diameter through which the current is passing.

For the manufacture of calcium carbide on a large scale, furnaces of the arc type are always employed. It would serve no useful purpose to describe each of the numerous designs for electric furnaces which have been patented for the manufacture of carbide, and a brief description of one of the arc furnaces (fig. 54) recently invented by W. S. Horry, of Niagara, must serve as a type of carbide furnaces in general, but further information relating to calcium carbide and the various furnaces which have been employed for its manufacture can be obtained by reference to Professor Lewes' exhaustive treatise on acetylene.

In the Horry furnace (fig. 54) the carbon pencils are placed in parallel vertical position, and are buried in the mixture of lime and carbon to be converted into calcium carbide. When the arc is produced between the lower ends of the two pencils the mixture in the neighbourhood of the arc fuses and is converted into a pool of liquid carbide. A portion of the superimposed mixture then falls into the liquid carbide, which spreads laterally until it passes beyond the field of reduction and solidifies. That portion of the solid mixture which has fallen into the molten carbide is acted upon by the electric arc, and is itself speedily converted into molten carbide. In this manner all the mixture in the lower part of the furnace is gradually converted into carbide. In order to bring the upper layers of mixture into the field of the arc, mechanism is provided whereby the furnace may be moved vertically downwards, so that the carbon pencils, which remain in a fixed position, may occupy a higher position in the furnace.

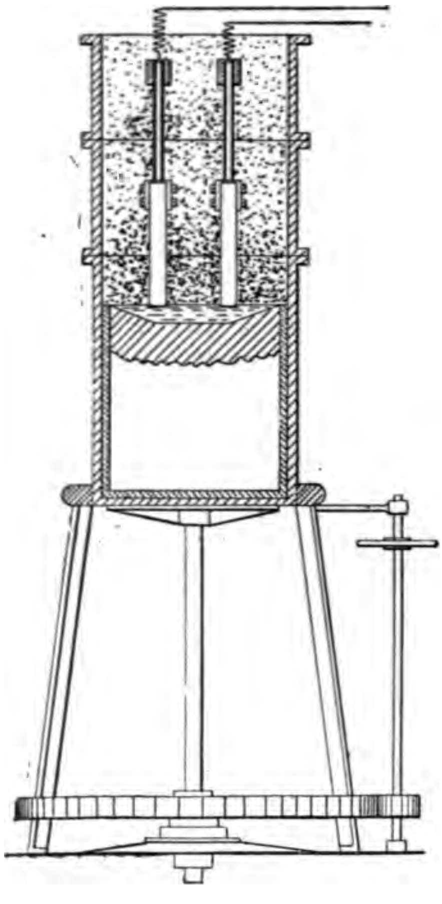


Fig. 54.—Electric Furnace for Producing Calcium Carbide.

The chemical name for quicklime is calcium oxide, and when a mixture of ground coke and lime is subjected to the heat of the electric arc, the carbon contained in the coke and the calcium contained in the lime enter into chemical combination to form calcium carbide, thus:—

$$\underset{\text{Quicklime}}{CaO} + \underset{\text{carbon}}{3C} \underset{\text{yields}}{=} \underset{\text{calcium carbide}}{CaC_2} + \underset{\text{carbon monoxide}}{CO}$$

The foregoing chemical equation shows that, theoretically, 56 parts by weight of quicklime will combine with 36 parts of carbon to produce 64 parts of calcium carbide and 28 parts of carbon monoxide. The carbon monoxide is a poisonous, inflammable gas, which burns at the mouth of the furnace, or may be utilised to assist in maintaining the high temperature of the furnace. In practice the lime and the carbon employed are never pure, and it is necessary to ascertain the proportion of the impurities present in them by chemical analysis, and to make allowance for them when calculating the relative proportions of lime and coke to be employed in the mixture to be converted into calcium carbide.

There are two forms of carbide on the market, known respectively as "ingot" carbide and "run" carbide.

Ingot Carbide.—When powdered lime and coke, mixed in the correct proportions for carbide manufacture, are heaped around the carbon poles in an electric furnace, that part of the mixture which is in closest proximity to the electric arc fuses and becomes converted into calcium carbide, but the outer portion of the mixture is not heated to a sufficiently high temperature for conversion into carbide. When the electric current is cut off and the material within the furnace is allowed to cool, the whole of it is found to have become conglomerated into one compact mass or "ingot," consisting of a core of high-quality calcium carbide with a crust which contains less and less carbide as its distance from the core increases.

The entire ingot as it leaves the furnace contains about two-thirds of its weight of commercially pure calcium carbide, while the remaining one-third consists of "crust," and contains a large proportion of lime and carbon which have escaped conversion into calcium carbide. When the ingot is broken into small lumps for distribution to consumers the worst portions of the "crust" are picked out, but a considerable amount of material of low quality, consisting partly of carbide and partly of useless lime and carbon mixture, is blended with the higher grade carbide. Occasionally a sample of carbide, consisting mainly of "crust" and yielding only about one-half of the normal quantity of acetylene, is found on the market.

Run Carbide.—If an excess of lime be added to the carbon and lime mixture to be converted into carbide, the additional lime acts as a flux, and renders it possible to convert the whole mixture into a molten mass, which may be run out of the furnace into suitable moulds. When producing ingot carbide the temperature of the furnace becomes so high that the furnace lining is rapidly destroyed, and it is found that by using an excess of lime and producing run carbide the destruction of the furnace lining is less rapid. Run carbide is more uniform in composition than ingot carbide, but as it contains an excess of lime it will not yield so large a volume of acetylene as the best selected ingot carbide. When, however, the crust obtained with ingot carbide is mixed with the core of the ingot the mixture may be of less value than run carbide. Every consumer who uses carbide in considerable quantity should provide himself with some means of ascertaining the volume of acetylene evolved from a definite weight of the carbide supplied to him, and should insist that the price of the carbide be regulated by its quality.

Protective Coverings for Carbide.—Many attempts have been made to protect carbide from the influence of atmospheric water vapour without interfering with its utility for the production of acetylene by contact with liquid water. The carbide has been soaked in glucose, which was intended to provide a coat which would be impervious to the atmosphere, but which would dissolve as soon as the carbide was immersed in water. The carbide has also been treated with liquid petroleum, paraffin-wax, tallow, glue, and other substances of a like nature, the object in some cases being merely to retard the rate of evolution of the gas when the carbide was brought in contact with water. In other cases the carbide has been sealed in metal cartridges to be dropped into the water and then perforated with a suitable pointed tool.

The steeping of carbide in glucose, oil, glue, or wax does not protect it efficiently from the action of atmospheric water vapour, for if a sample of carbide so treated be exposed to the air for a week, it will be found to be more or less completely decomposed. The sealing of the carbide in metal cartridges is not convenient when the gas has to be generated in comparatively large quantities, and the preservation of the raw carbide in stout metal drums with air-tight lids remains the best and safest method of storage.

CHAPTER XXII.

THE PROPERTIES AND GENERATION OF ACETYLENE.

The Properties of Acetylene.—Pure acetylene is a colourless gas possessing a sweet ethereal odour. Commercial acetylene has a stronger and more offensive odour owing to the presence of gaseous impurities. The chemical formula for acetylene is C_2H_2, which indicates that it consists of 92·3 per cent. by weight of carbon combined with 7·7 per cent. of hydrogen. It is soluble in water to a considerable extent, eleven volumes of gas being dissolved by ten volumes of water at ordinary atmospheric temperature and pressure. The gas is much less soluble in water which has been saturated with common salt, but strongly saline solutions exert a corroding influence on the metal vessels commonly used for the generation or storage of acetylene. Acetylene is much heavier than coal-gas, but somewhat lighter than air. The approximate specific gravities of acetylene and other gases extensively used for lighting or heating purposes are shown in the following table :—

Hydrogen	0·07
Coal-gas	0·42
Plain water-gas	0·54
Natural gas, U.S.A.	0·56
Carburetted water-gas (26 c.-p.)	0·62
Mond gas (power gas)	0·79
Acetylene	0·91
Air	1·00

Acetylene gas can be converted into a colourless, transparent liquid under normal atmospheric pressure by cooling it to −82 deg. C., or into a solid white crystalline mass by cooling it to −85 deg. C. The gas may be liquefied at a higher temperature if also subjected to high pressure. Acetylene is feebly poisonous, but it is less poisonous than ordinary coal-gas.

Acetylene an Endothermic Compound.—Some compounds absorb heat during their formation, and evolve that heat when they subsequently undergo decomposition. Such compounds are termed endothermic, and acetylene belongs to this class. Other compounds evolve heat when they are formed and absorb heat when they are decomposed, and are termed exothermic. The endothermic character of acetylene is a factor which must be taken into consideration when considering its explosive value for engine driving, or its flame temperature, since to the heat of combustion of its component hydrogen and carbon is added the heat absorbed during its formation.

Detonation of Acetylene.—Acetylene without admixture with air can be decomposed with explosive violence by firing in it a detonator such as mercuric fulminate, but unless the acetylene is under higher pressure than ordinary atmospheric pressure the explosion is extremely local, and is comparatively harmless, as the greater portion of the acetylene remains unaffected by the detonation. The products of the decomposition by detonation are amorphous carbon and gaseous hydrogen. This amorphous carbon or "acetylene black" is now manufactured on a large scale by compressing the acetylene under a pressure of two atmospheres and exploding it by means of an electric wire or spark, air being carefully excluded. The carbon thus produced is said to form a remarkably high-grade pigment.

Explosibility of Acetylene Mixed with Air.—Any mixture of acetylene and air containing from 3 to 82 per cent. of acetylene may explode when ignited. The most violent explosion is produced when the proportion of acetylene amounts to from 8 to 10 per cent. by volume of the mixture. In the presence of air acetylene can be ignited at a temperature of 896 deg. Fahr., which is considerably lower than the igniting point of coal-gas.

Illuminating Power of Acetylene.—Under the most favourable conditions acetylene will give a flame of 48 c.-p. when burning at the rate of 1 cubic foot per hour, but this result is seldom or never attained in practice. A good commercial burner consuming commercial acetylene at a rate of 1 cubic foot per hour will give a light of about 32 c.-p. The relative illuminating values of acetylene and coal-gas per cubic foot of gas consumed per hour under good working conditions may be stated as follows :—

	Per cubic foot of gas per hour.
Acetylene	32 candles.
Coal-gas, flat flames	$2\frac{1}{2}$,,
,, incandescent mantle...	20 ,,

Acetylene is so rich in carbon that no burner has yet been devised which will consume it at a rate of 5 cubic feet per hour without producing either a smoking flame or a flame of comparatively feeble luminosity. In practice it is found necessary to employ burners incapable of passing more than 1 cubic foot of gas under ordinary pressures, and a large number of burners which consume only $\frac{1}{2}$ or $\frac{3}{4}$ of a cubic foot per hour are in use.

The relative sizes of a coal-gas flame and an acetylene flame of equal illuminating power are shown in fig. 55.

(*a*)

Fig. 55.—*a* = 16-Candle Coal-gas Flame, consuming $6\frac{1}{2}$ c. ft. of gas per hour.

(*b*)

Fig. 55.—*b* = 16-Candle Acetylene Flame, consuming ½ c. ft. of gas per hour.

The photographs show a 16-candle coal-gas flame (*a*) obtained from a No. 6 flat-flame burner when consuming 6½ cubic feet of gas per hour under a pressure of 1 in., and an acetylene flame (*b*) which was photographed on exactly the same scale, and which was obtained from a Naphey burner passing ½ cubic foot of acetylene per hour under a pressure of 3 in. The best results with these particular burners were obtained with coal-gas under a pressure of 1 in., and with acetylene under a pressure of 3 in., the difference in pressure being necessitated by the difference in the specific gravities and carbon contents of the two varieties of gas, but with some acetylene burners of small size a pressure of 1½ inches is sufficient.

Heating Power of Acetylene.—The heating value of acetylene is much greater than that of any other gas commonly used for domestic or industrial purposes. The following table shows the relative heating values per cubic foot of each of the principal commercial varieties of gas :—

	Calories.
Acetylene	379
Natural Gas, U.S.A.	·225
Coal-gas...	156
Hydrogen	82
Water-gas (plain)	76
Mond gas (power gas)	39

Acetylene is therefore far superior, volume for volume, to coal-gas for engine driving or heating purposes, but its cost is in most cases prohibitive.

in which is situated a perforated basket (C) hal carbide. The basket is introduced into or remo generator by taking off the cover, which is held by a screw and cross-piece as shown in the The water slowly rises within the generato comes in contact with the lower portion of Acetylene is immediately generated, and passe condensing coil (E), from which condensed wa time to time drawn off. From the conden passes into the gasholder (F), or may be through a purifier and then into the gasholder. carbide basket is completely flooded with wa ceases to be evolved, the water-supply cock a (D) between the condenser and the generator the sludge in the generator is removed by lever cock at the base, the carbide basket is r its contents discharged, and the apparatus is t be recharged.

The water-tank is only slightly raised above t and the gas outlet pipe from the generator is higher than the top of the tank, so that it is in the water to flow over into the condenser. which admits water into the generator is of bore, so that water cannot flow into the gen rapidly, and in the event of any obstructio in the outlet pipe from the generator the the gas within the generator drives back the the carbide before the pressure has become con

The illustration (fig. 56) shows a plant i supply sixteen acetylene flames, each consum foot per hour, for a period of five hours with the holder.

When the quantity of acetylene to be man large, a number of these small generators ar in the form of a battery to one large gasholder (

This is preferable to making one large g contain all the carbide to be decomposed, decomposing a large bulk of carbide in this heat accumulated within the generator during of decomposition is apt to be excessive. The

Fittings, pp. 197—200.

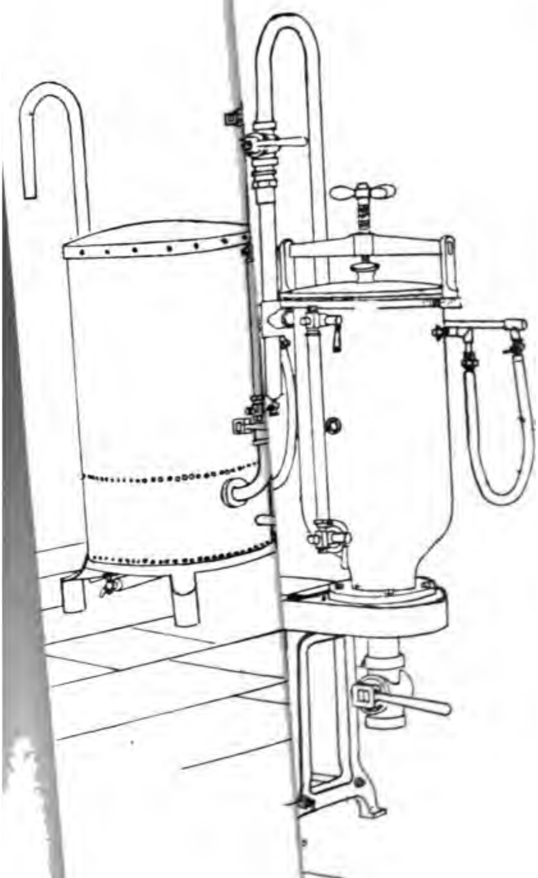


Fig. 57-[illegible]apacity.

are sometimes provided with water-jackets, but this is quite unnecessary, since no harm is done if the temperature of the generator does not rise above that which the hand can bear without discomfort, and there is no difficulty in decomposing the whole of the carbide without exceeding this temperature if the flow of water to the carbide is stopped when necessary. The battery of generators shown in fig. 57 is connected to a suitable condenser, and is adapted to fill a holder of 4,000 cubic feet capacity.

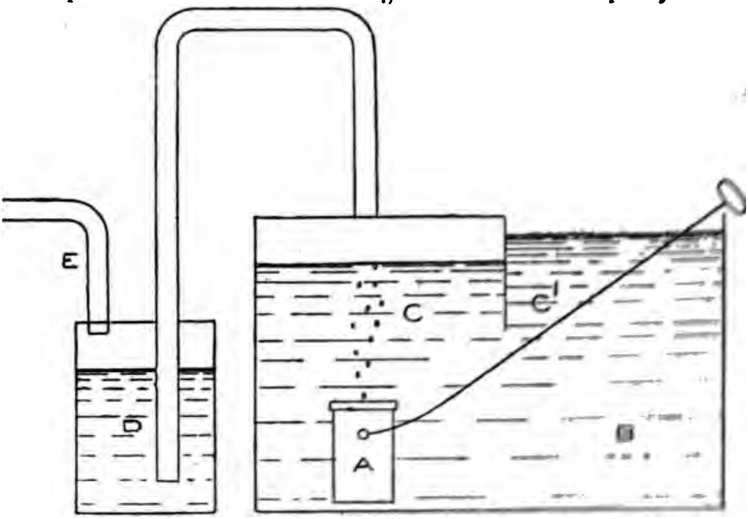


Fig. 58.—Non-Automatic Carbide-to-Water Generator.

In water-jacketed generators or in generators in which carbide falls into a large volume of water, overheating may occur even though the temperature of the walls of the generator be not materially raised.

Another form of non-automatic generator is that manufactured by the British Pure Acetylene Gas Syndicate (fig. 58). This apparatus also has the merit of extreme simplicity. The carbide is placed in an iron pot (A) hav a lid with a central perforation. This is plunge a tank (B), which is open to the air, into a water chamber (C) which is closed (by C1) from the open air. The water slowly enters the carbide pot through the perforation, and the gas generated bubbles up through the water, and passes through a washer (D), and from thence passes through a pipe (E) to a gasholder. When employing an apparatus of this type, a certain proportion of acetylene is lost owing to its solubility in water, and the water soon emits a disagreeable odour owing to the solubility of sulphuretted hydrogen, ammonia, and other impurities in the water. The foulness of the water is not, however, a matter of importance when the generator is situated at some distance from the dwelling supplied with acetylene, and the fact that the water removes a con-

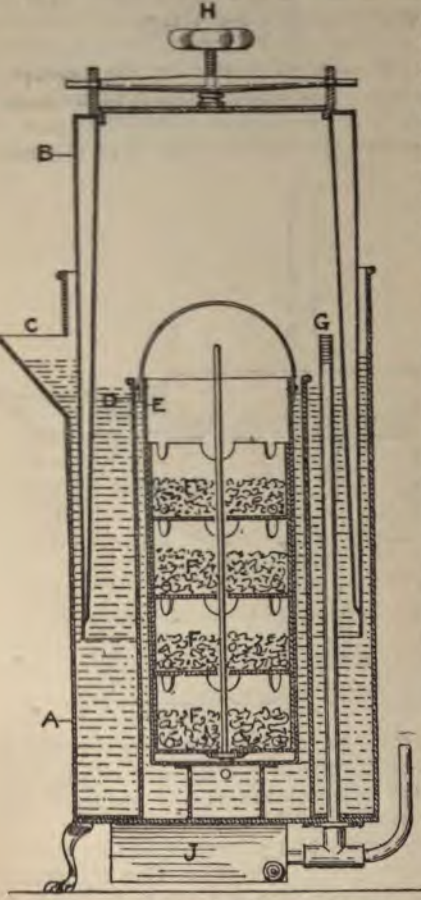


Fig. 59.—Automatic Water-to-Carbide Generator.

siderable proportion of the impurities from the gas is some compensation for the loss of acetylene which occurs.

Automatic Generators.—In Strode's "Simplicity" generator (fig. 59), which is manufactured for installations not exceeding twenty lights, water rises to carbide, the supply of water to the carbide being automatically controlled by the rise and fall of the bell of the gasholder. In the illustration, A is the gasholder tank, B is a tapered gas bell, C the lip for filling the tank with water, D a cylindrical chamber for holding the carbide container, E the carbide container attache to D by a bayonet joint, F are trays in which the carbide is placed, O is the gas outlet pipe, H the lid for introducing or removing the carbide container, and J is a trap for condensed water.

Each tray is half filled with carbide and placed in the generator. When the generator cover has been closed, the gasholder tank is slowly filled with water until sufficient gas has been generated to cause the gas bell to rise about 6 in. More water is then added until the water level mark is reached. The apparatus will then work without attention until the whole of the carbide has been decomposéd, because when the gas is generated at a faster rate that it is consumed the bell rises and the water level in the tank is in consequence lowered, and water ceases to flow into the generating chamber; while, if the consumption is more rapid than the generation, the bell descends, and, owing to its tapered form, the lower it descends the larger is the volume of water displaced, and the larger is the volume of water which flows to the generating chamber.

Strode's "Perfect" (fig. 60) generator is another form of automatic generator, but in this case the carbide is dropped into a large volume of water, instead of water being allowed to rise around the carbide. The carbide container (C) is situated above a revolving cone having a spiral chamber into which the carbide falls by its own gravity. The cone is actuated by a water-wheel (D) which discharges carbide into a wire-gauze chamber or strainer (F), which is immersed in the water con[illegible] generator-tank.

When water is discharg[illegible] ckets of the water-wheel until the po[illegible] turns a quarter revolution. The discharge of water into the pocket is regulated by the rise and fall of a tapered gasholder bell

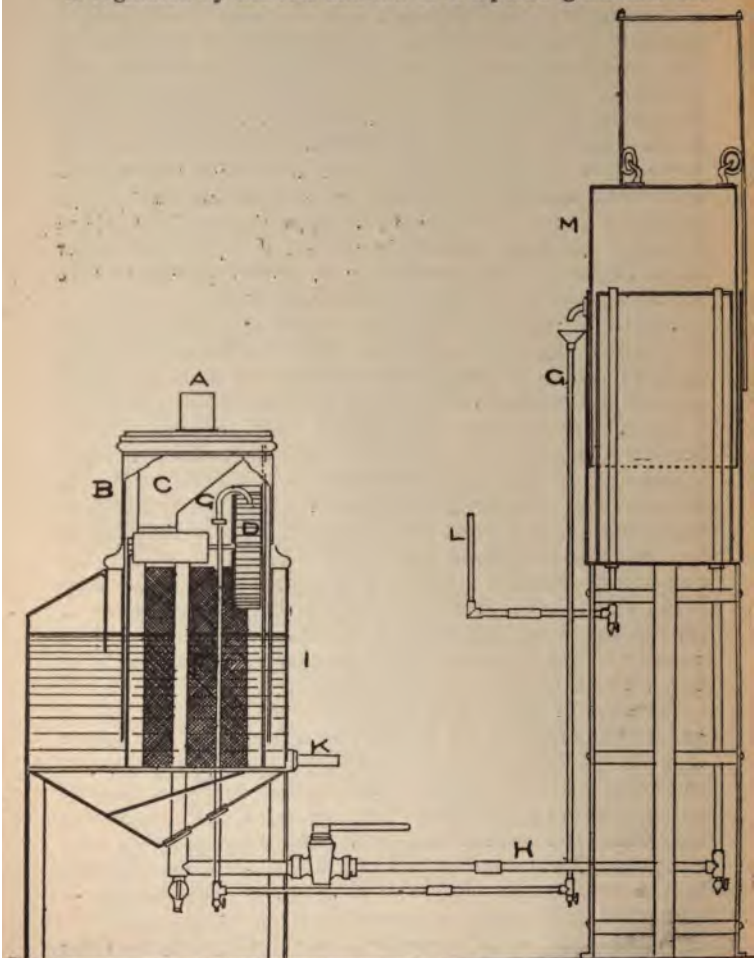


Fig. 60.—Automatic Carbide-to-Water Generator.

(M), the walls of which displace the water in the gasholder tank when the bell descends, and causes it to overflow and be discharged upon the wheel. The water employed to actuate the wheel falls subsequently into the generator tank (I), which is provided with a suitable overflow.

In order to maintain the necessary quantity of water in the gasholder tank, a water regulating tank fitted with double ball-valves and an overflow, and connected with the water main, is provided. A box-shaped cover (B) slips over the carbide container and water-wheel, and dips some distance into the water, thus forming a gas-tight seal. The container can be charged with carbide by removing the cap (A), water is conveyed from the gasholder tank and discharged over the wheel through the pipe (G), the gas produced passes from the generator to the gasholder through the pipe H, while K is the pipe employed for filling the generator tank with water, and L the pipe which conducts the acetylene from the gasholder to the burners.

Location of Generators. — Acetylene generators should never be fitted in the basement or any other part of a dwelling, for the operation of cleaning and recharging is always accompanied by the evolution of a disagreeable odour, which is so penetrating that it soon becomes disseminated throughout the entire building. The generator should be situated in a detached building, and should never be exposed to the action of frost, as the freezing of the water in the gasholder tank or supply cistern would put the apparatus out of action. The carbide may be stored in the generator house on platforms or shelves raised above the floor level, so that if a bucket of water be accidentally upset the water cannot come in contact with the vessels in which the carbide is stored. The generator should be charged in daylight, and no flames should be allowed in the generator house. When the charging cannot be performed by daylight a glazed window should be provided in the generator house, and a lamp should be fitted outside the house in such a position that sufficient light will be thrown by the lamp through the window into the generator house to enable the necessary work to be accomplished.

The waste sludge should never be passed directly into a sewer, but should be discharged into an open intercepting pit or tank, so that the evolution of gas from any portion of the carbide which may have escaped decomposition in the generator cannot result in the formation of an explosive mixture in a confined space.

CHAPTER [illegible]

THE PURIFICATION [illegible] OF [illegible]

The Impurities in Commercial [illegible].—[illegible] mercial [illegible] calcium [illegible] aluminium [illegible] under the [illegible] reaction [illegible] contaminated [illegible] Phosphuretted [illegible] sition of [illegible] decomposition [illegible] during the [illegible] addition to [illegible] flows from [illegible] and finely [illegible] is a matter [illegible] passing [illegible] allowed to [illegible]

Liquid Drawn from the Condenser.—[illegible] able proportion [illegible] leaves the generator [illegible] through a condenser, and [illegible] from time to time withdrawn [illegible] siderable quantity of [illegible] drawn from the [illegible] been found by Professor Lewes to contain the following substances:—

	Grams per Litre.
Lime	16·28
Sulphur	6·92
Phosphorus	4·01
Iron and Alumina	0·19
Ammonia	7·14

It is evident, therefore, that by simply passing the gas through a condensing coil it may be purified to a certain extent, and for outdoor illumination it is not necessary to subject the acetylene to further purification, but for indoor use it should be more completely purified.

Frank's Acid Cuprous Chloride as a Purifier.—For the more complete removal of the ammonia, sulphuretted hydrogen, and phosphuretted hydrogen, many systems have been proposed, but few are of any value for domestic use. Frank's purifier, consisting of a solution of cuprous chloride in hydrochloric acid has proved one of the most successful. The siliceous porous earth known as kieselguhr may be impregnated with this solution, since it is not attacked by the acid solution, and simply acts as an absorbent. It is found that the solid material thus prepared is less objectionable to handle than the liquid. The ammonia in the gas is neutralised by the acid and is converted into ammonium chloride, the sulphuretted hydrogen is decomposed and produces a black precipitate of copper sulphide, and the phosphuretted hydrogen is partly absorbed and partly precipitated as copper phosphide.

Ulmann's Chromic Acid as a Purifier.—Another good purifying agent is the solution of chromic acid mixed with sulphuric acid proposed by Ulmann. This liquid also removes ammonia, sulphuretted hydrogen, and phosphuretted hydrogen from the acetylene.

Bleaching Powder as a Purifier.—Bleaching powder may also be used for the removal of sulphuretted hydrogen and phosphuretted hydrogen, but the ammonia must first be removed by other means, because it may possibly react with the hypochlorite of lime to form an explosive chloride of nitrogen. The hypochlorite of lime in the bleaching powder oxidises the phosphuretted hydrogen and the sulphuretted hydrogen, and produces phosphate of lime and sulphate of lime respectively. To remove any traces of chlorine which may be carried forward from the bleaching powder, the gas after leaving a purifier containing bleaching powder should be passed through a vessel containing slaked lime. To render the bleaching powder more porous, Wolff mixes with it a small proportion of lead chromate, and the mixture then appears as a powder of a uniform yellow colour. Thorn and Hoddle employ a mixture of bleaching powder and oxide of iron.

It has been a common practice to mix sawdust with the bleaching powder to expose a larger surface of the powder to the action of the gas, but Ahrens has shown that under certain conditions reaction may take place between the sawdust and the bleaching powder, and be accompanied by the evolution of heat. Sawdust should therefore be discarded in favour of kieselguhr, powdered coke, lead chromate, or other substance unaffected by the bleaching powder. Professor Lewes considers that every precaution should be used when adopting bleaching powder as a purifying agent, because many cases of spontaneous ignition and explosion have occurred when air has been admitted to bleaching powder purifiers which have been in use for some time, and because it has long been known that free chlorine may cause the explosion of a mixture of air and acetylene.

White "Haze" Produced by Combustion of Acetylene.—When acetylene has been burning for a considerable period in a room not efficiently ventilated, a white haze is sometimes apparent in the atmosphere. This haze is only formed when the acetylene has not been purified from phosphuretted hydrogen, and is due to the formation of phosphorus pentoxide, which has a remarkable affinity for water vapour, with which it forms phosphoric acid. An extremely small proportion of phosphuretted hydrogen will give rise to the white haze, and it is imperative that this impurity should be removed before the acetylene is consumed in confined spaces.

The formation of the haze may often be prevented by simply passing the gas through a condenser, then through a washer, and finally through a dehydrating material such as quicklime; but it is always safer to pass the gas through one of the purifying agents previously mentioned.

Combustion of Acetylene.—For complete combustion one volume of acetylene requires 12·5 volumes of air, whereas one volume of coal-gas requires only about 5¾ volumes of air. To enable the acetylene flame to meet with sufficient air for its complete combustion, it is necessary to supply the gas to the burner under higher pressure than that employed for coal-gas luminous flames, and to use burners having smaller orifices than those provided for coal-gas. To produce a luminous flat flame with coal-gas, a gas pressure of about ¾ in. is, as a rule, most suitable, but for acetylene the best results are usually attained when the gas issues from the burner under a pressure of from 1½ to 3 inches. The exact degree of pressure required to obtain the best results varies with different burners, but it should be remembered that every burner requires to be supplied with gas under a certain definite pressure, and that any departure from that point, whatever it may be, must result in a reduction in the illuminating efficiency obtained from the acetylene.

The acetylene flame photographs reproduced in figs. 61, 62, and 63 show the effect of variations in pressure upon the appearance of the flame. The burner employed was a "one-cubic-foot-per-hour" burner of the Naphey type, and the three flames were obtained from the same burner.

For fig. 61 the gas was supplied to the burner under a pressure of 4 in. This pressure was excessive, and caused the top of the flame to become elongated and forked in the centre.

For fig. 62 the pressure was reduced to 1 in. This pressure was too low and resulted in an excessive thickening of the lower portion of the flame. The top of the flame had a tendency to become elongated at its outer edges, and became depressed in the centre. Although the blue spot in the lower part of the flames, which was so conspicuous when an excesive pressure was employed, almost disappeared, the flame was too smoky for practical use, and lost its extremely brilliant appearance.

For fig. 63 the gas pressure was adjusted until the most perfect flame was obtained, and was then found to be equal to a 2-in. column of water.

Fig. 61.—Pressure = 4 inches

Fig. 62.—Pressure = 1 inch.

Fig. 63.—Pressure = 2 inches.

Bray Burners for Acetylene.—Bray burners for acetylene resemble Bray coal-gas burners in outward appearance, but have extremely small orifices. They give a good result for a time, but gradually become choked a carbonaceous deposit. They can, however, be bought retail for 2d. each, and many acetylene consumers employ these burners, and discard them when they begin to yield a smoky flame, in preference to buying more costly burners which remain serviceable for a longer period.

The "Naphey" Burner.—The tendency of acetylene to burn with a smoky flame and to leave a carbonaceous deposit in the burner orifices greatly detracted from the practical utility of the gas when it was first adopted for domestic lighting. To overcome this trouble Bullier and others devised burners having air passages formed in the burner tip. A burner of this type is that known as the "Naphey" burner (fig. 64). It consists of a metal tube having two arms, which near their extremities are bent towards one another at right angles. The end of each arm is fitted with a steatite or lava tip having side holes for the admission of air, and a central passage for the exit of both gas and air. When the jets issuing from the two burner tips are ignited, the two flames impinge upon one another and produce a flat flame. Owing to the provision of the air holes, the flames do not quite touch the tips of the burner but burn just above them, and consequently the burner tips are not so speedily blocked with carbon as those of the Bray union-jet type. In these burners the air does not mix with the gas in sufficient volume to materially reduce its illuminating power, but merely forms an envelope around the issuing gas and protects it from contact with the heated burner tips. A modification of the Naphey burner which has also been extensively used is shown in fig. 65.

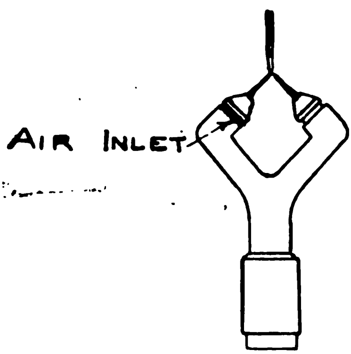


Fig. 64.—Naphey Burner.

The "Shaffer" Burner.—When the Naphey burner had been in use for some time it was found that the metal arms sometimes became warped, with the result that the two jets were displaced from their proper relative positions, and the flame became distorted and had a tendency to smoke. This trouble was, however, soon overcome by constructing the arms of the same rigid material as the burner's tips. Shaffer's burner (fig. 66) is a good example of burners of this type.

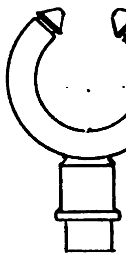


Fig. 65.—Modification of Naphey Burner.

A host of burners of both the Naphey and the Shaffer type are on the market, but it does not come within the scope of the present series of articles to attempt to discriminate between them, or to discuss the various claims for priority of discovery.

The "Phos" Burner.—A number of burners fitted with mechanical devices for removing the carbon deposits as soon as they are formed have been patented, but the only one which calls for mention is the "Phôs" burner (fig. 67). The construction of the burner will readily be

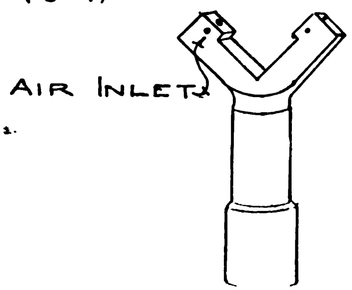


Fig. 66.—"Shaffer" Acetylene Burner.

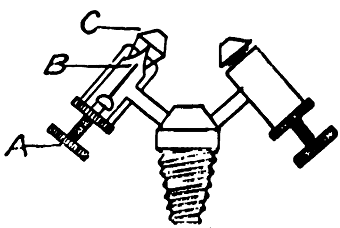


Fig. 67.—"Phos" Acetylene Burner.

understood by reference to the illustration. The deposit is removed by screwing up the button (A), which pushes the wire (B) through the burner tip (C). The arms of the burner are made of soft metal, and can be twisted into their proper position with the fingers if they ' warped and cause distortion of the flame.

Incandescent Mantles with Acetylene.—From time to time acetylene burners of the Bunsen type have been constructed with the intention of using them in conjunction with incandescent mantles, but although a higher lighting efficiency may be obtained from the mantles with acetylene than with coal-gas, the former gas is at present too costly and too difficult to use in atmospheric burners to be suitable for incandescent lighting.

Cooking and Heating Appliances.—Acetylene can be used with specially-constructed burners for cooking and heating purposes in the same manner as coal-gas, but it is more costly, and it is more difficult to construct satisfactory atmospheric burners for acetylene than for coal-gas, owing to the larger proportion of carbon contained in the acetylene and its wider range of explosibility. Acetylene has, however, been successfully adapted to ring burners for the boiling of water, and the troubles attendant upon its use as a heating agent for other appliances will no doubt be overcome after further experience. Luminous flames can be employed for heating and cooking in the same manner as luminous coal-gas flames, but have a greater tendency to emit free carbon.

CHAPTER XXV.

PIPES AND FITTINGS FOR ACETYLENE INSTALLATIONS — SOME PORTABLE ACETYLENE APPLIANCES.

Pipes and Fittings.—All buildings in which acetylene is used should be quite free from any odour of the gas, and where an odour is present it is due to the use of defective pipes or fittings. No compo pipe should be employed, but all pipes should be iron barrel of the best quality, and should be connected together without the use of packing or paint. White lead mixed with oil, and other substances of a like nature commonly employed when connecting pipes for coal-gas distribution, should not be used, because they are attacked by the acetylene, and their cementing power is soon destroyed. The threads may be dusted with finely-ground plumbago, but the pipes should be sufficiently well made and threaded to enable gas-tight joints to be made without the aid of any cementing material. The brackets and pendants should be constructed of stout metal, preferably iron. Fittings of the best quality which have been used for coal-gas may be employed for acetylene if they are thoroughly overhauled and refitted by a competent fitter, but cheap brass fittings of brazed tube must be rejected. When the work of connecting all the parts of an installation has been completed, the inst
should be tested until found to be perfectly
or gas-tight under a pressure of 20 in.
attempting to ignite the gas at any
gasholder should be filled with ac

tube should be attached to the gas-bracket or pendant most distant from the gasholder. The free end of the rubber tube should then be passed through a window into the open air, and acetylene from the holder should be allowed to pass through it until all the air in the pipes and fittings has been replaced by acetylene. The freedom of the acetylene issuing from the mouth of the rubber tube from contamination with air may be ascertained by passing it into an inverted test-tube. If the test-tube, after being filled with gas, be removed from the neighbourhood of the rubber tube, and the gas within it be ignited, it will burn quietly if free from air, but will ignite with a sharp explosion if air be present in dangerous quantity.

Portable Appliances.—The high illuminating power of the acetylene flame, even when the gas is being consumed at the rate of only ½ cubic foot per hour, renders this illuminant very valuable for all kinds of portable lamps. For the temporary lighting of building and engineering works, for searchlights and signalling, for carriage and hand-lamps, for the lighting of camps, and for isolated lamps in village streets or public or private grounds, acetylene is admirably adapted. For portable lamps automatic generators have always to be used, and the carbide has usually to be broken into pieces of very small dimensions. The yield of available gas per pound of carbide consumed is not, therefore, so large as that obtained with stationary non-automatic generators. Portable acetylene generators can be constructed to meet almost every conceivable requirement, and the ease and safety with which carbide can be transported, and acetylene generated by simple contact of the carbide with water, renders acetylene much preferable to oil as an illuminant for outdoor use. A number of acetylene table-lamps for indoor use have also been devised, but none are altogether satisfactory, and the garlic-like odour of impure acetylene is generally more or less noticeable in rooms in which they are employed. Even if they do not emit an odour when in use, the operation of cleaning and recharging the generator cannot be performed without creating a nuisance. The cleaning may, of course, be performed in the open air outside the house, but only

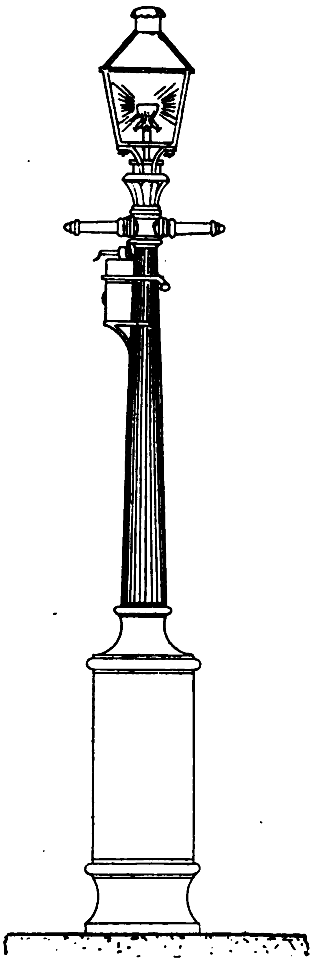


Fig. 68.—Generator affixed externally to Lamp Column.

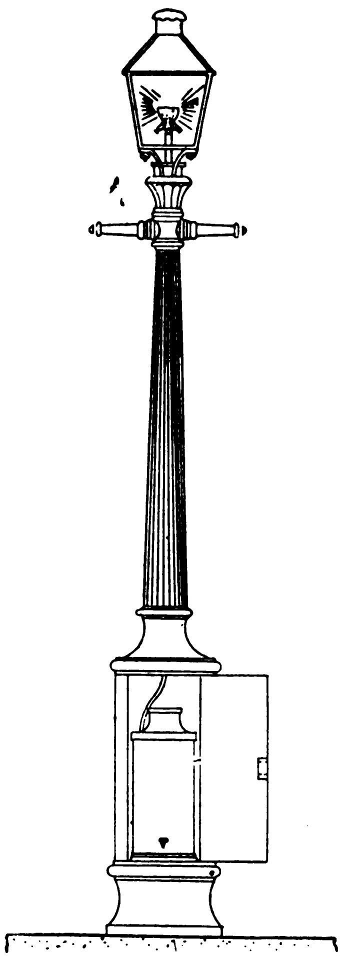


Fig. 69.—Generator located in Chamber at Base of Lamp Column.

an acetylene enthusiast will use a lamp requiring such treatment throughout the cold winter months.

Street Lamps.—Street lamps may be lighted with acetylene generated at a central station and conveyed through small gas mains to the lamps in the same manner as coal-gas; but where isolated lamps in villages or carriage drives have to be provided, a small portable generator may be attached to the upper part of the lamp column as shown in fig. 68, or may be located in a lock-up chamber in the base of the column as shown in fig. 69.

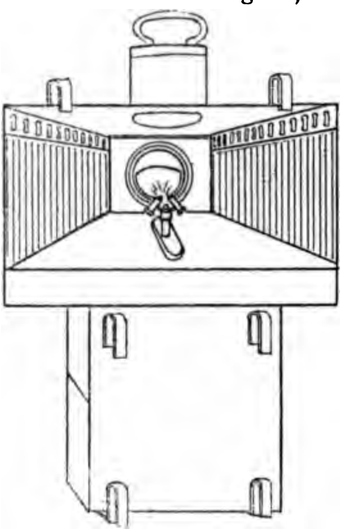


Fig. 70.—Acetylene Lamp for Cars or Omnibuses.

Lamps for Cars or Omnibuses. — A large number of cars and omnibuses are now lighted by acetylene, the "Phôs" Company alone having already fitted 2,000 of the London omnibuses with acetylene lamps in place of the oil lamps formerly employed. One of the "Phôs" lamps used for this purpose is shown in perspective in fig. 70, and the lower portion of the lamp in which the acetylene is generated is shown in section in fig. 71. The lamp is fixed on the right hand front of the car, and shows a light ahead at the same time that a comparatively brilliant light is thrown into the car. The carbide container is situated in the lower part of the lamp. The lid of the container is of wire gauze or perforated metal, and the base consists of a metal plate which is pressed upwards by a spring. The object of the spring is to press the upper layer of carbide against the perforated lid, and to thus ensure uniform and continuous decomposition. The water reservoir is situated above the carbide container, and is fitted with an adjustable valve from which water drips upon the perforated lid of the carbide container and comes in contact with the carbide. As the lamp is fitted outside the car no danger is incurred by its use; and no annoyance to inside passengers is caused by leakage of gas, if any leakage occurs.

All the different forms of "Phôs" lamps are constructed upon this principle, although slight modifications in constructive details are made to render each lamp suitable for the particular purpose for which it is intended.

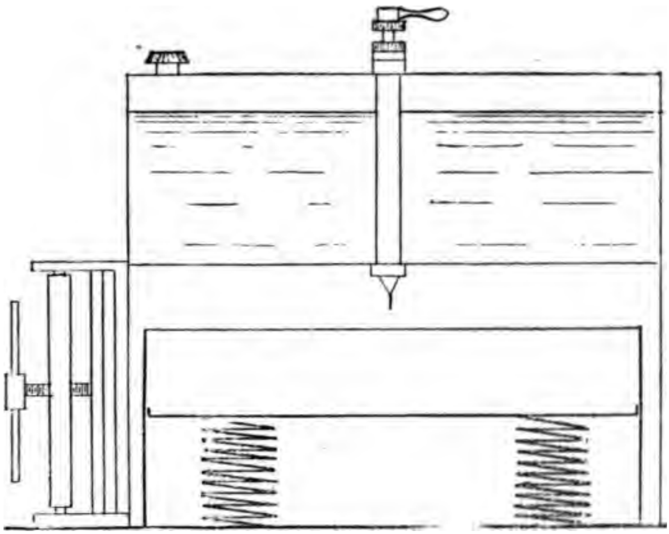


Fig. 71.—Generator for Omnibus Lamp.

Lamps for Building Works.—Hand lamps consisting of lanterns connected to portable acetylene generators are made in all sizes and designs. A form of lamp suitable for use on building and engineering works is shown in fig. 72.

Cycle Lamps.—Patents have been obtained for a great number of acetylene cycle lamps, many of which closely resemble one another in all essential details; but few, if any, of the lamps are altogether satisfactory. In some the carbide has to be used in the form of cartridges, and it is often difficult to obtain these at the moment when they are required. In others the water is admitted to the carbide through a porous medium such as felt or cotton wick, and this soon becomes choked with lime. Others are provided with a carbide container of insufficient capacity, and the lamp goes out before the evening's journey is completed. Many of the lamps cannot be used without the generation

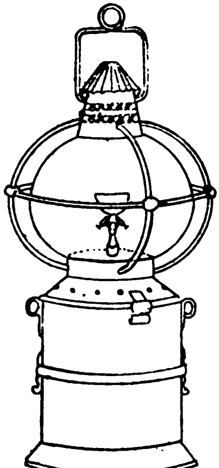


Fig. 72.—Acetylene Lamp for General Use.

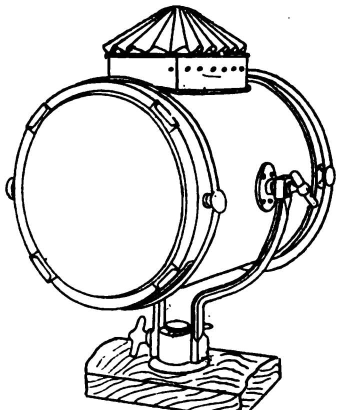


Fig. 73.—Projector for Use with Acetylene.

of an offensive odour, and in many the gas continues to be generated for a long period after the lamp has been extinguished. In spite, however, of all these disadvantages, and of the fact that acetylene is more costly than oil, acetylene cycle lamps remain very popular, and are in demand in every part of the country.

Signal and Searchlights.—The brilliancy and penetrating power of the acetylene flame, and the ease and freedom from danger with which calcium carbide, as compared with oil, may be transported, renders it extremely valuable for military purposes, and it may also be used with advantage as a searchlight when the more powerful electric arc light is not available. It has been proposed that acetylene searchlights should be used by fire brigades to enable the men to see more clearly through the steam and smoke in which the burning structure is frequently enveloped, and generators mounted on wheels, like those often used by contractors, have already been constructed for this purpose. The acetylene signal and searchlights constructed by different firms of generator makers are usually supplied with acetylene from flexible pipes connected to small generators which work upon the same principle as those provided for domestic lighting. A projector to be used with acetylene for searchlight purposes, which is supplied by the "Bon-Accord" Company, and which is intended especially for use on ships, but is adapted for use in other situations, is shown in fig. 73.

CHAPTER XXVI.

BRITISH LAWS AND REGULATIONS RELATING TO ACETYLENE AND CALCIUM CARBIDE—FIRE INSURANCE.

When calcium carbide was first placed upon the markets as an article of commerce very little was known by the general public concerning its nature and properties, and a number of acetylene generators were constructed which were a source of danger to those to whom they were sold. Fatal accidents, moreover, occurred in America and on the Continent, owing to the attempt to use acetylene compressed and liquefied in metal cylinders under high pressures, and it was not until acetylene in this condition had been proved to be an extremely dangerous explosive that the use of compressed or liquefied acetylene was abandoned. The British Government speedily recognised the desirability of safeguarding the public by introducing reasonable regulations as to the conditions under which carbide and acetylene may be used, and public confidence in the new illuminant has been restored by the fact that, since these regulations have been enforced, acetylene has been extensively used in this country under a great variety of conditions with very few serious accidents.

Acetylene has now been used for a sufficiently long period, and in sufficiently large quantities, to prove that it may be safely used by the general public for all ordinary illuminating purposes, provided that the conditions under which it is used do not violate any of the legal enactments, of which brief digests are given in the present chapter, and that such reasonable precautions are taken as are set forth in the printed Regulations issued by the Public Control Department of the London County Council for use within the area under the jurisdiction of that Council.

The Storage and Transport of Carbide.

Calcium Carbide placed under the Petroleum Acts.—By an Order in Council, dated February 26, 1897, calcium carbide is brought under the Petroleum Acts, 1871 to 1881, with the deletion of certain clauses which relate only to petroleum and similar liquids, and with the following additions :—

The label on a vessel containing calcium carbide must bear in conspicuous characters the words : —

"Carbide of Calcium."

"Dangerous if not kept dry."

"The contents of this package are liable, if brought into contact with water, to give off a highly inflammable gas."

Also every package or vessel must bear upon it :—

(*a*) The name and address of the consignee or owner, if the package is to be kept.

(*b*) The name and address of the sender, if the vessel is to be sent or conveyed.

(*c*) The name and address of the vendor, if the vessel is to be sold or exposed for sale.

Licence Required.—Under the Petroleum Acts it becomes unlawful for any person to keep any quantity of calcium carbide, whether for sale or for use, without a licence from the Local Authority. By an Order in Council, dated July 7, 1897, a quantity of calcium carbide not exceeding 5 lbs. is permitted to be kept without a licence on any premises, provided that it be kept in "separate, substantial, hermetically closed metal vessels containing not more than 1 lb."

Where calcium carbide is to be stored in greater quantities than 5 lbs. in 1 lb. tins, a licence, granted for a sum not exceeding 5s. per annum, must be obtained from the Local Authority, and must be renewed every year. The conditions to be attached to such licence rest entirely Local Authority, and may vary in different dis usually only such reasonable conditions as are required to afford protection in the use and storage of the carbide are written upon the licence. In most districts the issue of carbide licences is made from the office of the Surveyor to the Borough or District Council, but in the area controlled by the London County Council the licences are issued from the Public Control Department of the Council after inspection of the premises and of the vessels in which the carbide is to be stored, and the apparatus in which it is to be decomposed, by one of the Council's inspectors.

Acetylene.

Liquid or Compressed Acetylene Prohibited.—By an Order in Council, dated November 26, 1897, acetylene is declared to be an explosive when in a liquefied condition, or when subjected to a pressure exceeding 100 in. of water, and in such condition acetylene is "prohibited from being manufactured, imported, kept, conveyed, or sold."

Exception.—"If it be shown to the satisfaction of the Secretary of State that acetylene declared to be an explosive by this Order, when in admixture with any substance, or in any form or condition, is not possessed of explosive properties, the Secretary of State may by an Order exempt such acetylene from being deemed to be an explosive within the said Act."

Compressed Mixtures of Acetylene and Oil-Gas.—By an Order of the Secretary of State, dated March 28, 1898, it is ordered that a mixture of acetylene and oil-gas not containing more than 20 per cent. by volume of acetylene, and not subjected to a greater pressure than 150 lbs. to the square inch, shall not be deemed an explosive within the meaning of the Act, provided that the acetylene and oil-gas be mixed together before the gases are compressed.

Acetylene compressed into Porous Substances.—Certain substances have the property of absorbing a large proportion of acetylene when the gas is passed into them under pressure, and of evolving the acetylene in a continuous stream when the pressure is relieved or the temperature of the substance is raised. The substance containing this absorbed acetylene does not possess the explosive character of liquefied or highly-compressed acetylene. The liquid known as acetone is capable of absorbing 300 times its own volume of acetylene when the gas is passed into it under a pressure of 180 lbs. per square inch. An Order of the Secretary of State (No. 6), dated April 10, 1901, declares that acetylene, when compressed into porous substances, with or without acetone, shall not be deemed to be an explosive within the meaning of the Act, provided that the porous substances to be used shall be similar in every respect to samples deposited at the Home Office, that the pressure does not exceed 150 lbs. to the square inch, and that certain other conditions set forth in the Order be not violated.

Acetylene Mixed with Air Prohibited.—By an Order in Council, dated May 15, 1900, it is ordered that acetylene in admixture with air or oxygen shall be prohibited from being manufactured, imported, kept, or sold. Nothing in this Order applies to mixtures produced by admitting air into the burner, or to air unavoidably admitted into the generator when recharging.

Conditions of Licence from Local Authority.—Local Authorities may attach any conditions which they consider necessary to the carbide licences issued in the districts over which they have control, but the printed regulations issued by the London County Council may with advantage be used as a model by other Local Authorities, and the following extracts therefrom include all the essential conditions.

London County Council.—In addition to the regulations as to the labelling of vessels containing carbide to which reference has already been made, the London County Council has drawn up the following list of rules relating to acetylene and calcium carbide for use within the County of London:—

1. Application to the Council for a licence to keep carbide of calcium at any place in the County of London (except the City of London) must be made upon the form provided for the purpose, which can be obtained by application in writing, addressed to the Chief Officer,

Public Control Department of the London County Council, 6, Waterloo Place, S.W.

2. Every application must be accompanied by a fee of 5s. in money, or, if sent through the post, by cheque or postal order for that amount payable to the order of the London County Council. The fee will be returned to the applicant if the licence be not granted.

3. Every application must state—

(*a*) The quantity of carbide which the applicant desires to keep;

(*b*) The proposed place and method of storage;

(*c*) If the carbide is only to be kept in closed vessels, or if it is to be used in the manufacture of acetylene gas.

4. Carbide of calcium should be kept in strong metal vessels, and—

(*a*) Such vessels should be constructed and closed as to prevent the admission of water or atmospheric moisture.

(*b*) Such vessels should only be opened for the time necessary for the removal of any required quantity of carbide, or for the refilling of the vessels.

(*c*) No vessel should have a greater capacity than 3,696 cubic inches (equal to a cylindrical vessel 14 in. in diameter and 24 in. in depth).

(*d*) Every vessel of a greater capacity than 2 lbs. should be provided with a lock or be placed in a locked receptacle, so as to prevent unauthorised persons gaining access to the contents.

(*e*) Copper should not be used in the construction of vessels for containing carbide.

5. Vessels containing carbide of calcium should not be kept inside dwelling-houses, but preferably in dry and well-ventilated outbuildings.

6. Small quantities of carbide for sale or immediate use will, however, be allowed in shops, dwellings, or workshops, upon licensed premises, if the arrangements are satisfactory.

7. The Council proposes only to grant licences to keep carbide of calcium which is pure (in a commercial sense),

i.e., which contains no impurities liable to generate phosphuretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously.

8. Where carbide of calcium is kept for the manufacture of acetylene gas, it is desirable that such of the following precautions for ensuring safety as are applicable to the circumstances, should be adopted:—

(*a*) Every apparatus for generating and storing acetylene gas should be placed in an outbuilding. (This does not apply to portable apparatus holding a charge of less than 2 lbs. of carbide.)

(*b*) Such building should be situate as far as may be practicable from inhabited buildings, and should be well ventilated.

(*c*) No fire or artificial light as would ignite inflammable gas should be taken into or near the building or place where a gasmaking apparatus is situate.

9. Every apparatus (including generator and gasholder) used for acetylene gas should as far as practicable be constructed and used so as to provide against the special risk, *i.e.* :—

(*a*) Copper should not be used in any part of the apparatus;

(*b*) The various parts should be of adequate strength;

(*c*) Escape of gas from the apparatus should be carefully guarded against;

(*d*) Satisfactory provision should be made against dangerous development of heat;

(*e*) Satisfactory provision should be made against undue pressure by the employment of an adequate safety valve connected with a pipe discharging into the open air, and a suitable pressure gauge should be attached to the apparatus:

(*f*) Provision should be made for the residue of the carbide being mixed with at least ten times its bulk of water on being removed from the apparatus;

(*g*) No person should have charge of an appar until he has been properly instructed in its manag

10. Licences are granted for keeping carbide of calcium for periods not exceeding one year, and prior to expiration application must be made for their renewal. Notice of the expiration, and a form of application for renewal, is sent to each licensee at the proper time.

With reference to the foregoing regulations it may be mentioned that under certain conditions, which seldom exist in practice, copper may be attacked by acetylene, and a highly explosive compound, known as copper acetylide, formed. Danger from overheating or excessive pressure only exists when generators of faulty design or construction are employed.

Danger of spontaneous ignition of the acetylene through the presence of impurities in the carbide does not exist at the present time, because the quantities of phosphuretted hydrogen and siliciuretted hydrogen evolved from the carbide now manufactured are much below the danger limits.

The following is a copy of the "application form" for a carbide licence issued by the London County Council :—

LONDON COUNTY COUNCIL.

PUBLIC CONTROL DEPARTMENT.

PETROLEUM ACTS, 1871 TO 1881,

And Orders in Council dated February 26, 1897, and July 7, 1897.

............Reg. No.

Application to the London County Council for a Licence to keep Carbide of Calcium.

This application should be fully filled up in accordance with the following instructions, and forwarded to the Chief Officer of the Public Control Department, London County Council, 6, Waterloo Place, S.W., with a P.O. or cheque for 5s., payable to order of the London County Council, and crossed. This fee will be retained if the licence be granted, or returned to the applicant if the licence be refused.

State Christian name and surname of the applicant. If a firm, the names of each member in full. If a company, the name of the company and its secretary.	
State situation of the premises for which the licence is required.	
State quantity desired. If the quantity is 10 cwt. or more, a plan must accompany this application, showing the proposed place and method of storage, and the buildings within 50 ft. of such place. The plan must be to the scale of $\frac{1}{8}$ in. to 1 ft.	
State if the carbide will be kept and sold unopened in the vessels in which it is received, and, if not, what will be done with it.	
State in what vessels the carbide will be kept, capacity of vessels, how closed against moisture, and of what material constructed.	
State (*a*) in what part of the premises the carbide is to be kept; (*b*) the construction of the store; (*c*) if the store is used for other purposes, and, if so, what.	
State if the carbide is to be used for the manufacture of acetylene gas, and if so, state— (*a*) The make and capacity of the generator.	

Comparison of Thermometers.

Centi-grade or Celsius.	Fahren-heit.	Centi-grade or Celsius.	heit.	Centi-grade or Celsius.	Fahren-heit.	Centi-grade or Celsius.	Fahren-heit.
260	500	225	437	190	374	155	311
259	498·2	224	435·2	189	372·2	154	309·2
258	496·4	223	433·4	188	370·4	153	307·4
257	494·6	222	431·6	187	368·6	152	305·6
256	492·8	221	429·8	186	366·8	151	303·8
255	491	220	428	185	365	150	302
254	489·2	219	426·2	184	363·2	149	300·2
253	487·4	218	424·4	183	361·4	148	298·4
252	485·6	217	422·6	182	359·6	147	296·6
251	483·8	216	420·8	181	357·8	146	294·8
250	482	215	419	180	356	145	293
249	480·2	214	417·2	179	354·2	144	291·2
248	478·4	213	415·4	178	352·4	143	289·4
247	476·6	212	413·6	177	350·6	142	287·6
246	474·8	211	411·8	176	348·8	141	285·8
245	473	210	410	175	347	140	284
244	471·2	209	408·2	174	345·2	139	282·2
243	469·4	208	406·4	173	343·4	138	280·4
242	467·6	207	404·6	172	341·6	137	278·6
241	465·8	206	402·8	171	339·8	136	276·8
240	464	205	401	170	338	135	275
239	462·2	204	399·2	169	336·2	134	273·2
238	460·4	203	397·4	168	334·4	133	271·4
237	458·6	202	395·6	167	332·6	132	269·6
236	456·8	201	393·8	166	330·8	131	267·8
235	455	200	392	165	329	130	266
234	453·2	199	390·2	164	327·2	129	264·2
233	451·4	198	388·4	163	325·4	128	262·4
232	449·6	197	386·6	162	323·6	127	260·6
231	447·8	196	384·8	161	321·8	126	258·8
230	446	195	383	160	320	125	257
229	444·2	194	381·2	159	318·2	124	255·2
228	442·4	193	379·4	158	316·4	123	253·4
227	440·6	192	377·6	157	314·6	122	251·6
226	438·8	191	375·8	156	312·8	121	249·8

COMPARISON OF T[illegible]—[illegible]

Centi-grade or Celsius.	Fahren-heit.	Centi-grade or Celsius.	Fahren-heit.	Centi-grade or Celsius.	Fahren-heit.	Centi-grade or Celsius.	Fahren-heit.
120	248	85	185	[illegible]	[illegible]	[illegible]	[illegible]
119	246·2	84	183·2	[illegible]	[illegible]	[illegible]	[illegible]
118	244·4	83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
117	242·6	82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
116	240·8	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
115	239	80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
114	237·2	79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
113	235·4	78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
112	233·6	77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
111	231·8	76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110	230	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
109	228·2	74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
108	226·4	73	163·4	[illegible]	[illegible]	[illegible]	[illegible]
107	224·6	72	161·6	[illegible]	[illegible]	[illegible]	[illegible]
106	222·8	71	159·8	[illegible]	[illegible]	[illegible]	[illegible]
105	221	70	158	[illegible]	[illegible]	[illegible]	[illegible]
104	219·2	69	156·2	34	[illegible]	−1	[illegible]
103	217·4	68	154·4	33	[illegible]	−2	[illegible]
102	215·6	67	152·6	32	[illegible]	[illegible]	[illegible]
101	213·8	66	150·8	31	[illegible]	−4	24·8
100	212	65	149	30	[illegible]	[illegible]	23
99	210·2	64	147·2	29	84·2	[illegible]	21·2
98	208·4	63	145·4	28	82·4	−7	19·4
97	206·6	62	143·6	27	80·6	−8	17·6
96	204·8	61	141·8	26	78·8	−9	15·8
						−10	14
95	203	60	140	25	77		
94	201·2	59	138·2	24	75·2		
93	199·4	58	136·4	23	73·4		
92	197·6	57	134·6	22	71·6		
91	195·8	56	132·8	21	69·8		
90	194	55	131	20	68		
89	192·2	54	129·2	19	66·2		
88	190·4	53	127·4	18	64·4		
87	188·6	52	125·6	17	62·6		
86	186·8	51	123·8	16	60·8		

APPENDIX B.

TABLE OF ELEMENTS.

Elements.	Symbol.	Atomic Weight.	Elements.	Symbol.	Atomic Weight.
Aluminium ...	Al	27·0	Molybdenum ...	Mo	95·5
Antimony (Stibium)	Sb	120·0	Nitrogen	N	14·0
Arsenic	As	75·0	Nickel	Ni	58·6
Barium	Ba	137·0	Niobium	Nb	94·0
Beryllium	Be	9·0	Osmium	Os	190·8
Bismuth	Bi	208·2	Oxygen	O	16·0
Boron	B	11·0	Palladium... ...	Pd	105·7
Bromine	Br	80·0	Phosphorus ...	P	31·0
Cadmium	Cd	112·0	Platinum	Pt	194·4
Cæsium	Cs	133·0	Potassium (Kalium)	K	39·0
Calcium	Ca	40·0	Rhodium	Rh	104·0
Carbon	C	12·0	Rubidium... ...	Rb	85·3
Cerium	Ce	140·5	Scandium ...	Sc	44·0
Chromium ...	Cr	52·0	Selenium	Se	79·0
Copper	Cu	63·2	Silver (Argentum)	Ag	107·7
Chlorine	Cl	35·5	Silicon	Si	28·2
Cobalt	Co	58·6	Sodium (Natrium)	Na	23·0
Didymium ...	Di	142·5	Strontium... ...	Sr	87·5
Erbium	Er	165·9	Sulphur	S	32·0
Fluorine	F	19·0	Tantalum... ...	Ta	182·0
Gallium	Ga	68·8	Tellurium... ...	Te	127·6
Gold (Aurum) ...	Au	196·0	Thallium	Tl	204·0
Hydrogen... ...	H	1·0	Thorium	Th	233·4
Indium	In	113·4	Tin (Stannum) ...	Sn	118·0
Iodine	I	127·0	Titanium	Ti	48·0
Iridium	Ir	192·5	Tungsten (Wolfram)	W	184·0
Iron (Ferrum) ...	Fe	56·0	Uranium	U	236·5
Lanthanum ...	La	138·5	Vanadium ...	V	51·3
Lithium	Li	7·0	Ytterbium ...	Yb	172·8
Lead (Plumbum)...	Pb	206·5	Yttrium	Y	89·8
Magnesium ...	Mg	24·4	Zinc	Zn	65·3
Manganese ...	Mn	55·0	Zirconium ...	Zr	90·0
Mercury (Hydrargyrum)	Hg	200·0			

APPENDIX C.

WEIGHTS AND MEASURES.

British Avoirdupois Weights.			*Metric Weights.*	
16 Drachms	= 1 Ounce (oz.)	=	28·35	Grams.
16 Ounces	= 1 Pound (lb.)	=	0·453	Kilograms†
112 Pounds	= 1 Hundredweight (cwt.)	=	50·802	,,
20 Hundredweight	= 1 Ton	=	1016·048	,,

† A Kilogram is commonly called a "kilo."

Metric Weights.				*British Avoirdupois Weights.*
1000 Milligrams	=	1 Gram	=	15·432 grains.
1000 Grams	=	1 Kilogram	=	2·2046 lbs.

British Long Measure.				*Metric Measure.*
1 Inch			=	0·0254 metres.
12 Inches	=	1 Foot	=	0·3048 ,,
3 Feet	=	1 Yard	=	0·9144 ,,
1760 Yards	=	1 Mile	=	1·609315 kilometres.

Metric Long Measure.				*British Measure.*
1000 Millimetres	=	1 Metre	=	39·37079 inches.
1000 Metres	=	1 Kilometre	=	0·62138 mile.

British Measures of Capacity.				*Metric Measures.*
1 Pint			=	0·5679 litres.
8 Pints	=	1 Gallon	=	4·54348 ,,

Metric Measures of Capacity.				*British Measure.*
1 Millitre or cubic centimetre			=	0·0352 fluid oz.
1000 Millitres or cubic centimetres	=	1 Litre	=	0·220096 gallon.

British Cubic Measures.				*Metric Measures.*
1 Cubic inch			=	16·386 cubic centimetres.
1728 Cubic inches	=	1 Cubic foot	=	28·3153 litres.

ACETYLENE BURNERS.

Many of the acetylene burners used in England are manufactured on the Continent, and have stamped upon them a figure which represents the volume of gas which the burner is intended to pass per hour. These figures represent the volume in litres, and the following table shows the corresponding volume in cubic feet :—

10 Litres	=	0·353	cubic feet.
15 ,,	=	0·529	,,
20 ,,	=	0·706	,,
28 ,,	=	0·989	,,

APPEN-

The following table from the "Notification" of the
the observed volumes of gases. The height of the barometer
is 60° F. To correct the observed volume of any gas to
by the tabular number. For example, if when the volume
temperature of the gas is 70° F., the observed volume of
0·980. If the observed volume under the conditions men-
temperature and pressure would be only (5·0 × 0·980) 4·90
volume of acetylene, coal gas, or any other gas.

TABULAR NUMBERS, BEING A TABLE TO FACILITATE THE
DIFFERENT TEMPERATURES AND UNDER

Bar.	Ther. 40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	60°
28·0	·979	·974	·970	·965	·960	·956	·951	·946	·942	·937	·932
28·1	·983	·978	·973	·969	·964	·959	·955	·951	·945	·941	·936
28·2	·986	·981	·977	·972	·967	·963	·958	·953	·949	·944	·939
28·3	·990	·985	·980	·976	·971	·966	·961	·957	·952	·947	·942
28·4	·993	·988	·984	·979	·974	·970	·965	·960	·955	·951	·946
28·5	·997	·992	·987	·983	·978	·973	·968	·964	·959	·954	·949
28·6	1·001	·995	·991	·986	·981	·977	·972	·967	·962	·958	·953
28·7	1·004	·999	·994	·990	·985	·980	·975	·970	·966	·961	·956
28·8	1·007	1·003	·998	·993	·988	·984	·979	·974	·969	·964	·959
28·9	1·011	1·006	1·001	·997	·992	·987	·982	·977	·973	·968	·963
29·0	1·014	1·010	1·005	1·000	·995	·990	·986	·981	·976	·971	·966
29·1	1·018	1·013	1·008	1·004	·999	·994	·989	·984	·979	·975	·969
29·2	1·021	1·017	1·012	1·007	1·002	·997	·992	·988	·982	·978	·973
29·3	1·025	1·020	1·015	1·011	1·006	1·001	·996	·991	·986	·981	·976
29·4	1·028	1·024	1·019	1·014	1·009	1·004	·999	·995	·990	·985	·980
29·5	1·032	1·027	1·022	1·018	1·013	1·008	1·003	·998	·993	·988	·983
29·6	1·036	1·031	1·026	1·021	1·016	1·011	1·006	1·001	·996	·992	·986
29·7	1·039	1·034	1·029	1·025	1·019	1·015	1·010	1·005	1·000	·995	·990
29·8	1·043	1·038	1·033	1·028	1·023	1·018	1·013	1·008	1·003	·998	·993
29·9	1·046	1·041	1·036	1·031	1·026	1·022	1·017	1·012	1·007	1·002	·997
30·0	1·050	1·045	1·040	1·035	1·030	1·025	1·020	1·015	1·010	1·005	1·000
30·1	1·053	1·048	1·043	1·038	1·033	1·029	1·024	1·019	1·014	1·009	1·003
30·2	1·057	1·052	1·047	1·042	1·037	1·032	1·027	1·022	1·017	1·012	1·007
30·3	1·060	1·055	1·050	1·045	1·040	1·036	1·030	1·025	1·020	1·015	1·010
30·4	1·064	1·059	1·054	1·049	1·044	1·039	1·034	1·029	1·024	1·019	1·014
30·5	1·067	1·062	1·057	1·052	1·047	1·042	1·037	1·032	1·027	1·022	1·017
30·6	1·071	1·066	1·061	1·056	1·051	1·046	1·041	1·036	1·031	1·026	1·020
30·7	1·074	1·069	1·064	1·059	1·054	1·049	1·044	1·039	1·034	1·029	1·024
30·8	1·078	1·073	1·068	1·063	1·058	1·053	1·048	1·043	1·037	1·032	1·027
30·9	1·081	1·076	1·071	1·066	1·061	1·056	1·051	1·046	1·041	1·036	1·031
31·0	1·085	1·080	1·075	1·070	1·065	1·060	1·055	1·049	1·044	1·039	1·034

*** The numbers in the above table have been calcu-

the barometer in inches, *t* the temperature on the Farenheit
volume at *t*° and *h* inches pressure, and V the correspon

DIX D.

Metropolitan Gas Referees is exceedingly useful for correcting
adopted as a standard is 30 inches, and the standard temperature
standard temperature and pressure it is necessary to multiply it
of gas is measured the barometer stands at 30·2 inches, and the
gas must be multiplied by the corresponding tabular number
tioned were 5·0 cubic feet, the volume corrected to standard
cubic feet. This table may be used for the correction of the

CORRECTION OF THE VOLUME OF GAS MEASURED OVER WATER AT DIFFERENT ATMOSPHERIC PRESSURES.

Bar.	Ther. 62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
28·0	·927	·922	·917	·912	·907	·902	·897	·892	·887	·881	·875	·870
28·1	·930	·926	·921	·916	·911	·905	·900	·895	·890	·884	·879	·873
28·2	·934	·929	·924	·919	·914	·909	·904	·898	·893	·887	·882	·876
28·3	·937	·932	·928	·922	·917	·912	·907	·902	·896	·891	·885	·880
28·4	·941	·936	·931	·926	·921	·915	·910	·905	·900	·894	·888	·883
28·5	·944	·939	·934	·929	·924	·919	·914	·908	·903	·897	·892	·886
28·6	·947	·943	·938	·932	·927	·922	·917	·912	·906	·901	·895	·889
28·7	·951	·946	·941	·936	·931	·925	·920	·915	·909	·904	·898	·893
28·8	·954	·949	·944	·939	·934	·929	·924	·918	·913	·907	·901	·896
28·9	·958	·953	·948	·942	·937	·932	·927	·921	·916	·910	·905	·899
29·0	·961	·956	·951	·946	·941	·935	·930	·925	·919	·914	·908	·903
29·1	·964	·959	·954	·949	·944	·939	·933	·928	·923	·917	·911	·906
29·2	·968	·963	·958	·952	·947	·942	·937	·931	·926	·920	·914	·909
29·3	·971	·966	·961	·956	·950	·945	·940	·935	·929	·923	·918	·912
29·4	·975	·969	·964	·959	·954	·949	·943	·938	·932	·927	·921	·915
29·5	·978	·973	·968	·962	·957	·952	·947	·941	·936	·930	·924	·919
29·6	·981	·976	·971	·966	·960	·955	·950	·944	·939	·933	·927	·922
29·7	·985	·980	·974	·969	·964	·959	·953	·948	·942	·937	·931	·925
29·8	·988	·983	·978	·972	·997	·962	·957	·951	·946	·940	·934	·928
29·9	·991	·986	·981	·976	·970	·965	·960	·954	·949	·943	·937	·932
30·0	·995	·990	·985	·979	·974	·968	·963	·958	·952	·946	·941	·935
30·1	·998	·993	·988	·983	·977	·972	·966	·961	·955	·950	·944	·938
30·2	1·002	·996	·991	·986	·980	·975	·970	·964	·959	·953	·947	·941
30·3	1·005	1·000	·995	·989	·984	·978	·973	·968	·962	·956	·950	·945
30·4	1·008	1·003	·998	·993	·987	·982	·976	·971	·965	·959	·954	·948
30·5	1·012	1·006	1·001	·996	·990	·985	·980	·974	·969	·963	·957	·951
30·6	1·015	1·010	1·005	·999	·994	·988	·983	·977	·972	·966	·960	·954
30·7	1·018	1·013	1·008	1·003	·997	·992	·986	·981	·975	·969	·963	·957
30·8	1·022	1·017	1·011	1·006	1·000	·995	·990	·984	·978	·972	·967	·961
30·9	1·025	1·020	1·015	1·009	1·004	·998	·993	·987	·982	·976	·970	·964
31·0	1·029	1·023	1·018	1·013	1·007	1·002	·996	·991	·985	·979	·973	·967

lated from the formula $n = \frac{17·64\,(h-a)}{460 + t}$, where h is the height o
scale, and a the tension of aqueous vapour at is any
ing volume at 60° and 30 inches pressure.

APPENDIX E.

Melting Points of Metals.

To ascertain whether an excessive temperature is attained in an acetylene generator it is usual to bury wires of pure or alloyed metals of low melting point in the carbide to be decomposed, and to examine the lime residue after the whole of the charge of carbide has been decomposed. If the wires are found to have undergone fusion, conclusive evidence is obtained that an excessive temperature has been attained during the period of decomposition. The following table shows the melting point of the most common metals and of some readily fusible alloys :—

METALS.

Metals.	*Melting Point.*
Tin	235° C.
Bismuth	270° ,,
Cadmium	320° ,,
Lead	330° ,,
Zinc	412° ,,
Antimony	425° ,,
Aluminium ...	700° ,,
Silver	1000° ,,
Copper	1050° ,,
Iron, cast	1050—1200° C.
,, steel	1300—1400° ,,
,, wrought ...	1500—1600° ,,
Gold	1250° C.
Nickel...	1500—1600° ,,
Platinum	2600° C.

FUSIBLE ALLOYS.

	Alloy.		*Melting Point.*
Wood's Alloy	Bismuth...	38·4 %	75° C.
	Tin ...	15·4 ,,	
	Lead ...	30·8 ,,	
	Cadmium	15·4 ,,	
Rose's Alloy ...	Bismuth...	50 %	92° C.
	Tin	25 ,,	
	Lead ...	25 ,,	
Newton's Alloy	Bismuth...	50 %	95° C.
	Tin ...	19 ,,	
	Lead ...	31 ,,	
	Bismuth...	33·3 %	123° C.
	Tin ...	33·3 ,,	
	Lead ...	33·3 ,,	
	Tin ...	66·7 %	171° C.
	Lead ...	33·3 ,,	
	Tin ...	23 %	198° C.
	Lead ...	77 ,,	

INDEX.

A

B