

HANDBOOK
FOR
GAS ENGINEERS
AND
MANAGERS.

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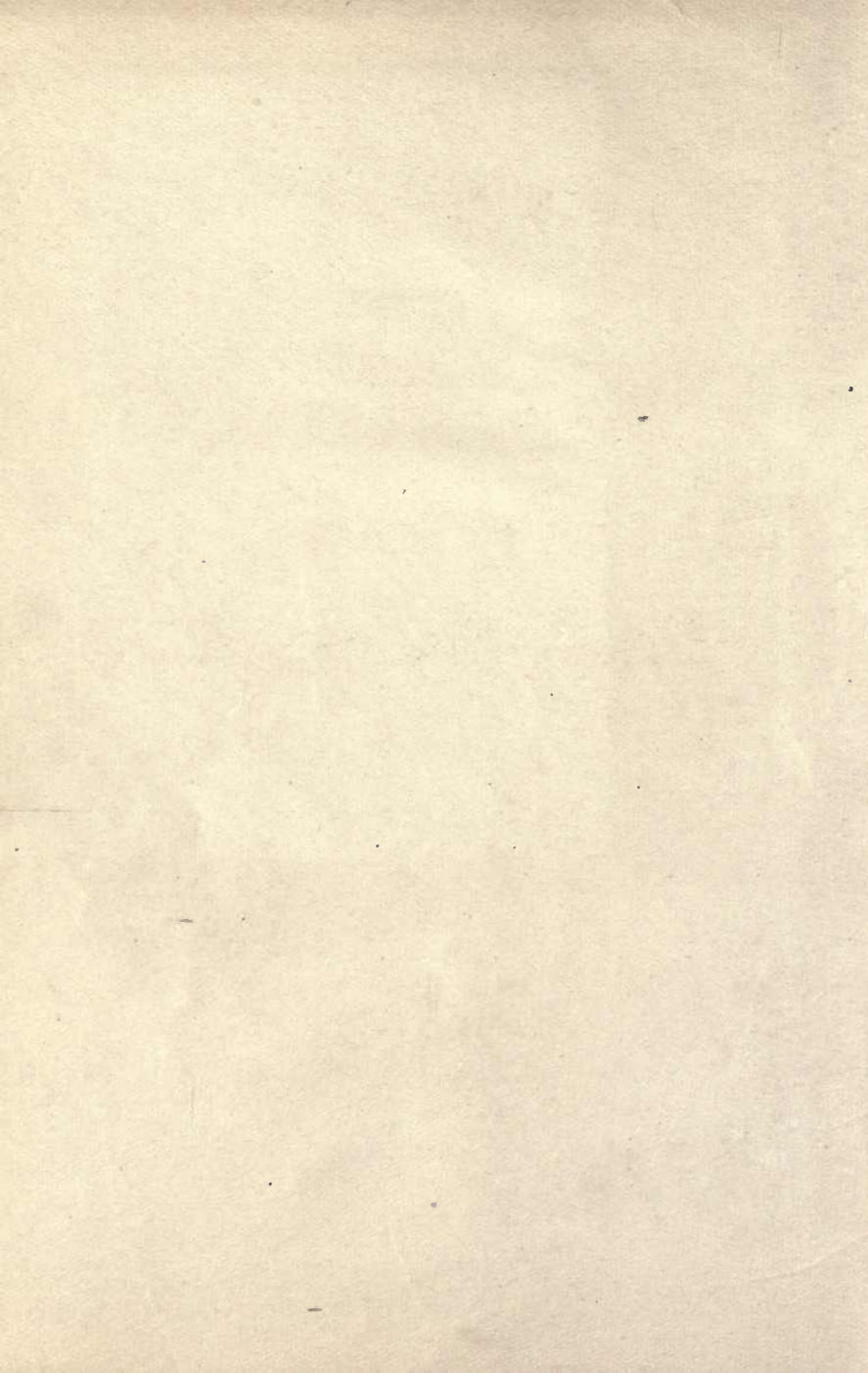
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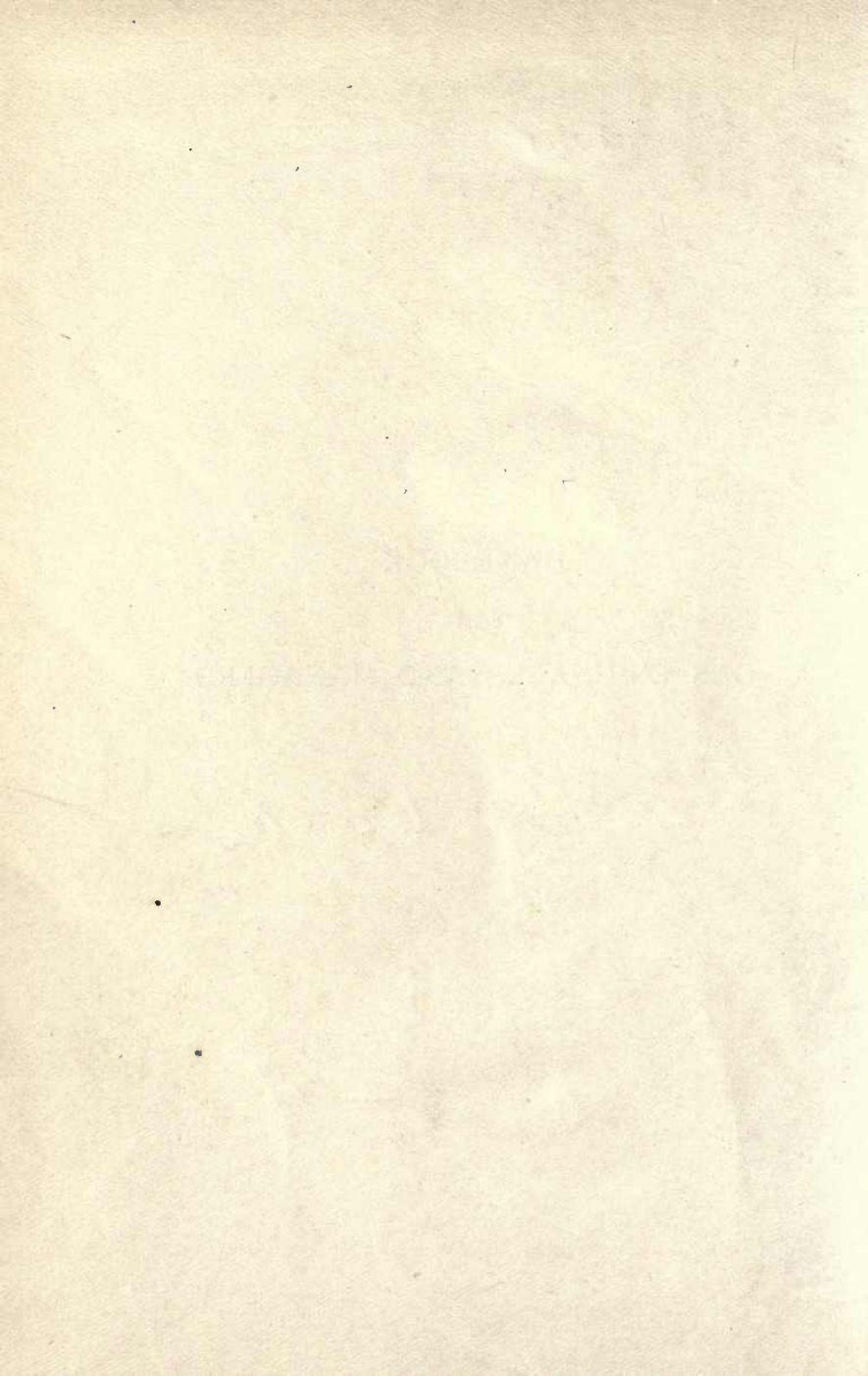
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HANDBOOK
FOR
GAS ENGINEERS AND MANAGERS





WILLIAM MURDOCH.

INVENTOR OF GAS LIGHTING.

HANDBOOK
FOR
GAS ENGINEERS
AND
MANAGERS

BY

THOMAS NEWBIGGING
D.Sc., M.INST.C.E.

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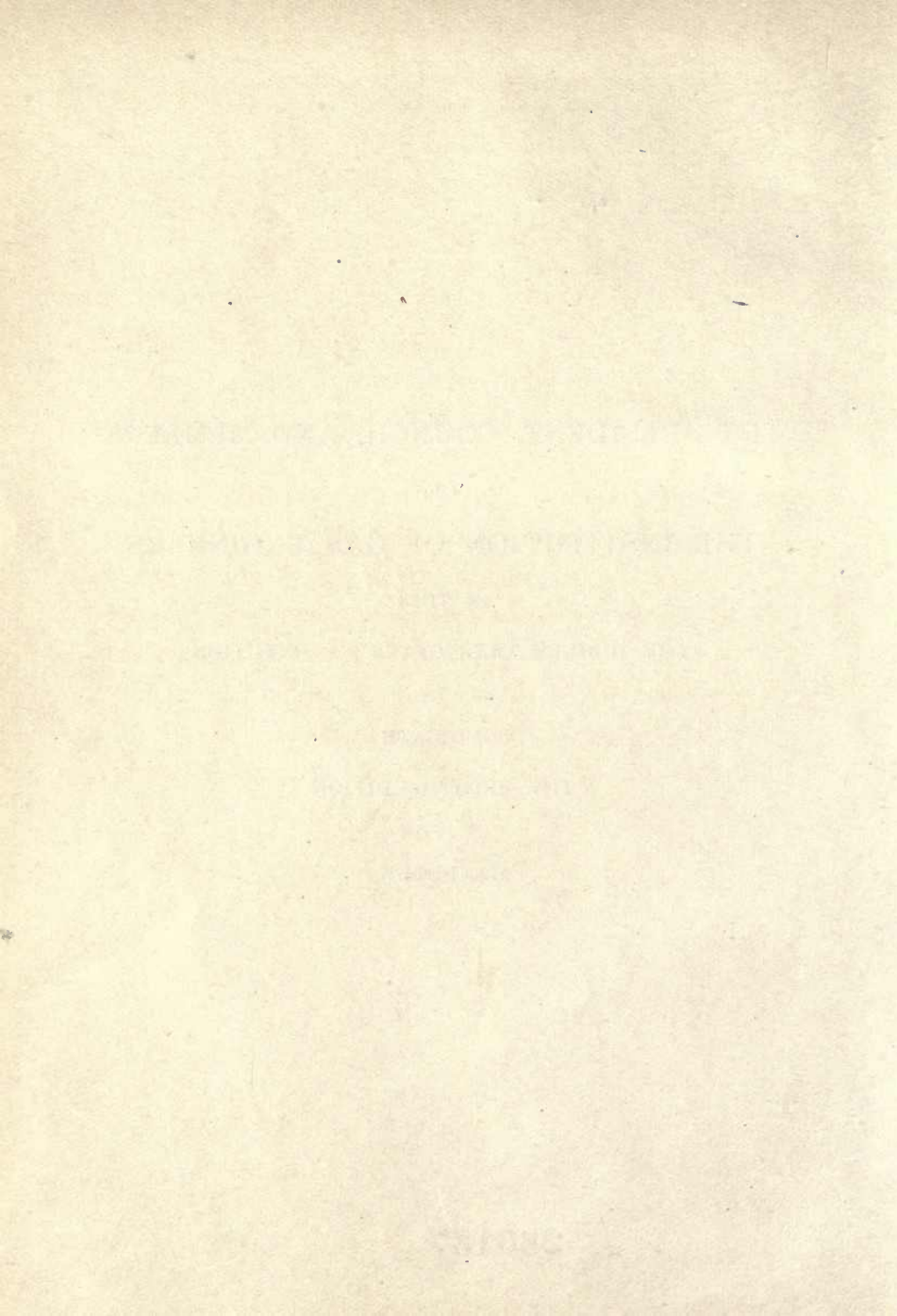
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TO
THE PRESIDENT, COUNCIL AND MEMBERS
OF
THE INSTITUTION OF GAS ENGINEERS
IN THIS
THE JUBILEE YEAR OF THE INSTITUTION
I
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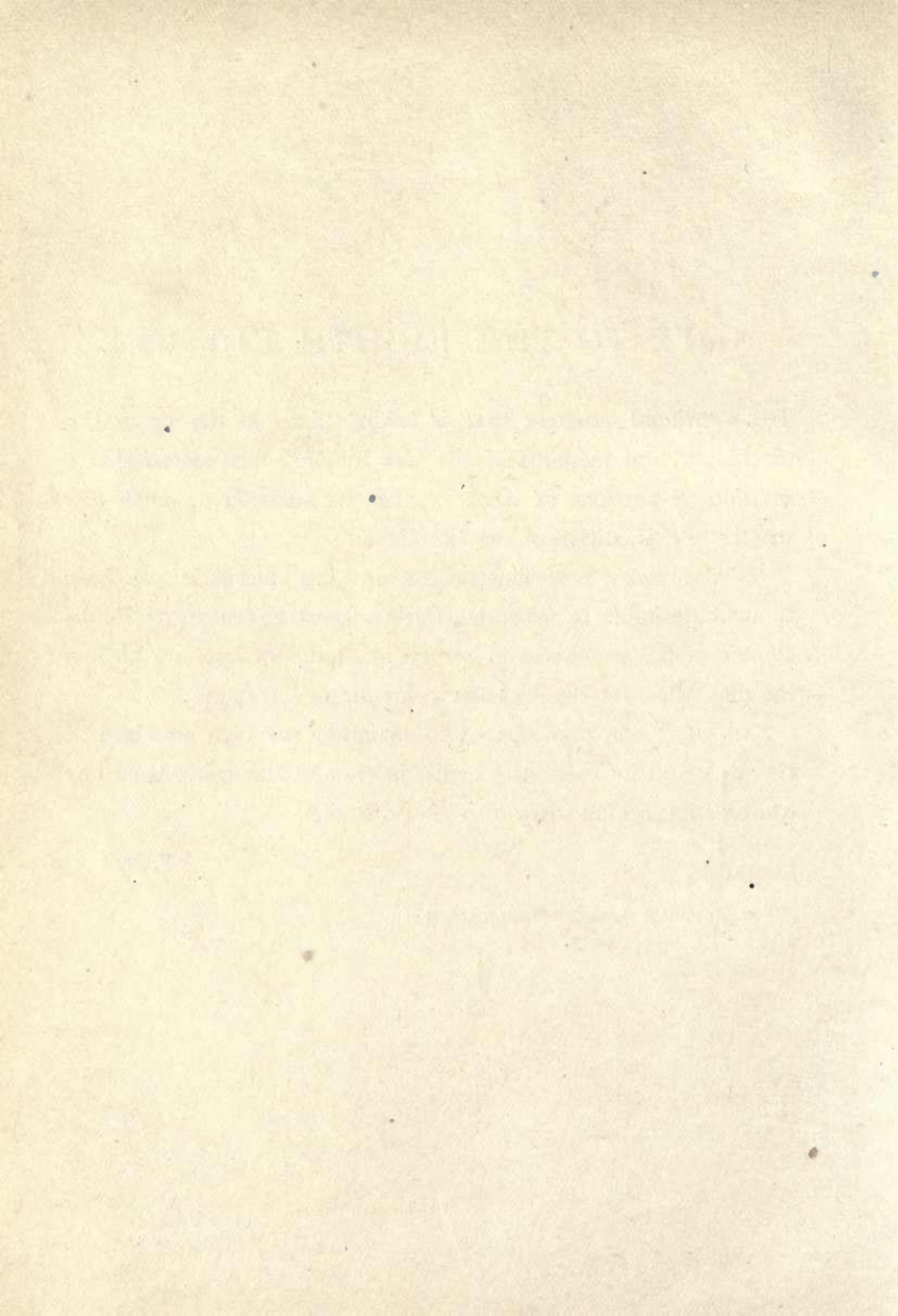
THE continual progress that is taking place in the apparatus, machinery, and methods of the Gas Industry has necessitated a revision of portions of the text and the addition of much new matter to this edition of the Handbook.

Whilst many new illustrations are introduced, it has been thought desirable to withdraw those suggesting designs for Public Illuminations, as makers in plenty of similar designs are now to the fore whenever the occasion arises for such displays.

No effort has been spared to maintain the high standard of the work and its usefulness to Engineers and Managers, as well as to Students seeking entry into the profession.

T. N.

5, NORFOLK STREET, MANCHESTER:
1913.



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NEWBIGGING'S HANDBOOK
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GAS ENGINEERS AND MANAGERS.

COAL GAS.

INTRODUCTION.

THE art of coal gas manufacture is more than a hundred-and-fifteen years old. Between 1792 and 1798, William Murdoch, its inventor, was engaged, first at Redruth in Cornwall, then at Old Cumnock in Ayrshire, and finally at Birmingham, in experimenting with different coals, and in devising apparatus for their distillation.

In 1797-98 lighting by coal gas became an accomplished fact, for Murdoch, by means of his experimental plant, first lit up his dwelling-house at Old Cumnock with the new illuminant, and, on his removal to Birmingham in the latter year, having erected an apparatus on a considerable scale, he lighted a portion of the premises of Boulton, Watt, & Co., Soho.

The circumstance that coal would yield an illuminating gas was known long before that time. Natural gas, as it was found to issue from the bowels of the earth in particular districts where coal deposits existed, had been the subject of frequent observation, and its lighting power proved by actual trial ; but no practical application was made of the knowledge till Murdoch bent his mind to the study of the subject.

A hundred and fifteen years is a long time in the history of an industry—longer than one exactly realizes at a first glance. The lapse of so many years since the discovery and application of gas-lighting confers something of the venerableness of age upon the art. This is more obvious when cognizance is taken of the initiation of other arts, and the advances made in them, and not less so in the progress of the sciences, within that period of time.

Take railways, for example. As compared with these, gas-lighting is old, for it had a start in life of thirty years before them. Nay, even the steam engine: that is no older than the art of gas-lighting, and much of its initiation and perfecting was due to the same fertile brain, for Murdoch was Watt's right-hand man at Soho, and invented the D slide-valve, the "sun and planet" motion, and the oscillating steam cylinder. As for the telegraph, the telephone, electric lighting, and wireless telegraphy, these are but of yesterday—the younger sisters of the useful arts. Even the science of chemistry was only emerging from its swaddling clothes when gas-lighting was invented.

Although Murdoch had thus realized his dream of employing the gas produced from coal as a lighting medium, there was still much to be done to render the new illuminant acceptable. The impurities in the crude gas were found to be many and objectionable, and means and appliances for their elimination had to be devised. Suitable pipes for the conveyance of the gas to the point of combustion were also required. Murdoch devoted much time and effort in these directions, washing the gas with water, and employing other means to purify it, and using tinned-copper and iron tubes for its distribution.

Other ingenious minds were early at work in the promising field thus opened out to the labourer. Lebon, in France; Winsor, at Frankfort, and later in London, where he projected "The National Light and Heat Company," afterwards incorporated by Royal Charter as "The Chartered Gaslight and Coke Company;" Samuel Clegg, who had been a pupil or apprentice at the Soho Works, Birmingham; Dr. Henry, of Manchester; Northern, of Leeds; Pemberton, of Birmingham; John Malam; Samuel Crosley and T. S. Peckston, of London; Reuben Phillips, of Exeter; and Melville, of Newport, Rhode Island, U.S.A.

Chief amongst these pioneers was Samuel Clegg, who possessed a rare mechanical skill, combined with much shrewd common

sense. In 1805 he began to apply himself to the invention and construction of gas apparatus, and introduced the new method of illumination into many large establishments in different parts of the country. Clegg invented the hydraulic main, and the lime purifier as a separate vessel, though Mr. (afterwards Dr.) William Henry, of Manchester, the distinguished chemist, was the first to suggest the use of lime as a purifying medium. Clegg also invented the wet gas meter (afterwards improved by Samuel Crosley), and evinced infinite resource in improving the apparatus of the gas factory in every department.

In these respects he was ably seconded by John Malam, who now stepped in and perfected the wet meter in such a way as to render it one of the most ingenious measuring appliances of this or any past age. Malam also invented the first dry meter; but this appliance, in the form now in use, was the invention of William Richards in the early 'forties, and afterwards improved by Thomas Glover. The arrangement of four purifiers, which, with the centre valve, holds the field to this day, was also the product of Malam's ingenuity.

The new art of gas-lighting was fortunate in many of these its early exponents.

The "Chartered" vessel, launched by Winsor and others associated with him, floundered about for a while in a troubled and, at times, a boisterous sea, due, no doubt, to the inexperience, but largely also to the incompetence, of some of those in charge; till, at length, the skilful pilotage of Samuel Clegg, who eventually assumed command (in 1813), brought her into smooth waters.

It is not surprising that mistakes were made at first, and that immediate success failed to attend the early efforts of the promoters of gas enterprise. The art was a new one; nothing akin to it was there to serve as a model or afford direction and guidance. All the appliances of manufacture, purification, storage, and distribution had not only to be made but invented. The prejudices of the public, too, had to be overcome.

Winsor, with the best intentions, scarcely helped to remove those prejudices. His enthusiastic advocacy, with something of foresight, had in it much of unwisdom. He projected the wildest schemes of gas enterprise ere yet the public—even the immediate public who listened to his harangues and read his pamphlets—had had time or opportunity to grasp the importance of the subject.

Gradually, however, confidence was established. Distrust gave way to admiration; for, under the daily improving management, the new artificial light was shown to be not only cheaper and safer, but vastly superior in lighting power, cleanliness, and handiness to anything previously in use.

Other companies were soon established in the Metropolis. One by one (like stars coming out at dusk) the larger towns of the kingdom had each its gas company, lighting the public streets and thoroughfares, and supplying its growing number of private consumers.

Thus the new art grew from precarious childhood into youth and sturdy manhood.

It is not too strong an assertion to make, that gas-lighting, during the century of its existence, has proved one of the greatest boons enjoyed by civilized humanity, and no industry that can be named has had a steadier or more abundant success.

This success has been due to two main causes: The inherent utility and value of the invention, and the skill, probity, and business capacity of most of those who, both in the earlier years and later, took a leading part in its furtherance.

The progress which has been made during the century in the machinery of gas manufacture is very striking. This has not been a mere advance in the capacity of the various appliances due to the growing demand for gas-lighting on the part of consumers, but is a positive revolution in constructive detail.

In the first days of the invention the retorts used were of iron, and were placed in the vertical position in the furnace. This was the mode of erection that would naturally be adopted at first, inasmuch as it lends itself to convenience in depositing the charge.

But it was very soon found that the difficulty of withdrawing the residual coke by way of the mouth was such that an alteration in the position was an absolute necessity. Accordingly, no long time elapsed before the retorts began to be laid, first, at an inclination, and then horizontally; and instead of only one retort, two, three, and eventually five, were set together and heated, at first by two furnaces, but later by one furnace only.

This was a manifest improvement, and it held its ground for many years. At the present time, in most gas-works, settings of six, seven, eight, nine, and even ten and twelve retorts are in vogue.

Gradually, it was found that a high temperature was necessary

for economical distillation, inasmuch as with the lower ranges of temperature it was seen that, instead of the evolution of gas, the products were largely in the liquid form.

The retorts themselves were originally of cast-iron, and continued so to be till well into the middle of the century. As the advantages of the higher temperatures of distillation began to be recognized, these were gradually replaced, though not without a struggle, by retorts made of moulded fire-clay, or built up of segmental bricks and tiles.

Instead of direct firing, the regenerative method of heating the retorts, whereby the solid coke is converted into gaseous fuel (CO), is generally applied, and with marked advantage, from every point of view.

The ironwork mountings of the retort bench have undergone considerable modification and improvement during the century. Self-sealing lids, the invention of Robert Morton, for the retort mouthpieces, have been introduced. The ascension, bridge, and dip pipes have been modified and enlarged; and the hydraulic main is now made of wrought-iron or mild steel, and of various improved patterns. Subsidiary or foul mains and tar mains have been added, by which the gas and liquid products are conveyed separately away.

The problem of the application of machinery in gas manufacture, and the consequent saving of manual labour, has been completely solved. This was the dream of the early gas engineers, some of whom attempted it without success. With an ingenuity and a persistency deserving of all praise, Mr. John West devised machinery for stoking, and has, year by year, improved both his hand and power charging and drawing machines. Mr. William Foulis was also a pioneer in the same direction, and his machinery for that purpose finds wide acceptance. Later successful inventors of charging and discharging machinery are R. Dempster & Sons, Fiddes & Aldridge, Drakes, and Bronder (of New York), whose machinery charges and draws four retorts at once.

Inclined or sloping retorts, set at an angle of 30 to 33 degrees, are largely in use in the carbonizing department of gas-works. Settings of this kind, employed by M. Coze, of Rheims, attracted much attention about twenty-two years ago, and have been adopted at many gas-works in this country and abroad. In Love's arrangement the retorts are set at an inclination of 45 degrees.

The inclined system simplifies the operations and mitigates the labour in the retort house, besides increasing the productive capacity of the available floor area. The idea of employing retorts set in the inclined position was not new, but an impetus was given to the system by its adoption, under improved conditions, at Rheims.

After Murdoch, Andrew Scott of Musselburgh, about the year 1874, invented a system of conical retorts set in the vertical position (see King's "Treatise," vol. i. p. 236). The bottom end of the retort rested in a trough containing water, which acted as a seal to prevent the escape of the gas, whilst allowing the coke to be easily withdrawn.

Within very recent years various other systems of carbonization in retorts set vertically have come to the front, chiefly (1) the Dessau system, (2) that of Woodall & Duckham, and (3) that of Glover & West. In the first, the charging and drawing are intermittent; in the two latter, continuous. With these, satisfactory results have been achieved, so that continuous carbonization may be considered as solved.

Machinery and appliances for the conveyance of coal and coke, and the lime and oxide used in purification, from one point to another, are being widely and successfully applied, and are fast becoming important labour-saving agencies.

The process of washing the gas has been advocated and condemned by various authorities at different periods. Washing was common enough in the early days, but by reason of a supposed deteriorating effect on the illuminating power it was discredited for a time, and scrubbing by an intercepting material presenting a large area of wetted surface to the gas was preferred.

The view has eventually prevailed that washing as well as scrubbing is indispensable, and the result is that apparatus to accomplish this object has been introduced by various makers with excellent effect.

It is now universally admitted that washing and scrubbing, both with ammoniacal liquor and clean water, are absolutely necessary in order to remove the lighter tars (the heavier tars having been deposited in the condenser) and arrest the ammonia impurity, as well as to eliminate a proportion of the sulphuretted hydrogen and carbon dioxide from the crude gas before it reaches the purifiers proper. It may be safely asserted that the gas of to-day,

as supplied to consumers, is absolutely free from the objectionable ammonia, with the further advantage that this is secured for sale at the gas-works. The same can be said as regards sulphuretted hydrogen. In all well-managed gas-works this impurity is absent from the distributed gas.

Lime was the only medium employed for arresting sulphuretted hydrogen in the earlier days of gas-lighting, till Mr. F. C. Hills introduced the use of hydrated peroxide of iron for that purpose; and although this has no affinity for carbon dioxide, the latter impurity is taken out by passing the gas through lime, either in the first instance or in the last stage of purification.

The advantage of using the oxide of iron is its economy, as it can be revived by exposure to the air after it has become foul, and can be used over and over again, till its bulk has been about doubled by the presence of free sulphur. It also secures another important desideratum—the reducing of the mountains of foul or spent lime that would otherwise accumulate in the gas yard, and for which, in some districts, there is no great demand on the part of agriculturists. True, a process of spent lime revivification has been invented by Mr. George Hislop; but although this is efficacious in action, it has not been widely adopted.

With the advent of Mr. (afterwards Sir) George Livesey as Engineer-in-Chief of the South Metropolitan Gas Company, a new era in gasholder construction may be said to have begun. It is interesting to note the progress made in his several remarkable structures. The first of his notable holders, erected at the Old Kent Road Station, consists of two lifts. It is 180 ft. in diameter, and the two lifts rise to a height of 90 ft. when fully inflated, the capacity being 2 million cub. ft. His next holder at the same station has a diameter of 214 ft., is in three lifts, and stands when full at a height of 160 ft., having a capacity of $5\frac{1}{2}$ million cub. ft. The third one, erected at East Greenwich, is in four lifts, 250 ft. in diameter, and rises to a height of 180 ft., its capacity being $8\frac{1}{2}$ million cub. ft. The latest and largest gasholder belonging to the Company is also erected at East Greenwich. This is a veritable monster in size, being 300 ft. in diameter, having no fewer than six lifts, and rising when inflated to a height of 180 ft.; its capacity being 12 million cub. ft.

But it is not their size only which makes these enormous vessels remarkable; their structural features are equally note-

worthy. Instead of the usual guide-framing, consisting of columns or standards of large bulk and weight, Sir George Livesey in his later structures introduced a guide-framing consisting of comparatively light members, the standards being braced together by diagonals and horizontal struts.

Although the two holders last referred to are of four and six lifts respectively, the guide-framing is not carried up to the full height reached by the inflated vessels. In the first, the inner or top lift rises beyond the framing; and in the second, the two innermost lifts ascend above the summit of the framing—their stability under wind pressure being sufficiently assured on cupping by the limited guide-framing applied.

It is safe to assert that it never entered into the dreams of the most advanced gas engineers of the first half of the century that holders of anything like the enormous proportions named would be called into existence.

Perhaps there is neither the scope nor the necessity in the provinces for holders of the size of the last named, but Mr. Charles Hunt, some years ago, before his retirement from the Windsor Street Station of the Birmingham Corporation Gas-Works, erected two with a capacity of $6\frac{1}{2}$ million cub. ft. each. These are in three lifts, rising to a total height of 150 ft., the diameter of the outer lift being 236 ft. in each instance.

The holder just completed at the Bradford Road Station of the Manchester Corporation Gas-Works, and designed by Mr. J. G. Newbigging, the engineer, is in four lifts, the diameter of the outer one being 282 ft. When fully inflated the holder reaches a height of 182 ft. and its capacity is close on $10\frac{1}{2}$ million cub. ft. The tank, which is of brick, is 285 ft. in diameter and 43 ft. deep.

A remarkable innovation in gasholder guiding, by which the upper framing is dispensed with altogether, is due to the inventive genius of Mr. William Gadd, of Manchester. Mr. Gadd solved the problem in a variety of ways. First, by means of torsional and tensional gearing fixed round the tank, and attached to the holder or floating vessel at its base; but more especially by the introduction of spiral guide-rails fixed to the sides of the tank or attached to the sides of the holder in a diagonal direction. The simplicity of this latter device is so self-evident that it is matter for surprise it had never been previously applied or thought of. The first holder of this class was erected at Northwich, in Cheshire,

by Clayton, Son, & Co., Ltd., of Leeds, having been designed from the inventor's patent specification by the present writer.

As frequently happens in other cases, there were other minds simultaneously engaged in the solution of the problem of guiding holders without upper framing. Mr. E. L. Pease, of Stockton-on-Tees, invented a system of guiding by means of wire-rope gearing; and Mr. J. W. Terrace, of Brechin, also devised a means of guiding by shafting, screws, and wheels. Mr. Gadd's, however, was the patent first in the field.

In the distribution department, improvements have been made from time to time. The open main joint, filled either with lead or some kind of cement caulking, was general down to the introduction of the turned and bored joint by Mr. Alfred King, of Liverpool, about the year 1826. This latter was without question a step in advance, and although there are engineers who still prefer the open joint, the preference arises more from prejudice than experience and knowledge. The turned and bored joint, with a recess in front for filling with cement or lead, is the most perfect joint possible for cast-iron main pipes laid in stable ground. Where the ground is liable to subsidence from any cause, wrought iron and steel main pipes, with screwed, flanged, rigid and open joints, are now extensively used.

In street lighting a marked advance has been witnessed. Perhaps this is due to some extent to the threatened competition of the electric light. Years ago Mr. William Sugg introduced his large argands for street lighting. These undoubtedly gave a magnificent light, but the difficulties attending the regulation of the flame at varying pressures proved an impassable obstacle to their success, and they were finally abandoned.

These were succeeded by the triform arrangement of large flat-flames, introduced almost simultaneously by Mr. Sugg and Mr. George Bray. For the illumination of streets, squares, and other wide open spaces, they were admirably adapted.

The Welsbach system of incandescent gas-lights, introduced in the year 1887, has created a veritable revolution both in street and domestic lighting. The success of the invention has been as great as it is deserved. Not only is gas economized by its use, but the illuminating value of the light is increased to the extent of 300 to 400 per cent., and even more than this where high pressure is applied. Gas at a pressure of 2 to 3 lbs. per square inch has

an efficiency with the incandescent burner of 60 candles per cubic foot.

The use of gas for cooking and heating, for the production of motive power, and for workshop purposes, has made vast strides of recent years. Fires, stoves, and ranges of all sizes and of excellent design, are produced by a number of first-class makers. The Otto gas engine, as made by Crossley Brothers, settled beyond question the economy and value of gas for motive power. Other makers of similar engines of great excellence are numerous. In the application of gas to industrial uses generally, the ingenuity of the late Mr. Thomas Fletcher found an outlet. In all these directions the field may be pronounced limitless.

The invention and introduction of the prepayment meter has encouraged the use of gas by the poorer class of consumers, and here also it is difficult to conceive of a limit to gas enterprise.

In no department of the gas industry has there been so remarkable a development as in that of dealing with the residual products. There is absolutely no waste in a well-managed gas-works. Everything is utilized, even to the dross yielded by the furnaces. This much can hardly be asserted of any other industry in existence, and this fact should be borne in mind by those who are sometimes inclined to decry the administrators of gas undertakings.

The tangible result of it all is that gas property has attained to a reputation for value and stability scarcely exceeded by any other class of investment; and, competition notwithstanding, there is ground for confidence that it will continue to maintain its deserved popularity.

COAL.

The geological position of coal in the earth's crust is shown in the annexed tabular view of the trias, permian, and carboniferous series in England and Wales, by Professor Hull:—

New red sandstone or trias	.	.	.	{	Keuper	{	Red marl.
							Lower Keuper sandstone.
							Upper mottled sandstone.
				{	Bunter	{	Conglomerate beds.
							Lower mottled sandstone.

- Permian rocks { Upper red sandstone of St. Bees, etc.
 Upper and lower magnesian limestones and marls of the Northern counties.
 Lower red sandstone of Lancashire, Cumberland, and Yorkshire, etc. (on the same horizon with)
 Red sandstones, marls, conglomerates, and breccia, of the Central counties and Salop.
- Carboniferous rocks { Upper carboniferous { Upper coal-measures, with limestone and thin coal seams.
 Middle coal-measures, with thick coal seams.
 Lower coal-measures, or Gannister series, with thin coal seams and lower carboniferous fossils.
 Lower carboniferous { Millstone grit, with thin coal seams.
 Upper limestone shale, or Yoredale rocks.
 Carboniferous limestone with shales, sandstones, and coal in the Northern counties and Scotland.
 Lower limestone shale.
 Old red sandstone and Devonian rocks.

The area of the coal-measures in the United Kingdom is as follows :—

Situation.	Area of Coal-Measures.		Entire Area of Country		Proportion of Coal to the whole.
	Square Miles.	Acres.	Acres.	Square Miles.	
In England	6,039	3,864,960	31,770,615	49,643	1-8th
In Scotland & Islands, exclusive of Lakes }	1,720	1,100,000	18,944,000	29,600	1-18th
In North Wales	210	134,400	4,752,000	7,425	1-6th
In South Wales	950	608,000			
In Ireland	2,940	1,881,600	20,399,608	31,874	1-11th
In Islands	—	—	1,119,159	1,748	—
Total	11,859	7,588,960	76,985,382	120,290	—

Exclusive of wood-coal and lignite formations, and some small undefined areas.

The chief kinds of coal in the United Kingdom are—

Cannel or Parrot Coal.—This is the richest gas-producing coal, and is easily distinguished by its hard, smooth texture. The best varieties are found in different parts of Scotland, in Wales, and at Wigan and Newcastle or their neighbourhood. The latter two yield coke of fair quality ; that from the other is less valuable, and much of it is useless as fuel.

Bituminous Coal.—For gas-producing purposes the coal most suitable is the bituminous class, which includes caking, splint, cherry, and other coals, not necessarily containing bitumen, but because of their resemblance to that substance under heat. It is found widely distributed throughout the kingdom, in Yorkshire, Lancashire, Cumberland, Northumberland, Durham, Derbyshire, Staffordshire, Gloucestershire, Somersetshire, portions of Scotland and Wales. It yields coke generally of excellent quality.

Anthracite or Glance Coal.—This is chiefly Welsh, containing a large proportion of fixed carbon (over 90 per cent.) and but little volatile matter. It glows rather than flames in burning, and is almost smokeless. It is excellent for steam-raising purposes and domestic use where a good draught is available, but is quite useless for the production of illuminating gas.

Lignite or Brown Coal.—This is found at Bovey Tracey, in Devonshire, in a small field near Lancaster, and near to Lough Neagh, in Ireland. It yields but little gas, and that of a low illuminating power and very unpleasant odour. In distillation, it gives off a large quantity of water charged with acetic acid, and the residual coke is valueless as fuel. It is, therefore, of no great interest to the gas maker.

The tables annexed show the specific gravity of coals, the chief substances of which they are composed, and their yield of coke per cent :—

NEWCASTLE COALS.

Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Willington	—	86·81	4·96	1·05	0·88	5·22	1·08	72·19
Tanfield	1·26	85·58	5·31	1·26	1·32	4·39	2·14	65·13
Bowden Close	—	84·92	4·53	0·96	0·65	6·66	2·28	69·69
Haswell Wallsend	1·28	83·47	6·68	1·42	0·06	8·17	0·20	62·70
Newcastle Hartley	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
Hedley's Hartley	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
Bates's West Hartley	1·25	80·61	5·26	1·52	1·85	6·51	4·25	—
West Hartley Main	1·26	81·85	5·29	1·69	1·13	7·53	2·51	59·20
Original Hartley	1·25	81·18	5·56	0·72	1·44	8·03	3·07	58·22
Average of 18 samples from different mines	1·25	82·12	5·31	1·35	1·24	5·69	3·77	60·67

LANCASHIRE COALS.

Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Ince Hall Company's Arley	1'27	82'61	5'86	1'76	0'80	7'44	1'53	64'00
Haydock, Rushey Park .	1'32	77'65	5'53	0'50	1'73	10'91	3'68	59'40
Blackbrook, Little Delf .	1'26	82'70	5'55	1'48	1'07	4'89	4'31	58'48
Wigan Four Feet . . .	1'20	78'86	5'29	0'86	1'19	9'57	4'23	60'00
Cannel	1'23	79'23	6'08	1'18	1'43	7'24	4'84	60'33
Caldwell and Thomp- son's Higher Delf . . .	1'27	75'40	4'83	1'41	2'43	19'98	5'95	54'20
Average of 28 samples from different mines . .	1'27	77'90	5'32	1'30	1'44	9'53	4'88	60'22

DERBYSHIRE COALS (Fiddes).

Earl Fitzwilliam's Elsecar	1'296	81'93	4'85	1'27	0'91	8'58	2'46	61'60
Holyland and Co.'s Elsecar	1'317	80'05	4'93	1'24	1'06	8'99	3'73	62'50
Butterley Co.'s Langley .	1'264	77'97	5'58	0'80	1'14	9'86	4'65	54'90
Staveley	1'270	79'85	4'84	1'23	0'72	10'96	2'40	57'86
Average of seven samples from different mines . .	1'292	79'68	4'94	1'41	1'01	10'28	2'65	59'32

GLOUCESTERSHIRE COALS.

Coleford High Delf (Forest of Dean) . . .	1'219	78'810	5'303	1'750	2'062	9'055	3'020	63'97
" " " " "	1'313	76'502	5'380	1'090	1'669	8'659	6'700	62'60
" " " " "	1'331	74'410	4'470	0'700	2'370	8'840	9'210	59'76
" " " " "	1'354	74'464	5'292	0'511	2'667	6'831	10'235	60'36
Trenchard	1'354	80'709	5'425	0'735	1'271	7'060	4'800	63'38
New Bowson, Cinderford	1'332	76'860	5'430	1'680	1'940	9'330	4'760	58'24
" " " " "	1'307	79'310	5'250	1'260	0'850	9'100	4'230	59'22
Parkfield	1'374	82'069	5'613	0'940	1'457	6'391	3'530	60'97
Hanham	1'277	75'340	4'630	0'630	2'440	5'480	11'480	58'86
Warmley	1'304	82'410	4'870	0'770	0'870	5'230	5'850	71'15

SCOTCH COALS.

Boghead	1'218	63'930	8'858	0'962	0'320	4'702	21'222	31'70
Wallsend Elgin	1'200	76'090	5'220	1'410	1'530	5'050	10'700	58'45
Grangemouth	1'290	79'850	5'280	1'350	1'420	8'580	3'520	56'60
Eglinton.	1'250	80'080	6'500	1'550	1'380	8'050	2'440	54'94

WELSH COALS (Fiddes).

Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Aberaman, Merthyr	1'300	90'940	4'280	1'210	1'180	0'940	1'450	85'00
Aberdare Co., Merthyr	1'310	88'280	4'240	1'660	0'910	1'650	3'260	85'83
Anthracite (Jones & Co.)	1'375	91'440	3'460	0'210	0'790	2'580	1'520	92'90
Coleshill	1'290	73'840	5'140	1'470	2'340	8'290	8'920	56'00
Llantwit	1'273	77'410	5'553	0'560	2'365	12'062	2'050	64'70
" "	1'252	77'310	5'642	0'420	2'037	10'366	4'225	58'82
Nantgarw Llantwit	1'326	79'130	5'610	0'700	3'450	7'330	3'780	61'67
Rhos Llantwit	1'282	76'995	5'455	0'700	1'643	12'875	2'332	63'30
" "	1'302	75'452	5'497	0'840	2'312	13'023	2'876	63'03
" "	1'302	73'410	5'507	0'350	2'414	14'276	4'043	65'32
Holly Bush	1'269	80'134	5'045	0'518	2'279	8'522	3'502	74'42
Tyr Filkens	1'368	82'117	5'054	0'595	2'537	5'794	3'903	64'86
Llanhilleth	1'274	87'640	6'085	1'120	1'636	2'209	1'310	70'39
Aber Rhondda	1'320	80'675	5'082	0'910	3'675	2'763	6'895	70'81
Pontypridd	1'311	79'820	5'470	0'700	3'950	3'750	6'310	65'80
Wallsend	1'317	78'270	5'380	0'770	1'860	8'900	4'820	66'00
Energlyn	1'312	83'120	5'840	0'980	1'870	5'890	2'300	71'30
Rock Vawr	1'290	77'980	4'390	0'570	0'960	8'550	7'550	62'50

The specific gravity both of cannel and bituminous coals averages about 1'270, distilled water at 62° Fahr. being 1'000.

The proportion of ash in the best class of bituminous coals averages 2'5, and in the residual coke 3'75 per cent. In cannel, the proportion of ash is much greater.

The colour of the ash varies, according to the nature of its constituents, from white, through all the gradations of grey, cream, fawn, yellow, pink, red, to deep red and brown.

The following is an analysis of the ash of a good Newcastle coal:—

Silica	59'56 per cent.
Alumina	12'19 "
Peroxide of iron	15'96 "
Lime	9'99 "
Magnesia	1'13 "
Potash	1'17 "

100'00

The proportion of sulphur in fourteen samples of cannel averaged 1'21, and in forty-two samples of bituminous coal 1'312 per cent.

In the same samples the volatile matter and coke were as follows:—

	Volatile Matter.	Residual Coke.
Cannel . . .	44·71 per cent.	55·29 per cent.
Bituminous coal	34·72 „	65·28 „

Everyday experience shows that variations occur in the quality of the coal obtained from the same seam and in the same locality. The identical seam of coal also varies in quality in different districts.

Coal got from those parts of the bed where the seam is thickest is more likely to possess uniformity of structure than that got near to the circumference of the basin.

Mr. E. W. Binney's observations led him to the conclusion that seams of coal are materially affected by the nature of the superimposed strata. If this is of an open character, such as sandstone, the gaseous matter can readily escape. On the other hand, if the roof is of almost air-tight black shale or blue blind, the gas is retained.

Further, it is not unreasonable to infer that the vegetable matter of which coal is composed would be deposited irregularly. For example, during the ages of primeval vegetable growth, a larger proportion of leaves would be deposited in some places than in others where the deposits of bark and cellular tissue would be in excess. These conditions would naturally tend to produce variations in quality.

In seams of cannel there is more uniformity of quality than in those of ordinary coal, due to the circumstance, as is supposed, of their having been formed from vegetable matter long macerated in water, thus insuring a more intimate admixture of the vegetable substances.

It is well known that variations in the gas-producing qualities of coal are caused by the material having been stacked for a length of time on the pit bank.

It is important that the coal which is to undergo distillation should be clean and dry.

When coal in a wet or moist condition is placed in the retorts, the results are unsatisfactory in several respects.

In the first place, the temperature of the retorts is reduced, and, as a consequence, extra fuel is consumed in restoring the temperature and in drying the coal by evaporating the moisture,

and driving it off as steam, before the coal is in a fit condition to undergo destructive distillation.

Again a portion of the moisture or steam is decomposed in contact with the sulphide of iron (FeS), produced by decomposition from the disulphide of iron (FeS_2), or iron pyrites contained in the coal. The oxygen combines with the iron, forming the oxide of that metal, and the hydrogen with the sulphur, producing sulphuretted hydrogen. Carbon disulphide (CS_2) and other sulphur compounds are also formed in considerable volume.

In this way the whole of the sulphur present in the coal is caused to pass off into the gas, and has to be subsequently removed in the process of purification, thus increasing the cost of manufacture.

On the other hand, when the coal is distilled in a dry condition, rather more than one-half of the sulphur present is left behind in the residual coke.

Sulphur exists in cannel in the free state, and in bituminous coals chiefly in combination with iron, as pyrites or disulphide of iron (FeS_2), and this in the retort is converted into the sulphide (FeS), or sesquisulphide (Fe_2S_3), or both.

The Storage of Coal.—In gas making it is economical to use the coal as fresh as possible from the pit ; but, to be prepared for emergencies, the covered storage room for coal and cannel should be of capacity sufficient to contain from six to eight weeks' stock of the material, reckoned on the basis of the heaviest day's consumption.

An exception to this rule may be made in the case of gas-works situated in the immediate vicinity of the coal fields from which the supply is derived. Under such circumstances, provision for two or three weeks' stock is ample.

In storing coal, 43 cub. ft. of space per ton is required.

All kinds of coal suffer deterioration by exposure to the weather, both as regards their heating, coking, and gas-yielding qualities.

When coal is so exposed, being stored in the open air without any protecting covering, it is not only liable to be wetted by rain on its outer surface, but it also absorbs and retains moisture within its structural interstices.

The effect of this excess of moisture is to cause disintegration, reducing the size of the lumps, and converting them to a considerable extent into dust and coom.

SOME RECENT ANALYSES OF COALS.
By T. AND W. NEWBIGGING.

Name of Coal.	Situation.	Specific Gravity of Coal.	Yield of Purified Gas per Ton in Cub. Ft.	Illum. Power in Standard Sperm Candles, Sugg's lbs. of Argand No. 1.	Value of Gas per Ton of Coal in Sperm.	Sulphur in Coal per cent.	Colts in lbs. per Ton, per cent.	Ash in lbs. per cent.
Barnsley Seam	Dalton Main Colliery, Rotherham	1.282	10.700	20.77	761.76	0.97	1.398	5.2
Batley Colliery Gas Coal	Batley	1.260	11.200	19.82	761.08	0.74	1.438	6.5
Beeston Coal	Dewsbury	1.263	10.300	21.28	751.48	0.45	1.390	2.75
Beeston Gas Coal	West End Collieries, Batley	1.290	11.150	17.84	758.45	2.08	1.500	10.0
Berham Main	North Wales	1.268	12.100	16.94	702.76	0.23	1.321	5.65
Black Bed	Crawshaw & Warburton, Soothill Upper District	—	12.200	16.42	686.82	1.58	1.453	5.25
Black Bed Gas Coal	West End Collieries, Batley	1.300	11.500	17.87	704.59	2.77	1.437	7.5
Black Bed Seam	Mirfield Colliery, Mirfield	1.275	12.300	20.84	828.83	2.07	1.328	5.0
Elsesear Coal	Earl Fitzwilliam; New Parkgate Colliery, Elsecar	1.286	12.300	18.03	760.33	0.82	1.453	8.25
Flockton Gas Coal	Waleswood Collieries, Sheffield	—	12.800	17.90	785.55	0.96	1.343	6.00
Garswood Four Feet, Slack Coal	Garswood Hall Collieries, Brynn	1.295	10.500	18.26	657.36	2.0	1.375	9.3
Haigh's "Black Bed" Coal	"	1.286	10.500	18.58	668.88	2.63	1.360	7.4
Beeston Nuts	Bruncliffe, nr. Leeds	1.314	11.350	18.36	714.46	1.46	1.409	3.48
" Top Seam	"	1.246	11.500	18.74	738.89	0.86	1.390	3.30
Hoyland Siltstone	"	1.267	11.800	21.34	863.35	0.89	1.375	8.05
" New Siltstone	Barnsley	1.278	11.950	17.72	726.01	1.06	1.500	6.0
Siltstone Cobbles	"	1.270	11.850	18.06	745.94	1.1	1.453	4.55
Low Moor Black Bed Screened Gas Coal	"	1.236	11.550	18.39	716.36	0.52	1.484	4.5
Middleton Coal	Soothill Wood, Batley	1.290	11.300	19.54	757.03	2.56	1.453	3.85
Main Screened Gas Coal	"	1.271	10.100	19.54	740.01	0.35	1.406	1.67
Orrel Four Feet	Dewsbury	1.268	11.575	18.98	753.23	1.29	1.406	2.5
Parkgate Bright Gas Coal	Soothill Wood, Batley	1.260	11.200	19.82	761.08	0.74	1.438	6.5
Parkgate Coal	Batley Colliery, Batley	1.265	12.050	21.36	891.56	0.37	1.398	3.41
Parker Mine	Wigan	1.273	10.600	21.36	799.14	0.83	1.359	6.0
Rodger Mine	Nunery Colliery, Sheffield	1.276	11.050	16.76	643.96	1.78	1.484	5.5
Siltstone Branch	Bradford Colliery, nr. Manchester	1.280	10.650	20.64	711.19	0.83	1.359	6.25
" Tops	Bredbury	1.286	12.800	19.29	704.36	1.02	1.335	10.1
" Bottoms	Tinsley Park Colliery	—	12.850	17.88	784.67	0.17	1.406	9.75
Top Beamshaw	"	—	11.800	15.12	666.14	0.27	1.468	9.25
Tydesley Coal Co. Arley Slack	Malby Main Collieries, Rotherham	1.287	12.000	18.12	618.59	1.03	1.390	11.8
" Gas Coal	Tydesley	1.257	10.000	17.86	745.51	0.22	1.328	4.0
Wall and Bench	Ruabon Collieries, Ruabon	1.273	10.444	17.33	620.55	1.53	1.500	13.0
		1.278	11.200	17.26	662.78	0.84	1.420	5.34
							1.437	4 Coal.

The exposure of the coal in the winter season in this climate is, of course, the most objectionable as regards disintegration. In hot climates the intense heat of the sun produces the disintegration.

The ill-effects of this absorption of moisture do not end there. Oxidation of the particles of the coal also ensues; and as this is only another name for *eremacausis* or slow burning, the material is not only reduced in weight, but its gas-producing power, both as to quantity and quality, and its coking qualities, are greatly impaired.

An absolute loss of weight, due to the evaporation or slow combustion of the more volatile constituents, is also experienced. This is particularly the case with bituminous or caking coal; cannel suffers next in degree, and anthracite the least. Varrentrapp found in one instance that coal which had been exposed for some years to the weather had diminished in weight to the extent of 38·03 per cent.

Wet or damp coal not only yields less gas, but gas of an inferior quality. The sulphur impurities given off from it are more, thus augmenting the cost of purification; whilst some of the sulphur compounds—notably carbon bisulphide—are not removable except by a greatly increased area of purification beyond what is to be found in most gas-works.

Spontaneous Ignition of Coal.—Coal containing a large proportion of iron pyrites (disulphide of iron), commonly called “brasses,” when stored in a compact mass in a wet or humid state, is liable to spontaneous ignition. This is not an unusual occurrence in the experience of the gas manager. The indications that combustion has begun are a sensible rise in the temperature of the coal store, a sickly odour, and a choking or smothering sensation in drawing breath.

There is this liability to spontaneous ignition in almost all bituminous coals of a friable nature. It is due to more than a single cause. It may arise from the condensation of oxygen within the pores of the carbonaceous particles, just as oily cotton-waste will fire spontaneously in the same way, by the rapid absorption of oxygen. According to Professor Abel and Dr. Percy, water or moisture does not accelerate, but rather retards, spontaneous ignition under these circumstances.

The danger of firing is greatest with those coals which contain

a large proportion of iron pyrites in the shape of nodules, or "brasses," as they are called, and which are stored in a deep mass in the wet condition. These "brasses" become oxidized by the atmospheric oxygen dissolved in the water with which the coal is saturated; and the heat thus generated raises the temperature of the coal to ignition point.

Notwithstanding a conflict of opinion on the subject, we believe that the best remedy for this is ventilation.

Various expedients are resorted to for effecting this object, amongst which may be mentioned the insertion in the mass of coal of perforated iron pipes with the ends exposed; coarse wickerwork baskets, without bottoms, are used with good results; and ventilating shafts of brick, or venetian shafts of wood, both horizontal and vertical, have proved efficient. Unless the ventilation is thorough, however, the admission of air will do more harm than good, as a sluggish current will not reduce the temperature, but rather tend to develop and increase it.

A thermometer let down through the pipes or shafts will indicate any rise of temperature, and iron rods thrust into the mass of coal, when withdrawn and touched by the hand will answer the like purpose.

When the pyrites is present to a serious extent, the coal should be hand-picked, either at the colliery or when discharging at the gas-works. It is only sheer necessity, however, that will justify the employment of coal of this character for gas-making purposes.

The Gases Occluded in Coal.—Besides the liability to spontaneous combustion or ignition, there is another strong reason why coal should not be stored in the open air, nor indeed under cover, for a longer time than is absolutely necessary.

In all bituminous coals a constant chemical change is in progress, by which gas is being liberated. This gas, though frequently several times the volume of the coal, is condensed within the solid substance, being occluded or enclosed therein, until by diffusion it escapes into the air, and to such extent the coal is depreciated for gas making.

In warm weather and in hot climates this deterioration proceeds more rapidly than in low temperatures.

Dr. Lyon Playfair and others in this country, and Dr. E. von Meyer in Germany, have investigated the subject, and the sub-joined table by the latter shows the quantity and composition of

the gas so occluded, obtained from freshly raised samples of coal submitted to him for analysis.

The plan adopted was to place 100 grammes of the coal in hot de-aërated water, which was then boiled as long as any gas continued to be given off, and the gas collected was analysed by Bunsen's methods.

Samples of Coal Submitted.

No.	Description	Fathoms from Surface.
No. 1.	Low Main Seam, Bewick Colliery, Newcastle	—
„ 2.	Maudlin Seam „ „ „	—
„ 3.	Main Coal Seam, Urpeth Colliery „ „ „	—
„ 4.	Five-fourth Seam „ „ „	30
„ 5.	„ „ Wingate Grange Colliery, Durham	74
„ 6.	Low Main Seam „ „ „	108
„ 7.	Harvey Seam „ „ „	148
„ 8.	„ „ Emily Vil, Woodhouse Close Colliery	25

ANALYSIS.

PERCENTAGE COMPOSITION OF THE GAS.

Coal as above.	CO ₂	CH ₄ Marsh Gas.	O	N	Cubic Centimetres of Gas from 100 Grammes of Coal.
No. 1 . . .	5.55	6.52	2.28	85.65	25.2
„ 2 . . .	8.54	26.54	2.95	61.97	30.7
„ 3 . . .	20.86	—	4.83	74.31	27.4
„ 4 . . .	16.51	Trace	5.65	77.84	24.4
„ 5 . . .	0.34	85.80	Trace	13.86	91.2
„ 6 . . .	1.15	84.04	0.19	14.62	238.0
„ 7 . . .	0.23	89.61	0.55	9.61	211.2
„ 8 . . .	5.31	50.01	0.63	44.05	84.0

1 cubic centimetre = 0.061028 cubic inch.
1 gramme = 0.0022 lb. avoirdupois, 100 = 0.22 lb.

The Testing of Coal for its Producing Qualities.—It is almost impossible to judge from the appearance of a coal whether its gas and coke yielding qualities are good, bad, or indifferent. So far as outward indications go, nothing is so deceptive to the inexperienced in such matters; and even to those who have had large

practice in coal-testing, it is very difficult to forecast with an certainty the result of a trial of any particular sample.

The most favourable signs are when the coal exhibits traces of calcium carbonate and charcoal deposits on the surfaces exposed by fracture, and the appearance of a brownish-coloured streak on being scored with a hard, blunt point. This latter is an invariable sign of richness.

Some of the poorest coals and cannels have a fatty, unctuous appearance, suggestive of richness in gaseous properties. Again, the most valuable cannels and shales, yielding gas in extraordinary abundance, have a dull earthy cast, which might readily be taken as indicating poverty of composition and yield. The rich Boghead (Scotland), Sydney (New South Wales), Cloverport (Kentucky) cannels or shales, and the new Abram cannel, Wigan, are striking examples of this latter kind. On the other hand, this does not hold good of the Brazilian shales or "Turba." These have a dull, clayey appearance, and are very indifferent both in the yield and in the illuminating power of their gas. The importance of being able to test samples of coal or cannel, before entering into a contract for the material in bulk, is therefore obvious.

A test may be made either on a working scale or in the experimental apparatus in the gas manager's laboratory. In the former case several tons of the material have to be used, and the trial of a single sample is a formidable and tedious process, extending over many days, until the old gas in the apparatus and holder has been replaced by the new. It is obviously impossible to test a variety of samples in this manner within a reasonable period. Besides, such a method of testing is not always satisfactory. The manager has to take a good deal for granted; he is largely dependent on subordinates for the attention and care that ought to be exercised, because his constant personal supervision throughout the time occupied by the test is out of the question.

The experimental test is to be preferred for many reasons. The small apparatus is more under the command of the operator. Full justice is done to the material. The best results it is possible to obtain are secured. Time is economized in making the tests, because a number of samples can be tried in the course of, say, ten to fourteen days.

It may be urged against the experimental, or laboratory, test, that, in practical working, equal results are unattainable. If this

be the fact, it only proves that either the practical working is at fault to the extent of the difference in result, or that the bulk of the material is not equal to the sample tested.

Assuming, however, that the sample is a fair average of the whole, whatever the deficiencies of practical working may be, the coal at least should not be depreciated below its intrinsic value through defective heats and other faulty methods of carbonization; and although the actual everyday working of the material may afterwards fall short of the results obtained in the trial apparatus, these latter are a standard at which to aim. As a general rule, the difference between the results of actual use and the experimental results, with efficient plant and careful supervision, will not exceed seven to ten per cent. in favour of the experimental test.

To argue that the quality of a coal should be judged and determined solely by the results yielded in actual working, is just about as reasonable as to say that the illuminating power of gas should be decided by the methods of consumption through possibly defective fittings, and some of the burners in use by consumers. Whether coal or gas, the means best calculated to develop its intrinsic qualities should be adopted.

Care should be taken to obtain a fair sample of the coal to be operated upon. For that purpose a full section of the seam should be obtained. It should then be broken up into small pieces and thoroughly intermixed, and from this, three several charges should be taken without selection.

The charge employed in the laboratory trial is the 100th part of a ton—viz., 2·24, say $2\frac{1}{4}$, lbs.

The following are the details of the testing apparatus (Fig. 1):—

RETORT.—Cast iron; \cap -shaped; 5 in. wide, $4\frac{1}{2}$ in. high inside; 2 ft. 3 in. long outside; $\frac{1}{2}$ in. metal.

ASCENSION PIPE.—2 in. wrought tube.

CONNECTIONS.— $1\frac{1}{2}$ in. wrought tube.

CONDENSER.—12 vertical $1\frac{1}{2}$ in. wrought tubes, 3 ft. 6 in. long each.

WASHER.—1 ft. long, 6 in. wide, 6 in. deep.

PURIFIER.—1 ft. 2 in. square, 12 in. deep, with two trays of lime.

GASHOLDER.—Capacity, 12 cubic feet, with graduated scale attached.

The retort should be got up to, and maintained throughout the charge at, a bright red heat. If from any cause the temperature is much reduced, the test will not be satisfactory. This is especially the case in testing cannel and the rich shales. The time required to work off the charge of $2\frac{1}{4}$ lbs. will range from about twenty to forty minutes, according to the character of the coal.

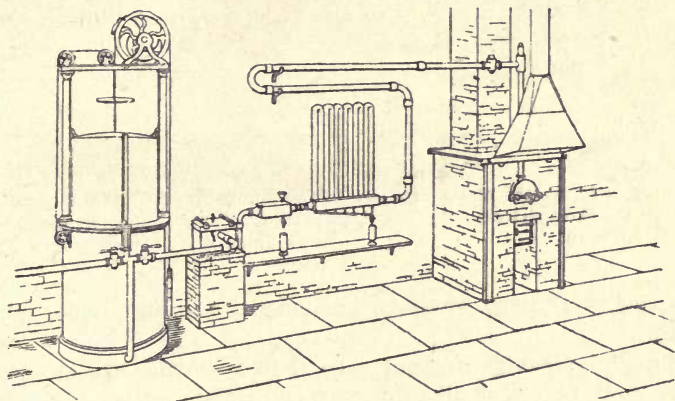


FIG. 1.

The illuminating power of the gas given out from each charge should be ascertained by the Standard photometer, no other being sufficiently trustworthy for that purpose. The average of the three tests is then taken, both for yield of gas and coke, and for the illuminating power of the gas, and this fairly represents the capabilities of the coal.

The further conditions to be observed are that the holder be entirely emptied of air, or of the previous charge of gas, and that the condenser be drained of its contents. The test charge may be continued until the whole of the gas is expelled, or otherwise, depending on circumstances. In comparing two coals, an equal production from both may be obtained, and the comparative illuminating power then ascertained.

The coke and breeze should be carefully drawn from the retort into a water-tight receptacle made of sheet-iron, closed by a lid. This is then placed in a bucket or other vessel of cold water, and, when sufficiently cooled, the contents are taken out and weighed.

For ascertaining the quantity of tar and ammoniacal liquor produced, drain the yield of the three charges from the condenser and washer, and measure this in a graduated liquid measure. The number of fluid minims in a gallon is 76,800.

Thus :

60 fluid minims	=	1 dram.
8 drams	=	1 ounce.
20 ounces	=	1 pint.
8 pints	=	1 gallon.

Then :

lbs.	lbs. per ton.		
As 6.75 (the weight of the three charges of coal)	: 2240 ::	The number of minims of tar and liquor ob- tained	: The total minims of tar and liquor per ton of coal.

And this $\div 76,800$ gives the gallons of tar and liquor yielded per ton.

Specific Gravity of Coal.—To determine the specific gravity of the coal, take a small piece, suspend it by means of a horsehair from the under side of the pan of a carefully adjusted balance

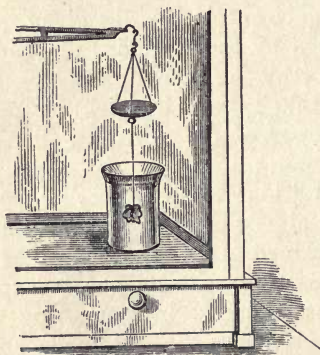


FIG. 2.

(Fig. 2), and weigh it both in and out of water (fresh distilled); divide its weight in the air by the loss of weight in the water, and the quotient is the specific gravity.

EXAMPLE.

A piece of coal weighs, say 260 grammes.

Loss of weight when weighed in water 204 „

Then $\frac{260}{204} = 1.274$ specific gravity of the coal compared
with water as 1.000.

Note.—Specific gravity is the relative weight of equal bulks of different substances, distilled water at 62° Fahr. being taken as the standard of comparison. At this temperature a cubic foot of water weighs 1000 ounces avoirdupois. Hence, the specific gravity of a body is also its weight in ounces avoirdupois per cubic foot. So that, knowing the specific gravity, the weight of any quantity of matter may be calculated by simple measurement. For example: In the instance just given, the specific gravity is shown to be 1.274; the weight of the coal per cubic foot is, therefore, 1274 oz., or 79.62 lbs. avoirdupois.

Calorific Values of Coal and Coke.—To ascertain the calorific values of coal and coke, a number of calorimeters have been designed, notably the Lewis Thompson, the Bryan Donkin, Wild's, and the Bomb designed by Berthelot and Mahler and modified by Dr. Kroeker.

In testing a coal for its heating value, it is essential that a full section of the seam should be taken.

In the case of coke, any quantity, but not less than a hundred-weight, may be taken for sampling purposes.

The coal or coke, as the case may be, is broken up and spread out in a layer of any depth. It is then divided in two; and one of the halves is taken and further broken up into smaller pieces. This is then divided into four quarters, and one quarter is taken and ground to fine powder. The fuel is then ready for testing.

The method of procedure now depends upon the type of calorimeter used. The main principle, however, is, that the fuel is ignited in a vessel immersed in a measured quantity of water of which the temperature is known. The temperature of the water, after ignition of the fuel, is then taken until the maximum temperature is reached. The difference between the maximum and the minimum multiplied by the value of the calorimeter in water (which latter is supplied with each make of calorimeter) is the value of the fuel in calories. This latter is converted into British thermal units by multiplying by 3.97.

Ash in Coal and Coke.—To determine the quantity of ash in a coal or coke, a portion of the fuel is finely ground in a crushing machine or in a mortar.

A portion, preferably 10 grammes, is accurately weighed in a platinum crucible, and heated in a muffle furnace, until the fixed carbon is completely burned off.

The residue is the proportion of ash in the quantity of fuel taken, and from this data the percentage is calculated.

EXAMPLE.

Weight of crucible, say	50 grammes
„ „ and coke, say	60 „
„ of coke	10 „
„ of residue, say „	0.5 „

∴ If 10 grammes of coal contain 0.5 of ash, what will 100 grammes contain ?

$$\frac{0.5 \times 100}{10} = 5 \text{ grammes, or 5 per cent.}$$

Coal Distillation.—Coal is a complex organic compound, and, like all organic substances, the action of heat upon it is to resolve it into its elementary constituents, the chief being carbon, hydrogen, oxygen, and nitrogen.

But there are many stages to be passed through before this final result is attained.

It may be said that each degree of temperature in the distillation of coal has its own products of decomposition, and each degree of rise in temperature produces a further breaking-up and rearrangement of the compounds which previously existed.

From this it will be gathered that the products from coal distilled at a low temperature, say, 800° Fahr., will consist chiefly of members of the paraffin series along with olefines. The lower members of these series are liquid, and the higher ones solid, so that coal distilled at a low temperature will yield comparatively little permanent gas. As the distillation temperature is increased, the paraffin and hydrocarbons are destroyed, and benzenoid hydrocarbons, free carbon, and an increased production of permanent gas formed.

The usual temperature attained in actual practice is from 1800° to 2000° Fahr., at which temperature there is a maximum yield of benzene, toluene, phenol, etc., in the tar, with a maximum of illuminating power in the gas.

Should the temperature be taken beyond this, there will be a larger production of gas, at the expense of its light-giving constituents. The tar also that is produced at a very high temperature contains a large percentage of naphthalene, phenanthrene, pyrene, etc., at the expense of the much more valuable benzene, etc.

The final stage of distillation, in which coal is split up into its elementary constituents, cannot be reached in practice, and of course is not desired, at any rate from a gas maker's point of view.

As has been said, the tar produced at different temperatures varies greatly both in composition and appearance, but the study of tar comes more under the province of the tar distiller than of the gas manufacturer.

Nuts and Slack or Dross, whether of coal or cannel, require very high temperature for carbonization. When the heat is not high they cake together in a mass, and at the end of the charge are drawn from the retort in a comparatively unspent condition.

A table by Dr. Henry exhibits the qualities of gas at different periods of distillation—

From Half-a-Ton of Wigan Cannel.

Time from Beginning of Distillation.	100 Measures of Impure Gas contain		100 Measures of Purified Gas consist of			100 Measures of Purified Gas	
	Sulphuretted Hydrogen.	Other Compounds of Nitrogen and Hydrogen.	Olefiant Gas.	Other Inferior Gases.	Nitrogen.	Consume Oxygen.	Give Carbonic Acid.
½ an hour .	½	5½	16	64	20	180	94
1 hour .	3	3½	18	77½	4½	210	112
3 hours .	2½	2½	15	80	5	200	108
5 " .	2½	2½	13	72	15	176	94
7 " .	2	2½	9	76	15	170	83
9 " .	½	2½	8	77	15	150	73
10 " .	—	2	6	74	20	120	54
12 " .	—	½	4	76	20	82	36

From Half-a-Ton of Common Wigan Gas Coal.

1 hour .	3	3	10	90	—	164	91
3 hours .	2	2	9	91	—	168	93
5 " .	3	2	6	94	—	132	70
7 " .	1	3	5	80	15	120	64
9 " .	1	2½	2	89	9	112	60
11 " .	1	1	—	85	15	90	43

The rate of production of gas from 2 cwt. of Wigan coal in an experimental retort was found to be as follows :—

$\frac{1}{2}$ hour	. . . . .	275 cubic feet.
1 "	. . . . .	245 "
$1\frac{1}{2}$ hours	. . . . .	200 "
2 "	. . . . .	140 "
$2\frac{1}{2}$ "	. . . . .	80 "
3 "	. . . . .	40 "
$3\frac{1}{2}$ "	. . . . .	20 "
4 "	. . . . .	15 "
Total		1015 cubic feet.

The annexed table, by Miller, exhibits the quantity and specific gravity of the gas obtained from two bushels of coal during each of five hours' heating in an ordinary retort, and shows the importance of restricting the time during which the coal is subjected to the action of heat in the manufacture of gas. The rich hydrocarbons diminished, and carbon monoxide and hydrogen increased in quantity as the experiment progressed.

	Cubic Feet.	Specific Gravity.
In the 1st hour	345	0'677
" 2nd "	203	0'419
" 3rd "	118	0'400
" 4th "	54	0'322
" 5th "	20	—

With cannel the carbonization takes place in less time than with ordinary coal.

For roughly estimating the weight of coal or cannel required to produce a given quantity of gas—

RULE.—Strike off the last four figures from the quantity of gas produced, and the figures remaining will represent the coal or cannel in tons.

Thus : 20 | 0,000 cub. ft. of gas = 20 tons coal.

This will be evident, if we assume that a ton of coal or cannel produces 10,000 cub. ft. of gas. Should, however, the production rise above or fall below this standard, one-tenth of the coal must be

deducted for every 1000 cub. ft. rise, and one-tenth added for every 1000 cub. ft. fall, in the production.

The average weight of coal per cubic yard is—

Anthracite, per cubic yard, solid	2160 lbs.
Bituminous " " " " " "	2133 "
Cannel " " " " "	2160 "
Coal, stored in the usual way, per cubic yard	1400 "
Coke, per cubic yard	670 "
Breeze " " " " "	950 "

The average percentage yield, by weight, of good bituminous coal is as follows :—

Gas	22 per cent.
Coke and breeze	64 "
Tar	5 "
Ammoniacal liquor	9 "
	100

In order to find the value of gas in grains of sperm per cubic foot from the given illuminating power—

RULE.—Multiply 120 (the grains allowed per hour for the consumption of the standard sperm candle) by the illuminating power, and divide by 5 (consumption of gas in cubic feet per hour by the standard burner). The answer will be the value of the gas in grains of sperm per cubic foot.

EXAMPLE.—What is the value of gas in grains of sperm per cubic foot, the illuminating power of which is 19.46 candles ?

$$\frac{19.46 \times 120}{5} = 467 \text{ grains of sperm, value.}$$

To find the value of any coal per ton in pounds of sperm, the yield of gas and illuminating power being known—

RULE I.—Multiply the cubic feet produced per ton by the value of the gas in grains of sperm per cubic foot (ascertained by the previous rule), and divide by 7000 (the number of grains in 1 lb. avoirdupois). The answer will be the value of the coal in lbs. of sperm per ton.

EXAMPLE.—What is the value of a certain coal in lbs. of sperm

per ton, whose yield of gas is 10,540 cub. ft., and illuminating power 19.63 standard sperm candles ?

$$\frac{19.63 \times 120}{5} = 471.12, \text{ value of the gas in grains of sperm per cubic foot. Then } \frac{10,540 \times 471.12}{7000} = 709.37 \text{ lbs. of sperm per ton, value.}$$

Or by

RULE 2.—Divide the yield per ton by 5 (cubic feet of gas consumed per hour by standard burner) ; multiply by the ascertained illuminating power and by 120 (consumption of standard sperm candle per hour in grains) ; lastly, divide by 7000 (number of grains in 1 lb. avoirdupois). The answer will be the value of the coal in lbs. of sperm per ton.

EXAMPLE.—What is the value of a certain coal in lbs. of sperm per ton, whose yield of gas is 10,540 cub. ft., and illuminating power 19.63 standard sperm candles ? Then

$$\frac{10,540}{5} = \frac{2108 \times 19.63 \times 120}{7000} = 709.37 \text{ lbs. of sperm per ton, value.}$$

To ascertain the relative value of different coals and cannels, attach approximate or actual market prices to the sperm pounds as ascertained above, and to the several residual products, cast up the various items, and compare them by the ordinary rule of proportion.

EXAMPLE.—The two coals to be compared are—

No. 1, yielding—

	£ s. d.
10,600 cub. ft. of gas per ton, 17½ candles value=636 lbs. sperm at ½d.	1 6 6
13½ cwt. coke at 5d.	0 5 7½
10 gals. tar at 1½d.	0 1 0½
22 gals. ammoniacal liquor at 1d.	0 1 10
	1 15 0

No. 2, yielding—

	£ s. d.
9700 cub. ft. of gas per ton, 16¾ candles value=557 lbs. sperm at ½d.	1 3 2½
14 cwt. coke at 5d.	0 5 10
9 gals. tar at 1½d.	0 0 11¼
20 gals. ammoniacal liquor at 1d.	0 1 8
	1 11 7¾

Assuming that No. 1 is 12s. 6d. per ton, the relative value of No. 2 will be found as follows:—

As £1. 15s. 0d. : £1. 11s. 7½d. :: 12s. 6d. : 11s. 3½d. value per ton of No. 2.

Farmer's rule to find the relation between quantity of gas per ton and illuminating power may be quoted here, but it must not be assumed as absolutely correct. It is only approximately so, and that only within a limited range. If a given coal yields a known volume of gas of a known illuminating value, to ascertain how much gas it will yield of another value—

RULE.—Multiply yield of gas by the illuminating power, divide by the *required* power, and the quotient is the quantity.

EXAMPLE.—A coal yields 10,600 cub. ft. per ton of 16-candle gas; how much will it yield of 14 and 17 candle gas respectively?

10,600 × 16 = 169,600. Then

$$\frac{169,600}{14} = 12,114 \text{ cub. ft. and } \frac{169,600}{17} = 9976 \text{ cub. ft.}$$

The above presupposes that the period of distillation is extended or abridged, as the case may be.

GAS PRODUCTION.

Carbonization.—This, the first process in gas making, is also the most important. Any want of economy here (and the word “economy” implies efficient apparatus, proper conditions of working, and good management generally) cannot be compensated for in any of the subsequent stages or processes to which the gas has to be subjected, or through which it has to pass before it reaches the consumer.

The carbonization or destructive distillation of coal for the production of gas is accomplished in hermetically sealed vessels known as retorts.

In the earliest days of gas manufacture, the retorts, which were of cast iron, were placed or arranged in the vertical, the inclined, and the horizontal position.

Retorts placed in the vertical position were the first to be tried. These proved objectionable by reason of the coal consolidating in a mass, thus preventing the free exit of the gas and making it a matter of difficulty to remove the resultant coke. Another

objection was the impossibility of carbonizing the comparatively large bulk of coal in anything approaching a uniform manner.

Modern skill and ingenuity, however, have succeeded in overcoming the early difficulties which confronted the practical use of retorts set in the vertical position; and the carbonization of coal in such retorts is now an accomplished fact.

Retorts set in an inclined or horizontal position were an important advance on the early retorts as set vertically, and were so considered by gas engineers. But when we say that retorts were set in an inclined position, it must not be presumed that they were set on the scientific principle of the present-day "inclined retorts." They were set at any angle between the vertical and horizontal, though generally at a smaller angle than that at which inclined retorts are now set, and various devices were arranged whereby the coal was assisted mechanically through the retort. But with lack of proper coal-handling machinery, and through other causes equally adverse to success, retorts set at an angle were discarded in favour of those set horizontally, until a comparatively recent date, when M. Coze, of Rheims, set inclined retorts on the principle of the angle of repose of coal—viz. about 32 degrees.

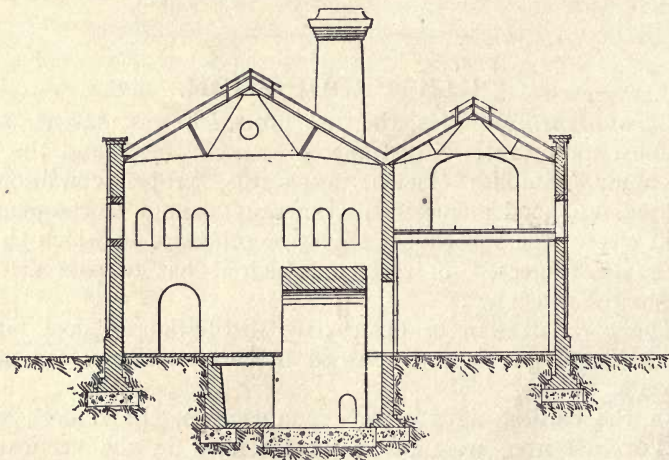


FIG. 3.

Retort House.—The retort house may be designed for a single or double stack of retorts on either the horizontal or inclined system, and may be of the ground-floor or stage-floor type of erection.

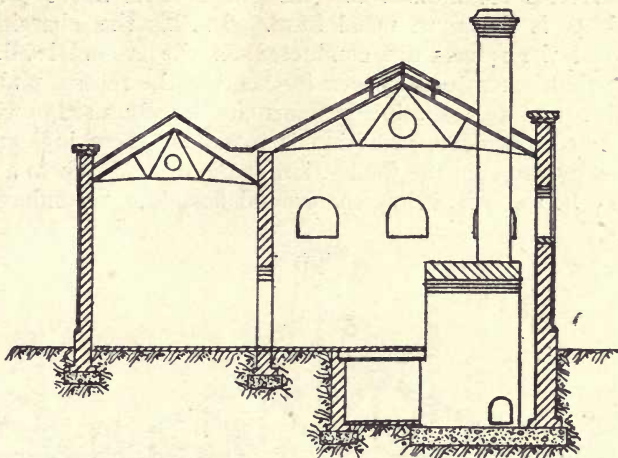


FIG. 3A.

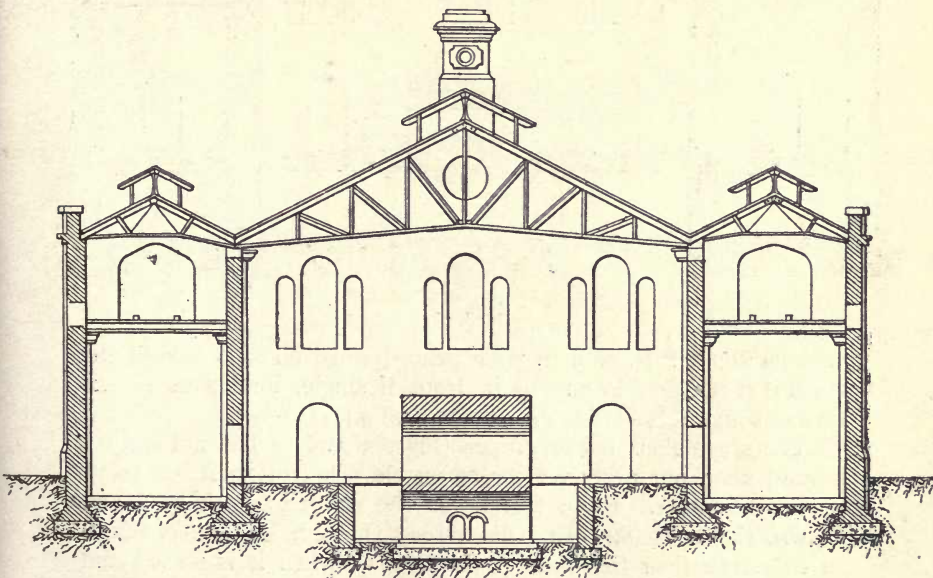


FIG. 4.

For retorts set horizontally the ground floor house (Figs. 3, 3A, and 4) is the most usual form. In this the charging and drawing of the retorts are conducted on the ground level.

Now that generator furnaces for heating the retorts under the generative and regenerative systems are largely used, owing to their proved efficiency, provision is made for them in houses of this class by carrying the foundation of the retort stack to a depth of from 9 ft. to 10 ft. below the ground floor line, an underground

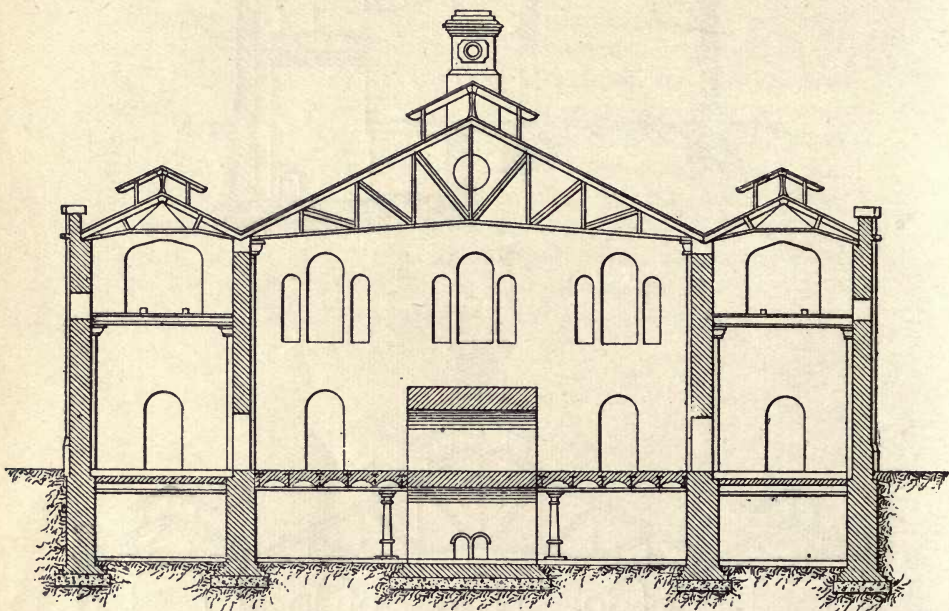


FIG. 5.

passage about 8 ft. or 9 ft. wide being formed on each side of the stack if it is a double one, or in front if single, for access to the furnaces and flues. (See Figs. 3, 3A, and 4.)

The stage floor house proper (Figs. 5 and 6) has not only a ground floor, but a stage floor at an elevation of 10 ft. or 12 ft. above the other. From this latter the retorts are charged and drawn, the hot coke being discharged through suitable openings in the stage floor (see Figs. 7, 8, and 21), when it is slaked and wheeled or otherwise conveyed away into the coke yard.

A house of this description costs more than a ground floor house; but, in large works especially, it can be operated with more economy, and the advantages it offers for the removal of the coke, the application of the generative and regenerative systems, and in other ways, are very great.

The clear space in front of a stack with horizontal retorts should not be less than 18 ft. When it is intended to employ machinery for charging and drawing the retorts, 22 ft. is required.

For convenience in hand charging and drawing, a slight inclination—say, 6 in. to 9 in. in the whole width—towards the

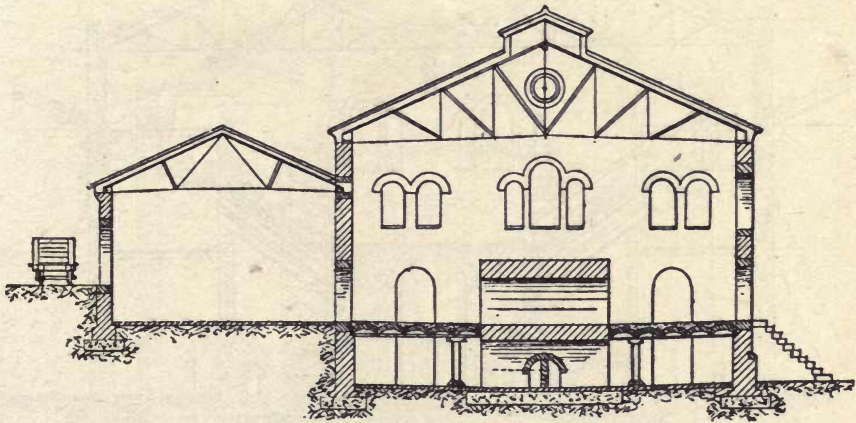


FIG. 6.]

stack, should be given to the floor. This allows the waste water to drain away, and is also handier for the stokers in charging.

The height of the walls from the charging stage is generally from 28 ft. to 32 ft., the latter dimension being necessary where charging and drawing machinery is to be used.

A house designed to contain retorts on the inclined system, whether for a single stack or for a double stack, either face to face, as in Fig. 7, or back to back, as in Fig. 8, differs materially from a house containing horizontal retorts. The house is necessarily higher, and the dimensions in front and behind the stack require modifying considerably under the new conditions of working.

As to whether, in the case of a double stack of retorts, they

should be set face to face (Fig. 7) or back to back (Fig. 8) is a matter of opinion. We much prefer Fig. 7, as admitting of better ventilation on the higher operating floor. On this floor, with back to back retorts the heat is often unbearable.

The following may be taken as convenient sizes :—

House for a single stack of horizontal retorts.—Width inside, 32 ft. Height from charging floor to springing of roof, 21 ft.

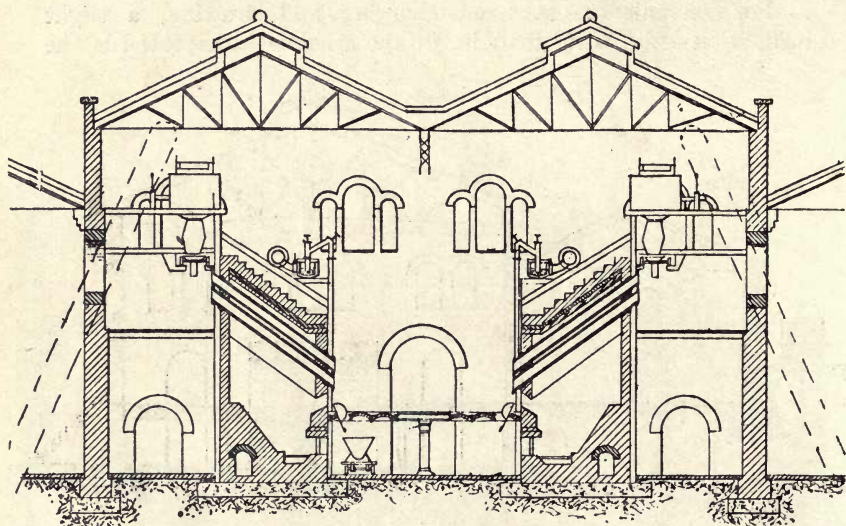


FIG. 7.

House for a double stack of horizontal retorts.—Width inside, 60 ft. Height from charging floor to springing of roof, 28 ft. Height from basement to springing of roof, 38 ft.

House for two stacks of 20 ft. inclined retorts, set face to face.—Width inside, 99 ft. or 100 ft. above the set off. Height from basement floor to charging roof 22 ft. 6 in. Height from charging floor to springing of roof, 31 ft. 6 in. Height from basement floor to drawing floor, 10 ft. Width of stack, 17 ft. Width of charging stage, 18 ft. Width of drawing stage between stacks, 30 ft.

ROOFS.—The retort house roof should be constructed of either wrought-iron or steel, and slated. The design of the roof will, of

course, vary with the width. For houses up to 60 ft. wide some form of king post roof is generally adopted. Above this width—and this applies to inclined retort houses—the roof may be either elliptical, semicircular, or, as in Fig. 7, divided into two; the valley end of principals being carried by a girder extending the length of the house.

Corrugated-iron sheeting may be used to cover the principals

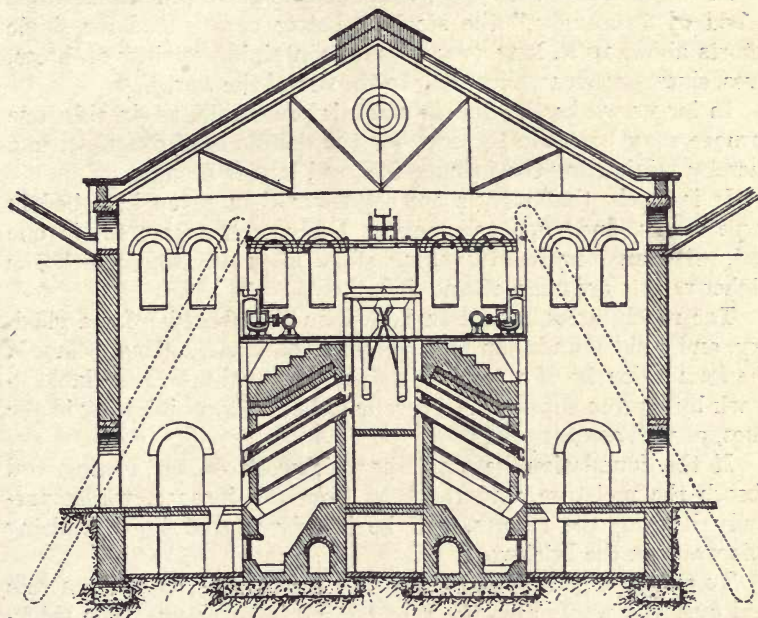


FIG. 8.

in the place of slates, and, being much lighter than slates, the principals may be lighter in construction and farther apart, so reducing their number. The first cost of a roof of this description is less; but its durability is inferior to a slated roof. The sheets should not be thinner than No. 20 gauge.

Ventilation.—Suitable openings should be left in the walls of the retort house at a height slightly above the stack, for the admission of air and light. The ventilation should be good, and, with this object in view, louvres should extend from one end of

the roof to the other, and be of ample capacity. Ventilating tubes or towers are sometimes used alone, or in addition to the louvre ventilator. These are efficient, and present a good appearance.

Retort Stack.—This necessarily varies in size and general construction according to the system of heating adopted, and the number, dimensions, and general arrangement of retorts in the setting.

In the smaller-sized works, where it is inconvenient to let down a bed of "throughs," the stack is better constructed for single retorts about 10 ft. long over all, and containing settings of threes, fives, sixes, or sevens, according to the size of the works.

In larger works the double stack is preferable, as, in this, one furnace may be made to serve for the double or through setting, thereby minimizing the furnace fuel and labour account.

It is rarely that retorts are set fewer than seven in a bed in large works, and even as many as twelve retorts are set in one bed, with an elevated travelling stage in front, from which the higher retorts are charged and drawn.

Too much stress cannot be laid upon the necessity for a good, dry, and solid foundation for the retort stack and setting. Should the foundation be of a yielding nature, the setting will be liable to crack by uneven subsidence, thereby causing short-circuiting in the flues, as well as other evils.

If the foundation be wet, the brickwork of the setting will absorb the moisture, and the heat from the furnace, whilst partially heating the retorts, will be largely wasted in volatilizing this water in the brickwork.

To ensure a good foundation there should be a bed of concrete laid over the whole area the retort stack is to cover. The thickness of the concrete will, of course, depend to a large extent on the nature of the ground; but in ordinary solid ground, and for direct fired retorts, the concrete should not be less than 1 ft.; for generator and regenerator benches, $1\frac{1}{2}$ ft.; and for an inclined retort stack, $2\frac{1}{2}$ ft. thick.

On this concrete bed the footings of the stack will be built, and a double layer of red bricks laid for the floor or setting foundation.

The division walls or piers of the stack should not be less than 18 in. thick, and built of best fire-clay bricks, set in fine, well-tempered fire-clay.

With thinner walls there is considerable radiation when the setting next to the one working is let down; whilst with walls of this thickness, each setting conserves within itself nearly all the heat generated in its furnace.

The end or buttress walls should be from 2 ft. 3 in. to 3 ft. thick, according to circumstances—the larger dimension preferred—lined on the inside with 9 in. of fire-brick, and faced on the outside with the same; the intervening space being built in ordinary red brickwork.

The whole of the brickwork in a retort stack, whether fire-brick or otherwise, should be set in fire-clay, as ordinary mortar rapidly crumbles away when subjected to heat.

The main arches for seven retorts, and under, to a setting, should be semicircular; for a setting of more retorts than seven, the arch is generally either segmental or elliptical.

The semicircular arch may be built in ordinary fire-brick rings, three half-rings deep. Elliptical and segmental arches, being weaker than the semicircular, require greater care in building. They are best built with a 9-in. ring of purpose-made slabs and a $4\frac{1}{2}$ -in. ring of arch bricks, carefully set in fire-clay with fine joints. A space of from 3 to 4 in. is sometimes left above the top of the fire-brick arch to allow for expansion. But the tendency is for the arch to sink, and to help to counteract this the floor of the bench is given a slight curvature upwards from the front and back to the centre.

The top of the stack should be haunched up five courses of brickwork above the top of the arch, of good common bricks, faced with fire-bricks, laid solid, and finished with cornice or coping. In the case of an inclined stack, the haunching is stepped.

To prevent undue radiation, the front wall of the oven should be a brick and a half, or 14 in., thick.

Fig. 9 gives a good idea of the construction of a bench containing a setting of seven direct-fired retorts.

Flues and Draught.—The main flue for direct-fired furnaces is generally built along the top of the stack, and communicates with the setting by means of flue holes in the crown of the arch. These should be 12 in. square and provided with damper tiles, 27 in. long, 16 in. wide, 3 in. thick.

With settings on the generator and regenerative systems, the main flue should be built at the back of the furnace and in the lower

portion of the stack. This ensures the heat from the waste gases being kept within the setting.

For a double stack containing eight or ten ovens or benches on each side, the chimney being in the centre, the main flue should also be double, and the internal dimensions of each division not less than 36 in. in depth by 15 in. in width. For even a less number of ovens the size of flue should not vary greatly from the above.

An insufficient draught, whilst it invariably results in

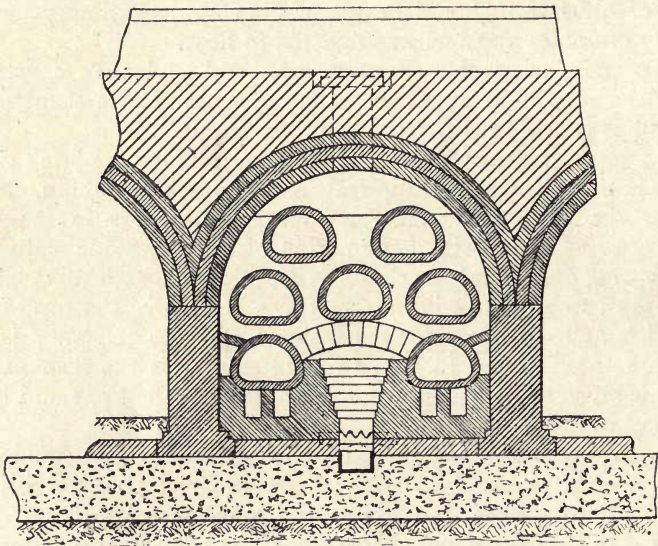


FIG. 9.

diminished heats, causes a waste of fuel, from the consequent incomplete combustion in the furnace and the usual hard firing that accompanies it. The flame which is occasionally seen at the top of a retort house chimney is significant of this defect. The flame is produced by the unconsumed carbon monoxide uniting with its due proportion of oxygen on coming in contact with the atmosphere, and, by combustion, being converted into carbon dioxide. When the proper quantity of air is supplied to the combustion chamber, the carbon monoxide produced is there converted into

carbon dioxide, and the heat thus generated is utilized for the distillation of the coal contained in the retorts.

An excessive draught through the ovens is to be avoided, as well as an obstructed one. If too much air is drawn in, its effect is to reduce the heat, as well as to cause the consumption of an excess of fuel. Hence the importance of being able to control the draught by means of a damper placed at the entrance of the cross flue into the main flue of the bench.

According to the experiments of Dulong—

1 lb. of hydrogen,	burning to water,	yields 62,535 units of heat.
1 „ carbon,	„ to carbonic acid,	„ 12,906 „
1 „ carbon,	„ to carbonic oxide,	„ 2,495 „
1 „ carbonic oxide,	„ to carbonic acid,	„ 4,478 „

NOTE.—The English standard unit of heat is the quantity of heat necessary to raise the temperature of a pound avoirdupois of water 1° Fahr. The French *calorie* is the quantity of heat required to raise the temperature of a kilo. (2.2 lbs. avoirdupois) of water 1° Cent.

As a rule, when firing with coke, cleaning off the fire bars once in twelve hours is sufficient. Too frequent cleaning entails a waste of coke, besides reducing the heat of the oven.

Instead of the tall chimney stalk at the end of the retort house, it is the custom to erect chimneys or shafts of less altitude immediately over the bench, or between the benches, rising a few feet above the roof, and serving for four or more double ovens on each side. These are found to produce a sufficient draught, they are more uniform and regular in their action, and their cost is necessarily less. But as they deliver the products of combustion into the atmosphere at a low level, their use should be restricted to neighbourhoods where the nuisance is unobjectionable.

When the room can be spared, it is best to erect the chimney between, and apart from, the retort benches; so that when the latter need to be taken down and rebuilt, the chimney, being a more permanent structure, remains undisturbed.

Sometimes each bench is supplied with a small shaft for its own use. In some American gas-works the main flue and chimney are dispensed with altogether, the opening in the crown of the bench being found sufficient, it is said, to afford the requisite draught. Even assuming the draught, under such conditions, to be ample for ensuring perfect heating and carbonization, which may be doubted, the objections to allowing the hot fumes to

escape into the retort house underneath the roof are sufficiently obvious to cause the practice to be condemned.

The following is a useful rule for determining the size of the vertical opening in retort house chimneys about 70 ft. in height: Allow $1\frac{1}{2}$ sq. in. of area for each lineal foot of retort, or, say, 15 in. per mouthpiece. Example: Required the internal sectional area of a chimney stalk serving ten double benches of eight retorts, or sixteen mouthpieces each, five benches on each side of chimney; retorts 20 ft. through; total, 160 mouthpieces. Then—

$$160 \times 15 = \frac{2400}{144} = 16.66 \text{ sq. ft. area.}$$

Retorts.—The materials of which retorts, for the distillation or carbonization of coal, are made, are fire-clay and cast-iron.

In the early days of gas-lighting, and for many years later, cast-iron retorts were used exclusively, but clay retorts, in the face of much prejudice and opposition at first, gradually advanced in popularity as their merits became known, until at the present time their adoption is almost universal.

There were many reasons why iron retorts should give place to those of the more refractory clay.

The iron retorts were incapable of withstanding a heat sufficiently high for the distillation of coal in the most economical manner; the highest temperature at which it was advisable to work being 1830° Fahr., a bright cherry red. They were also liable to rapid oxidation, rendering necessary the frequent removal of the scale, if the proper temperature was to be maintained.

Cast-iron retorts are now only employed in very small works, and in coal-testing plants, as here they possess an advantage over clay, in bearing letting down frequently without suffering damage.

The round, 15-in. diameter, and the \square -shaped, 15 in. by 13 in., are the handiest, and 7 ft. 6 in. is a convenient length. They are usually made $1\frac{3}{8}$ in. thick, with an ordinary flange to which the mouthpiece is attached. Their weight is 16 to 18 cwt.

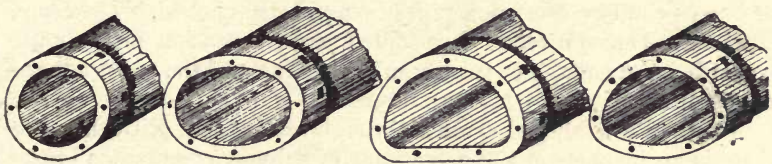
Iron retorts should always be scurfed before being let down, otherwise the unequal contraction of the incrustated carbon and the metal of the retort in cooling will cause fracture.

The duration of an iron retort is equal to the production of from 700,000 to 800,000 cub. ft. of gas.

Clay Retorts.—The chief advantages clay retorts possess over those of iron are, the higher temperature to which they may be subjected without collapse, with a consequent greater yield of gas per mouthpiece, and a longer life.

Until within recent years hand-moulded retorts were chiefly in use. Such retorts, however, are not of a uniform consistency throughout; consequently, when they are heated, uneven expansion and contraction takes place, with the result that cracks appear. This want of consistency is no doubt due to the slow process of hand moulding, in which it is almost impossible to thoroughly work the material together.

This fault has been overcome by the introduction of machinery in retort manufacture, in which the clay is subjected to great pressure. For inclined retorts, which are not parallel throughout



FIGS. 10, 11, 12, 13.

their length, an expanding die is used. Besides its uniform consistency, it is further claimed for the machine-made retort that its surfaces are smoother, and therefore offer less attraction to the deposition of carbon.

The usual section of the clay retort is either the round (Fig. 10), the elliptical (Fig. 11), or the \cap (Fig. 12), with a modification of the latter known as the dished \cap (Fig. 13).

Clay retorts are usually made 3 in. thick and parallel throughout their length. The front portion of the retort to which the mouthpiece is attached may be flanged or swelled 4 in. thick and 9 in. broad, and holed for the insertion of mouthpiece bolts; or the retort may be 3 in. throughout its entire length and the mouthpiece socketed on to the retort. Of the two methods of attachment we prefer the latter.

“Single” retorts are usually made in one piece, with a stopped end. When the retorts are through, they are usually in three pieces, jointed together, and have a mouthpiece at each end.

The advantages gained in using this kind of retort are important in some respects. The accumulation of carbon is less, owing to the absence of backs. The current of air which is drawn through their interior every time they are charged tends to loosen any carbon deposit that takes place. More heating surface for carbonization is obtained without additional expense, and that in the hottest part of the oven. They are also drawn with greater facility. The scoop (Fig. 51) is, in the absence of machinery, generally used in charging these retorts. As they have to be drawn and charged at both ends simultaneously, they cannot, where the scoop is used, be conveniently worked where the stokers are fewer than six in number.

With the use of through retorts, however, the gas has a tendency to travel up only one of the ascension pipes at a time, either owing to there being a greater seal in one of the hydraulics or by reason of one of the two ascension pipes being partly choked. Therefore, where the through retort is adopted, each ascension pipe should be made large enough to readily take the whole of the gas produced in the retort.

Further, it is alleged against through retorts that with their use there is an increase in the percentage of sulphur compounds in the gas, and also that they have a tendency to produce naphthalene deposits.

The following are useful and convenient sizes of clay retorts :—

Round	.	16 in. diam.	} Inside measure, and 10 ft. long outside.
Oval	.	21 × 15 in. "	
⊔-shaped	.	21 × 15 in. "	
⊔	„	22 × 16 in. "	

The weight of a clay retort of the above sizes is from 14 to 17 cwt.

For very small works, the following sizes are more suitable :—

Round	.	14 in. diam.	} Inside measure, and 9 ft. long outside.
Oval	.	18 × 14 "	
⊔-shaped	.	18 × 14 "	

Retorts made of fire-bricks and tiles or blocks rebated or grooved and jointed with fire-clay are still preferred by some engineers (Fig. 14). In the matter of durability, they possess a clear advantage over the moulded clay retort, their life being

three or four times that of the other ; and though their first cost is more, this is compensated for by the saving in wear and tear.

Large retorts of this class, 30 to 50 in. wide, which at one time were common enough, are objectionable for many reasons. A large area is exposed to the cold air every time the charge is drawn, and the time occupied in drawing them is necessarily considerable. Again, there is a tendency to allow carbon to accumulate in such retorts, because in the ample space the inconvenience of the presence of a thick body of carbon is not felt by the men in drawing and charging. If the required temperature, however, is kept up under these circumstances, it must be at an excessive expenditure of fuel and labour.

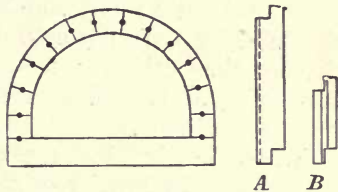


FIG. 14.

The greater depth of the coal, and the constant inequality of carbonization between the inner and outer portions of the charge, are also serious drawbacks to their use.

By reason of its shape, the round retort is the strongest and most durable, but it is not equal to the others as a carbonizer, and when it has been tried in inclined settings, it has not been a success, owing to the jamming of the coke in discharging.

For inclined settings it has been found necessary to modify the usual sections of the retorts somewhat, so as to facilitate the discharging of the coke. It will be readily understood that the coke in an inclined retort is liable to jam during its progress downwards. To overcome this, the retort, usually \cap -shaped, is made to taper from the bottom to the top, not less than 4 in. in the 20 ft.

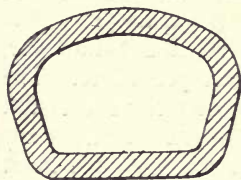


FIG. 15.

The modification (Fig. 15) of the \cap retort, introduced by Mr. Herring, at Edinburgh, is the outcome of a study of this question.

The usual sizes of the inclined \cap retort are from 21 to 26 in. wide by 15 in. deep at the bottom, and from 18 to 22 in. wide by 15 in. deep at the top.

The length of the inclined retorts varies from 15 to 20 ft. ; but it

will be recognized that the labour in filling and drawing a 20-ft. retort is very little more than that for a 15-ft. retort.

It has been found by experience that it is a mistake to taper the cast-iron mouthpieces of inclined retorts, as was at one time practised. The section of the retort should be continued right through the mouthpiece.

In moderate-sized works, where coke firing is employed, each single horizontal retort should be of capacity sufficient to hold a charge of from $2\frac{3}{4}$ to 3 cwt. of coal; and with five or six hours' charges the yield per mouthpiece with good bituminous coal should be at the rate of 6500 to 7500 cub. ft. per diem of twenty-four hours.

Where heating by regenerative furnaces is adopted, the charges may be heavier or more frequent; and the twenty-four hours' yield per mouthpiece will range from 7000 to 9000 cub. ft., according to the quality of coal used. Even this yield is exceeded where the retorts are heated and worked under the best conditions.

Now, eighteen months' continuous production at the rate of, say, only 7000 cub. ft. per mouthpiece per day, is equal to a total production of over $3\frac{3}{4}$ million cub. ft. of gas.

The duration of clay retorts greatly depends on the setting. When the retorts are properly supported, and suitably protected from a cutting heat from the furnace, they will last for two or three years; otherwise—and this is nearer their average life—they will be burnt out in fifteen to eighteen months.

The system of completely or nearly filling the retorts, and the adoption of ten- and twelve-hour charges, materially increases the production per mouthpiece. Sufficient data has not, however, as yet been obtained as to the wisdom of this procedure. The system is one, however, that holds out promise of being successful.

It is an error to suppose that the brickwork in the walls supporting the retorts causes a diminution in the available heat. Take the case of two benches of retorts set, the one with as much brickwork as is required for proper support without obstructing the draught or unnecessarily covering the retort surfaces; and the other having the least possible quantity of brickwork, supporting (say, for example) the retorts only at their extremities. In getting these benches in action for the first time, there can be no doubt the latter would be the first to attain the desired temperature; but although the former would require a little longer time, and the

expenditure of more fuel at first, the superior regularity of its action over the other in distilling the gas from the coal will scarcely be questioned.

No doubt the thinner the retorts themselves, compatible with strength, the better, so that the heat may the more readily pass to their interior. But the circumstances attending the retort as the vessel containing the material for distillation are not to be confounded with those appertaining to the adjacent brickwork. This need not be more than is reasonable, but it is better to err on the side of excess than too little.

Dimensions for Settings of Retorts on the Direct-Fired System.—For three 18 in. by 14 in. ovals or \cap 's, 9 ft. long :—

Width of oven, 5 ft. 2 in. ; height, 6 ft. 3 in. ; depth, 9 ft. 1 in.

Width of furnace at grate bars, 9 in.

Width of furnace at springing of arch, 16 in.

Length of furnace, 30 in.

Height from floor-level to underneath the flanges of the two bottom retorts, 2 ft. 3 in.

Number of grate bars, two ; 30 in. long each, made of 2 in. square bar-iron.

For five 21 in. by 15 in. ovals or \cap 's, 10 ft. long :—

Width of oven, 8 ft. ; height, 7 ft. 6 in. ; depth, 10 ft. 1 in.

Width of furnace at grate bars, 10 in.

Width of furnace at springing of arch underneath the middle retort, 18 in.

Length of furnace, 30 in.

Height from floor-line to underneath the flanges of the bottom retorts, 2 ft. 8 in.

Number of grate bars, two ; 30 in. long each, made of 2 in. square bar-iron.

For seven 21 in. by 15 in. ovals or \cap 's, 10 ft. long :—

Width of oven, 8 ft. 6 in. ; height, 8 ft. ; depth, 10 ft. 1 in.

Width of furnace at grate bars, 12 in.

Width of furnace at springing of arch, 20 in.

Length of furnace, 36 in.

Height from floor-line to underneath flanges of two bottom retorts, 16 in.

Number of grate bars, three ; 36 in. long each, made of 2 in. square bar-iron.

Vertical retorts in cross section may be circular, oval, elliptical, or rectilinear but with rounded ends, as experience may dictate as the best.

The following are the respective sizes of the Dessau, Woodall-Duckham, and Glover-West retorts in some recent settings:—

	Cross Section at Top of Retort.	Cross Section at Bottom of Retort.	Length over all.
Dessau	9 in. × 22 in.	13½ in. × 27 in.	13 ft.
Woodall-Duckham	46½ in. × 8 in.	63 in. × 20 in.	25 ft.
Glover-West	27 in. × 10½ in.	33 in. × 18 in.	25 ft.

But all these dimensions are subject to modification.

Chamber Ovens.—The carbonization of coal in chamber ovens is being extensively introduced abroad. Twenty-four hour charges of 8 to 10 tons of coal are adopted, and it is claimed that this system produces a larger yield of gas with a higher lighting and heating value than any other system at present in use; also that the coke produced can be used for metallurgical purposes.

The Heating of Retorts.—There are in present practice two distinct systems whereby horizontal retorts are heated.

The first system, known as the "direct fired," is that in which solid fuel is burned to carbon dioxide by the admission of an unregulated supply of air to the underside of the fire-bars, the retorts being heated by direct contact with the products of combustion.

That this system is imperfect is well known, and it is only in the smallest works, or where water in the foundations and other difficulties are encountered, that it is adopted. On the other hand, a stage floor with the regenerator arrangements above ground might be adopted.

The better system, that of gaseous firing, is one in which solid fuel is converted into combustible gases, these being conducted to the region where the heat is required, and there mixed with sufficient air for their perfect combustion.

From a practical as well as from a theoretical point of view, gaseous firing has everything to recommend it. The saving in fuel is considerable, even on the best results obtained by direct coke firing. Clinkering at the base of the retorts is avoided, and consequently wear and tear of the setting is reduced, the heats are higher and steadier, and heavier charges can be employed, increasing the production of gas per mouthpiece and economizing space in the retort house.

The application of gaseous firing has a much greater field than is provided by its use in gas-works, but the main feature of all gaseous firing is the "producer."

There are many types of producer, notably those of Siemens and Liegel, but, though they vary in the details of construction, the principle of action in each is identical.

As applied to use in gas-works, the producer is best contained within the arch of the retort bench, and the usual forms are as shown in Figs. 16 to 22.

It is always advisable, where circumstances permit, to have a full depth producer, inasmuch as a deep bed of fuel gives the maximum efficiency.

Its dimensions will, of course, depend upon the amount of work it has to do. A producer of a fuel capacity of about 75 cub. ft. and 6 to 7 feet in depth of fuel is sufficient for a setting of eight 20-ft. through retorts.

The closed hearth producer, as shown in Fig. 17,

has many points in its favour, both in regard to working efficiency and cost of maintenance; but owing to difficulties in clinkering, the open hearth with ash-pan and fire-bars is more generally adopted.

The producer is filled through the charging door at the top, a shoot being generally employed for this purpose, and the coke rests on the hearth (Fig. 17) or fire-bars (Fig. 19).

The air necessary for combustion is admitted through nostrils or ports at the bottom of the producer, the openings in them being regulated by means of slides, so that the air admitted is under absolute control.

The action in the producers is, that the air entering the furnace causes the combustion of the fuel, with carbon dioxide as the product.

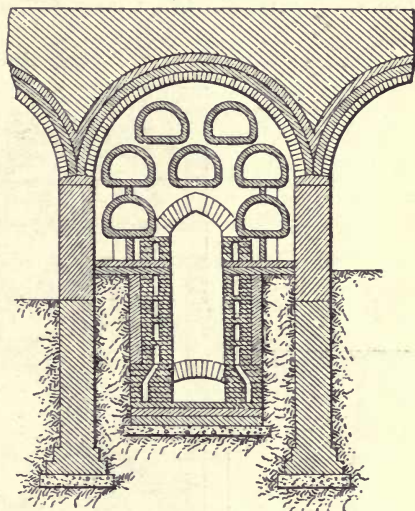


FIG. 16.

The carbon dioxide then passes through the incandescent fuel in the higher portion of the producer, and is there converted into the combustible gas, carbon monoxide, according to the equation,



From this it will be readily seen that the size of the producer must be such, and the quantity of air admitted to it must be so governed, as to produce the maximum of carbon monoxide at the top of the producer. Hence follows the rule that there should

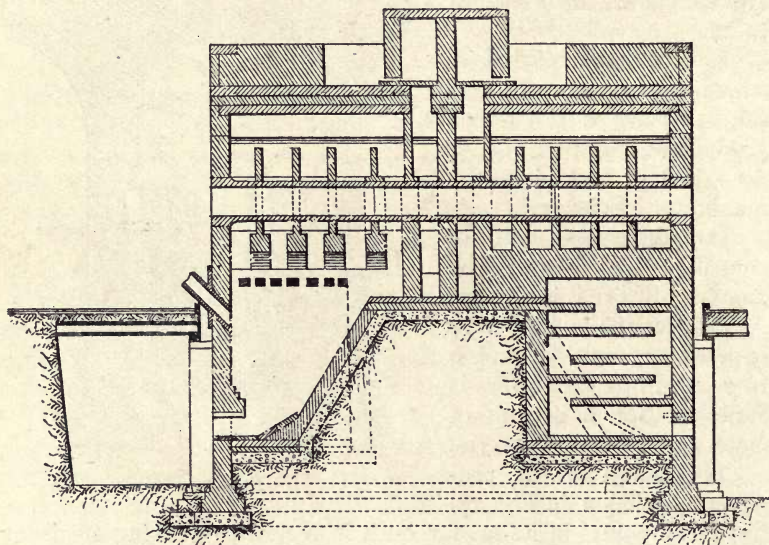


FIG. 17.

always be a good depth of fuel within the producer, so that all the carbon dioxide formed may be converted into carbon monoxide.

It is usual to have either a steam supply to the producer or a stream of water running on to drip-plates (Fig. 18), and from thence falling to the ash-pan, which should be kept full of water.

The advantage of the steam or water supply to the producer is threefold. It disintegrates the clinker, keeps the fire-bars in good condition, and helps in the formation of the combustible gases from the producer.

The steam entering the producer and meeting with the in-

candescent fuel is split up into its constituents, hydrogen and oxygen. The oxygen assists in the combustion of the fuel, and the hydrogen passes on through the fuel, and adds to the volume of the combustible gases.

But the use of steam is limited in application, owing to the large amount of heat absorbed from the furnace in its dissociation. This heat is rendered latent in the hydrogen, and evolved again in its combustion in the combustion chamber.

Without the use of steam the temperature in the producer is about 2700° Fahr., but such a high temperature is not necessary for the reduction of carbon dioxide into carbon monoxide, the minimum temperature required being about 2200° Fahr.; so that steam may be used to the extent necessary to keep down the temperature to this point, which is equal to about 18 parts of steam to 100 of carbon.

The arrangement of one producer to a number of settings has been tried in several instances, but not with any permanent success so far.

From the producer, the combustible gases pass to the combustion chamber, generally arranged beneath the bottom middle retort, where they meet with the air provided for their complete combustion.

The difference between the two systems of applying gaseous firing, known as the generator (Fig. 17) and regenerative (Fig. 19) systems, arises with the question of the supply of air ("secondary air," as it is called, to distinguish it from the "primary air" admitted to the producer) to the combustion chamber.

On the generator system the secondary air is provided in two ways. It either passes direct and in a cold condition to the

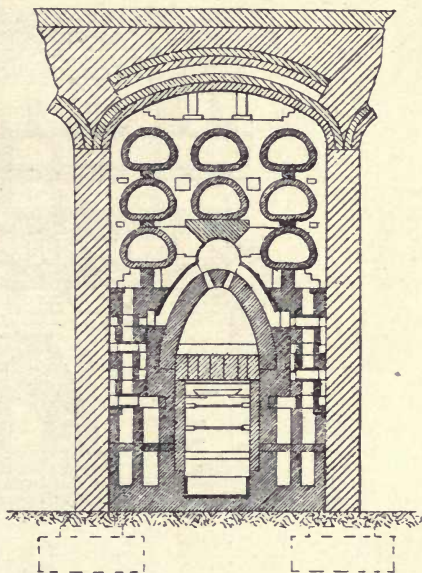


FIG. 18.

combustion chamber, or through channels arranged alongside the producer, thereby absorbing by conduction a certain quantity of heat from the producer before it reaches the combustion chamber.

On the regenerative or recuperative system, the secondary air is heated by being made to traverse more or less tortuous passages intersected by flues down which the waste gases are passing from the furnace to the chimney for further work; the waste gases finally leaving the setting at a temperature of about 600° Fahr.

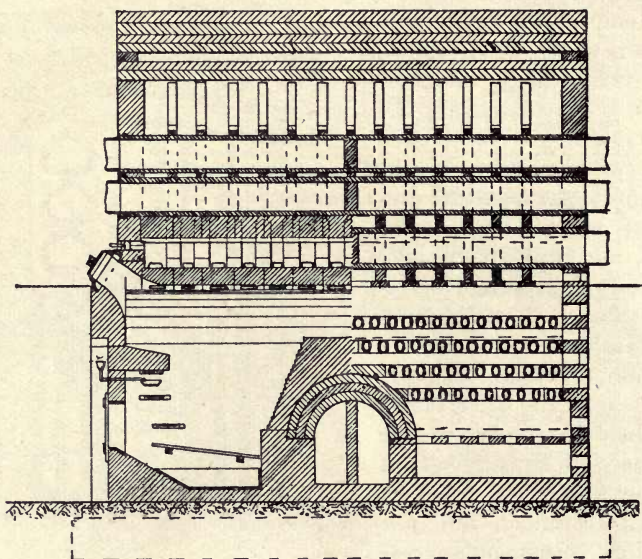


FIG. 19.

There are many forms of the regenerative part of the furnace in actual use, but they resolve themselves into two main types according as to whether the inventor considered that air takes up heat slowly or quickly. In one case we have long, tortuous passages for the secondary air to travel along before reaching the combustion chamber. In the other case the passages are short.

The regulation of the primary and secondary air supplies depends upon the design of the setting, and no rule can be furnished that will be applicable to retort settings generally. The flue areas, and conditions of draught, are so varied that only by experience can the proper working be insured.

Semi-regenerators are sometimes adopted. In these a cavity of about 3 or 4 ft. in depth is made in the floor in front of the retort bench, being covered with cast-iron plates, and having a movable door or lid to give access underneath. We do not recommend them, as the workmen are subjected to an objectionable degree of heat in clinking and removing the ashes.

If there is one point which necessitates greater care and consideration in the construction of the retort setting than another,

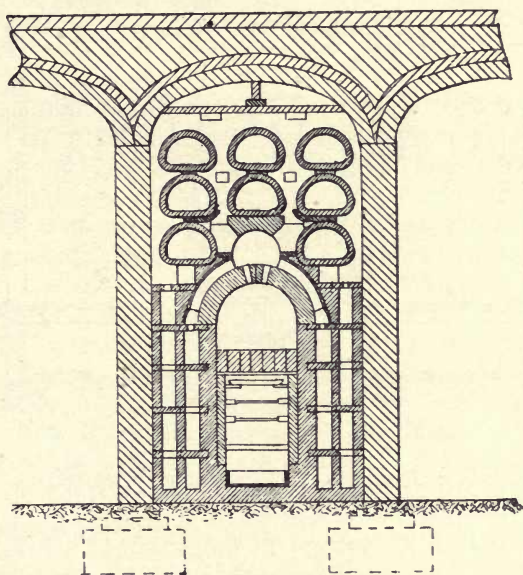


FIG. 20.

it is that with regard to the position and size of the combustion chamber.

With the ordinary direct firing where the retorts are heated by conduction, it is necessary that the products of combustion impinge as much as possible on the surface of the retorts.

With gaseous firing, however, such a policy is wrong. Here we have the combustible gases from the producer mixing with the secondary air at the combustion chamber, with ignition. The flame should not impinge, if it can be prevented, upon any surface, such as the retort, in which the heat is at a lower potential than itself, otherwise the combustion will be more or less destroyed

and incomplete, and also the cutting heat of the flame will rapidly destroy the retort or brickwork upon which it impinges.

The flame should have full play, so that the retorts may be

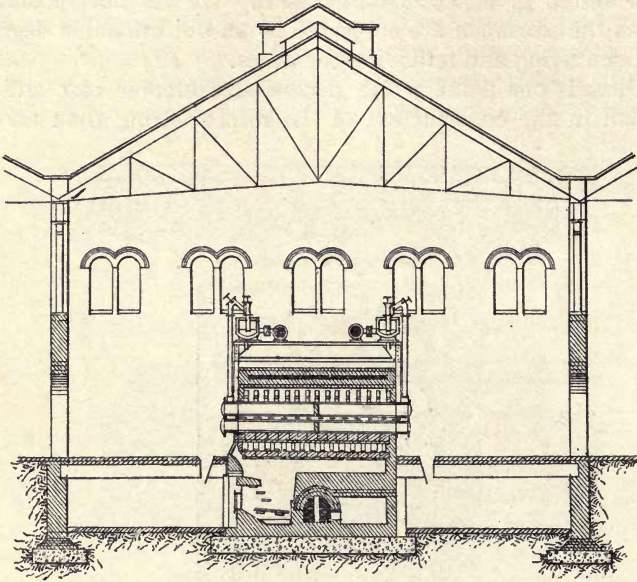


FIG. 21.

heated by *radiation* from the flame, and afterwards by *conduction* from the products of combustion.

This points to a large combustion chamber, and the larger this

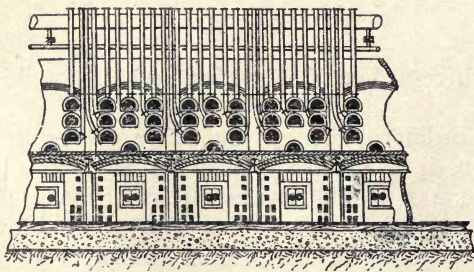


FIG. 22.

is the less liability there will be for burning out the centre retort. Undoubtedly the ideal position would be to range the retorts in four

and even five tiers of two retorts each. The objection to this is that in small works, or works where charging and drawing machinery are not employed, difficulty would be experienced in drawing and charging the top tiers of retorts.

On the principle of regeneration, as applied to the heating of retorts, it may be pointed out that dry air, though diathermanous to radiant heat, takes up heat with extreme rapidity when brought in contact with a hot surface. It is not necessary, therefore, that the hot-flue passage through which the secondary air is caused to travel in order to be heated before coming in contact with the combustible gases from the generator, should be long extended and tortuous in its course.

The advantages of the so-called regenerative arrangements as applied to retort furnaces are due not only, or chiefly (though this is important) to the heating of the secondary air, which is readily accomplished, but largely to the circumstance that the heat of the waste gases, as the latter traverse the passages constructed alongside the furnace, is at a potential higher than that to which the brickwork in the base of the setting, and in the sides of the generator in the absence of the waste gas flues, could possibly attain. The effect of this is to insulate, as it were, the heat of the furnace, minimizing outward radiation and conduction.

Heat, like water and electricity, tends to establish an equilibrium; and the lower the temperature of a body in contact with another at a higher temperature, the greater the abstraction of heat from the latter by the former.

From this it will be evident that the function fulfilled by the heat of the waste gases cannot properly be considered as "regenerative," in the strict sense of that word. Their temperature is necessarily lower than that of the furnace and the inside of the oven. Heat cannot travel from a lower to a higher potential any more than water under normal conditions can travel uphill, and therefore it is not possible for the lower temperature to "regenerate" the higher. The chief function of the heat of the waste gases is by insulation, as already explained, to conserve, in the ratio of their own temperature, the heat generated by combustion in the furnace. If it were possible to enclose the heated ovens of a retort stack on all sides with an envelope of heat, it is obvious that the heat of the ovens would be conserved, a higher and steadier temperature maintained, and that economy of fuel would result.

At the risk of some repetition, it may be pointed out that the secrets of success in generator furnace-building and retort-setting are—

- (1) To make sure that the system adopted is a good one.
- (2) To ensure a sound, unyielding, and dry foundation.
- (3) To use only the best materials and workmanship.
- (4) To have the joints of the brickwork throughout as thin and close as possible.

And in the working of these—

- (1) To get up the heat very slowly and gently at the outset, drying the brickwork gradually and thoroughly at a low temperature.
- (2) To charge the producer with hot coke as drawn from the retorts.
- (3) To regulate with care the air supply, both primary and secondary, and the exit gases, and keep the ash-pans full of water.
- (4) To insist on the generators being kept full of coke. If this is not done, CO_2 instead of CO will be produced in them, the concentrated heat melting down the brickwork instead of doing good service in the ampler area of the retort oven. The generators should be filled up every time the retorts are drawn.

If a gas manager has complaint to make of the regenerative system and settings and their results, then one or other, or all, of the above points have been neglected.

If the "Boncourt" system for producing radiant heat by means of flameless incandescent surface combustion can be economically applied to the retort furnaces in a gas-works, it will be an advance in the practice of carbonization.

Inclined Retorts.—Following the example of M. Coze, of Rheims, settings of seven, eight, and nine retorts placed at an angle of about 32 degrees, have been adopted by many engineers in this country.

That the modern settings of inclined retorts are a success, so far as the actual carbonization of the coal goes, there can be no doubt. As to whether they would be financially so, if applied generally in the smaller works, is open to question.

Where it is impossible to reduce, in any material degree, the manual labour already employed, and where there is therefore

little, if any, likelihood of a reasonable return being made on the extra capital expended on an installation of inclines, the older system of horizontal retorts must still be retained.

Again, with regard to the very large works, where power-stoking is already employed in such a way as to show an appreciable reduction in the cost of carbonization over the hand system of stoking, and allowing for interest on the capital outlay on the machinery, little or no advantage could be looked for by a substitution of inclined retorts.

There is, however, between the small and the very large works, a vast number of medium-sized works not large enough to allow of the application of power-stoking being profitable, where the introduction of inclined retorts would be of material advantage, and would show a reduction on the cost of carbonization, including all capital charges.

There were two great difficulties to be overcome before inclined retorts could be worked satisfactorily.

The first difficulty was with regard to the uniform heating of the retorts, the tendency with the earlier installations being for the top end of the retort to become considerably hotter than the lower end.

This difficulty has been overcome by building a solid division wall separating the front portion of the setting from the back portion, each being worked by its own dampers and having its own secondary air supply.

The regenerative system of heating is employed for these settings, with the furnace on the drawing side of the stack.

The second difficulty was with regard to the even distribution of the coal along the bottom of the retort. In the original Coze system, the mouthpieces were a prolongation of the retorts, and were bent upwards, all reaching to the same level. The fall of coal, therefore, from the tipping waggons took place from one uniform level, which was 8 ft. 4 in. higher than the bottom tier of retorts, 6 ft. higher than the middle tier, and 3ft. 9 in. higher than the top tier.

It is evident that if a drop of 3 ft. 9 in. was right for the higher tier of retorts, one of 6 ft. and 8 ft. 4 in. could not be right for the middle and bottom tiers, the retorts all being inclined at the same angle. As a matter of fact, irregular charging was the result.

In the modern installations of inclined retorts, instead of the

mouthpieces being bent upwards and brought to one common level, with trucks containing the coal passing above them, the retorts are stopped off level with the front of the stack, and are provided with cast-iron mouthpieces and lids as for the horizontal retorts.

A continuous coal-storage hopper extends the whole length of the house, and the coal is fed into the retorts by means of travelling measuring chambers and adjustable shoots.

Not only is the system of inclined retorts a great advance in the method of charging, but it is also equally advantageous for discharging the resultant coke. This slides out by gravity on opening the bottom lid and removing the stop which is put in to prevent the coal sliding into the mouthpiece. Sometimes the coke will stick, but it can easily be set in motion by pricking with an iron rod.

With the advances that have been made of recent years in the construction of conveying machinery, the hot coke can be conveyed straight from the retort house to the coke store or open yard, and quenched on its way.

In Love's system of inclines (Fig. 23), the retorts are set at an angle of 45 degrees, whereby a heavier charge,

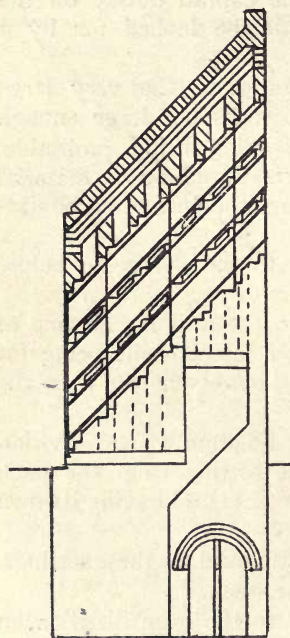


FIG. 23.

and even a full charge of coal, and an easier discharge of coke, are obtained.

This form of setting marked the advent of full-retort charges.

Gaiting.—A setting should never, when it can be avoided, be put into action immediately on completion, as the application of strong heat to the damp clay is liable to crack and open the joints and cause "short-circuiting," besides destroying the brickwork. The setting ought to be allowed to stand at least fourteen days, in order that it may be gradually dried and hardened. A slow

fire should then be lighted in the furnace and kept going for another fourteen days to complete the drying process, the damper to the main flue being entirely closed, but the feeding door and the sight and hand holes kept fully open.

On putting the bench or oven into action, the heat should be applied gently at first, the damper being gradually opened a little more each day until the proper temperature is attained. When the retorts have reached a dull red heat, a light charge of coal thrown into them assists the development of the required temperature, and tends to preserve them in good condition. By careful attention to these points, the cracking of clay retorts on first "gaiting" may be entirely avoided.

A setting will break down not only from wear and tear and high heats, but owing to the contractility of the materials composing it. The lesson to be drawn from this is that only such materials as are thoroughly shrunk by hard firing should be used.

Machine Charging and Drawing of Horizontal Retorts.—The problem of applying machinery to the charging and drawing of retorts is one which has occupied the minds of gas engineers from the very introduction of gas-lighting.

A retort house of to-day is not considered complete unless some effort has been made to minimize the arduous labour of charging and drawing the retorts by hand.

The extent to which mechanical charging and drawing appliances can be applied to any particular works depends to a large extent upon the number of retorts in use, so that the machines adopted may show a reasonable return, in the direction of labour saving, on the extra capital expended.

The retort charging machines in use for horizontal settings are of two kinds. First, those in which a portion of the machine actually enters the retort, either as a scoop or pusher; and second, the arrangements whereby the coal is projected into the retort.

The West, Arrol-Foulis, and Fiddes-Aldridge are of the first kind.

In the West power stoker (Fig. 24), the coal is fed automatically to the scoop during the time that this is making its progress to and into the retort. The machine may be fitted with a large coal hopper to carry a supply of coal for a number of retorts, or it may be provided with a small receiving hopper. In the latter case it is necessary to provide overhead hoppers extending the whole

length of the retort house. The machine is designed to charge and discharge through retorts at one operation. The motive power of the machine is either electrical or compressed air motors, or hydraulic power.

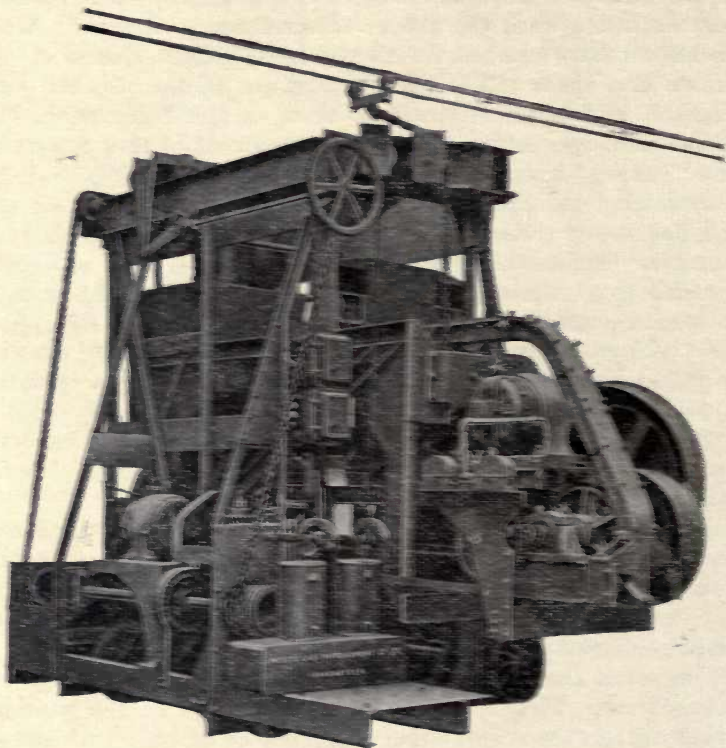


FIG. 24.—The West Power Stoker.

The Arrol-Foulis machine (Fig. 25) carries the coal into the retort by means of a "pusher" working along a shoot driving measured quantities of coal, and depositing same by a series of strokes, each about eighteen inches nearer the mouthpiece than the previous one. In this way, and aided by the form of the pusher-plate, the coal is evenly distributed along the bed of the retort. All the motions of the machine are by hydraulic power.

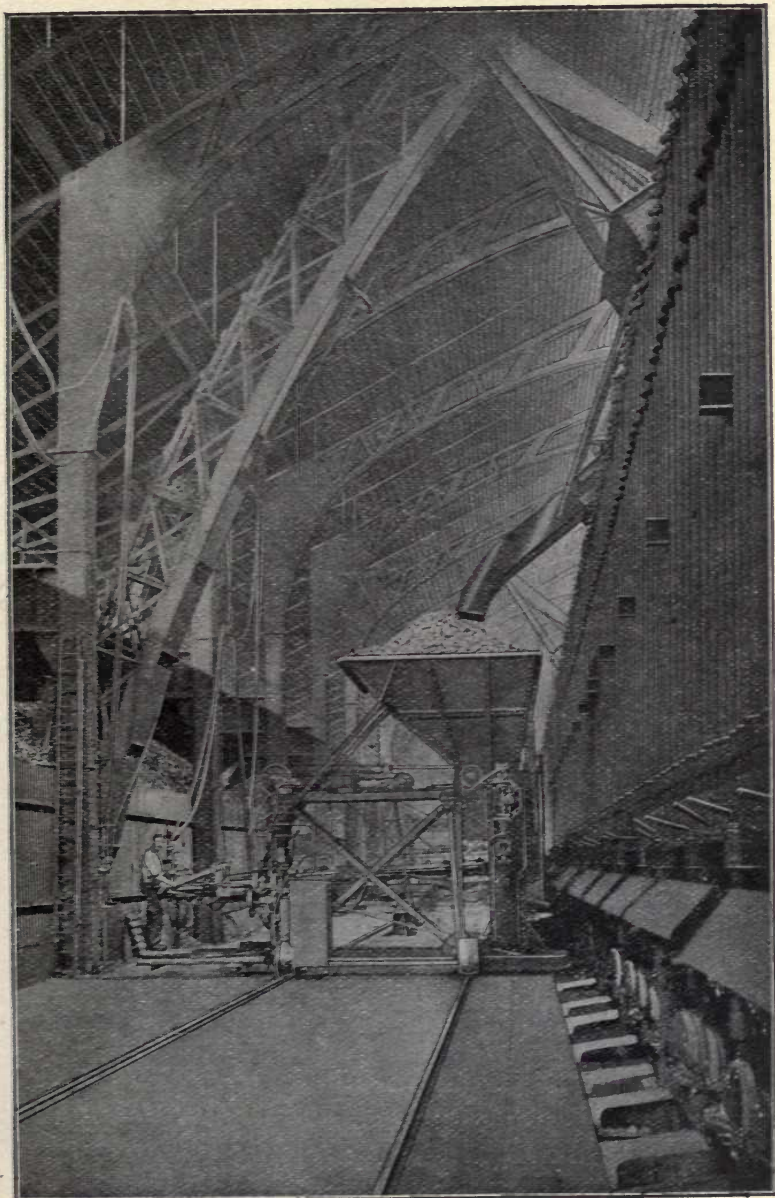


FIG. 25.—The Arrol-Foulis Power Stoker.

A discharging machine, Hunter & Barnett's patent hydraulic coke pusher, has been designed to work along with the Arrol-Foulis charger. This consists of a mild steel framing attached to a carriage fitted with traversing wheels. The beam with actuating rams for working the pusher head is suspended from the top of the framing by chains and pulleys to give it its rising and falling motion so as to suit different heights of retorts. The hydraulic rams for the pusher head are made telescopic, and have internal drawback arrangements. The working stroke of these machines is usually 20 ft., though they can be made to suit any length of retort.

The Fiddes-Aldridge simultaneous charger and discharger (Fig. 26) is one of the latest types in use with horizontal retorts. The machine consists of a movable inner frame constructed of mild steel, in which is placed the necessary gearing together with the motor and controlling gear. This frame is suspended by wire ropes from an outer frame of mild steel running on rails beneath a series of coal hoppers, or one continuous coal hopper.

The coal from the overhead hopper is automatically fed into an adjustable measuring chamber carried on the top of the outer frame. It then passes downwards through a telescopic shoot into a conveyor chain. This consists of pairs of parallel sheet plates placed vertically, and kept apart by distance pieces or archstays. Archstay pushplates are swung in such a manner as to carry the coal in a forward direction only.

The coal in entering the chain is carried forward by means of the pushplates through the retorts into the discharging side, at the same time pushing out the coke from the previous charge. The coke having been discharged from the retort, the motion of the chain is reversed and the pushplates automatically rise over the deposited coal, and level same on withdrawal. This machine is usually driven by electricity, but rope driven, compressed air, and hydraulic power can also be utilized.

The second method of charging horizontal retorts is well illustrated in the De Brouwer system (Fig. 27).

The machine is driven by electricity, a dynamo of about three horse power being all that is required to work same.

The machine consists of a light iron framework suspended by chains to a travelling carriage running on rails beneath a line of overhead coal hoppers. Fixed in the framework is a large pulley with a grooved face.

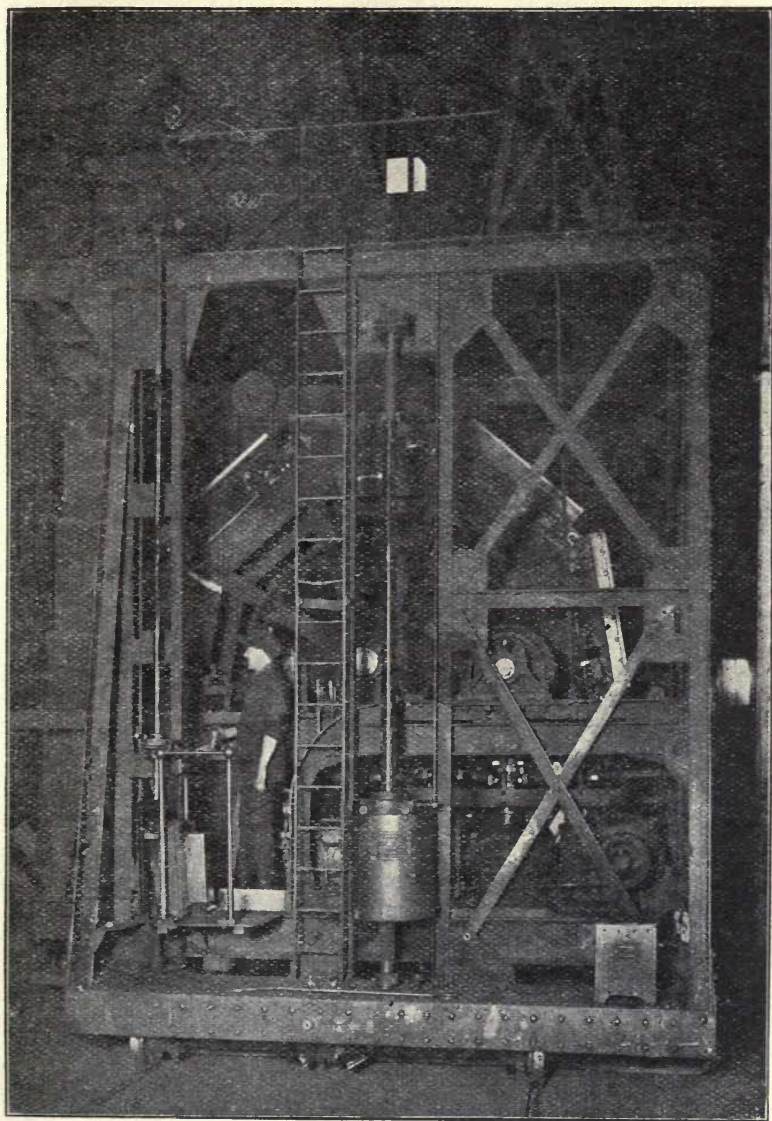


FIG. 26.—The Fiddes-Aldridge Power Stoker.

A funnel-shaped mouthpiece guides the coal from the overhead hoppers on to the back of this grooved-face pulley. Against the back and the bottom face of the pulley there travels a leather

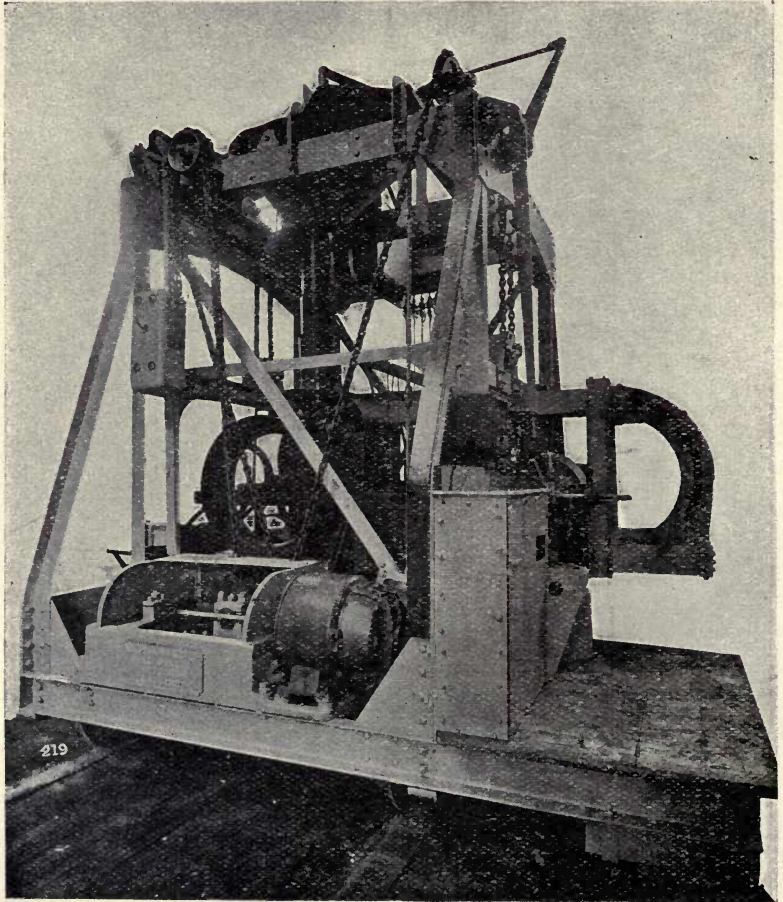


FIG. 27.—The De Brouwer Power Stoker.

belt working on two small pulleys. So that the top side of the belt is at a right angle with the large grooved pulley working in the angle.

The coal travels down the spout formed by the grooved pulley

and the leather belt, and the centrifugal force imparted to the coal is sufficient to shoot the same to the far end of a 20-ft. retort. Suitable controlling power is fixed to the machine to diminish the speed of the belt, and thereby enable the coal to be laid from back to front of the retort in an even layer. A discharging machine has been designed to work in conjunction with the projector.

A complete stoker or charging and discharging machine (Fig. 27) by the same makers is electrically driven, with travelling

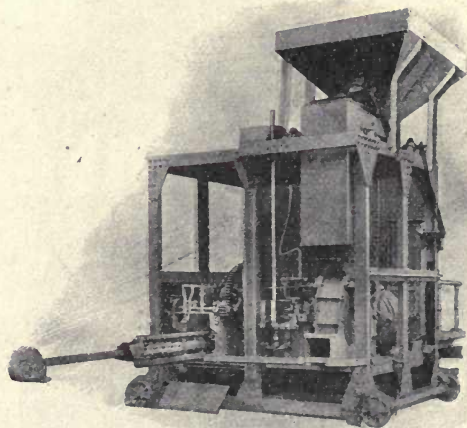


FIG. 28.—Dempsters' Stoking Machinery.

and hoisting gear, and is designed to work under a set of continuous overhead coal storage hoppers.

R. Dempster & Sons' stoking machinery is of the projector charging and pusher discharge type.

The charging machine, Toogood's patent, rotates at 80 revolutions per minute when charging a 20-ft. retort.

The pusher discharger machine, Dempster & Ordish's patent, is electrically operated, the motion being imparted by steel wire ropes, and the ram operates its own controller as it approaches the end of each stroke. The ram is made in two

sections, which the makers consider is an improvement over the three sections.

A combined machine or complete stoker (Fig. 28) has been

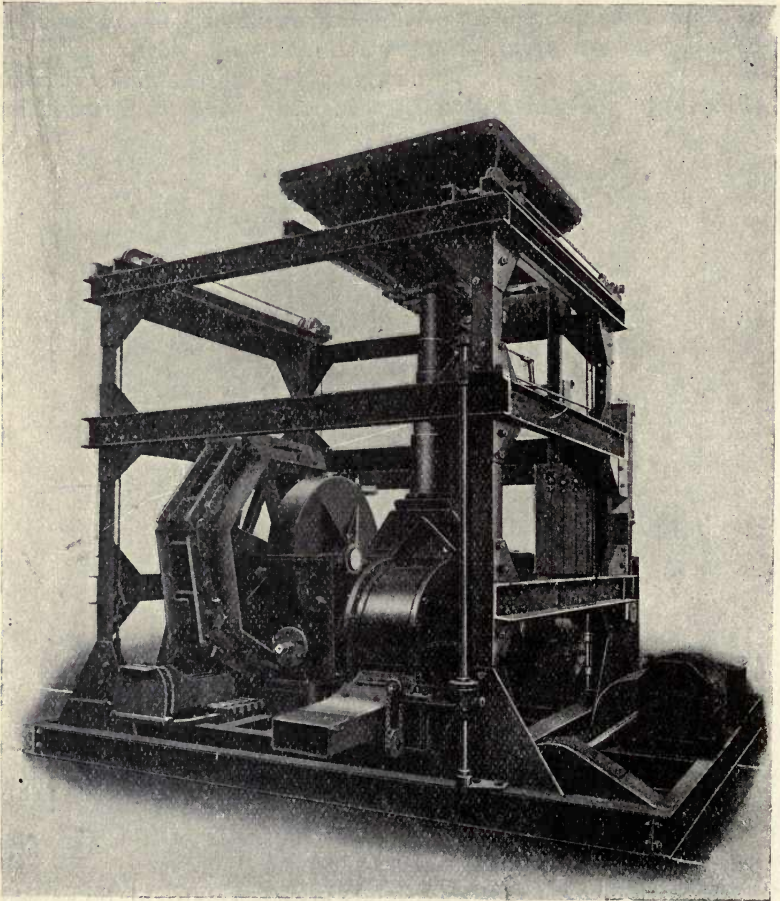


FIG. 29.—The Drake Power Stoker.

designed in which the projector and discharger are mounted on one framework, and is provided with rack and pinion motion for raising and lowering.

A coal hopper of a capacity of 25 to 30 cwt. is fixed at the top

of the main frame and is provided with a feed regulator to the charger. An index gear records the progress of the charge.

Drake's charging and discharging machine (Fig. 29) is of the push drum and projector side feed type, driven by electric motors and provided with the necessary appliances for collecting the current from overhead copper wires.

The projector consists of a cast-steel centre disc fitted with mild steel vanes on both sides. These are fed by a side feed, and the coal is projected in two layers at the same time into the retort to any depth, or to completely fill it. Claim is made for an advantage of the side feed over back or single feed. The pusher is constructed of steel links wound spirally round a drum, forming a rigid strut in unwinding, keeping the pusher always in a straight line in the centre of the retort, so preventing wear and tear on the bottom.

Manual Stoking Machinery.—For medium-sized works a manual stoking machine has been designed by Mr. West, so that, whilst manual labour is still required, the stoking is a much easier operation.

Overhead fixed coal hoppers supply the coal to a travelling hopper running on rails in front of the retort bench, and a light frame suspended beneath this hopper carries the "charger." The charger is filled by a feed box immediately beneath the mouth of the coal shoot, and is governed by a hand wheel. The charger consists of two semicircular scoops carried by a light carriage on wheels, which are arranged so that by twisting the drawing handle after the scoops are in the retort, the scoops turn over and the coal is deposited. Suitable propelling gear worked by a hand wheel enables the machine to be easily moved along the retort house.

The drawing machine consists of a rake bar and frame suitably mounted on a travelling frame and capable of being raised or lowered to the several tiers of retorts.

Another machine for use in medium-sized works is the "Rapid" manual and power charging apparatus of Biggs, Wall, & Co. It consists of an overhead travelling frame with a pair of rails running parallel to the length of the retort house. On these rails a carriage with lifting gear is arranged, and from the lifting gear the charging scoop is suspended. The length of travel of the carriage is such that the scoop is pushed half-way along the retort, but the impetus

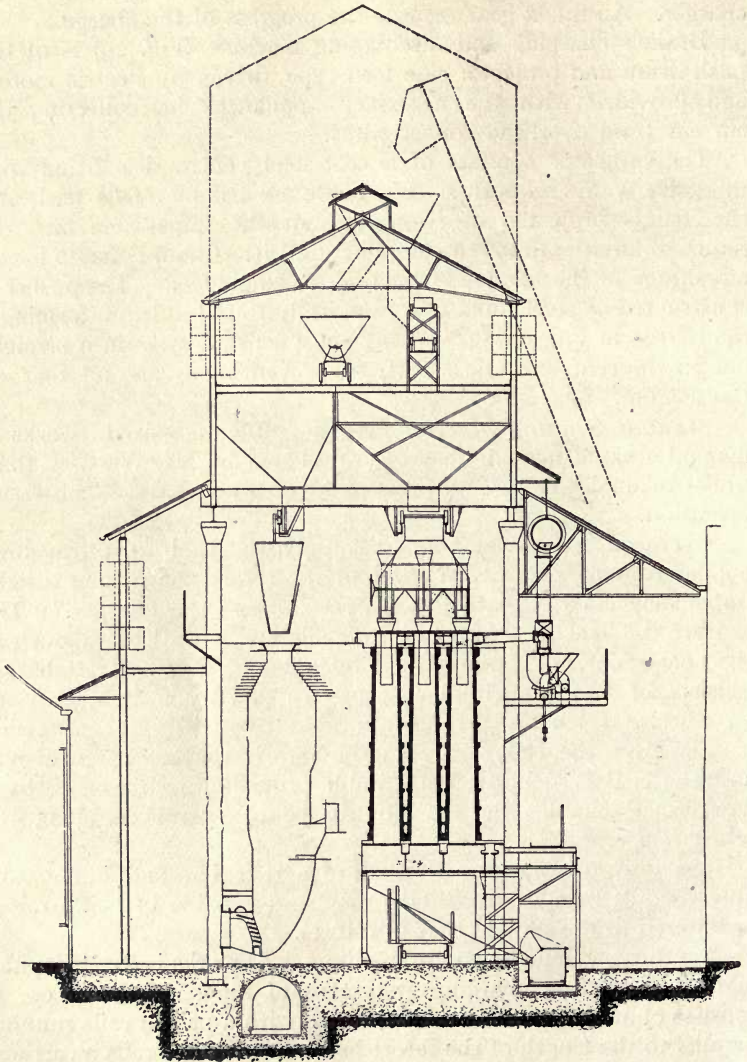


FIG. 30.—The Dessau Vertical Retort Installation.

given to the scoop by the driver is sufficient to carry it the full length of the retort.

Vertical Retorts.—Retorts set in the vertical position are now being largely adopted both abroad and in this country.

The Dessau or Bueb setting, Fig. 30 (called after its inventor, Dr. Bueb) was the first vertical retort system to be adopted on a commercial scale. This setting, latterly known as the "Dessau" (from the town in Germany where it was first adopted) is an intermittent system of carbonizing coal—that is to say, the retort is filled with coal and then closed until distillation is complete, when it is opened and the resultant coke withdrawn.

The settings are in parallel rows with as many as eighteen retorts to an oven; the length of the retorts being either 13 ft. 1½ in. or 16 ft. 5 in., according to local requirements. The heating of the retorts is on the regenerative principle, and is accomplished by a generator arranged alongside the oven. A feature of the heating is that the temperature is so regulated that the hottest part of the retort is at the base.

Above the retort stack are a series of hoppers into which the coal is deposited by means of an elevator and tipping waggon. From these hoppers the coal is fed into a travelling charger which shoots it direct into the retorts.

In this system, advantage is taken of the full retort of red hot coke for the production of a proportion of "blue" water gas, by the injection of steam near the end of the period of distillation.

Woodall-Duckham.—This is an automatic and continuous system of carbonization (Fig. 31).

The coal is so regulated in its descent that on entering at the top it is gradually carbonized in its continuous passage through the retort, and is converted into coke by the time it arrives at the bottom.

The installation usually consists of settings of four retorts with one or two generators to each setting according to the size of unit required, and is supported on a steel joist floor, supported by steel stanchions.

The retorts are 25 feet long, formed of bricks, grooved and tongued, and tapered from bottom to top. They are heated on the regenerative principle, with vertical flues. Combustion of the gases takes place at the top of the flues, and the arrangement is

such that the heat can be regulated in its application to any portion of the retort.

The coal and coke hoppers are formed in one continuous line above the retorts and supported by stancheons.

The quantity of coal admitted to the retorts, and the rate at which the charge descends, are both automatically governed

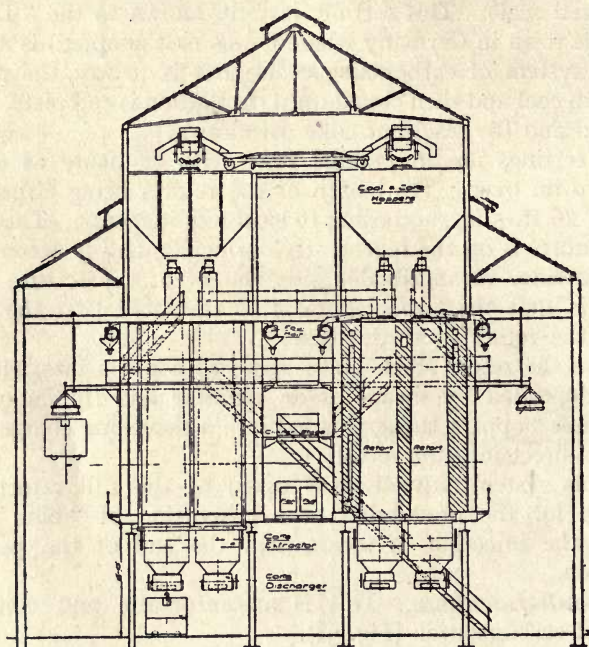


FIG. 31.—The Woodall-Duckham Vertical Retort Installation.

by the rate of extraction of the coke from the bottom of the retort.

The coal feeding device consists of an auxiliary or feeding hopper attached to the mouthpiece casting. This is supplied with coal from overhead storage hoppers. Each feeding hopper has an indicator attached by which the rate of coal feed and also the position of coal in the hopper can be ascertained.

There is a continuous discharge of coke into a receiving chamber fixed at the bottom of the retort, by means of what is called an

extractor roller. This, as it rotates, allows the coke to pass over it into the receiving chamber, which has a capacity of three hours' discharge.

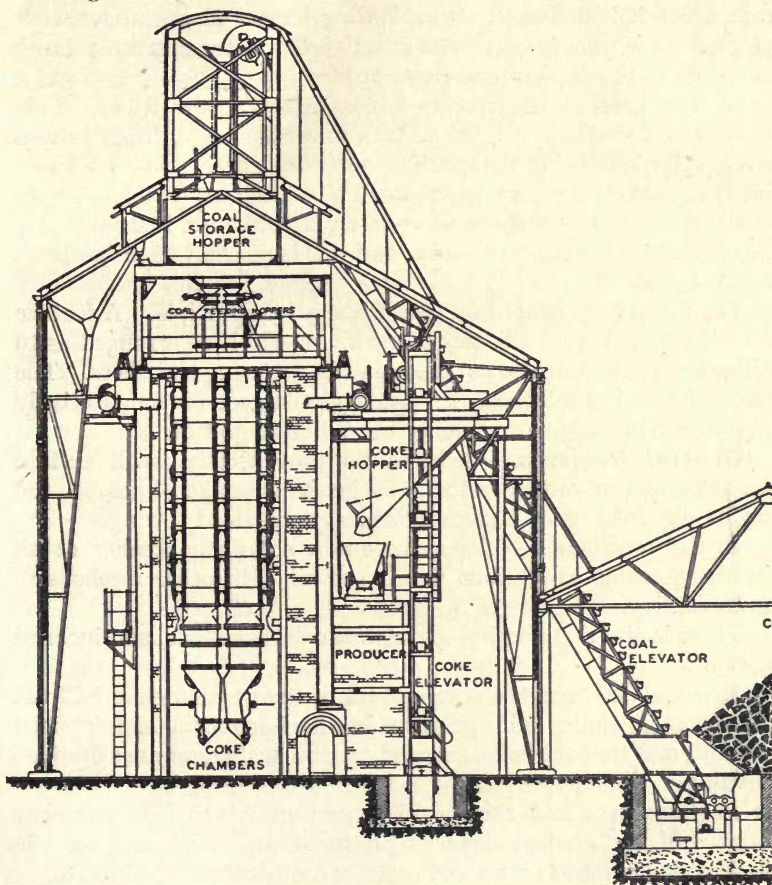


FIG. 32.—The Glover-West Vertical Retort Installation.

Glover-West.—The Glover-West (Fig. 32), like the Woodall-Duckham, is an automatic and continuous system of carbonization, the retorts being 23 or 25 feet in length and tapered from bottom to top. The number of retorts to an oven is determined by the capacity of the plant. In the Manchester installation there are

eight retorts to an oven, and each setting is provided with its own generator.

The coal is elevated from the store to an overhead bunker, from which it is delivered into a feeding hopper placed above each retort, from whence it gravitates into the retorts at a speed regulated according to the discharge of the coke.

At the base of the retorts a coke extractor is fitted. This consists of a slowly revolving worm of special design, made in two halves, one half being detachable from the other. The object of this is to provide, by partially removing one half, a space for inspection and access to the retort. A receiving chamber is fixed below the extractor to receive the coke, and this is discharged at intervals of two hours.

The retorts are heated on the regenerative principle. A feature of the heating is that the secondary air supply is so arranged as to utilize the heat from the hot coke, in the receiving chambers. The effect of this is that the coke, when discharged, is comparatively cold, and there is great economy in fuel consumption.

General Remarks.—It has been proved, that with certain coals distilled in vertical retorts, an increased make of gas per ton can be obtained, over either horizontal or inclined settings.

In the continuous systems there is a complete absence of all the disagreeable conditions which prevail with other methods of carbonization.

There is also a saving in ground area over horizontal and inclined systems.

It is claimed that the composition of the gas as delivered from the retort is more uniform than in the horizontal and inclined systems, and that the coke, tar, and ammoniacal liquor are improved in value.

Furthermore, and this is all important, there is a complete absence of naphthalene deposits in the street mains and services where vertical retorts are used.

The advisability of the adoption of vertical retorts depends to a large extent upon local circumstances. That the system offers advantages which the horizontal and inclined systems do not possess, is unquestionable. Whether the advantages are applicable to each individual works is for each engineer to consider. That there is a decided change in the character of the coke produced is certain.

Coal Elevating and Conveying Machinery.—During recent years much progress has been made in minimizing the labour involved in the handling of coal.

In the case of works situated near to a quay or canal, three systems of mechanical transport present themselves for the removal of the coal from the barge, viz. : (1) a travelling jib crane and grab ; (2) an adjustable bucket elevator ; and (3) the removal of the coal by a telpher or temperley transporter.

In the case of works situated near to a railway, a siding is generally brought into the coal store. The coal is thence conveyed by means of a band conveyer to the breakers and bucket elevators.

Where circumstances permit, a high level siding may be constructed and the coal waggons fitted with bottom doors allowing the coal to be deposited by gravitation into bunkers fixed above the breaker-pit.

A handy method of emptying the coal in bulk out of the waggon is by the application of a waggon tipper. This consists of an appliance for raising the hind part of the waggon to such a height as to allow the whole of the contents being discharged at once.

The telpher arrangement (see next page), for the conveyance of coal has not yet been largely adopted, but there are many works where this method of transport would undoubtedly be found advantageous.

It is usual to have a jigger-screen in front of the breaker to separate the dust and the small pieces which are passed directly into the boot of the bucket elevator.

The coal after being broken is raised from the breaker-pit to the storage hoppers in the retort house by means of an elevator of the bucket type, which, in turn, feeds a push-plate conveyer running the whole length of the house immediately above the hoppers. The coal then falls from the trough of the conveyer into the hoppers through openings fitted with sliding doors.

Hot Coke Handling Plant.—The removal of hot coke from the retort house is one which plays an important part in the economy of retort house labour, and with the advent of heavy charges of coal, and coke discharging machinery, mechanical removal of the hot coke is necessary.

In small works, however, the removal of the coke in barrows cannot be improved upon.

There are at present chiefly three systems by which the removal

of hot coke may be effected, viz. : (1) by steel barrows propelled by hand, or rope haulage ; (2) by endless chain conveyers ; and (3) by some form of telfer or crane arrangement.

The first method, although in many cases efficient for its purpose, is not one we can recommend in preference to the chain conveyer. There is always a tendency for the coke to be unduly broken in its fall from the retorts to the barrows.

The second method, that of the endless chain conveyer, is largely adopted, and consists of a chain of special design working in a trough generally about 2 ft. 6 in. wide, and placed either on the stage floor or underneath.

There are many makers of gas plant who make a speciality of conveyers for hot coke, but the general principle of these is practically the same.

The third method, the telferage system, has many points in its favour. The coke is deposited from the conveyers into steel skips and these are transported to the storage hopper for cart and waggon loading, or to the coke yard as required ; or the skips may be taken direct to the front of the retorts to receive the coke.

The telfer travels along a length of overhead mono-rail, and is constructed of steel with a covered-in cab for the workman in charge, in which are placed controllers and other levers. Two electric motors are provided, one for travelling and one for hoisting, and they are usually of the enclosed or dust-proof type.

The quenching of the hot coke is effected either by hose pipe or sprinklers, or by immersing the skips with their contents in a water tank.

Carbon Deposit in the Retorts.—In the distillation of coal a deposit of carbon takes place within the retorts, which, if allowed to go on accumulating, eventually seriously contracts their internal area, and causes a diminution in the heats.

This deposit is due principally to the decomposition of the hydrocarbons that are first formed, and to the pressure produced by the resistance offered to the passage of the gas through the different apparatus.

Its removal by scurfing with chisel bars in the ordinary way is always more or less attended with damage to the retorts ; the more so as they require to stand off for six or twelve hours, to loosen the carbon by the admission of air, before applying the bar.

Different methods of scurfing have been tried with varying

success, the best probably being that by which a current of air and steam is made to impinge upon the carbonaceous deposit; but, after all, the best plan of obviating the difficulty is to prevent the deposit as much as possible, by minimizing the dip in the hydraulic, or dispensing with the latter altogether (see p. 94), by employing an exhauster to reduce the back pressure, and by frequently scurfing the surface of the retorts with a rounded steel scraper.

Coke Slaking.—In the slaking or quenching of hot coke, water is a necessity. It is true that if the coke is drawn from the retorts into iron barrows, and a close cover placed over it, the confined gases, in the absence of atmospheric oxygen, will gradually arrest combustion in the mass; and this method of dealing with the coke is sometimes adopted with a view to abating the nuisance of the escape of steam charged with sulphurous vapours from the retort house, and to preserve the coke for sale in a dry and bright condition. Where the production of coke is great, however, as in the case of large works, this is an inconvenient, if not impossible, method of dealing with the material.

The quantity of water absorbed by the coke when it is slaked in the ordinary way is comparatively small, not exceeding, on the average, 15 per cent. of the weight of coke in the first instance, and the bulk of this evaporates when the coke is deposited outside the retort house in the open air, about 3 per cent. of moisture being permanently retained.

Proportion of Coke used for Firing.—In moderate-sized works, skilfully conducted, about $3\frac{1}{4}$ cwt. of coke, or 25 per cent. of the production (say, 13 cwt.) of coke per ton from Newcastle and other high-class bituminous coals, is used as fuel to carbonize one ton of coal.

In large works, under the most favourable conditions, and with the ablest management, the consumption of coke for heating the ovens may be reduced as low as 15 to 20 per cent. of the production. With inclined and vertical retorts it has been reduced to 10 per cent.

In small works, one-third the production of coke is nearer the average consumption.

Radiation from the benches is reduced, and fuel economized to an extent greater than might be supposed, by temporarily bricking up the furnace doors and the mouths of all retorts in beds not in use in proximity to others in action.

Tar used for Firing.—Where tar is unmarketable, or but of low value, and there is a ready sale for coke, the former should be employed in heating the retorts.

Its application is exceedingly simple. When applied to an ordinary furnace, the ash-pan is first filled up with breeze; the door is then removed and the door space bricked up, leaving two holes, one above the other, about 4 by 3 in. The tar is supplied through the top hole, the bottom hole being for the admission of air, and to allow of the fire being stirred when required. A piece of 2-in. angle iron, or a grooved fire-clay slab, or other convenient channel, is inserted into the furnace through the top hole, and down

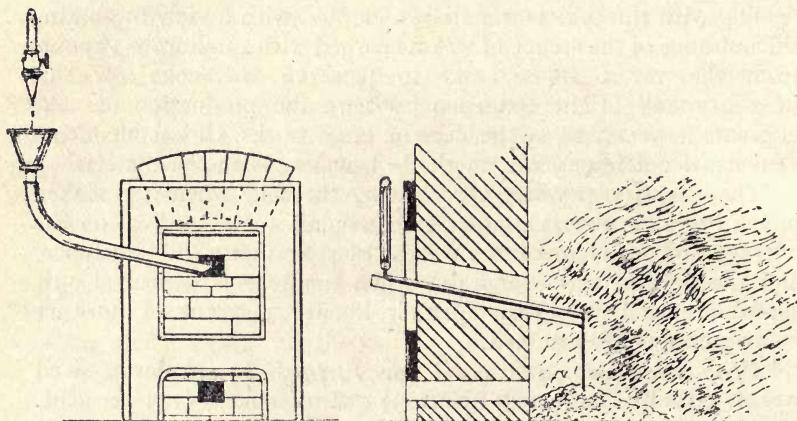


FIG. 33.

this the tar is made to flow in a stream about $\frac{3}{16}$ in. thick. (Fig. 33.)

The tar can be taken direct from the hydraulic main, or back main, in the bottom of which a 1-in. wrought-iron ferrule, having a stop-cock attached, is screwed. A $\frac{1}{2}$ -in. reducing coupling is then put on, and this size of pipe brought down to the side of the oven, where the tar is supplied to the trough through a nozzle of the proper dimensions; or a jet of steam directed through the nozzle may be used to spray the tar into the furnace.

As the hydraulic and back mains will not supply all the tar necessary, a pipe should also be brought from a tank or cistern erected in some convenient place outside the retort house. If this tank is placed inside the retort house, the dust arising from the

coal mixes with the tar and hinders its flow. Into this tank a supply of tar should be pumped from the tar well as required.

The objection to the use of tar as fuel, as above applied, is that the intense heat which is generated at the point of combustion soon destroys the arch or tiles underneath the middle retort, breaking the latter down.

As this retort, in the ordinary setting of fives and sevens, is the one usually first burnt out, it is advisable to restrict the use of tar to those benches that have been at work for a length of time, and in which the middle retort is either much burnt or already destroyed.

Numerous other expedients for firing by tar have been put forward, but the above has the merit of efficiency with cheapness and extreme simplicity. In the event of a deficiency in the supply of tar, this furnace is readily reconverted for coke firing.

About 50 gallons of tar used as fuel will carbonize $2\frac{1}{2}$ tons of Newcastle coal, or a mixture of Wigan coal and cannel, in twenty-four hours.

At this rate about 6 gallons of tar are equal to a sack 3 bushels) of coke.

Retort Stack Bracing.—The brickwork of the ordinary retort stack is braced together with buckstaves, cross girders, and tie rods, applied both longitudinally and transversely, to enable it to resist the expanding action of the heat. The buckstaves are made of steel, either rolled H (Fig. 34) or rail section (Fig. 35), or formed of two flat bars 6 in. wide and 2 in. thick, with cast-iron distance pieces between, through which the two flat bars are riveted together with $\frac{3}{4}$ -in. rivets (Fig. 36).



FIG. 34.



FIG. 35.

The cross girders, which also serve as supports for the hydraulic and back mains, are of rolled H section, excepting where the buckstaves are as shown in Fig. 36, when the cross girders are usually constructed of channel and angle steels and transverse tie rods $1\frac{1}{2}$ -in. in diameter.

If the transverse tie rods be taken through the division walls of the stack they should be encased in 4-in. cast-iron piping, so as to allow of air circulating round them, otherwise they are soon burnt away.

The longitudinal tie rods are of round mild steel, or wrought-iron

from 2 to 3 in. diameter, depending upon the size of the stack, threaded with square threads and furnished with open coupling boxes and strong hexagon nuts and washers.

A $\frac{3}{4}$ -in. steel plate, extending the width of the stack, and 2 ft. deep, placed in a recess at the two end or buttress walls, opposite the springing of the arches, and underneath the buckstaves, helps materially to bind the brickwork together, and prevents undue expansion.

The boss A, on Fig. 36, with hole therein, is intended to receive the wrought-iron pipe, 1-in. diameter, leading from the 3-in. water main on the top of the retort stack. To the end of this pipe a brass swivel is attached, and from this again a piece of 1-in. steam tubing, 11 in. long, projects, having a brass swivel-cock at its end; a tube of $\frac{3}{4}$ in. diameter is screwed thereto, and terminates in a 4-in. brass rose jet through which water is discharged for slaking the coke as it is drawn from the retorts (Fig. 37).

The question of bracing the retort stack becomes one of much greater importance when treating with inclined retorts as compared with those set horizontally.

Not only are the front, back, and end buckstaves to be strengthened, but additional vertical and horizontal bracing is required for the front and back walls of the setting.

For a stack containing five settings of eight 20-ft. inclined retorts each, the following bracing is suitable:—

Six front buckstaves formed of two 8 in. by 6 in. rolled steel joists with $\frac{1}{2}$ -in. cover plates.

Six back buckstaves, 16 in. by 6 in. and 62 lbs. per foot rolled steel joists.

Eight end buckstaves, 16 in. by 6 in. and 62 lbs. per foot rolled steel joists.

Six transverse girders, 12 in. by 6 in. and 54 lbs. per foot bolted to front and back buckstaves and resting on brackets.

Four longitudinal rods $2\frac{1}{2}$ in. diameter with forged-steel open coupling boxes.

Bracing to front and back walls of setting of 8 in. by 6 in. and 7 in. by 5 in. rolled steel joists.

In addition to binding the brickwork of the setting together, the back buckstaves carry the coal storage hoppers and shoots (Fig. 7).

Furnace Fittings—These consist of the ash-pan, furnace and clinking doors, sight-hole boxes, fire-bars and bearers, drip-plates, etc.

The particular design and size of the furnace fittings will depend upon the type of furnace adopted.

Before heating a retort stack for the first time, care should

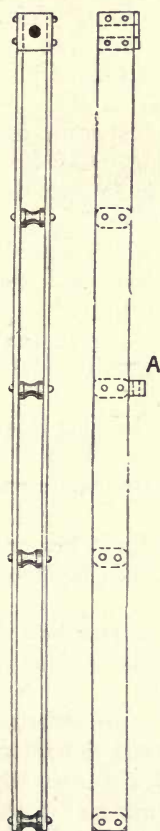


FIG. 36.

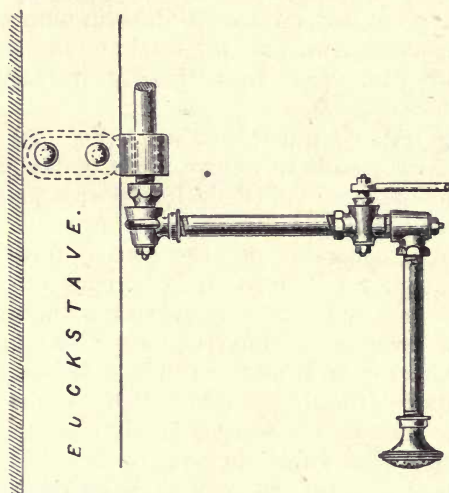


FIG. 37.



FIG. 38.

be taken that the tie rods are not screwed up so as to put a strain on them, otherwise, on the stack expanding, either the threads will be torn off the tie-rod coupling or the rods themselves will snap.

The following are the details of the fittings required for a direct-fired furnace:—

The ash-pan may be of wrought plate-iron $\frac{5}{16}$ in., or of cast-

iron $\frac{7}{16}$ in. thick. The usual dimensions are : Length 5 ft., width 12 in., depth 10 in., outside (Fig. 38). The pan should always be kept charged with water. The water, heated by the glowing coke, gives off steam in considerable volume, and this, rising underneath and between the furnace bars, contributes to their durability by keeping them comparatively cool. A tidy fire-about, with the ash-pan charged with water and reflecting the bright fire between the bars, is an indication of good stoking.

The grate bars are two or three in number and 30 in. to 36 in. long, made of 2-in. wrought bar-iron, and supported on two bearing bars 3 in. square in section, 24 in. long, their ends built into the brickwork.

The furnace frame and door (Fig. 33) are of cast-iron, the latter with pocket to receive a tile or fire-brick lining. Cast-iron cleaning-out and sight-hole boxes with plugs are built into the front wall of the setting.

For a generator or regenerative furnace the ash-pan needs to be about 2 ft. 9 in. wide, 5 ft. long by 10 in. deep, and the furnace bars and bearers made to suit the width of furnace.

The furnace (or clinkering) door and frame differs from that for a direct-fired furnace, when it is designed so as to admit of the regulation of the air passing through it to the furnace.

The fuel for the furnace is admitted through a charging door provided with an air-tight cap.

The sight-hole boxes and plugs are similar to those for a direct-fired furnace.

Other furnace fittings are the drip-plates and their bearers. These are placed across the furnace behind the clinkering door, and are usually 6 in. wide and $\frac{3}{4}$ in. thick.

Retort Mouthpieces.—The retort mouthpiece, of cast-iron, is round, \sqcap -shaped, or oval, to suit the retort, and, for horizontal retorts, usually 15 in. deep from front to back.

The top and bottom mouthpieces for inclined retorts are different in size and shape, owing to the increase in width of the retort at the lower end ; and since, with inclined retorts, the gas is usually taken off by one ascension pipe, and that at the lower end of the retort, there is no necessity for the ascension pipe socket on the top mouthpiece.

The usual dimensions of the lower mouthpiece are 24×16 in., and those of the top mouthpiece 22×16 in.

Lugs are cast on the sides of the mouthpiece for the door fastenings.

The mouthpieces are either provided with a flange for bolting to the retort, or with a socket for fitting round the retort. In either case, rails of rail-steel should be placed across the front of the flanges and secured to the front buckstaves, so as to keep the mouthpieces in position.

The following are the details of a mouthpiece for an oval retort

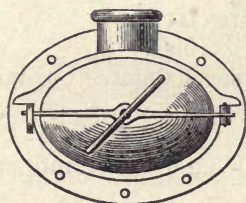


FIG. 39.

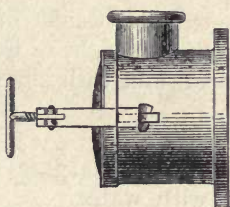


FIG. 40.

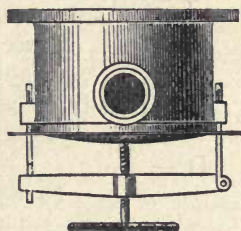


FIG. 41.

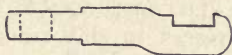


FIG. 42.

21 in. by 15 in., and will serve as a model for any other size and shape, allowance being made for varying dimensions. (See Figs. 39 to 42.)

Depth from front to back, over all, 15 in.

Thickness of metal in front portion, $\frac{5}{8}$ in.

„ „ in lip, 1 in., and planed level.

„ „ in flange, 1 in.

Width of flange in front, $3\frac{3}{8}$ in.

„ „ at back, 4 in.

Number of bolt holes, eight ; diameter, 1 in.

Ear-box on each side, with slot 2 in. by $\frac{5}{8}$ in.

Socket, to receive end of ascension pipe, 5 in. in height and $6\frac{1}{2}$ in. diameter inside ; centre, 5 in. from front.

Bolts, for securing mouthpiece to retort, eight ; diameter, $\frac{7}{8}$ in. ; screwed and nutted at both ends.

Lugs of wrought-iron, 14 in. long, 2 in. broad, and $\frac{5}{8}$ in. thick ; one with jaws and pin for hinging cross-bar, the other

cranked and notched as in Fig. 42. Slit at opposite end, 2 in. long, $\frac{1}{4}$ in. wide; wedged to ear-box.

Cross-bar of wrought-iron, 25 in. long, 2 in. broad at each end, and $\frac{1}{2}$ in. thick. Middle part $2\frac{1}{2}$ in. broad, swelled out to 2 in. thick, with 1 in. screwed hole through centre.

Screw, 10 in. long, with square thread 7 in. of its length.

Cross handle, 14 in. long, $\frac{3}{4}$ in. round-iron.

Lid, $\frac{1}{4}$ in. thick, plate-iron, dished, with lug on each side.

Cements for Jointing Mouthpieces—

To clay retorts—

Three-fourths by weight of fire-clay.

One-fourth by weight of iron borings.

When ready to connect, mix with ammoniacal water. Use no sulphur.

Or—

20 lbs. gypsum (calcium sulphate) made into a pulp with water.

10 lbs. iron borings saturated with a strong solution of sal ammoniac.

Mix well together till of a consistency fit for use.

In fixing the mouthpieces to clay retorts, the flange or face of the retort should be notched all over with a sharp-pointed hammer, or a slight channel cut all round (this is best done by the retort maker in course of manufacture), for the cement to bed into when the bolts are screwed up.

For iron retorts—

2 lbs. fine clean iron borings.

1 oz. sal ammoniac.

1 oz. flowers of sulphur.

Mix together and keep dry. When required for use, add water to bring the mixture to a proper consistency.

Besides being fastened with bolts, mouthpieces should always be supported by cross-bars pressing against the flanges, the ends being secured to the buckstaves.

Luting for Retort Lids.—Ordinary lime, or spent lime from the purifiers mixed with fire-clay or common clay, and worked up into mortar.

The following makes a tough, persistent luting:—

1 part lime.

2 parts moulding sand.

Ground up together, with water, in a mortar mill.

Self-sealing retort lids and mouthpieces are generally used for horizontal retorts, and exclusively so for inclined, and are of the eccentric lever or eccentric screw type. The lid is not removed from the mouthpiece in charging the retort, but swivels round with the hinged cross-bar, to which it is secured. It is made in any form to suit the shape of the retort, with upturned semicircular edge, faced true. This pressing against the flat edge of the mouthpiece, which is also faced, makes a gas-tight joint without the intervention of luting.

The ascension or stand pipes are of cast-iron, and should not be less than 5 in. diameter for horizontal retorts. Pipes tapering from 6 in. to 5 in., and pipes 6 in. diameter, are commonly adopted.

For inclined retorts the ascension pipes should not be less than 7 in. diameter.

The best caulking material for ascension pipes at their junction with the mouthpiece socket is ordinary ground fire-clay, or slaked lime, made of the consistency of putty. These, when pressed down into the space between the spigot and socket, make a perfectly tight and durable joint, and are easily removed when the retorts need renewing. On the other hand, when the joints are caulked with iron cement, the labour in cutting it out and the risk of splitting the socket are considerable.

Choking of Ascension Pipes.—Ascension pipes occasionally become choked to a greater or less degree with thick tar, pitch, and other carbonaceous matter. When this occurs, it is well to let as many as can be spared at once stand off for a shift (provided the retorts are in condition to admit of this), drawing the charge, and removing the bonnet or plug from the top of the bridge-pipe. The heated air making its way through the smallest aperture will thoroughly clear them of the obstruction.

The causes of choking are various, and they are not always overcome. These are the chief:—

High Heats.—Excessive heating is conducive to the decomposition of many of the gases formed, with the result that carbon is deposited either in the retort or in the ascension pipes or in both. In the early days when low distillation temperatures were in vogue, there was but little trouble with stopped ascension pipes.

To the pipes being in too close proximity to the bench owing to the mouthpieces being too short.

To great radiation of heat from the bench, owing to the front walls of the setting being too thin.

To the charge of coal being laid unevenly in the retort, and to the latter being cracked and porous, allowing the furnace gases to be drawn in, and to the coal being left too close to the mouthpiece.

To heavy dips in the hydraulic main causing heavy back pressure.

Some coals are more liable than others to cause stoppages.

A change in the direction of the wind will sometimes both cause and remedy stoppages.

The remedies that are tried are :—

Causing water to trickle down inside of the ascension pipes.

Coating the front walls of the settings with non-conducting cement to keep in the heat.

Maintaining a level gauge in the retorts and a liquor seal in the hydraulic main, or dispensing with it altogether.

After all, drawing off the thick tar from the hydraulic main and allowing free exit of the gas from the latter, and keeping the pipes cool, are the best preventives of choking. This latter may

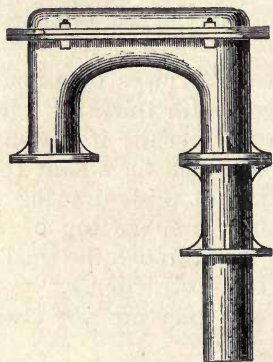


FIG. 43.

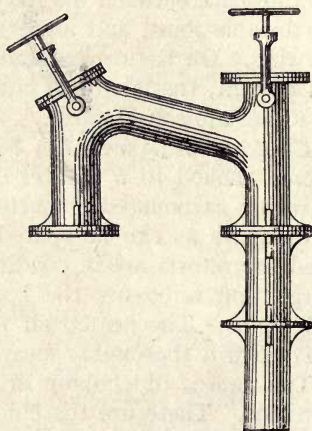


FIG. 44.

be accomplished to a great extent by making the front walls of the ovens $1\frac{1}{2}$ bricks thick, so preventing undue radiation from the bench, and having the mouthpieces of the retorts so constructed as to allow of the pipes standing 6 in. or 8 in. away from the front wall of the oven.

The Bridge and Dip Pipes are of cast-iron, and 5 in. and 6 in. are the usual diameters. The bridge-pipes are made in various useful

forms (Figs. 43 and 44). The chief consideration in the design should be to secure easy access to their interior for clearing purposes in case of blocking with thick tar. The following dimensions will be useful for a setting of horizontal retorts :—

Internal diameter of bridge and dip-pipes, 5 in.

Height of bridge-pipe, 16 in.

Width, centre to centre, 21 in.

Connecting flanges, diameter 10½ in.

Bolt-holes, four in number, centre to centre across, 8¼ in.

Diameter of bolts, ¾ of an inch.

Many arrangements of the arch and dip-pipes, especially of the latter, have been patented, with a view to getting rid of the dip and consequently of mitigating, as is supposed, the trouble of stopped pipes. Any success attained, however, has not been such as to warrant their general adoption.

The Hydraulic Main.—The hydraulic main, as a general rule even in small works, should not be less than 20 in. in width at the water-level.

Hydraulic mains of cast-iron are now only adopted in small works, mains constructed of steel or wrought-iron being both lighter and less liable to fracture.

The usual section of the main is that of a rectangle with the

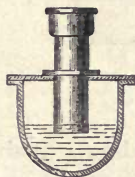


FIG. 45.

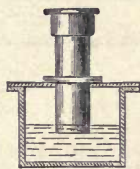


FIG. 46.



FIG. 47.

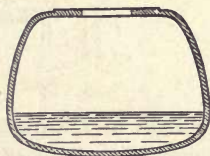


FIG. 48.

bottom dished to the extent of 4 or 5 in. (Fig. 49). This section of main has superseded those whose section was either U-shape (Fig. 45) with the flat side up, square (Fig. 46), or round (Fig. 47), which only serve for an accumulation of thick tar.

The "Livesey" hydraulic (Fig. 48), is a great improvement on the old sections, and, but for the greater cost of manufacture, possesses all the advantages of the more modern section. The chief object of the modification in form is to allow only a shallow

depth of liquid, and this being kept in motion by the issuing gas, deposit to any great extent is prevented.

Fig. 49 shows an arrangement of ascension, bridge, and dip-pipes, with hydraulic and back main, and valve between.

The steel and wrought-iron mains are usually constructed with sides and bottom $\frac{1}{4}$ in. thick, and top $\frac{7}{16}$ in. thick. The top plate is bolted with $\frac{3}{4}$ -in. bolts to 3 in. by 3 in. by $\frac{3}{8}$ in. angle-steel riveted to the top of side plates. Of course these dimensions would be modified according to the size of the main.

Where cast-iron mains are adopted they should be $\frac{3}{4}$ in. thick.

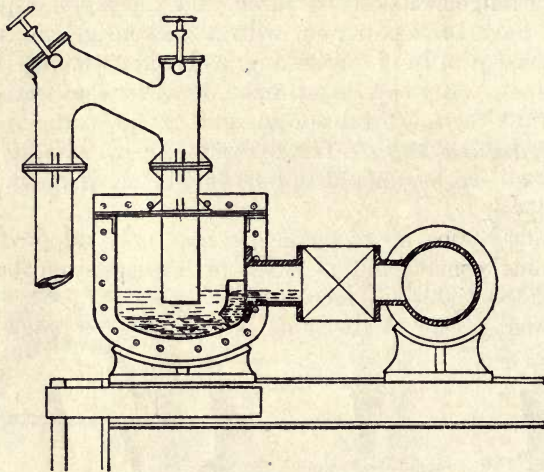


FIG. 49.

Instead of allowing the heavy tar from the hydraulic main to pass over with the gas, and by so doing allowing the tar to absorb a large percentage of the illuminating constituents, many arrangements have been adopted whereby the tar is taken from the hydraulic main by a separate main to that by which the gas leaves.

A very good arrangement is that in which (Fig. 50) a 6-in. cast-iron main running beneath the hydraulic is connected to each section by a 4-in. branch with a valve, the lower end of the main being connected to a stand-pipe at the end of the stack. The stand-pipe should be of sufficient capacity to contain one day's production of tar.

To govern the depth of seal within the hydraulic main there

is a 3-in. overflow pipe with a weir valve connected to the stand-pipe at the level of the liquor in the hydraulic; the overflow pipe is carried down to the ground and there connected to the tar main. A water connection to the hydraulic, and a tar outlet with valve connected to the bottom of the stand-pipe, complete the apparatus.

Its working is as follows: The hydraulic main and stand-pipe

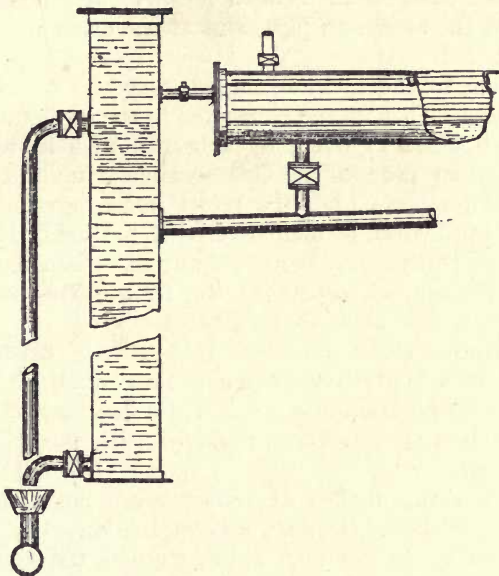


FIG. 50.

are filled with liquor, and the weir valve set so as to give the required seal in the hydraulic main. As the tar is formed, it settles to the bottom of the hydraulic, and flows down the tar-pipe beneath to the stand-pipe, which it gradually fills, the displaced liquor flowing over the weir valve and down the overflow-pipe.

Each day the tar is run off from the stand-pipe and fresh liquor run into the hydraulic, care being taken that the tar does not flow away quicker than fresh liquor is supplied.

The hydraulic main should rest on brackets secured to the cross girders. The height of the cross girders above the top of the stack is from 2 ft. to 2 ft. 6 in.

To erect the main on standards resting on the top of the bench is not a good plan, as any settlement of this will affect the seals in the hydraulic.

In some instances the hydraulic main is placed against the retort house wall, being supported on brackets or cantilevers attached thereto. This plan necessitates a strong wall to bear the weight of the main and its contents, and also a long length of pipe overhead, fixed in an inclined position, attached at one end by a bend to the ascension pipe, and at the other to the dip-pipe on the main.

In addition to the hydraulic main, a second or back main is often laid along the bench, and connected to the former at the water-level, at each bench or oven, by a branch with a valve upon it for closing when necessary. This secondary main conveys the gas and fluid products from the retort house, and admits of the isolation of the hydraulic main over each setting of retorts. By this arrangement it is easy, in case of any disturbance of the bench through settlement or otherwise, to restore the several short lengths of hydraulic main to the true level.

Retort House Governors.—The improved results that can be obtained in carbonization, both as regards quality and quantity of gas, by the installation of a retort house governor, in addition to the ordinary by-pass governor employed with the exhauster, are now recognized.

There are many makes of retort house governors, but the construction is either of the float or counterbalanced type.

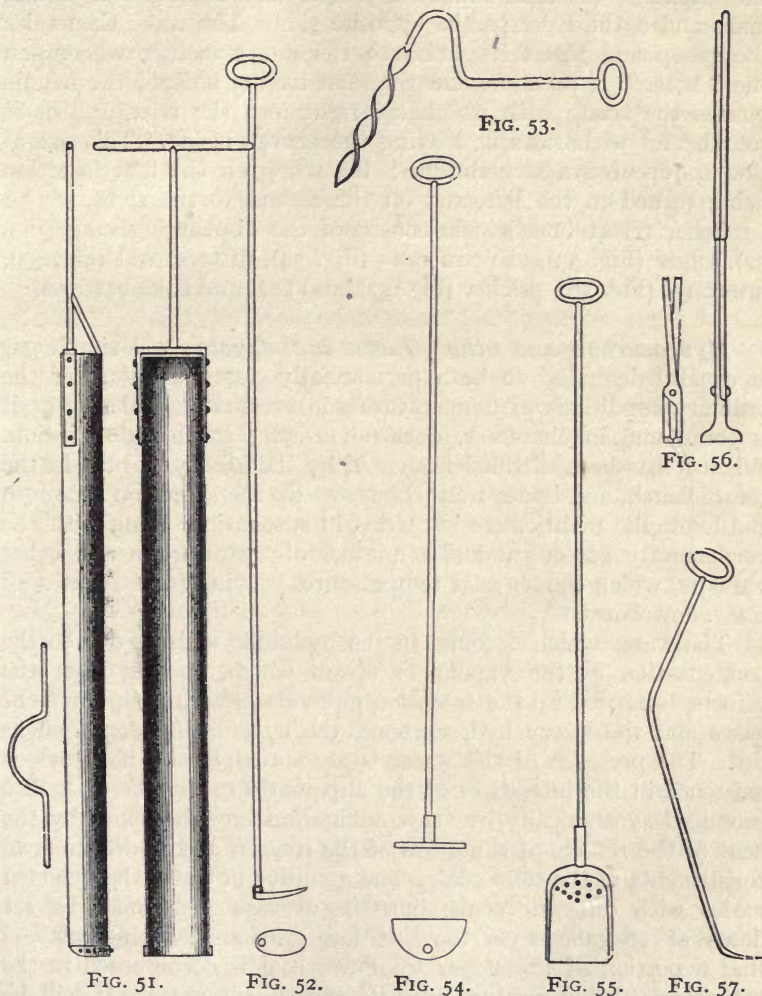
The objects of the governor are to regulate the suction exerted on the retorts by the exhauster in the direction of preventing oscillation, and to maintain more constant pressure conditions in the hydraulic main. The governor is placed on the foul main and generally about 6 ft. from the end of the retort stack.

Retort House Tools and Appliances.—For charging retorts by hand, the shovel or the scoop is used.

Shovels with riveted handles are not good in or about a retort house. The heat soon causes the wood to dry in, and the rivets give way and become jagged, lacerating the hands of the men who use them. Socketed handles are the best.

A good handy-sized shovel for charging retorts of the ordinary size is one 16 in. long by 11 in. wide. Firing shovels (for coke) are best made an inch wider. Both should be well turned up at the sides.

The scoop (Fig. 51) is a semicircular trough of sheet-iron or steel, the length of half the through retort, and of capacity to



contain about $1\frac{1}{2}$ or $1\frac{3}{4}$ cwt. of coal. It is inserted twice into the retort at each end. Six men are required to charge a through retort with the scoop—*i.e.* three at each mouthpiece. The

method of using it is as follows: On its being filled with coal one man takes hold of the handle at the end, raises it slightly, the "horse" (as it is called) is placed underneath by a second man, and a third grasps the opposite side. The three then raise the scoop and insert its end into the retort mouth, whereupon the "horse" is released, and the man having hold of the handle pushes the scoop with its charge right into the retort, turns it round, and withdraws it, leaving the charge inside. This operation is repeated a second time; the scoop on the first insertion being turned to the left, and on the second to the right.

Other retort house tools consist of the discharging rake (Fig. 52), auger (Fig. 53), ash-pan rake (Fig. 54), ditto shovel (Fig. 55), fire-tongs (Fig. 56), pricker (Fig. 57), and coal and coke barrows.

Hydrocarbon and other Gases and Vapours.—A simple gas is usually described to be a permanently elastic fluid under the ordinary conditions of temperature and pressure. Coal gas, as it is compound in character, does not answer to that description. When it has been distilled from coal by the agency of heat in the retort bench, and issues from the retort up the ascension pipe into the hydraulic main, there is carried in suspension, along with the permanently gaseous fluids, a number of hydrocarbon and other vapours, which condense at temperatures varying from about 200° Fahr. downwards.

The water which is found in the hydraulic main is due to the condensation of the vapour or steam which, coming from the retorts, is carried up the ascension pipes along with the permanent gases and the heavy hydrocarbons, the latter being deposited as tar. The presence of the water is accounted for by its previous existence in the interstices of the apparently dry coal. It is also produced synthetically by the combination brought about by the heat of the retorts of a portion of the oxygen and hydrogen, two constituents of the solid coal. The quantity of water thus yielded varies with different coals, but the average yield may be set down at 16 gallons per ton. It has previously been explained that a portion of the steam from wet coal is decomposed in the hot retorts, being resolved into its constituent gases. It will be seen, therefore, assuming the correctness of this hypothesis, that two opposite processes are being carried on simultaneously in the retorts—the analytical and the synthetical—and this apparently

inconsistent action may be explained by the original character of the substance acted upon—the steam in the one instance, and the gases, oxygen and hydrogen, in the other—and their proximity to, and period of contact with, the hot surface traversed by them.

The strong affinity which exists between this water and the ammonia impurity in the crude gas causes the absorption of much of the latter by the former, producing what is, roughly speaking, a solution of ammonia. This again, by reason of its affinity for sulphuretted hydrogen and carbon dioxide, absorbs a proportion of the gases named, reducing the amount of these impurities in the gas, and thus is produced the complex liquid designated “ammoniacal liquor.”

The hydrocarbons contribute largely to the illuminating power of the gas, and it is therefore desirable to retain them in the permanently gaseous form. Some of them, especially such as are of the greatest density, are reduced to the liquid state by the mere mechanical reduction of their temperature; whilst others of equal specific gravity, and many of those of lower density, undergo a change from the gaseous to the liquid condition, by reason of the solvent or absorbent action of the liquid contents of the hydraulic main, through which, by reason of the dip, they have to pass; or with which, in the absence of the dip, they come intimately in contact. The former may be classed as hydrocarbon vapours, the latter as gaseous hydrocarbons. It is thus evident that the process of condensation begins at the hydraulic main, the results there produced materially affecting the quality of the gas.

Those hydrocarbons that are changed to the liquid form by this slight diminution of temperature, it is probably impossible to retain in the gas under any circumstances whatsoever. With the more volatile, though still heavy, hydrocarbons, the case is different; the power of retaining them in the permanently gaseous form is within the bounds of possibility, and these are, therefore, of the greatest interest to the gas manufacturer.

A further class of hydrocarbons are not liquefied at all under ordinary conditions, and there should never be any difficulty experienced in keeping them in the gaseous state.

The retention in the gas of the second class of hydrocarbons—viz., those which, though of high specific gravity, it is practicable to retain in the gaseous state—and how this is most likely to be accomplished, greatly concerns the gas maker. It has been

assumed that the mere reduction of temperature between the retort mouth and the hydraulic main will not affect their gaseous condition. Under what other circumstances, then, are they condensed in the hydraulic main, and in the subsequent mains leading to the condenser? The answer is clear, and is what has been already indicated—viz., by the affinity which exists between them and the already liquefied hydrocarbons present in the mains.

The cooling of the gas gradually is a provision the wisdom of which is unquestionable, and the plan of causing it to make the circuit of the retort house in pipes is probably the best method of accomplishing this; but the deposited tar in the hydraulic main and in the foul main at the point, as near as can be ascertained, when its temperature has fallen to about 110° or 100° Fahr.—the temperature at which its absorbent powers come into most active operation—should be drained away direct to the tar well by its own separate conductor.

The chief advantages believed to accrue from lengthened contact of the gas with the tar are, first, the absorption by the latter of naphthalene that would otherwise be carried forward to be deposited, by reason of the decrease in temperature and other causes, in the mains on the works, and even in the street mains, service pipes, and the internal fittings on the premises of consumers; and, secondly, the absorption also of a considerable portion of the obnoxious sulphur and other compounds.

These advantages will not be forfeited by the direct removal of the bulk of the tar, because sufficient light tar will be left in the circuitous gas main to absorb any excess of naphthalene vapour present, and even to assimilate a portion of the sulphur and other impurities. Besides this, as the general effect will be to leave a larger proportion of the gaseous hydrocarbons in the gas, these, by virtue of the power which they possess in common with the liquid hydrocarbons, of assimilating—and, in this special case, of suspending—other hydrocarbons, will necessarily assist in retaining in the permanent form a portion of the naphthalene that would, in presence of the greater bulk of tar, have been liquefied and deposited. By a similar train of reasoning, the fact of the inferior quality of the tar produced from the richer cannels, as compared with that from coal, may be explained.

In dealing with this subject, it has been assumed by some that no absorbent action is likely to result so long as the tar with

which the gas is in contact is at a temperature of about 100° Fahr., and above; and that, therefore, the dip in the hydraulic main causes no diminution in the amount of hydrocarbon gases present. It has even been assumed that the tar in the main gives off a proportion of hydrocarbon vapour, and in this way increases the illuminating power of the gas. On reflection, however, it will be plain that this argument is altogether untenable, for it is scarcely possible to conceive that hydrocarbons which have already been liquefied at a high temperature, can again, at a lower temperature, assume the gaseous or vaporous form. There can be no doubt that the heavy tars have an absorbent action, less or more, at all temperatures, being greatest at the lowest; and this being so, the passage of the gas through such tars, by reason of the dip in the hydraulic main, must have a prejudicial effect upon the illuminating constituents of the gas. On the other hand, where means are employed for removing the heavy tars from the main as rapidly as possible after they are deposited, the disadvantages of the dip into the lighter liquors contained therein are reduced almost to *nil*. This is especially true where the arrangements are such that, by careful adjustment, and an adequate area at the water level, the dip is limited to about $\frac{3}{4}$ of an inch.

It is desirable that the ends of the dip-pipes in the hydraulic main should be sealed with the ammoniacal liquor in preference to the tar, the latter not only robbing the gas to some extent of its richest illuminating substances, but offering greater resistance to its passage. Various expedients to accomplish this end have been devised and are in use in well-regulated gas-works.

Livesey and Tanner's Differential Tar and Liquor Overflow and Tar Screen is a useful provision for separating the tar and liquor by means of a perforated screen, preventing the oscillation of the

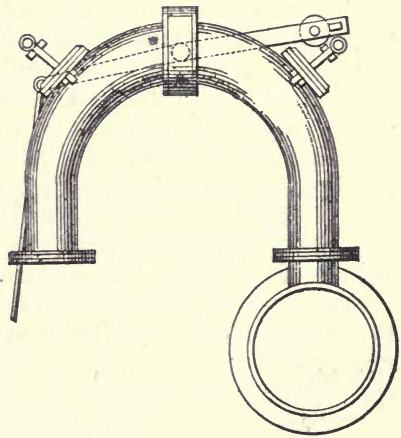


FIG. 58.

liquor in the main and allowing of a minimum of seal. The arrangement for adjusting the difference of seal required for drawing off the tar and liquor separately, according to their specific gravities, is also very ingenious and useful.

The hydraulic main, and consequently the dip or seal, can be dispensed with altogether by employing a bridge-pipe with a wing valve in the centre of the bridge (Fig. 58). This is shut by means of a rod depending from the end of the lever, during the operation of drawing and charging, and opened again when the retort lid is closed.

It is well known that the gas as it ascends to the hydraulic main, after being in contact with the intensely heated surface of the retorts in which it is generated from the coal, is of a comparatively low temperature. The reason of this is not apparent at a cursory glance.

At first sight it would appear as though the action upon the gas in a retort would be similar to the effect upon air by the ovens of blast-furnaces, where a million cub. ft. are heated in the space of an hour to 633° Fahr., the melting point of lead. So far from this being the case, the permanent gas at its highest temperature does not probably exceed 135° Fahr., though generated in a heat usually reaching 2200° . The reason of the difference in the effect produced in the two instances given, is explained by the fact of the rapid absorption of heat by the volatile constituents of the coal in assuming the gaseous form; this heat becoming latent in the gas, as in the case of the formation of steam in an open boiler.

The following is a record of experiments made by the writer to determine the temperature of the gas as it issues from the retort :—

Experiment No. 1.

This experiment was conducted entirely under the usual conditions of working.

Clay retort, 20 ft. through, one in a setting of seven.

Heat, bright cherry red.

Hole drilled in both ascension pipes 3 ft. above the mouthpiece.

Retort charged with 4 cwt. of cannel.

Temperature indicated on insertion of thermometer through the hole on one side of bench, 193° Fahr.

Temperature indicated on insertion of thermometer through the hole on the other side, 510° Fahr.

The temperatures indicated were clearly not those of the gas. In attaining the higher temperature especially, the mercury rose by starts at the rate of 3° to 5° at once, evidently caused by hot particles of solid carbon, or other solid or semi-fluid substances, coming suddenly in contact with the bulb of the thermometer.

The remarkable difference in the temperature of the two sides is accounted for in this way. On the side in which 193° was indicated the dip-pipe was probably sealed to a greater depth in the hydraulic main, and consequently the flow of gas was neither as abundant nor as rapid on that side as on the other. This was evidenced by the thermometer on withdrawal being found less thickly coated with tar than in the other case. The gas was in a more quiescent state, and therefore there was not the same rush of hot semi-solid particles against the bulb to raise the temperature abnormally.

It may be noted incidentally here, that indications of temperature thus obtained would prove whether the ascension pipes at the two ends of a through retort were each taking their due share of the gas being produced.

Experiment No. 2.

The conditions were the same as in the previous instance ; but instead of inserting the thermometer directly through the hole in the ascension pipe, the end of a piece of india-rubber tube, 12 in. long, $\frac{3}{4}$ -in. bore, was pressed against the orifice, and the gas allowed to flow in a stream through the tube. The object of employing the tube was to obviate, if possible, the contact of the semi-solid or semi-fluid substances previously referred to.

The result was: Temperature indicated on one side 250° , ditto on the other side 324° .

The rise of the mercury was still somewhat irregular, and the instrument, so much as was inserted, was again thickly coated with tar.

Experiment No. 3.

One end of the through retort was now bricked up, being made perfectly gas-tight, the gas passing away by one only of the

ascension pipes ; in point of fact, the retort was made single instead of through.

In a short double-flanged piece of the ascension pipe, within 8 in. of the top of the mouthpiece, were inserted six layers of iron wire netting, cut into discs, accurately fitting the bore of the pipe. Three of these discs had meshes $\frac{1}{8}$, and the other three $\frac{3}{8}$ of an inch gauge ; and the discs were kept $\frac{3}{4}$ of an inch apart by sheet-iron rings inserted edgewise into the pipe.

The charge, 2 cwt. of cannel, thrown into the retort, happened to be taken from a heap that had been exposed to the rain, and there was considerable moisture present.

The hole through which the thermometer was inserted, as in the previous experiments, was 3 ft. above the mouthpiece.

The following were the temperatures indicated :—

Time.	Temperature.	Time.	Temperature.
10 minutes	. 200° Fahr.	55 minutes	. 177° Fahr.
15 "	. 198° "	60 "	. 174° "
20 "	. 195° "	65 "	. 172° "
25 "	. 192° "	90 "	. 160° "
30 "	. 190° "	105 "	. 158° "
35 "	. 188° "	120 "	. 150° "
40 "	. 184° "	130 "	. 150° "
45 "	. 182° "	140 "	. 148° "
50 "	. 179° "	150 "	. 142° "

Through all the higher temperatures, down to 172°, steam was condensed into drops upon a piece of paper held in the stream of gas issuing from the hole. Tar, though not entirely absent, was nearly so, the instrument on each withdrawal being but slightly coated. The temperature, with but few exceptions, rose with great regularity from that of the atmosphere of the retort house (74°) to the rates observed, showing that the semi-solid particles, which were evidently the cause of the high temperatures previously indicated, had been nearly all arrested by the wire netting.

The higher temperatures, we are of opinion, were due to the presence of steam in the gas in varying proportions, and this latter would be caused by the moisture in the coal.

Experiment No. 4.

The retort was again charged, this time with 2 cwt. of cannell in a drier state. All the other conditions were as in the previous trial.

The following were the results obtained:—

Time.	Temperature.	Time.	Temperature.
2 minutes	. 158° Fahr.	1 $\frac{3}{4}$ hours	. 129° Fahr.
7 "	. 174° "	2 "	. 123° "
12 "	. 177° "	2 $\frac{1}{4}$ "	. 122° "
17 "	. 172° "	2 $\frac{1}{2}$ "	. 119° "
22 "	. 171° "	2 $\frac{3}{4}$ "	. 118° "
27 "	. 169° "	3 "	. 116° "
32 "	. 168° "	3 $\frac{1}{4}$ "	. 113° "
75 "	. 141° "	3 $\frac{1}{2}$ "	. 110° "
90 "	. 134° "		

During the first half-hour of the charge, the presence of steam, mixed with the issuing gas, was indicated as before, but less abundantly, though still, doubtless, affecting the results obtained. When the temperature of the gas within 3 ft. of the mouthpiece was at 174°, it stood at 132° in the bridge-pipe, 14 ft. higher up.

Temperature of the Gas in the Bridge-Pipe, 14 feet from the Retort Mouthpiece.

Experiment.	2-cwt. Charges.	Temperature of the Gas.
No. 1	. . retort charged 1 hour	. 135° Fahr.
" 2	. . " " 3 hours	. 116° "
" 3	. . " " 4 $\frac{1}{2}$ "	. 119° "

It may be suggested that the effect of passing the gas through the wire netting would be to lower its temperature, just as the wire gauze on a Davy lamp reduces the temperature of the flame impinging against it. The conditions of the two cases, however, are entirely different. The meshes were sufficiently large to admit of an easy passage for the gas, and the metal would be immediately covered with a thick coating of tar, virtually producing insulation. In addition to that, the temperature within 6 inches of the front of the bench was 208°; and the metal of

the ascension pipe, as well as the inserted wire netting, would, as a rule, be above the temperature of the gas. The results of these researches will be found to confirm, in a remarkable manner, the deductions of earlier investigators.¹

¹ Mr. J. T. Sheard differs from the conclusions attempted to be drawn from the experiments recounted above, and his opinion carries weight with the writer. In a communication, he says—

“Coal must be raised to 600° Fahr. before any volatile matters whatever are given off, and so-called permanent gases are not formed until a temperature of about 1100° Fahr. is attained. Without being able to dogmatize, it is safe to assume that heavy hydrocarbons—volatile at the temperature of the retort, but liquid, or even solid, at atmospheric temperatures—are first formed, which, with more heat, are gradually broken up into lighter compounds of less complex composition; permanent simple gases being the ultimate products. With the first class of substances the action is similar in effect to the melting of ice into water, and its conversion into steam when sufficient heat is applied. A great portion of the total heat supplied becomes latent in the steam, *but the steam is evolved at the boiling temperature, 212° Fahr. at least*; that is, it has itself acquired the temperature at which it was formed. So the hydrocarbon vapours formed at 600° Fahr. or 1000° Fahr. must, at the instant of liberation, be themselves of the temperature at which they were evolved from the coal or semi-liquid intermediate product from which they were formed.

“Your contention, I take it, however, is that the permanent gases are in a different category because of their greater latent heat, and the fact that they are naturally gaseous at a much lower temperature than that at which they are formed in the retort. It seems impossible to put the matter directly to the test, but I cannot conceive how a particle of gas, formed, say, within a mass of hydrocarbon vapour, can be liberated at a temperature much lower than that of the atmosphere in which it is created. In default of proving the point in a direct manner, I have tested it indirectly by inquiring whether, assuming the gas to be liberated at the higher temperature, the known laws of cooling are sufficient to account for the great loss of heat which you observed immediately after the gas had left the hot retort.

“The temperature of the gas in the ascension pipe, 3 ft. from the mouthpiece, was found to be 174° Fahr., while in the bridge-pipe, 14 ft. higher up, it was 132° Fahr.

“I assume that the retort was yielding gas at the rate of 6000 cub. ft. per day, or, say, 9 lbs. of gas and 9 lbs. of tar and liquor = 18 lbs. total weight of gases and vapours evolved per hour. I take the specific heat of the gas at 2·2, and of tar and liquor vapours at 0·6, or a mean of 1·6. Assuming the temperature of the gas as it leaves the retort to be 1000° Fahr.,² while at 3 ft. above the mouthpiece it was found to be only 174° Fahr., then the heat dissipated between those points in one hour is as follows:—

$$18 \text{ lbs.} \times 1\cdot6 \text{ sp. heat} \times (1000^\circ - 174^\circ) = 23,790 \text{ units.}$$

“The temperature of the air surrounding the pipe I take at 208° Fahr. Probably it would be much lower, as that was the temperature found within 6 in. of the front of the setting. Therefore the difference to be dissipated is—

$$\text{“ Mean temperature of gas to be cooled, } \frac{1000 + 174}{2} = 567^\circ - 208^\circ = 379^\circ \text{ Fahr.}$$

² The temperature within the mass of coal, 3 ft. from the mouthpiece and one hour after charging, has been found to be about 1150° Fahr.

CARBURETTED WATER GAS.

A carburetted water gas plant is a useful adjunct to the ordinary coal gas plant of a gas-works. The plant is used both for gas making and for gas enriching, and consists of a generator, carburettor, superheater (or fixing chamber), condensers, purifiers, and relief gasholder. In some cases the carburettor and fixing chamber are constructed in one.

The generator is a steel cylinder, fire-brick lined, with furnace feeding door at the top and clinkering doors near the base. Between the steel shell and the fire-brick lining a non-conducting material is used to conserve the heat or minimize its loss.

The carburettor is of similar construction to the generator, and is filled with chequer bricks so arranged as to form a series of baffles to the gas. At the top of the carburettor heated oil is sprayed in the form of mist and meets the gas from the generator.

From the carburettor the gas passes on to the superheater (or fixing chamber) which also contains chequer bricks similar to the carburettor, and in this chamber the gas is made permanent.

The gas is made by admitting superheated steam at 100 to 120 lbs. pressure through the bed of incandescent coke in the generator, where it is decomposed into its constituent gases, oxygen and hydrogen. The resultant oxygen combines with the carbon of the coke, forming carbon dioxide, which, rising through the higher layers of the incandescent coke, is reduced to carbon monoxide, and this mixing with the hydrogen constitutes what is known as "blue" gas. This is non-luminous, and is afterwards

"By Webber's formula (*Journal of Gas Lighting*, vol. xxxii. p. 14), the heat lost by radiation and contact is—

$$[0.7583 \times 379 \times 6.5] + \left[\left(0.421 + \frac{0.307}{5} \right) + 379 + 2 \right] = 2250$$

units of heat per square foot of exposed surface per hour. Total heat actually lost as above, 23,790 units. Calculated surface required = $\frac{23,790}{3250} = 10\frac{1}{2}$ sq. ft. In the mouthpiece 21 in. by 15 in. by 15 in. there is, say, $6\frac{1}{2}$ sq. ft. In 3 ft. of 6-in. pipe there is $4\frac{1}{2}$ sq. ft. Total, 11 sq. ft., or more than sufficient cooling surface to produce the observed result.

"Calculating in a similar manner for the difference between the temperature at 3 ft. from mouthpiece 174°, and that in the bridge-pipe 132° Fahr., I find there is similar accord between theory and practice, calculation and observation, which appears to give further ground for accepting the assumption started with as a correct one."

enriched with oil in the carburettor as above mentioned, which imparts to the gas its light-giving properties.

The process of manufacture may be continued as long as the fuel in the generator is sufficiently high in temperature to reduce the carbon dioxide to the monoxide. Usually, after six to seven minutes' gas making the temperature of the fuel falls too low for this reduction to take place. The steam and oil supply is then shut off and an air blast turned into the generator, thus again raising the temperature of the fuel. A period of three to four minutes is generally sufficient, after which the steam and oil are turned on again.

A relief holder is necessary in the working of a carburetted water gas plant in order to store the intermittent makes, and to supply a constant flow for mixing with the ordinary coal gas.

The following figures may be taken as fair average working results and costs in this country of manufacturing 1000 cubic feet of 18 candle carburetted water gas, with oil at $2\frac{1}{2}d.$ per gallon and coke at 10s. per ton :—

Illuminating power, tested with the Metro-	
politan argand burner No. 2	18 candles
Candles per gallon of oil	8 „
Coke used for generators and boilers per 1000	
cubic feet.	48 lbs.
Oil used per 1000 cubic feet	$2\frac{1}{4}$ gallons
Total cost per 1000 cubic feet, including fuel,	
generating wages, purifying and labour,	
salaries, water, stores, wear and tear and	
sundries	$8\frac{3}{4}d.$

Dellwik-Fleischer Water Gas is a "straight" or "blue" gas, and is non-luminous.

The plant for producing it consists of a generator and scrubber. The generator is lined with fire-brick and has a thin lining of mica or slag wool to prevent radiation. There is no provision in the plant for enrichment as in the case of carburetted water gas, this being obtained by the use of a separate plant.

COKE OVEN GAS.

The gas from coke ovens is now being supplied for lighting and heating purposes.

The Little Hulton Urban District Council (recently supplied

with gas from Salford) now takes its supply from the coke ovens of Lord Ellesmere. The gas has an illuminating power of 16 candles tested with the Metropolitan argand burner No. 2, and a calorific value of 597 B.Th.U's., gross. (See pages 371 and 407 for an explanation of the term gross as here used.)

The composition of the gas is as follows:—

Hydrogen	48·8
Marsh gas	30·9
Carbon monoxide	6·9
Heavy hydrocarbons	3·8
Carbon dioxide	2·1
Oxygen	0·4
Nitrogen	7·1

PYROMETERS AND HEAT RECORDERS.

The temperature of distillation can only be ascertained correctly by the aid of some form of pyrometer or heat recorder.

There are many types and forms of pyrometers, but the chief are (1) thermo-electric, (2) electrical resistance, (3) optical, (4) thermo-electric radiation, and (5) calorimetric. Watkin's "heat recorders" consist of a number of fusible pellets enclosed in separate compartments in a refractory case, the pellets being standardized to fuse at different temperatures.

Radiation pyrometers, of which the Féry is a type, are perhaps the most useful for gas works purposes. The latter is specially adapted for recording the temperatures of the producer, combustion chamber, retort, and waste gas flues. It can also be used for determining the temperatures in water gas manufacture.

The Féry pyrometer is made in two types—the thermo-electric radiation and the spiral. By the former, to ascertain the temperature, the hot body is sighted through an eyepiece, and the radiation emitted by means of a concave mirror upon the junction of a special thermo-couple, which is arranged within the telescope and connected to a terminus fixed to the body of same. A galvanometer and length of armoured cable complete the apparatus. The galvanometer is of the pivoted moving coil type, requires no levelling, and is an improvement on the pattern formerly used.

This type of pyrometer can be used either for giving instantaneous readings or for obtaining a continuous record of temperature.

The spiral type pyrometer is similar in principle to that of the above, but instead of the radiation being focused on a thermocouple, it is thrown on to a flat spiral. The spiral is made of two dissimilar metals having widely different co-efficients of expansion. These are soldered together, the inner side of the spiral being made of the metal with the greater co-efficient of expansion.

The spiral is fixed at its inner end on a small steel stem which is supported centrally in the telescope, while the outer end carries a light aluminium pointer, deflections of which indicate on the scale the amount of heat radiated on to it by the hot body, the scale being calibrated to read directly in degrees of temperature. This instrument is not quite so accurate as the thermo-electric type, but it has the advantage of being extremely portable and robust.

The following table by Pouillet gives the colours corresponding to various high temperatures:—

Faint red	977° Fahr.
Dull red	1290° „
Brilliant red	1470° „
Cherry red	1650° „
Bright cherry red	1830° „
Orange	2010° „
Bright orange	2190° „
White heat	2370° „
Bright white heat	2550° „
Dazzling white	2730° „
Melting point of cast-iron—	
White	1920° to 2010° „
Grey	2010° to 2190° „

The carbonizing temperature of clay retorts ranges from 2010° Fahr. (orange) and upwards.

ANALYSIS OF FURNACE GASES.

With the direct-fired furnace, in which, beyond governing the consumption of fuel by the aid of dampers regulating the chimney draught, no control of the furnace is possible, an analysis of the waste gases from the furnace is of little practical value.

With the adoption of gaseous firing, however, the great advantage of which rests in the means it affords of obtaining

a combustion which, in theory, is approximately perfect, a full knowledge of both the producer gases and the waste gases is almost, if not wholly, synonymous with efficient working.

Theoretically, the producer gas should contain $34\frac{1}{2}$ per cent. of carbon monoxide and $65\frac{1}{2}$ per cent. of nitrogen; but an average analysis will generally show 25 per cent. of carbon monoxide, 60 per cent. of nitrogen, 8 per cent. of carbon dioxide, and 7 per cent. of hydrogen and methane. The waste gases should contain not more than $1\frac{1}{2}$ per cent. of oxygen, no carbon monoxide, 21 per cent. of carbon dioxide, and $77\frac{1}{2}$ per cent. of nitrogen.

A wrought-iron tube is employed for collecting the sample. This is made to project into the centre of the top flue, and is continued some distance outside, so as to cool the gas. To better obtain an average sample, it is well to aspirate a much larger quantity of gas than is required, and take off the sample simultaneously by a branch tube.

There are three or four efficient apparatus for ascertaining the composition of producer and waste gases, but that of Orsat is perhaps the simplest and most compact.

The Orsat apparatus (Fig. 59), and its manipulation, may briefly be described as follows:—

The measuring tube or burette, A, consists of an elongated bulb, terminating at the top in a capillary tube, and diminished at the bottom into a tube of uniform bore, graduated in tenths of a cubic centimetre. The tube contains from the zero mark to the upper capillary end exactly 100 c.c. at normal temperature and

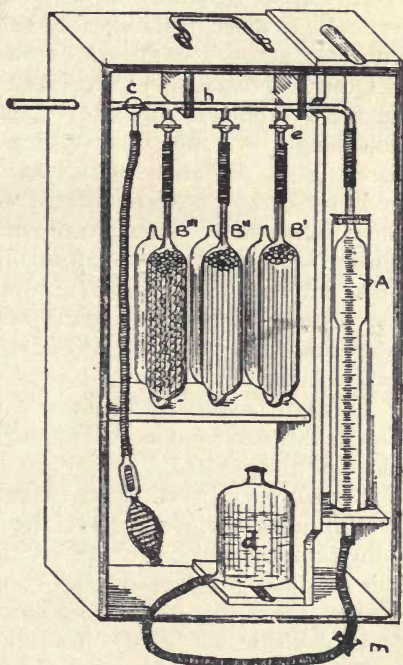


FIG. 59.

pressure To keep the burette as much as possible from the influence of sudden changes of temperature, it is provided with a water jacket.

The lower end of the tube is connected by means of caoutchouc tubing with a water "level" bottle, *d*, which can be raised or lowered at the will of the operator.

The upper capillary tube is bent at right angles with the vertical, a short distance above the measuring tube, and is continued across the apparatus on wooden supports.

Other capillary tubes, provided with stopcocks, are fused into the main capillary, and are connected at their lower end by a short length of caoutchouc tubing with the U-shaped absorption vessels, B' B'' B''', filled with bundles of glass tubes; the object of the latter being to expose a large surface to the gases under test. These absorption vessels are half filled, respectively, with a solution of caustic potash, an alkaline solution of pyrogallate, and a concentrated solution of cuprous chloride in hydrochloric acid. The vessel B' will then absorb any carbon dioxide in the gas to be analysed, the vessel B'' any oxygen, and the vessel B''' any carbon monoxide.

It is not customary to analyse for the hydrogen and methane, though this can be done by the addition of a palladium apparatus following the vessel B'''.

The nitrogen is estimated as residue.

Manipulation.—See that the absorption vessels nearest the main capillary tube are full to the mark in the capillary neck. This is done by opening the connecting taps and lowering the level of the water in the measuring tube, for which purpose the "level" bottle, *d*, is used. Then shut off the cocks.

The measuring tube must then be filled with water up to the capillary part, by raising the level bottle. The outer end of the capillary tube, *h*, must now be connected with the tube through which the gas to be tested has to pass, and the lower end of the three-way cock, *c*, with an india-rubber pump, by which the air is removed from the connected tube.

Now aspirate the gas by lowering the level bottle, *d*, and turning the tap, *c*, through 90°. Run off the water a little below the zero mark, close the tap, *c*, raise the level bottle, *d*, so as to compress the gas and allow the excess of water to run out to zero by cautiously opening the pinch cock, *m*. To finish the operation, the tap, *c*, is

opened for an instant to equalize the pressure, whereupon exactly 100 c.c. of gas will be confined within the burette.

The gas is now ready for testing, first by the absorption of carbon dioxide by conveying the gas into the vessel B', containing a solution of caustic potash. This is done by raising the level bottle, *d*, and opening the tap, *e*. The absorption is quickened by raising and lowering the level bottle two or three times, care being taken not to draw any of the reagent into the capillary tube.

The level of the solution in B' is then brought up to the mark on the capillary tube, and the tap, *e*, closed. The reading can then be taken by raising the level bottle until the water in the bottle and the water in the burette are at the same level.

The decrease in volume found indicates the percentage by volume (since 100 c.c. were taken) of carbon dioxide.

In like manner the oxygen is absorbed in B'' and the carbon monoxide in B''', the unabsorbed residue representing the nitrogen and a small percentage of hydrogen and methane.

Reagents.—The caustic potash solution should be of 1.2 to 1.28 specific gravity.

The alkaline pyrogallate is prepared by adding 18 grs. of pyrogallol to the above caustic potash solution.

The cuprous chloride solution is prepared by adding 35 grs. of copper chloride to 200 c.c. of strong hydrochloric acid and a few strips of sheet copper; this solution to be kept well stoppered for two days and well shaken, after which add 120 c.c. of water.

The vessel B''' should contain either strips of copper or copper wire, to keep the cuprous chloride up to strength.

CONDENSATION.

The cooling or condensing of the crude gas is an indispensable preliminary to its purification. Although the heavier tars are deposited in the hydraulic and foul mains within the retort house, there are lighter tars which continue suspended in the gas in the form of vapour, and are carried forward until a reduction in the temperature causes their deposition.

Although it is commonly said that "thorough condensation is half the purification," the degree of condensation to which coal

gas should be subjected after leaving the retorts, and before entering the purifiers, has never been determined with that scientific accuracy which the importance of the subject demands.

With respect to one point there cannot be two opinions—viz. the necessity of guarding against a lower temperature in the gas than 50° Fahr. If condensation is carried beyond this, the lighter hydrocarbons are in danger of being deposited, and the gas impoverished.

The bad effects of excessive refrigeration are shown in the following table, which exhibits the loss of illuminating property in coal gas on exposure to the temperature of freezing point, 32° Fahr. :—

Name of Gas.	Hydrocarbons condensed from 1000 Cubic Feet of Gas on Exposure to a Temperature of 32° Fahr.
Boghead cannel	4'42 cubic feet.
Ince Hall „	0'37 „
Methyl „	0'33 „

From which it appears that the richest gas suffers the greatest deterioration on being subjected to cold.

Experience has sufficiently proved that rapid or sudden, as well as excessive, condensation is an evil to be avoided, and that to prevent the deposition of naphthalene in the pipes, and preserve some of the richer illuminants, the gas should be allowed to travel in contact with the lighter tars until the latter are reduced in temperature to about 100° Fahr. before separation takes place.

With this object in view, the pipe leading from the hydraulic main may be carried with a gradual inclination round the interior of the retort house or other convenient building, and from thence to the condenser ; provision, of course, being made to allow the thicker tar to run off at a point near to the hydraulic main. By this arrangement the gas is slowly reduced in temperature, and some of its most valuable light-giving hydrocarbons, which would otherwise be condensed, are retained within it in the permanent state.

Naphthalene.—In dealing with the subject of condensation, that of the formation or deposition of naphthalene may be appropriately discussed. This hydrocarbon when deposited in the solid state in the apparatus and mains of a gas-works, and in the distributing pipes in the streets, is exceedingly troublesome, sometimes

entirely blocking the passage of the gas, and entailing much labour and expense in its removal.

It is generally believed that the presence of naphthalene in coal gas is due to two causes: first, pyrogenic synthesis, and, second, polymerization of the hydrocarbons consequent on the high heats necessarily used in the carbonization of the coal. In the early days of gas-lighting, when iron retorts were used exclusively, and the heats were comparatively low, naphthalene as now found in the mains in the solid state was almost unknown. It was not until clay retorts came to be employed, and the heat of carbonization was increased, that naphthalene made its appearance.

It is well known by its flaky crystalline structure and its peculiar ethereal odour. It is not soluble in water, but easily so in naphtha; hence its removal is effected by steaming with naphtha vapour, or by pouring that liquid into the obstructed mains and apparatus.

Naphthalene is deposited most freely from gas produced from bituminous coal. Some kinds of coal yield it in greater abundance than others. By using a proportion of cannel along with the coal, the gas, being enriched, is enabled to retain some or the whole of the naphthalene in suspension within it in the gaseous condition. The richer the gas, the more capable it is (under ordinary conditions) of retaining the constituents which contribute to its enrichment, and *vice versa*.

The gas should be cooled to a temperature slightly lower than, or equal to, what it will experience in the mains and services. The percentage of naphthalene that can be retained in a gas is in proportion to its temperature and vapour tension. Gas at a high temperature will hold more naphthalene in suspension than gas at a low temperature. Therefore, if gas is not properly condensed—that is to say, if it is not reduced to the temperature to which it will be likely to fall in the mains and services—then the excess of naphthalene held in the gas will be deposited.

The experiments of M. Brémond are here recounted as being of historical interest, and also to show the philosophy underlying the facts, rather than for the purpose of recommending his remedy, which would be cumbrous in practice.

In the year 1877 M. Brémond published an account of a series of valuable researches made by him on the question of the formation of naphthalene and its deposition, in which he showed that (to

use his own words) "naphthalene is produced wherever there is condensation of the aqueous vapours contained in the gas ; that its deposition is preceded by the phenomenon of the condensation of the water ; and that gas absolutely deprived, as far as possible, of aqueous vapour does not deposit naphthalene under the ordinary conditions of temperature and pressure."

It is clear, therefore, that the subject of condensation is one of the utmost importance, if naphthalene, or an excess of it, is to be got rid of. But however perfect the ordinary condensing apparatus may be, it is almost impossible to deprive gas of its aqueous vapour by this means. M. Brémond therefore adopted other means of drying the gas ; and for this purpose he employed an ordinary lime purifier. But instead of filling it with slaked or hydrated lime, he charged it with unslaked lime in lumps. By passing the gas through this unslaked lime he completely desiccated the gas, with the interesting result that the aqueous vapour, and consequently the excess of naphthalene also, was arrested. The gas thus deprived of its moisture was found to have increased in illuminating power to a considerable extent.

This remarkable result of drying the gas had previously been observed by the first London Gas Referees. They found that the gas made at Beckton actually gained in illuminating power in traversing the long length of mains from Beckton to London, and they remark as follows : "In considering the satisfactory result of the novel and somewhat perilous enterprise, the Referees are inclined to account for it [the increase in the illuminating power] mainly by the slow and gradual withdrawal of aqueous vapour from the gas in its long journey. This condensation is very different in character from the sudden withdrawal of aqueous vapour produced by the application of great cold ; for it takes place very gradually, so that the water is deposited without any appreciable portion of the hydrocarbons being condensed along with it. In order to ascertain the effect of withdrawing the aqueous vapour from gas, we made several experiments by passing the gas through porous calcium chloride ; the results showing that dry gas has a superiority in illuminating power over ordinary gas to the extent of from 6 to 8 per cent."

Quite a number of remedies, more or less successful, have been adopted for the suspension or elimination of naphthalene.

Mr. Botley has accomplished the retention of naphthalene by

carburetted the gas after the holders with petroleum oil in the form of mist, produced mechanically.

Another method, which has proved efficient, is to vaporize carburine by means of steam, mixing it in the proportion of about 12 gallons of the oil per million cubic feet of gas passing into the holders.

Various other vaporizers have been designed with a fair amount of success for the purpose of adding to the gas a quantity of the vapour of suitable hydrocarbons, with the object of giving it a greater power of retaining the naphthalene in the gaseous form (see pp. 408-10).

The obvious objection to all the above is that, owing to the almost universal use of the incandescent mantle, gas of a lower illuminating power than formerly is now generally supplied, and therefore enrichment is not required.

Various other methods adopted for the removal of naphthalene are based on the known fact that it can be dissolved by various solvents.

The late Mr. Alfred Colson's process consists in washing the gas in some form of washer—such as the "Livesey"—with an oil consisting chiefly of those distillates of coal tar which have their boiling point between 338° and 419° Fahr.

Mr. Ferguson Bell washes the gas with warm tar, and afterwards with heavy naphtha; the quantity of naphtha used being one-fifth of a gallon per ton of coal carbonized.

It may be pointed out, also, that the provision of a tar extractor before the condenser has been found to give beneficial results in the reduction of naphthalene.

Tar Fog.—Too sudden condensation of the crude gas often results in the formation of tar fog—*i.e.*, tar is condensed in minute globules, a conglomeration of which offers a large surface in contact with the gas. When these conditions exist, the gas not only loses some of its illuminants, but a proportion of tar is carried forward to the purifiers.

Different forms of apparatus for the removal of tar fog have been devised in which the principles employed are the division of the gas into numerous small streams, or its subjection to friction or impingement.

Dr. Colman applies the principle of centrifugal force at the inlet of the condensers.

His apparatus consists of a wrought or cast iron cylinder under which there is an inverted conical portion, the lower end being attached to a syphon for the removal of the liquids that are separated in the apparatus. The gas enters at a tangent, and sets up a whirling motion of the whole contents of the separator. Under the influence of this force the solid and liquid particles are driven to its circumference, where they coalesce and fall down the sides, being conveyed away by the syphon.

The Pelouze and Audouin condenser (see p. 119) is also used both as a tar extractor and tar fog eliminator.

Everitt's extractor is a modification of the latter, and consists of a horizontal iron vessel containing a series of screens of iron wire gauze. The screens are fixed vertically and about $\frac{1}{4}$ inch apart by means of metal separating rings at their circumference. Between the screens, exhaust steam is intermittently injected in such a manner as to cause the precipitation of the tarry matter and the breaking up of the vesicles, thus liberating their contained gases.

Crossley's patent centrifugal tar extractor is also an efficient apparatus for the removal of tar fog.

A slow cooling of the gas, however, by the aid of a back main and long foul main, will alleviate and often entirely prevent the formation of tar fog.

Tar Fog in Water Gas.—The elimination of tar and tar fog from water gas is much more difficult than from coal gas.

The application of centrifugal force is the only method by which success may be obtained.

Crossley Brothers, as above mentioned, have invented a tar extractor of the centrifugal type. It consists of a revolving fan or disc in a casing. The gas enters at the centre and is driven at a high speed against the periphery of the extractor, with the result that the minute tarry particles coalesce and condense. About one gallon of water per 1000 cub. ft. is introduced with the gas, and this being whirled at a high speed against the periphery of the fan effects the removal of 96 per cent. of the tar.

A special arrangement of symmetrical blading causes the gas to enter and leave the extractor at the same pressure. A minimum of power only is thus required to drive the fan.

Temperature and Station Meter Registration.—The make of gas, as indicated by the station meter, is materially affected by the temperature at which it is registered.

At the temperature of 60° Fahr., with the barometer at 30 in., gas is at its standard volume; and as all aëriform bodies expand

$\frac{1}{491.4}$ of their bulk at 32° Fahr. for every additional degree of tem-

perature, or about 1 per cent. for 5°, it follows that a quantity of gas, say 10,000 cub. ft., registered at 60°, would at 70° become 10,203.5, and at 80° 10,407.

The quantity of heat which will raise a cubic foot of water one degree, will raise 2850 cub. ft. of gas or atmospheric air to the same extent.

TABLE.

EXPANSION OF AIR AND PERMANENT GASES BY HEAT.

Temp. Fahr.	Expansion.	Temp. Fahr.	Expansion.	Temp. Fahr.	Expansion.	Temp. Fahr.	Expansion.
Deg.		Deg.		Deg.		Deg.	
32	1000	52	1040.700	72	1081.400	92	1122.100
33	1002.035	53	1042.735	73	1083.435	93	1124.135
34	1004.070	54	1044.770	74	1085.470	94	1126.170
35	1006.105	55	1046.805	75	1087.505	95	1128.205
36	1008.140	56	1048.840	76	1089.540	96	1130.240
37	1010.175	57	1050.875	77	1091.575	97	1132.275
38	1012.210	58	1052.910	78	1093.610	98	1134.310
39	1014.245	59	1054.945	79	1095.645	99	1136.345
40	1016.280	60	1056.980	80	1097.680	100	1138.380
41	1018.315	61	1059.015	81	1099.715	110	1158.730
42	1020.350	62	1061.050	82	1101.750	120	1179.080
43	1022.385	63	1063.085	83	1103.785	130	1199.430
44	1024.420	64	1065.120	84	1105.820	140	1219.780
45	1026.455	65	1067.155	85	1107.855	150	1240.130
46	1028.490	66	1069.190	86	1109.890	160	1260.480
47	1030.525	67	1071.225	87	1111.925	170	1280.830
48	1032.560	68	1073.260	88	1113.960	180	1301.180
49	1034.595	69	1075.295	89	1115.995	190	1321.530
50	1036.630	70	1077.330	90	1118.030	200	1341.880
51	1038.665	71	1079.365	91	1120.065	212	1366.300

In instituting a comparison between the production per ton of material at different works, and in testing the productive value of different coals, it is therefore necessary to take into account the temperature of the gas at the time of measurement.

In ascertaining the specific gravity of gas, and in conducting photometrical observations, the same care should be taken to note the temperature at the time and place of making the experiment.

TABLE.

Giving the Mean Temperature (Fahr.) of every Tenth Day in the Year in the Central District of England. (Box.)

Month.	1st.	11th.	21st.	Month.	1st.	11th.	21st.
	Deg.	Deg.	Deg.		Deg.	Deg.	Deg.
January	36·5	35·6	37·1	July	61·2	61·5	62·0
February	37·2	37·5	38·5	August	62·5	61·7	60·6
March	40·1	41·0	41·9	September	58·8	57·4	55·5
April	43·6	45·0	47·0	October	53·5	51·4	49·0
May	50·0	51·3	53·8	November	46·4	44·0	42·0
June	56·4	57·5	59·8	December	41·7	40·2	38·4

Condensers.—The Atmospherical horizontal condenser (Fig. 60) is one of the earliest forms of the apparatus. Its efficiency has

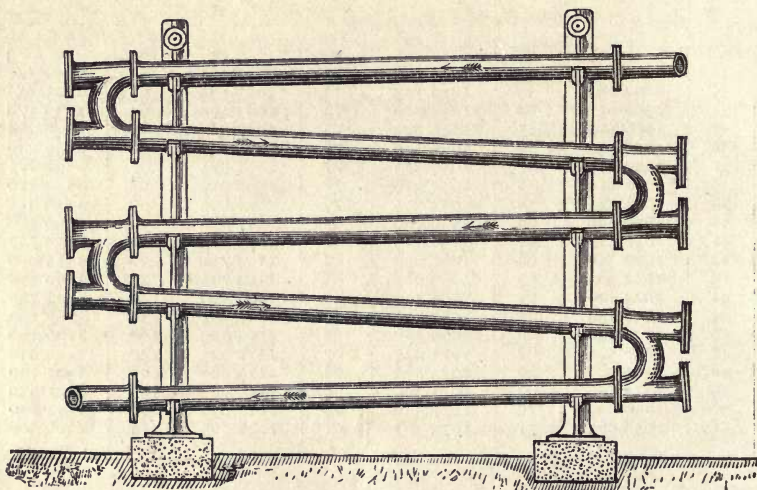


FIG. 60.

not been generally recognized, owing to the want of a correct appreciation of the conditions on which the condensation of coal gas ought to be conducted, and this has led to its being generally discarded in favour of the vertical form.

The earlier method of construction was to fix it against the

outside of the wall of a retort house or other convenient building ; the several pipes rising with a slight inclination one above the other to allow of the flow of the condensed products, their ends being connected by \supset -shaped bends.

Graham's condenser (Fig. 61) is an improvement on this. It consists of a series of pipes arranged in pairs, side by side, and supported on framework, the end of each length being joined to that of the next. From the inlet at the top, through the entire run of the condenser to the outlet at the bottom, there is a gradual inclination, so that it is simply a flat screw or spiral, such as might be represented by winding a length of soft wire round a piece of board, in which case the two ends of the wire would answer to the

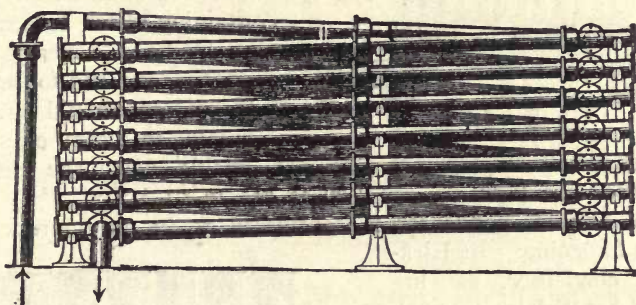


FIG. 61.

inlet and outlet of the condenser. Blank flanges are bolted on the end of each length for convenience in cleansing:

In this arrangement there is a recognition of the fact that *length* rather than *height* is the desideratum in an atmospherical condenser. In the ordinary vertical form of the apparatus, the cooling effect of the air on the surface of the upper parts of the pipes is almost *nil*. This will be obvious when it is considered that the air contiguous to the lower part of the condenser, being assimilated to the temperature of the latter, expands, and so, becoming lighter than the surrounding air, ascends in contact with the pipes, extracting less heat in proportion as it rises.

In addition to the other advantages, the ammoniacal liquor on leaving the horizontal condenser is of a strength equal to 5° Twaddell

—a result which it is impossible to obtain from the ordinary vertical form.

The ordinary atmospherical condenser (Fig. 62) consists of a series of pipes, usually 18 ft. long, put together in two lengths, and placed upright, through which the gas passes up and down alternately. These enter a rectangular cistern at bottom, in which the condensed vapours are deposited, and from whence they flow to the tar well. At the top is another cistern, containing water to seal the movable hoods covering each pair of pipes; and for further refrigeration, should such be required, in warm or sunny

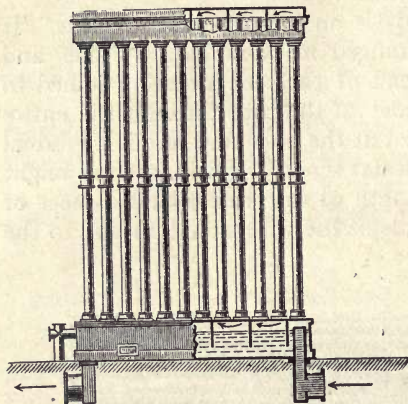


FIG. 62.

weather, small streams are made to trickle down the exterior surface of the pipes.

The annular condenser is considered to be an improvement on the foregoing. In Kirkham's condenser, as improved by Wright (Fig. 63), the pipes are placed in the vertical position, and are of large diameter, each one enclosing a smaller pipe; the two forming an annular space through which the gas is made to flow. Other pipes, placed diagonally, connect the top and bottom of the condensing columns alternately. By this arrangement the gas passes through the annular space always in the downward direction, whilst the current of air moves upward through the interior ventilating pipe. In cold weather movable

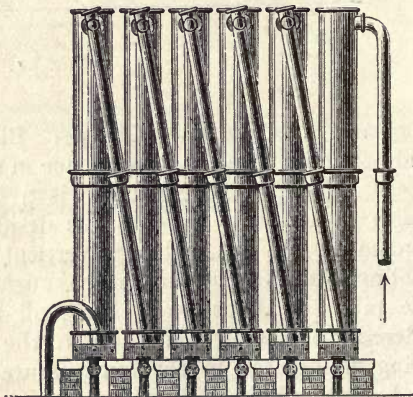


FIG. 63.

covers are placed over the latter, or butterfly valves are fixed at the foot, for closing, to regulate the air draught, which might otherwise reduce the temperature of the gas below the desired standard. A small pipe is connected to the bottom of each column to carry away the deposited tar and water into a main laid alongside the condenser and leading into the tar well.

The annular atmospheric condenser (Fig. 64) is a modification of the latter, and is the one most generally adopted. The gas travels by way of the annular space through the two columns ; but,

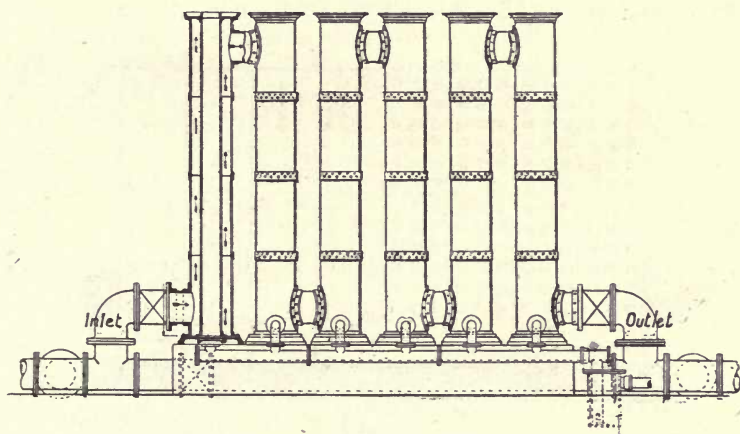


FIG. 64.

instead of the columns being connected diagonally, they are connected to each other alternatively top and bottom by means of cast-iron flanged branches riveted to the outer columns. The inner tube or cylinder in each column is open to the atmosphere throughout its length, and an air slide or butterfly valve fixed at the base acts as a controller of the air passing up the column. At the base of each outer tube a cast-iron pipe is fixed so as to remove the products of condensation which are conveyed into the syphon pot.

Cleland's slow-speed condenser consists of a series of vertical pipes, connected together at the top by a tubular cornice or cap, which serves as the common inlet to the whole series. The stream of gas, being thus divided equally amongst the several columns,

travels through them in a downward direction and at a comparatively slow speed.

In the lower part of each column, to about a fifth part of its length, is inserted a "bottle brush" of wood or other material, with a drip-ledge above it to divert the descending liquor on to the centre of the brush, which has the effect of converting the apparatus, to that extent, into a scrubber.

The general result is superior efficiency in condensing and the yield of a high strength of liquor.

An excellent apparatus (atmospherical) is that known as the battery condenser (Fig. 65). This is an oblong vessel, 12 to

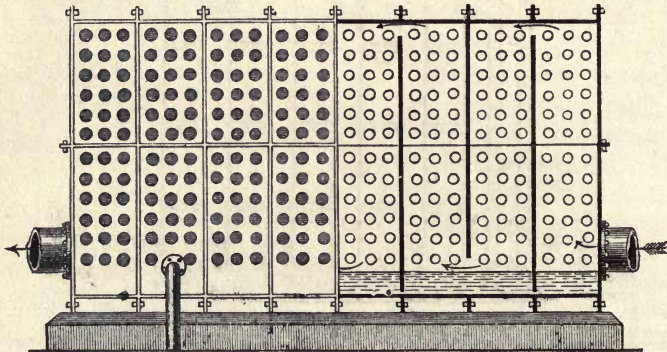


FIG. 65.

24 in. wide, 12 to 18 ft. in height, and of length suitable to the requirements of the works. It is divided by internal plates or mid-feathers (placed at distances, equal to the width, apart), extending to within a few inches of the top and bottom of the chest alternately; and the gas passes from the inlet, up and down each division, till it arrives at the outlet. To augment its condensing power, small tubes, 2 in. in diameter, through which the air has free circulation, are passed through from side to side of the vessel and there securely jointed. These transverse tubes serve the double purpose of cooling the gas and, by breaking it up and retarding its progress, inducing a natural settlement of the heavy condensable vapours.

It may be taken as a general rule that about 10 superficial ft. of atmospherical condensing surface for each 1000 cub. ft. maximum

gas production per day of 24 hours should be provided. This includes the length of foul main extending from the hydraulic main. Moreover, the condenser should be protected from the direct action of the sun's rays ; or, otherwise, water should be made to trickle down the outer surface of the pipes during sunshine.

Sir George Livesey, in some of his condensing arrangements, adopted a plan of placing the condensing pipes in a tank divided into channels, through which water is made to flow, and which can be regulated according to the make of gas. The water enters the tank at the point where the condensed gas makes its exit, and, flowing in the opposite direction to the gas in the pipes, is gradually raised in temperature by the latter till it reaches its outlet where the crude gas enters. Thus a more uniform condensation is obtained than is possible in the atmosphere.

In this connection the following table by Peclet, showing the relative effects of water and air as cooling agents, is interesting and useful :—

Excess of Temperature in the Gas over the Atmosphere.	Quantity of Heat lost by a Square Unit of Exterior Pipe Surface.	
	When radiating in Air.	When plunged in Water.
For an excess of 10° . . .	8 . . .	88
„ „ 20° . . .	18 . . .	266
„ „ 30° . . .	29 . . .	5,353
„ „ 40° . . .	40 . . .	8,944
„ „ 50° . . .	53 . . .	13,437

Water is thus shown to be the superior cooling agent, requiring the exposure of much less radiating surface than air ; but, for the reasons already adduced, the temperature of the water must be regulated in order to avoid any sudden condensation.

An apparatus that is being rather widely adopted is the water tube condenser. This is made in different forms, the principle of each being the same. It is constructed either of ordinary pipes having small tubes passing through their interior, or of cylindrical or square chambers filled with such tubes, and placed either horizontally or vertically, the latter by preference. Through the tubes a stream of water is made to flow in the opposite direction to that of the gas which surrounds them, so that by the time the water reaches the inlet of the condenser it has, by absorbing the heat

of the gas, attained a comparatively high temperature, and thus any sudden cooling of the gas at the entrance is avoided. The ease with which the cooling power of the apparatus can be varied and controlled, by increasing or diminishing the flow of the water, is a strong recommendation in its favour.

There are advantages to be gained by having the condenser reversible. By occasionally reversing the flow of gas and water, obstruction in the condenser is minimized.

The underground condenser is so called because the pipes are placed in the ground, out of reach of the fluctuations of temperature in the atmosphere, with a view to obtaining uniformity of action in the process of condensation. By this system, however, a much longer length of piping is required than by any other, owing to the small amount of radiation from the surface of the buried pipes.

There is an advantage in this process of gradual condensation ; but it is advisable, wherever in use, to supplement it by finally passing the gas through one of the other forms of condensers having less than the usual area.

In some works condensation is effected by means of dry scrubbers—cast-iron vessels of large diameter—charged with coke, drain tiles, or other material, breaking up the gas into very minute streams, which, being thus cooled, deposits its tar and water. A natural settlement of the condensable matter also takes place irrespective of the action of the contained material, owing to the velocity of the flow of the gas being reduced on entering the larger area. The rapid fouling of these vessels, however, necessitating frequent changing of the filling material to prevent undue back pressure and maintain their efficiency, renders their use objectionable.

Precipitating chambers of large size are also employed, without any filling material, in which the gas sleeps, as it were, and deposits its condensable particles. The large volume of gas also serves as a cushion to counteract pulsatory action between the exhauster and the retorts. But it is a dangerous piece of apparatus, and we do not recommend its adoption. On a works being restarted after being temporarily shut down from any cause, the mains and this large chamber are liable to become charged with an explosive mixture of air and gas ; and in the event of any of the dip-pipes in the hydraulic being unsealed, the

mixture is likely to be fired, with the inevitable explosion as the result. A recent serious accident at a gas-works was due to this cause.

The principle of Pelouze and Audouin's condenser differs from that of any of the other apparatus described. In construction it consists of an outer cylindrical cast-iron chamber, with the usual inlet for gas, and outlets for gas and liquids, and contains a cylinder of perforated sheet-iron constituting the condenser. The sides of the condensing chamber are two thin sheets of iron with a concentric space between. The inner sheet is perforated with holes $\frac{1}{20}$ of an inch in diameter, and the outer with slots of large size; the outer sheet being so arranged as to offer a blank surface opposite the small holes in the inner sheet. The gas and condensable vapours pass through the small perforations, the vapours being as it were wire-drawn, and striking against the opposite solid surface are deposited thereon, and flow down into the receptacle below, and thence to the tar well. The gas passes on through the slots in the outer cylinder to the outlet pipe.

The condensing cylinder is so balanced as to rise and fall in an annular space containing tar or liquor which acts as a seal. As the make of gas increases or decreases, the cylinder rises or falls, and consequently a larger or less number of openings are uncovered for the passage of the gas. The result is a more complete separation of the tar from the gas than is attainable by any other form of condenser.

It has been attempted, though with doubtful success, to condense and carburet the gas at one and the same time. The Aitken and Young analyser, and the St. John and Rockwell apparatus, were each designed by their inventors to enrich the gas by carburation. The tar and gas were both conveyed direct from the hydraulic main to the apparatus, their temperature at the inlet being maintained as high as possible. Means were even adopted of raising the temperature if required, in order that the heavier hydrocarbons present in the crude gas and tar might be permanently suspended, and so become fixed illuminants in the gas, notwithstanding the subsequent reduction of temperature in the ordinary course of purification. Great hopes of the process were at one time entertained, but it failed to meet the expectations of the inventors.

In connection with the subject of condensation, the following table, comparing the English and foreign thermometers, will be found useful :—

Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.
212	80°0	100°0	160	56°8	71°1	108	33°7	42°2	56	10°6	13°3
211	79°5	99°4	159	56°4	70°5	107	33°3	41°6	55	10°2	12°7
210	79°1	98°8	158	56°0	70°0	106	32°8	41°1	54	9°7	12°2
209	78°6	98°3	157	55°5	69°4	105	32°4	40°5	53	9°3	11°6
208	78°2	97°7	156	55°1	68°8	104	32°0	40°0	52	8°8	11°1
207	77°7	97°2	155	54°6	68°3	103	31°5	39°4	51	8°4	10°5
206	77°3	96°6	154	54°2	67°7	102	31°1	38°8	50	8°0	10°0
205	76°8	96°1	153	53°7	67°2	101	30°6	38°3	49	7°5	9°4
204	76°4	95°5	152	53°3	66°6	100	30°2	57°7	48	7°1	8°8
203	76°0	95°0	151	52°8	66°1	99	29°7	37°2	47	6°6	8°3
202	75°5	94°4	150	52°4	65°5	98	29°3	36°6	46	6°2	7°7
201	75°1	93°8	149	52°0	65°0	97	28°8	36°1	45	5°7	7°2
200	74°6	93°3	148	51°5	64°4	96	28°4	35°5	44	5°3	6°6
199	74°2	92°7	147	51°1	63°8	95	28°0	35°0	43	4°8	6°1
198	73°7	92°2	146	50°6	63°3	94	27°5	34°4	42	4°4	5°5
197	73°3	91°6	145	50°2	62°7	93	27°1	33°8	41	4°0	5°0
196	72°8	91°1	144	49°7	62°2	92	26°6	33°3	40	3°5	4°4
195	72°4	90°5	143	49°3	61°6	91	26°2	32°7	39	3°1	3°8
194	72°0	90°0	142	48°8	61°1	90	25°7	32°2	38	2°6	3°3
193	71°5	89°4	141	48°4	60°5	89	25°3	31°6	37	2°2	2°7
192	71°1	88°8	140	48°0	60°0	88	24°8	31°1	36	1°7	2°2
191	70°6	88°3	139	47°5	59°4	87	24°4	30°5	35	1°3	1°6
190	70°2	87°7	138	47°1	58°8	86	24°0	30°0	34	0°8	1°1
189	69°7	87°2	137	46°6	58°3	85	23°5	29°4	33	0°4	0°5
188	69°3	86°6	136	46°2	57°7	84	23°1	28°8	32	0°0	0°0
187	68°8	86°1	135	45°7	57°2	83	22°6	28°3	31	— 0°4	— 0°5
186	68°4	85°5	134	45°3	56°6	82	22°2	27°7	30	— 0°8	— 1°1
185	68°0	85°0	133	44°8	56°1	81	21°7	27°2	29	— 1°3	— 1°6
184	67°5	84°4	132	44°4	55°5	80	21°3	26°6	28	— 1°7	— 2°2
183	67°1	83°8	131	44°0	55°0	79	20°8	26°1	27	— 2°2	— 2°7
182	66°6	83°3	130	43°5	54°4	78	20°4	25°5	26	— 2°6	— 3°3
181	66°2	82°7	129	43°1	53°8	77	20°0	25°0	25	— 3°1	— 3°8
180	65°7	82°2	128	42°6	53°3	76	19°5	24°4	24	— 3°5	— 4°4
179	65°3	81°6	127	42°2	52°7	75	19°1	23°8	23	— 4°0	— 5°0
178	64°8	81°1	126	41°7	52°2	74	18°6	23°3	22	— 4°4	— 5°5
177	64°4	80°5	125	41°3	51°6	73	18°2	22°7	21	— 4°8	— 6°1
176	64°0	80°0	124	40°8	51°1	72	17°7	22°2	20	— 5°3	— 6°6
175	63°5	79°4	123	40°4	50°5	71	17°3	21°6	19	— 5°7	— 7°2
174	63°1	78°8	122	40°0	50°0	70	16°8	21°1	18	— 6°2	— 7°7
173	62°6	78°3	121	39°5	49°4	69	16°4	20°5	17	— 6°6	— 8°3
172	62°2	77°7	120	39°1	48°8	68	16°0	20°0	16	— 7°1	— 8°8
171	61°7	77°2	119	38°6	48°3	67	15°5	19°4	15	— 7°5	— 9°4
170	61°3	76°6	118	38°2	47°7	66	15°1	18°8	14	— 8°0	— 10°0
169	60°8	76°1	117	37°7	47°2	65	14°6	18°3	13	— 8°4	— 10°5
168	60°4	75°5	116	37°3	46°6	64	14°2	17°7	12	— 8°8	— 11°1
167	60°0	75°0	115	36°8	46°1	63	13°7	17°2	11	— 9°3	— 11°6
166	59°5	74°4	114	36°4	45°5	62	13°3	16°6	10	— 9°7	— 12°2
165	59°1	73°8	113	36°0	45°0	61	12°8	16°1	9	— 10°2	— 12°7
164	58°6	73°3	112	35°5	44°4	60	12°4	15°5	8	— 10°6	— 13°3
163	58°2	72°7	111	35°1	43°8	59	12°0	15°0	7	— 11°1	— 13°8
162	57°7	72°2	110	34°6	43°3	58	11°5	14°4	6	— 11°5	— 14°4
161	57°3	71°6	109	34°2	42°7	57	11°1	13°8	5	— 12°0	— 15°0

To convert Degrees of Fahrenheit into those of Centigrade and Réaumur, and conversely.

To convert Fahr. into Cent.—

RULE 1st.—Subtract 32, and divide the remainder by 1·8, thus :

$$\text{Fahr. } \frac{167 - 32}{1\cdot8} = 75 \text{ Cent.}$$

Or by—

RULE 2nd.—Subtract 32, multiply the remainder by 5, and divide the product by 9, thus :

$$\text{Fahr. } \frac{(167 - 32) \times 5}{9} = 75 \text{ Cent.}$$

To convert Cent. into Fahr.—

RULE 1st.—Multiply by 1·8, and add 32, thus :

$$\text{Cent. } 75 \times 1\cdot8 + 32 = 167 \text{ Fahr.}$$

Or by—

RULE 2nd.—Multiply by 9, divide by 5, and add 32, thus :

$$\text{Cent. } \frac{75 \times 9}{5} + 32 = 167 \text{ Fahr.}$$

To convert Fahr. into Réau.—

RULE 1st.—Subtract 32, and divide by 2·25, thus :

$$\text{Fahr. } \frac{113 - 32}{2\cdot25} = 36 \text{ Réau.}$$

Or by—

RULE 2nd.—Subtract 32, multiply by 4, and divide by 9, thus :

$$\text{Fahr. } \frac{(113 - 32) \times 4}{9} = 36 \text{ Réau.}$$

To convert Réau. into Fahr.—

RULE 1st.—Multiply by 2·25, and add 32, thus :

$$\text{Réau. } 36 \times 2\cdot25 + 32 = 113 \text{ Fahr.}$$

Or by—

RULE 2nd.—Multiply by 9, divide by 4, and add 32, thus :

$$\text{Réau. } \frac{36 \times 9}{4} + 32 = 113 \text{ Fahr.}$$

Drory's Main Thermometer.—The illustrations, Figs. 66 and 67, show the improved arrangement invented by Dr. Drory for ascertaining the temperature of the gas passing through the condenser and other apparatus and the mains. It consists of an outer shell fitted with a conical hollow plug having an aperture corresponding to that in the outer shell. The tester which fits

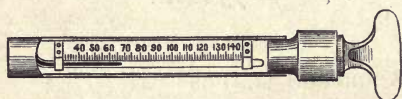
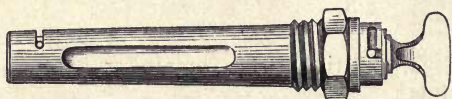


FIG. 66.

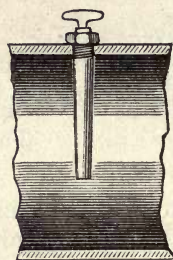


FIG. 67.

into the plug contains a thermometer, which on being turned opposite to the apertures is in immediate contact with the gas, and on withdrawal the temperature is ascertained. For attaching the tester, a hole suitable for a 1-in. wrought-iron pipe is drilled and tapped in the pipe or side of the apparatus, and the instrument is screwed therein.

THE EXHAUSTER.

The exhauster is best placed to follow the condenser. The *raison d'être* of this apparatus, which is really nothing more nor less than a pump, is to relieve the retorts of the pressure caused by the obstruction offered to the gas in its passage through the washers, scrubbers, purifiers, and station meter into the holders.

Exhausters are now made of almost any size, down to the smallest; and there are but few gas-works, however small, where they cannot be applied with advantage. The invariable result of the use of the exhauster is to increase the production per ton, to improve the quality of the gas (provided air is not drawn in), and to lengthen the duration of the retorts, by preventing, in a

great measure, the deposition of carbon—the removal of which with the ordinary chisel bars is so destructive and unsatisfactory.

Mechanical exhausters are of two kinds: the rotary and the reciprocating. Both descriptions have their advocates, and much may be said in favour of each.

Beale's exhauster was the first one constructed on the rotary principle. Its early form is shown in Fig. 68. Its parts consist

of a cylinder, inside which a drum revolves, and is provided with pistons or slides which have a radial motion. The drum is smaller in diameter than the inside of the cylinder, and the centre lines or axes of both are parallel and horizontal. But the drum is placed eccentrically in the cylinder, so as to be in contact with it at the bottom, without resting on it. The inlet and outlet passages are on the two opposite sides of the cylinder, and as the slides are guided by segments in the end plates, so that their outer ends are always in contact with the inside of the cylinder, the gas enters one side,

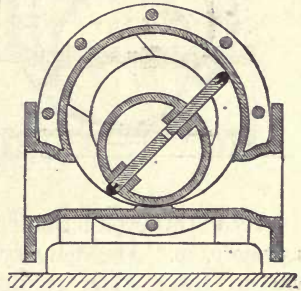


FIG. 68.

is carried round over the drum to the other side, and is forced out at the outlet. This form of exhauster is the one now most generally adopted, and whilst the original type is retained, important modifications and improvements have been effected in its construction and action by various makers of recent years—notably by Gwynne & Co., Bryan Donkin & Co., W. H. Allen & Co., and George Waller & Son.

The illustrations (Fig. 69) show sections of a Beale's exhauster as made by Gwynne & Co., under their patents, and containing several improvements on the machine as first invented, by which the areas of wearing surfaces have been augmented so as to greatly increase the durability of the machine. These include the double slides, large segments, steel pins fastened in the segments and extending through the whole length of the slides, and the outside bearings for the axle.

In order to prevent oscillation and to reduce friction to a minimum, exhausters with three and four blades have been devised, and are a great improvement on the two-bladed form.

Fig. 70 shows a section of Waller's three-blade exhauster which is suitable for works with a daily production up to half a million cubic feet.

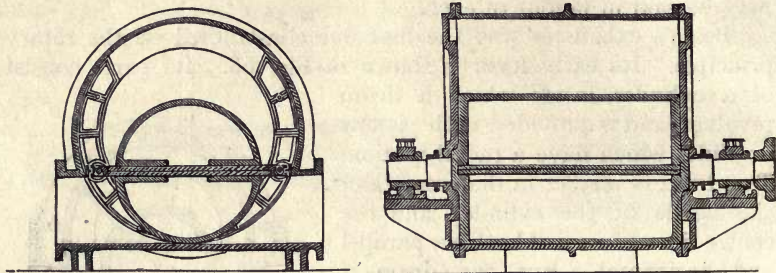


FIG. 69.

Above this production per diem the four-blade exhauster (Fig. 71) is preferable. The delivery is divided into four parts, instead of two or three, thus giving a steadier gauge. The exhausters can be run in either direction, using either branch pipe as the inlet or outlet. But the direction for running is always from the inlet. The blades of all these exhausters turn on a centre spindle and are radial with the cylinder, which is a true circle.

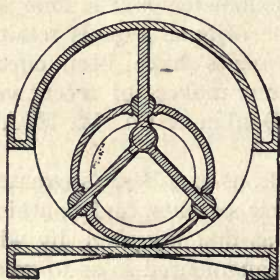


FIG. 70.

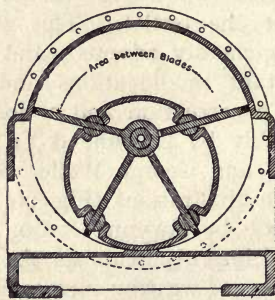


FIG. 71.

Anderson's exhauster, which may be taken as the type of the reciprocating form of the apparatus, is shown in Fig. 72. This works in the vertical position, but others, like Dempster's, have the engine and pumps placed horizontally.

The rotary exhauster may be driven either by a strap from a line shaft actuated by a steam or gas engine, or by an engine

coupled direct. The reciprocating exhauster is always driven directly by the engine.

By employing two of these latter exhausters, and working them from one engine, the slides of the exhausters being placed at right angles to each other, a perfectly steady vacuum and pressure are maintained.

The essential features of a good exhauster are that it should be simple, and work with a minimum of friction and power; that it should give the steadiest possible flow of gas; and that the parts

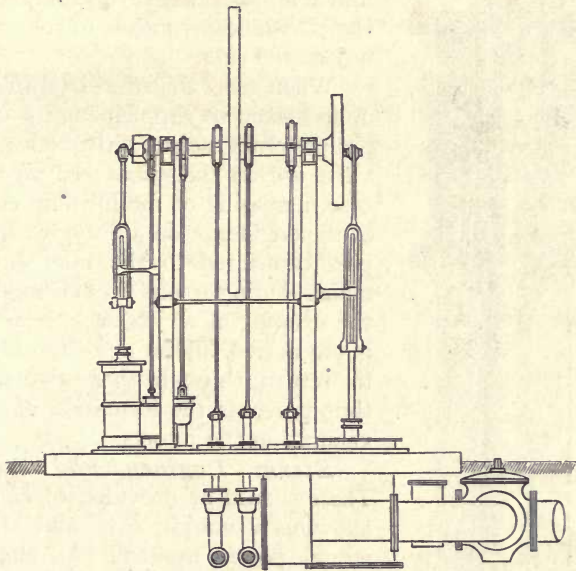


FIG. 72.

should be perfectly gas-tight. The commonest fault is want of tightness; and when it is remembered that, under a pressure equal to a 14-in. column of water, about 9000 cub. ft. of gas will pass per hour through an opening of only one square inch in area, the absolute necessity of the best workmanship only being used in exhausters will be evident.

Crude creosote oil is the best lubricant for the cylinder and slides of an exhauster when the surfaces become "pitched" with tar.

The steam-jet exhauster (Fig. 73), invented by Mr. Cleland and improved by Körting Brothers, is another form of exhausting apparatus. This operates by projecting a jet of steam, at about 45 lbs. pressure, through an arrangement of pipes or nozzles, without the intervention of any other mechanical appliances—

the steam being afterwards extracted by condensation. The capacity of the exhauster is regulated by the adjustable screw and spindle at the end, and by a movable inner sleeve opening or closing the port-holes by means of the screw and nut at the side.

When an exhauster is employed, it is necessary to supplement its use by a gas governor, acting either on a throttle valve within the steam feed-pipe, in this case increasing or diminishing the speed of the engine, or on a valve within a by-pass connected to the inlet and outlet mains leading to and from the exhauster, the opening of which, when the exhaust is too active, allows a portion of the gas to return through the exhauster, and thus prevents the formation of a partial vacuum in the retorts.

Steam Engines and Boilers.—

These should be provided of ample size, allowing a margin over and above the actual power needed. An engine and boiler barely fitted to do the work required of them are a nuisance.

The engine, besides turning the exhauster, may be used in pumping water and tar; and the boiler, in addition to supplying steam for the

engine, is useful for steaming the mains and apparatus on the works.

Duplicate boilers of the required size should be provided, to allow for periodical cleaning and examination.

For firing the boiler, breeze may be used, mixed with a portion

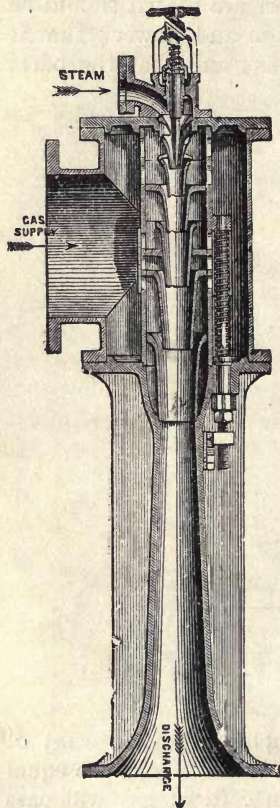


FIG. 73.

of coke or coal. Or if, instead of the chimney draught, a forced draught is employed, breeze and much of the furnace refuse will serve as fuel.

One pound weight of coal of average quality requires for its perfect combustion 150 cub. ft. of air. In actual practice, however, about double this quantity of air passes through the furnaces of steam boilers.

Wherever practicable and convenient, the boiler may be set in such a position as to allow of its being heated with the waste heat from the retort stack.

In small works, if a steam boiler cannot be employed for want of space, or should a boiler be considered objectionable on other grounds, the exhauster can be driven by a gas engine.

The boiler most suitable for a gas-works of moderate size is the Cornish type, with flat ends and single internal tube containing the furnace. For large works, the Lancashire or double-flued boiler is best adapted.

The nominal horse power of a boiler is found by multiplying the sum of the diameters of the outer shell and internal flue by the length, and dividing the product by 6.

EXAMPLE.—Required the power of a Cornish boiler, whose diameter is 4 ft. 6 in., diameter of tube 2 ft. 6 in., and length 12 ft.

$$\frac{(4' 6'' + 2' 6'') \times 12'}{6} = 14\text{-horse power.}$$

Again—

Required the power of a Cornish boiler whose diameter is 6 ft., diameter of tube 3 ft., and length 20 ft.

$$\frac{(6' + 3') \times 20'}{6} = 30\text{-horse power.}$$

Again—

Required the power of a Lancashire boiler whose diameter is 7 ft., diameter of tubes 2 ft. 9 in., and length 24 ft.

$$\frac{(7' 0'' + 2' 9'' + 2' 9'') \times 24'}{6} = 50\text{-horse power.}$$

In high-pressure or non-condensing engines, with

Steam at 25 lbs. per sq. in., 13.6 circular inches on piston = 1-horse power.

 " 30 lbs. " 11.3 " " " " " "

The diameter of the piston in inches squared = circular inches.

The following table gives the diameter of cylinders for high pressure (non-condensing) steam engines, from 3 to 16 horse power, with steam at 25 lbs. and 30 lbs. per square inch, respectively, and the length of stroke for the different sizes :—

Nominal Horse Power.	Diameter of Cylinder in Inches.		Length of Stroke. Inches.	Nominal Horse Power.	Diameter of Cylinder in Inches.		Length of Stroke. Inches.
	Steam per Sq. In.				Steam per Sq. In.		
	25 lbs.	30 lbs.	25 lbs.		30 lbs.		
3	6 $\frac{1}{4}$	6	12	8	10 $\frac{1}{2}$	9 $\frac{1}{2}$	20
3 $\frac{1}{2}$	6 $\frac{3}{8}$	6 $\frac{1}{2}$	12	8 $\frac{1}{2}$	10	9 $\frac{3}{8}$	20
4	7 $\frac{1}{8}$	6 $\frac{3}{4}$	14	9	11	10 $\frac{3}{8}$	22
4 $\frac{1}{2}$	7 $\frac{3}{8}$	7 $\frac{1}{4}$	14	10	11 $\frac{1}{2}$	10 $\frac{3}{4}$	22
5	8 $\frac{1}{4}$	7 $\frac{1}{2}$	16	11	12 $\frac{1}{2}$	11 $\frac{1}{4}$	24
5 $\frac{1}{2}$	8 $\frac{3}{8}$	7 $\frac{3}{4}$	16	12	12	11 $\frac{3}{8}$	24
6	9	8 $\frac{1}{4}$	18	13	13 $\frac{1}{2}$	12 $\frac{3}{8}$	26
6 $\frac{1}{2}$	9 $\frac{1}{2}$	8 $\frac{3}{8}$	18	14	13 $\frac{3}{8}$	12 $\frac{3}{4}$	26
7	9 $\frac{3}{4}$	9	18	15	14 $\frac{1}{2}$	13	28
7 $\frac{1}{2}$	10 $\frac{1}{8}$	9 $\frac{1}{4}$	20	16	15	13 $\frac{1}{2}$	30

The foregoing are the rough and ready methods of estimating the dimensions and power of boilers and engines. The more scientific methods of determining the proportions of engine and boiler appropriate for any particular case are most conveniently based on the actual power required from the engine, and the amount of steam required to produce that power.

An engine of the plain slide-valve, single-cylinder, non-condensing type is generally preferred for gas-works, and steam supplied at a boiler pressure of about 60 lbs. per square inch above the atmosphere. If the engine is arranged to cut off at half stroke, it will require to be supplied with about 50 lbs. of steam per indicated horse power per hour. An earlier cut-off is not practicable in this type of engine.

Engines of other types will consume much less steam per horse power, but at a greater outlay in capital, cost of maintenance, and more liability to stoppage by derangement. Engines of higher class are however often worthy of serious attention, on account of the reduction of fuel cost which is thereby effected. The long hours of working in a gas-works, as compared with those of an ordinary manufactory, invest this point with a special degree of importance.

The ratings of engines given in the tables on p. 130 are stated

in indicated horse power, which is the most convenient standard for definite test—especially as all engines should be frequently indicated in order to verify adjustment of valves and general conditions. The ratings in the first table should be regarded as the maxima and not subject to any appreciable increase.

Where a suitable supply of water is available, a steam condenser may be applied, by which means any of the engines given in the first table will drive a load of about 33 per cent. greater than is shown, or at a reduction of 25 per cent. in the steam consumed per indicated horse power per hour.

The second table of compound condensing engines of a high class shows a much more economical use of steam, especially when a high pressure is adopted. Here the engine will stand an overload of 40 per cent. with 80 lbs. steam pressure, or 80 per cent. with steam at 160 lbs. pressure. In each case the diameter of each high-pressure cylinder is stated as half the diameter of the low-pressure cylinder. The high-pressure cylinder may however vary considerably in diameter—more especially if steam of low pressure is employed.

The next tables are given for Cornish and Lancashire boilers respectively. In each case the boiler is assumed to be fired with good coal at the rate of about 18 lbs. per sq. ft. of grate per hour. Assuming that coke, breeze, or an inferior coal is used, then larger grates are required and a correspondingly larger boiler.

Forced draught is sometimes used, either to relieve an overloaded boiler or to facilitate the use of an inferior fuel. This is best effected by means of a fan or by steam jets. In case of either of these being applied, the quantity of steam required for operating them should not be overlooked.

In high-class plants for large powers, coal is burnt at the rate of from 20 to 25 lbs. per square foot of grate per hour.

In connection with the non-condensing engines, the feed water is assumed to be heated by the exhaust steam from the engine, and the rate of evaporation to be 6.5 lbs. of steam produced per lb. of coal burnt.

Where the plant is sufficiently large, and the water is not very hard, an economizer may be adopted for heating the feed water by means of the waste gases from the boilers, and the rate of evaporation thereby increased about 10 per cent. An economizer is, however, seldom applied in connection with boilers for supplying steam to non-condensing engines.

Steam Engines.

STEAM ENGINES.—SIMPLE, NON-CONDENSING.

Indicated Horse Power.	Cylinder Diameter.	Stroke.	Revolutions per Minute.	Steam Required.
	Inches.	Inches.		Lbs. per hour.
10	6	12	200	500
20	8	16	150	1000
30	10	20	120	1500
40	11½	22	110	2000
50	13	24	100	2500

STEAM ENGINES.—COMPOUND, CONDENSING.

Indicated Horse Power.		Cylinder Diameter.		Stroke.	Revolutions per Minute.	Steam Required. Lbs. per Hour.	
80 lbs. Steam.	160 lbs. Steam.	H.P.	L.P.			At 80 lbs. Pressure.	At 160 lbs. Pressure.
		Ins.	Ins.	Inches.		@ 15'5 lbs.	@ 12'0 lbs.
77	100	10	20	30	80	1200	1200
145	188	12½	25	36	80	2250	2250
244	317	15	30	42	80	3800	3800
379	493	17½	35	48	80	6000	6000
556	724	20	40	54	80	8600	8600

Boilers.

CORNISH BOILERS.

Steam Produced.	Diameter of Shell.	Diameter of Tube.	Length.	Heating Surface.	Grate Surface.
Lbs. per hour.	Ft. Ins.	Ft. Ins.	Feet.	Sq. Ft.	Sq. Ft.
500	4 0	2 2	10	140	5
1000	4 6	2 4	14	215	8
1500	5 0	2 7	20	345	13
2000	6 0	3 0	24	480	18
2500	7 0	3 5	26	620	21

LANCASHIRE BOILERS.

Steam Produced.	Diameter of Shell.	Diameter of Tubes.	Length.	Heating Surface.	Grate Surface.
Lbs. per hour.	Ft. Ins.	Ft. Ins.	Feet.	Sq. Ft.	Sq. Ft.
2750	7 0	2 9	22	630	23½
3500	7 6	3 0	26	820	30½
4500	8 0	3 2	30	1000	39
5000	8 6	3 5	30	1100	42

Cement for Stopping Leaks in Boilers.

Powdered fire-clay 6 parts by weight.
 Fine iron filings 1 part „

Made into a paste with boiled linseed oil.

Cement for Metallic Joints.

Equal weights of red and white lead, mixed with boiled linseed oil to the consistency of putty.

THE WASHER.

The washer was one of the very earliest appliances used in the purification of coal gas, and naturally so, owing to the cooling and condensing property of water and its power of absorbing ammonia and of arresting the tar. Its construction, however, was often faulty at first, and the limits of its functions misunderstood; so that the misuse, or overuse, of the apparatus (resulting in the reduced illuminating power of the gas exposed to its action) caused it to fall for a time into disrepute.

The principle of its action is that of causing the gas to pass in finely divided streams through a body of water contained in a vessel, so that a portion of the ammonia and other gaseous impurities, and the whole of the floating particles of tar which have escaped condensation, may be removed before the gas enters the scrubbers. However ample the usual condensing appliances may be, some of the lightest tar vapours escape their action. These are arrested in the washer, or tar-extractor, as it is sometimes called.

This apparatus should always be used in conjunction with the scrubber, and the gas passed through it in the first instance. It is generally employed as a separate and distinct apparatus, but sometimes it is placed at the bottom of the tower scrubber, of which it constitutes a part.

When the washer is exposed to outside atmospheric influence, it is necessary in winter to employ means to prevent the water from falling below a temperature of 50° Fahr.; otherwise the gas, especially a rich gas, passing through it will suffer deterioration.

All washers give an amount of back-pressure, varying from

1 in. to 4 in., according to the depth of water traversed. There are numerous designs of the apparatus, but the principal ones are here described.

Anderson's washer consists of a cast-iron outer vessel, containing a number of trays, having on their under side a series of serrated bars extending from side to side. These dip into the water or liquor, and the gas in passing through the serrations is divided into minute globules. The pressure given can be regulated by raising or lowering the overflow with which the apparatus is provided. A four-way valve is used for shut-off and by-pass. Weak ammoniacal liquor from the condenser is run in at the top, and drips from tray to tray till it reaches the bottom. The washer is made either single or double as required.

In Cathels' washer the usual oblong or square vessel is divided into sections, as many as may be desired, each elevated higher than the others in the form of steps. The gas enters at the bottom, passes in divided streams through a number of curtain serrations extending the full length of the vessel, and so on through the rest, and out at the top of the higher compartment. When the liquor in the lowest section is of the strength required, it is run off, and the contents of the several sections transferred one step lower, the last or uppermost being charged with fresh water. This apparatus is also arranged in the vertical position, to occupy less ground space.

Livesey's washer is a compact and efficient apparatus, occupying less room for the work done than any other. In a rectangular cast-iron box of any size (depending on the make of gas) is a series of rectangular tubes of wrought-iron, to which wrought-iron perforated plates are fastened, turned down at the sides till they dip into the liquor. The perforations are $\frac{1}{10}$ of an inch diameter, and $\frac{1}{5}$ of an inch apart.

The gas passes down between the tubes and through the side perforations into spaces filled with liquor, and, bubbling upwards, is again broken up by finding its way through the horizontal perforations into the open space above, and so along to the outlet of the apparatus. Means are provided for securing an active circulation of the liquor, which is constantly flowing through it from the adjacent scrubber, and away by an overflow to the well.

Walker's washer is somewhat similar to the foregoing, with the exception of one or two details. It is constructed of cast-iron

plates and is rectangular in form. The gas enters at the bottom into a central chamber, from which it passes into a number of longitudinal inverted troughs, open at the bottom and closed at the end. The lower ends of the troughs are slotted and sealed in liquor. The gas in passing into the top portion of the troughs displaces the liquor seal and bubbles through the slots to the surface, and on to the outlet.

Other makes of washers are those of Cockey & Sons, Kirkham, Hulett, & Chandler, and R. & J. Dempster.

THE TOWER SCRUBBER.

The tower scrubber (Fig. 74) is a cast-iron vessel, either rectangular or cylindrical (the latter shape being preferred), erected on end, through which the gas is made to pass in an upward direction after issuing from the washer.

Its primary use is to purify the gas from ammonia by the aid of water, advantage being taken of the well-known great affinity of ammonia for that liquid. Water, at mean temperature and pressure (60° Fahr., barometer 30"), dissolves 783 times its volume of ammoniacal gas—that is, *undiluted* ammoniacal gas. When the latter is mixed with other gases, as in the case of coal gas, the power of water to arrest it is not nearly so great. It also arrests a considerable proportion of the sulphuretted hydrogen and carbon dioxide.

This is accomplished by filling the vessel wholly or in part with either coke, boulder-stones, brickbats, roof or draining tiles, furze, or layers of thin boards set on edge, about 5 to 7 in. in width, $\frac{3}{8}$ of an inch thick, and from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch apart; the material

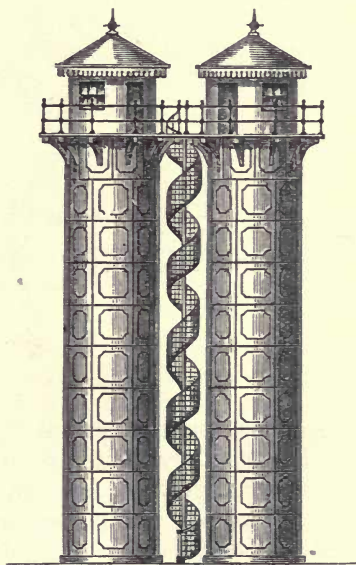


FIG. 74.

being kept constantly moistened by a stream of water trickling from a suitable distributing apparatus fixed in the crown.

When the coke or other material is placed in layers, it is supported on grids fixed at convenient distances apart; and opposite each space a manhole, secured by a movable lid or cover, is provided, so as to afford access to the interior, either for examination or renewal of the contained material.

The Livesey scrubber is fitted with boards $\frac{1}{2}$ of an inch thick,

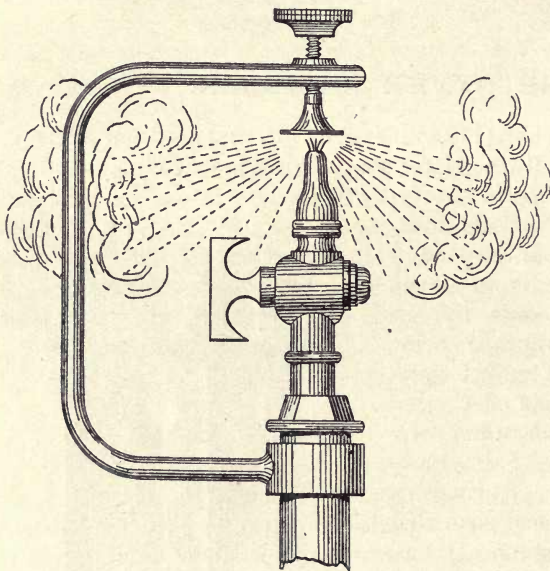


FIG. 75.

11 in. wide, placed on edge, and kept apart by strips or blocks of wood $\frac{3}{4}$ of an inch square; thus making one board to 1 in. The tiers are separated by 2-in. square cross sleepers.

The first cost of filling with boards is greater than when coke or other material is employed; but it possesses the marked advantage of not fouling up, and will rarely or never need renewing. The gas

cannot form narrow channels in its passage through the vessel, but is constantly being broken up and brought in contact with the water that drips from all sides. Green's filling medium consists of canvas screens depending from transverse rods. Open scrubbers are also used without any of the materials above mentioned. In such cases the column of gas in its upward progress is met by a descending shower of spray from a Gurney jet (Fig. 75).

The most efficient tower scrubber is the cylindrical, standing in height about five to seven times its diameter. Owing to the difficulty of securing an equal distribution of water or liquor,

the diameter should not exceed 10 ft. in the largest works. As a general rule, 8 ft. diameter is preferable; for, to obtain the full benefit to be derived from this apparatus, there should be immediate contact of the gas with the water or liquor in a state of minute subdivision. Height is an important factor in a tower scrubber. Experience has proved that the best filling is thin, rough-sawn boards, placed in alternate layers on edge one over the other, or canvas screens, as before described. When coke is used as the scrubbing material, it may be placed in six or eight layers, with a space of about 6 in. between each. Whatever material is used in filling the scrubber, it is important that all parts of its surface should be wetted as equally as possible. The proper action of the scrubber depends on this.

The necessity of a good water distributing apparatus is therefore obvious. Not only should this be of good construction in the first instance, but it should always be maintained in efficient working order. The gas enters at the bottom of the vessel, and the water or liquor at the top. The gas in travelling upwards is completely broken up, fresh surfaces being constantly presented to the descending drip, and to the wetted sides of the filling material, against which it is rubbed or scrubbed all the way up until it emerges by the outlet at the top. A trapped overflow at the bottom conveys the liquor to either the washer or the tar well.

The gas, before entering the scrubbers, should have the whole of the tar eliminated from it; and to ensure this, a washer or tar extractor may be employed, either as a separate apparatus, or placed in the bottom of the tower.

The weak ammoniacal liquor from the hydraulic main and condenser may be employed for distribution through the tower. The object of using this is to arrest a proportion of the carbon dioxide and sulphuretted hydrogen, as well as the other sulphur compounds, for which ammonia has a strong affinity, thus relieving the lime and oxide purifiers, and saving labour and purifying materials. The weak liquor is also by this means brought up to the requisite commercial strength.

One method frequently adopted of applying the water or liquor is by a pipe passing through the crown or side of the vessel, from which pipe smaller tubes, pierced with holes, radiate towards the circumference. This may be made either fixed or revolving, the latter being the most efficient. In the Mann scrubber, the

uppermost part of the tower containing the distributor is made about 2 or 3 in. wider than the rest, in order that the sides of the vessel may be wetted as well as the contained material. In this wider portion, and underneath the distributing tubes, there is a revolving layer of birchwood twigs, lessening in depth towards the circumference, and the water falling upon this is equally distributed throughout. This arrangement requires the use of a small engine and gearing to produce the slow rotary motion.

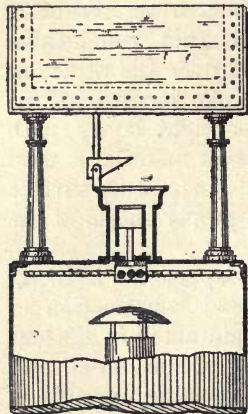


FIG. 76.

Fig. 76, where a balanced tumbler is constructed to hold a quantity of water or liquor, and takes its supply from an overhead tank. The construction of the tumbler is such that, when filled with water or liquor, it overturns and empties its contents through a sealed pipe, when it returns to its original position. Where the quantity of liquor supplied is large a small turbine may be adopted for turning the distributor.

With the introduction and perfecting of the rotary washer-scrubber has come a gradual modification of the views formerly held in regard to the superiority of the tower form. It is now admitted that the rotary apparatus is of much excellence, being more under control and more certain in its action than the other. It by no means follows, however, that the tower scrubber should be discarded. The best provision to make for scrubbing purposes is to apply one tower and one rotary apparatus for each stream of gas. That is to say: Assuming a works where the gas is sent in one continuous stream through the different appliances of purification, then one tower and one rotary scrubber will suffice. Thus:—

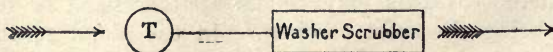


FIG. 77.

When the make is sent through the apparatus in several streams—as should be the case in large works—the like provision is made for each stream. Thus :—

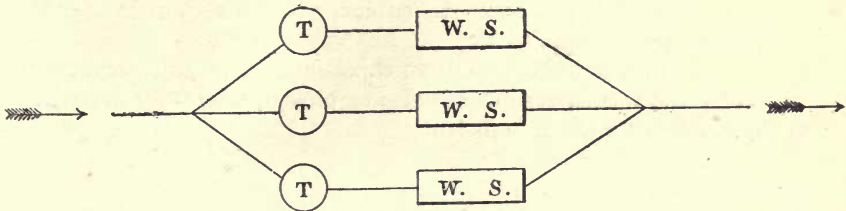


FIG. 78.

The question as to the capacity of the washer-scrubbers will be decided by the quantity of gas they are intended to pass ; whether half, one, or two million cubic feet, and so on, per day of twenty-four hours.

Adopting this arrangement, the tower scrubber would be supplied exclusively with weak ammoniacal liquor, and the washer-scrubber with clean water ; the supply of liquor, which should be plentiful, being moderated or increased according to the season of the year and the quantity of gas being passed.

In works where there are no washer-scrubbers, but towers only, the latter are most economical and effective when they are used in pairs (Fig. 74), the gas being passed through first one and then the other. In such case, weak ammoniacal liquor should be pumped liberally through the first, and fresh water, in the proportion of 2 to 3 gallons per 1000 cub. ft. of gas passing, through the second scrubber. When more than one pair of tower scrubbers are employed, the gas should be distributed in equal proportion through the several pairs simultaneously—not through each in succession.

Tower scrubbers, when used alone, and not in conjunction with the washer-scrubber, should have an aggregate cubical volume of at least 9 ft. for each 1000 cub. ft. of gas made per day of twenty-four hours, taking the *maximum* production as the basis of the calculation. For example, take a works producing in the depth of winter 600,000 cub. ft. of gas per day of twenty-four hours—

Then,

$$600 \times 9 = 5400 \text{ ft.}, \text{ cubical volume required.}$$

This would be supplied by

Two scrubbers, each 8 ft. diameter and 56 ft. high.

Or again, take a works producing 1,000,000 cub. ft. per day—

Then,

$1000 \times 9 = 9000$ ft., cubical volume required.

This would be supplied by

Two scrubbers, each 10 ft. diameter and 58 ft. high.

Where the washer-scrubber is also employed, one tower in each of the above instances is sufficient.

THE WASHER-SCRUBBER.

The washer-scrubber has come largely into use and deservedly so, as it is capable of removing the last vestige of free ammonia from the gas, with also a proportion of the other impurities. The predominant feature of the several forms of washer-scrubbers is a cast-iron tank or vessel, either cylindrical or rectangular, with semicircular top. The vessel is divided laterally into a number of compartments, the lower portions of which are kept supplied with liquor or water, and through these, chambers containing wood balls or bundles, or other filling medium, exposing a large surface, are made to revolve on a central shaft, at a slow speed.

This apparatus, as has already been said, has largely supplanted the tower scrubber, by reason of its being more manageable, as well as more certain in its action as an ammonia extractor.

Amongst the modern designs of washer-scrubbers in the market, the "Standard" of Kirkham, Hulett, & Chandler, the "Eclipse" of Clapham Brothers, the "Brush" of W. C. Holmes & Co., and the "Whessoe," rank as foremost.

The "Standard" washer-scrubber (Fig. 79) is in the form of a cylinder with a central revolving shaft, and to this are keyed strong cast-iron collars, each collar bearing an iron frame, to which boards $\frac{1}{8}$ in. thick are attached, kept $\frac{3}{16}$ in. apart by means of wood deflectors. These latter, being notched at one end, pick up the liquor at each revolution of the shaft, and distribute the same over the boards, which also pass through the liquor. The division plates in the "Standard" washer fill the whole diameter of the vessel, with a circular opening made at the centre for the passage of the gas.

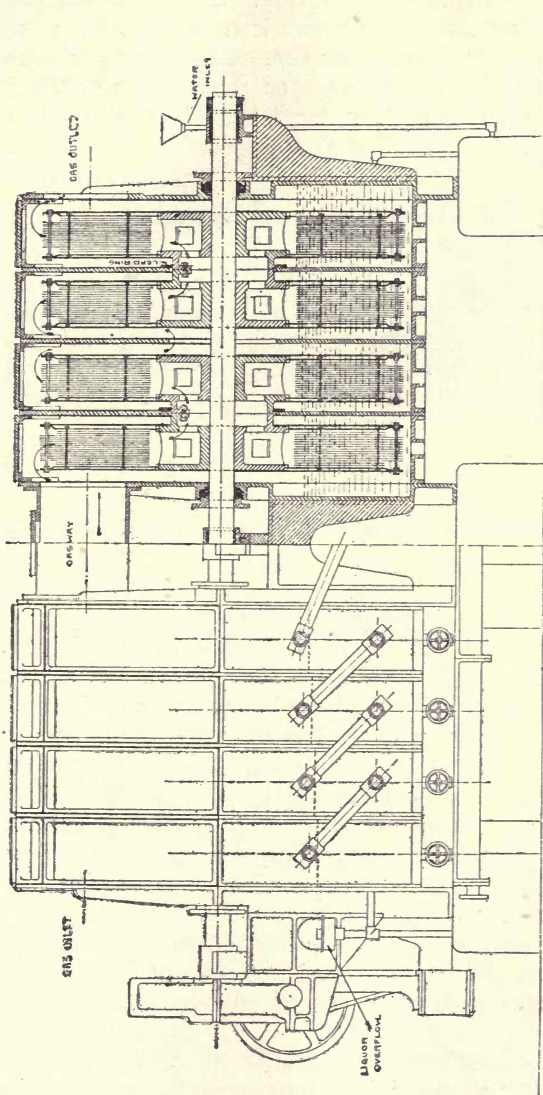
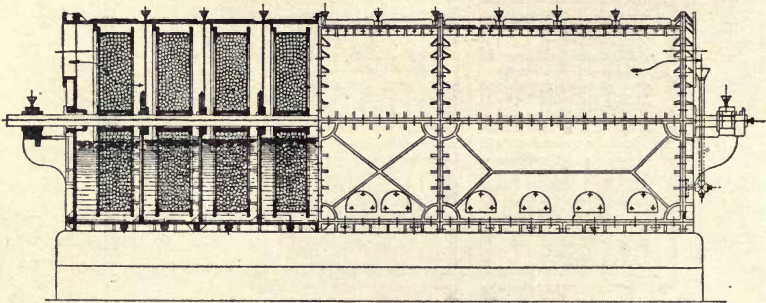


FIG. 79.—Kirkham, Hulett, & Chandler's "Standard" Washer-Scrubber.

The "Eclipse Ball" washer-scrubber (Fig. 80) consists of a rectangular vessel with semicircular top. The lower portion of the vessel is divided laterally by cast-iron plates into a series of chambers, these chambers being kept full of liquor or clean water, as the case may be, depending upon the position of the chamber with regard to the fresh water inlet. Keyed to the central revolving shaft are a number of cylinders, one to each chamber,



• FIG. 80.—Laycock & Clapham's "Eclipse Ball" Washer-Scrubber.

faced as to their outer edges, so as to work gas-tight against the outer case, thereby preventing "short-circuiting" of the gas from one compartment to another. The cylinders are divided into a number of divisions by perforated steel plates, and each division is filled with wooden balls $1\frac{1}{4}$ in. diameter, having a hole $\frac{1}{2}$ in. diameter through the centre. The balls are kept thoroughly wet by means of perforated buckets attached to the cylinders which dip into the liquor at each revolution of the main shaft.

The "Brush" washer-scrubber (Fig. 81) is cylindrical in form, and is divided internally into a number of compartments by means of wrought-iron plates bolted between the flanges of the outer shell. Other circular iron plates, one to each compartment, are keyed to the central revolving shaft, and to these plates are secured circular brushes, which press close to the fixed sides of the compartments, the gas reaching each compartment only by passing through the wet brushes.

The "Whessoe" washer-scrubber (Fig. 82) consists of a cylindrical outer vessel divided into separate chambers similar to the other rotary types. The washing devices consist of segmental

clusters of sheet steel, or thin boards, spaced with wooden distance pieces, and keyed to the central shaft.

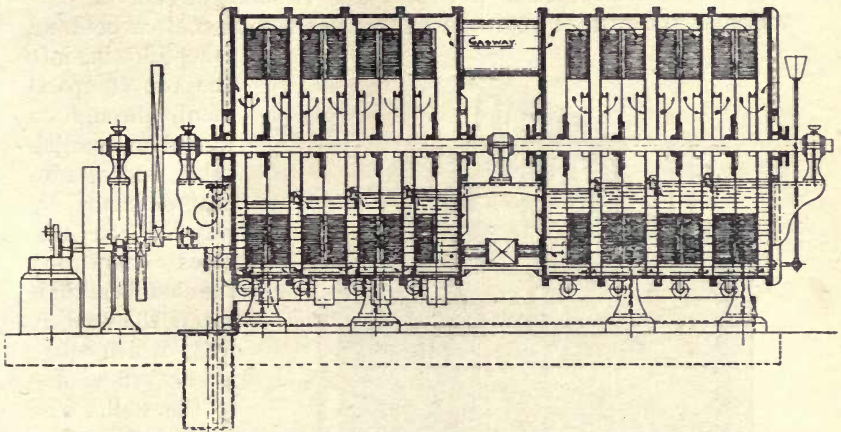


FIG. 81.—Holmes & Co.'s "Brush" Washer-Scrubber.

In this washer the end plates are made \sqcap -shaped, the object being to prevent oscillation and also to dispense with the use of cradles.

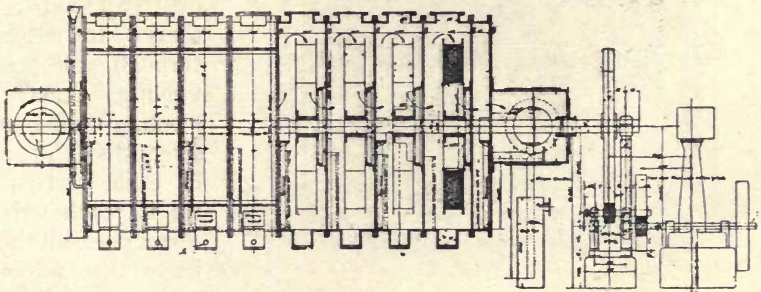


FIG. 82.—"Whessoe" Washer-Scrubber.

Anderson's combined washer and scrubber consists of a rectangular cast-iron vessel, standing on end, and in height about five times its width. The vessel is divided into compartments, each containing a drum caused to revolve by suitable gearing. The circumference of each drum is fitted with a brush of whalebone or other fibre. These fit exactly into the

space allotted for them, and, in revolving, dip into the liquid which partially fills the several divisions. The scrubber stands on an Anderson washer (see p. 132). A small stream of pure water at the rate of 10 to 12 gallons per ton of coal carbonized,

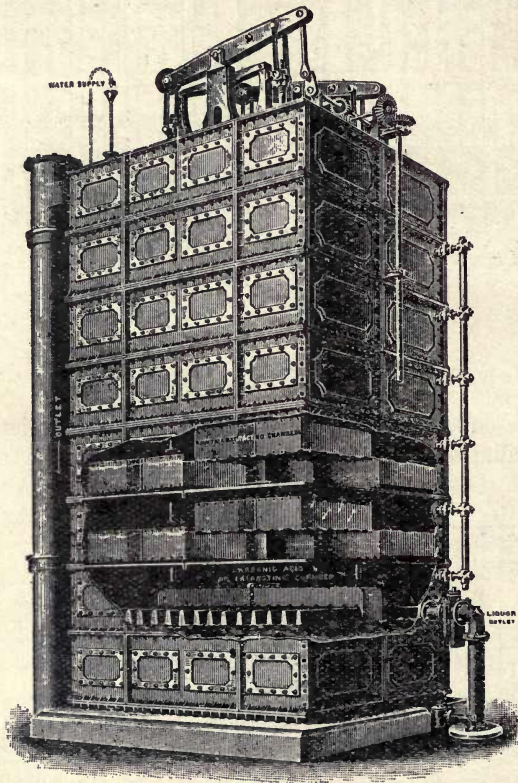


FIG. 83.—Walkers' "Purifying Machine."

is kept flowing into the top compartment through a funnel and sealing tube, and gradually descends by way of the gas-pipes connecting the chambers till it enters the washer, from which there is an overflow pipe to the well. The gas enters the washer at the bottom, and is first relieved of the tar remaining after condensation; thence it passes through the revolving brushes, meeting different strengths of liquor in each division, till it reaches the upper one containing pure water, and away by the outlet. By this

means the whole of the ammonia and a large proportion of the other impurities are removed.

In addition to the apparatus described above, the "purifying machine" made by C. & W. Walker, is a powerful washer and scrubber combined.

The machine (Fig. 83) consists of a rectangular cast-iron vessel containing in the lower part a Walkers' washer.

The gas, after leaving the washer, ascends through rectangular openings, over which are fixed devices containing wetted boards, into the next chamber above, and then from chamber to chamber, having to pass between the wetted boards in each tier, until it arrives at the top of the machine freed from all traces of the impurities.

In each of the superposed chambers over the inlets are placed device boxes containing thin boards $\frac{3}{8}$ in. apart, and through these spaces the gas travels on its way to the outlet. The frames containing the devices and boards are attached on each tier to the vertical shafts, which are themselves actuated by dipping beams on the top of the machine, and by this means are frequently immersed in the gas liquor or clean water contained in each tier of the machine.

Clean water is admitted into the top of the machine through a self-acting seal box, at the rate of 10 gallons per ton of coal carbonized.

Centrifugal Washers of the vertical type are now being manufactured. The feature of this type is that the gas has to pass through a number of finely divided sprays of water or liquor. The washers of Dr. Feld, Kirkham, Hulett, & Chandler, W. C. Holmes & Co., and R. Dempster & Sons are of this description.

Feld's centrifugal washer—the invention of Dr. Feld, a German chemist—consists of a number of cast-iron chambers, cylindrical in form, and placed one above the other, with a central shaft to which are attached sets of cones, each set consisting of four plates placed one inside the other. The lower ends of the cones dip into a dish-shaped casting containing water or other liquid.

The central shaft with the cones attached revolves at the rate of about 120 revolutions per minute and causes the liquor contained in the castings to be drawn up on the inside of the cones and then thrown off at a tangent, at the upper edges, with great velocity against the walls of the chambers.

The gas travels in an upward direction from chamber to chamber through openings arranged in the castings, and in so doing passes through the spray of liquor in each chamber.

Kirkham's "Standard" centrifugal washer (Fig. 84) consists of a vertical cylindrical cast-iron vessel divided into a number of chambers and traversed by a shaft to which are attached spraying devices for lifting and spraying the washing liquid, thus bringing it into intimate contact with the gas.

The gas is admitted into the lowest washing chamber, and passes through the spray to the central opening in the bottom of the second washing chamber, through the spray; then into the third chamber, and so on throughout the vessel.

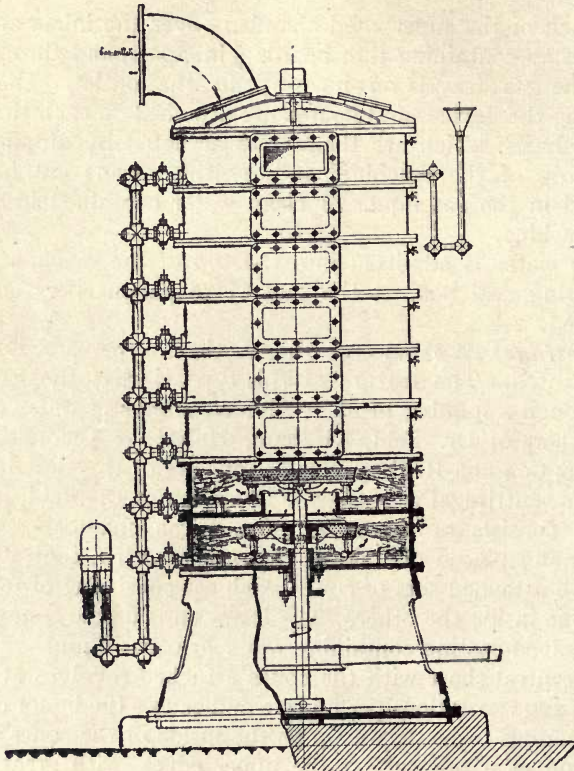


FIG. 84.—Kirkham, Hulett, & Chandler's Centrifugal Scrubber.

The washing liquid is admitted at the top of the apparatus, and flows through the centre openings from chamber to chamber, and is finally run off.

The machine is driven by pulleys and belt, by bevel gearing and belt, or by bevel gearing direct from an engine crankshaft.

Dr. Frankland gives the following useful table, showing the

number of volumes of various gases which 100 volumes of water at 60° Fahr. and 30 in. barometric pressure can absorb :—

Ammonia	78,000 volumes.
Sulphurous acid . .	3,300 „
Sulphuretted hydrogen .	253 „
Carbon dioxide . . .	100 „
Olefiant gas	12.5 „
Illuminating hydrocarbons	{ Not determined, but probably more soluble than olefiant gas.
Oxygen	3.7 volumes.
Carbon monoxide . . .	1.56 „
Nitrogen	1.56 „
Hydrogen	1.56 „
Light carburetted hydrogen	1.60 „

When water has been saturated with one gas, and is exposed to the influence of a second, it usually allows a portion of the first to escape, whilst it absorbs an equivalent quantity of the second. In this way a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

BY-PASS MAINS AND VALVES.

In connection with the foregoing apparatus—viz., the condenser, exhauster, washer, tower scrubber, washer-scrubber and centrifugal washer—by-pass mains closed with valves or water-traps should be provided, in order to allow of any of them being put out of action for cleaning or repairs. The exhauster by-pass is closed with a flap valve, so that, in case of sudden stoppage of the machinery, the valve opens by the pressure of the gas being thrown against it, and allows the gas to flow unchecked.

TAR AND LIQUOR WELLS AND TANKS.

The tar and ammoniacal liquor underground wells may be built either of bricks laid in cement and carefully puddled at the bottom and sides, or of cement concrete rendered over the whole inside surface, or formed of cast or wrought-iron or steel plates, bolted together, and having either planed or caulked or riveted joints. The iron vessel is preferable when the construction of a good foundation is likely to be a matter of great expense.

The well or wells should be of capacity sufficient to contain

six weeks' make of material, reckoning from the maximum daily production. Less than six weeks' storage space will serve when the liquor is manufactured into sulphate of ammonia on the premises.

Another well of smaller dimensions, the size depending on the magnitude of the works, ought to be provided, to serve as a lute or seal, into which the drip-pipes from the different apparatus should dip. From this, at a depth of about 15 or 18 in. below the surface of the ground, an overflow-pipe or channel conveys the condensed products into the larger reservoir.

In some works the tar-pipe is taken direct from the hydraulic main into the large well, and there sealed by being made to dip into a vertical pipe secured to the bottom of the tank. This is objectionable, as, in case of stoppage, it is difficult of access. Again, there is always the liability of an escape of gas from that portion of the pipe within the well. Further, where flushing of the hydraulic main is practised, the rushing liquor carries with it a quantity of gas which is liberated within the well. It is also important that the tar should be cooled somewhat before entering the larger receptacle. In each of these cases the gas or vapour, mixing with the contained air within the well, would explode with disastrous consequences on contact with a light. Accidents which have occurred have been due to one or other of these causes.

In all cases the wells should be covered over to exclude surface and rain water, and prevent the possible loss of ammonia by evaporation.

In addition to the underground well, an elevated cast-iron

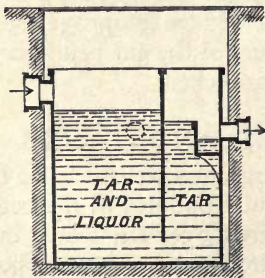


FIG. 85.—Vertical Section.

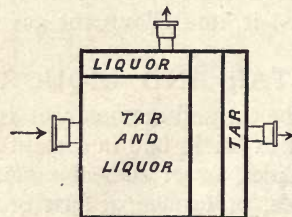


FIG. 86.—Plan.

cistern or tank is indispensable in a well-appointed gas-works. Into this the tar and liquor are pumped from the underground well, and suitable draw-off pipes, furnished with stopcocks or valves, serve

to discharge the material into the barrels, trucks, or barges of the purchasing contractor.

The cistern may be divided in two by means of a partition plate reaching to within about 6 in. of the top, over which the ammoniacal liquor will flow, separating itself from the tar by reason of its lower specific gravity.

A tar and liquor separator, for placing in the ground in any convenient position near to the underground well, is shown in sectional elevation and plan in Figs. 85 and 86. It consists of a cast-iron vessel, about 4 ft. square and $4\frac{1}{2}$ ft. deep, for a considerable sized gas-works. The division plate extends from the top of the vessel to within 4 in. of the bottom; the diaphragm, over which the tar escapes into its separate well, being placed $1\frac{1}{2}$ in. lower than the other diaphragm for the ammoniacal liquor.

TABLE.

Contents of Circular Tanks or Wells in Gallons for each Foot in Depth.

Diameter.	Gallons for each Foot in Depth.	Diameter.	Gallons for each Foot in Depth.	Diameter.	Gallons for each Foot in Depth.
Ft. In.		Ft. In.		Ft. In.	
9 0	397'6	16 6	1336'4	24 0	2827'4
9 3	420'0	16 9	1377'2	24 3	2886'7
9 6	443'0	17 0	1418'6	24 6	2946'5
9 9	466'6	17 3	1460'7	24 9	3006'9
10 0	490'9	17 6	1503'3	25 0	3068'0
10 3	515'7	17 9	1546'6	25 3	3129'6
10 6	541'2	18 0	1590'4	25 6	3191'9
10 9	567'3	18 3	1634'9	25 9	3254'8
11 0	594'0	18 6	1680'0	26 0	3318'3
11 3	621'3	18 9	1725'7	26 3	3382'4
11 6	649'2	19 0	1772'1	26 6	3447'2
11 9	677'7	19 3	1819'0	26 9	3512'5
12 0	706'9	19 6	1866'6	27 0	3578'5
12 3	736'6	19 9	1914'7	27 3	3645'1
12 6	767'0	20 0	1963'5	27 6	3712'2
12 9	798'0	20 3	2012'9	27 9	3780'0
13 0	829'6	20 6	2062'9	28 0	3848'5
13 3	861'8	20 9	2113'5	28 3	3917'5
13 6	894'6	21 0	2164'8	28 6	3987'1
13 9	928'1	21 3	2216'6	28 9	4057'4
14 0	962'1	21 6	2269'1	29 0	4128'3
14 3	996'8	21 9	2322'1	29 3	4199'7
14 6	1032'1	22 0	2375'8	29 6	4271'8
14 9	1068'0	22 3	2430'1	29 9	4344'6
15 0	1104'5	22 6	2485'0	30 0	4417'9
15 3	1141'6	22 9	2540'6	30 3	4491'8
15 6	1179'3	23 0	2596'7	30 6	4566'4
15 9	1217'7	23 3	2653'5	30 9	4641'5
16 0	1256'6	23 6	2710'8	31 0	4717'3
16 3	1296'2	23 9	2768'8	31 3	4793'7

PURIFICATION.

Impurities in Crude Coal Gas.—Though the removal of anything which otherwise would leave the gas impure is, strictly speaking, an act of purification, and purification therefore commences in the hydraulic main and is carried on from this point through all the apparatus preceding the purifiers, the word *purification* is generally used as meaning the process in the “purifiers” proper whereby the carbon dioxide and compounds containing sulphur are eliminated from the gas.

The chief impurities that are removed from the crude gas before it reaches the purifiers are : aqueous vapour, tar, and ammonia.

The aqueous vapour and tar begin to condense and are partially removed in the hydraulic main and pipes leading to the condensing apparatus, where, if this is of sufficient capacity, and otherwise adapted to the performance of the work required of it, the tar should be nearly all removed.

Owing to the strong affinity of ammonia for carbon dioxide and for sulphuretted hydrogen, and to the partial solubility of these acid radicals in water, the hydraulic and foul mains, condensers, washers, and scrubbers are also efficacious in removing a portion of these impurities from the gas.

The gas as it leaves the scrubbers usually contains from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent. by volume of carbon dioxide, and though the removal of this impurity is not compulsory by statute, its elimination is a necessity where the sulphur compounds are to be dealt with. Further, the presence of 1 per cent. of carbon dioxide will reduce the illuminating value of gas of 17-candle power by at least half a candle.

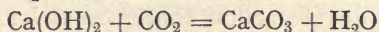
The impurities containing sulphur are of two kinds : (1) Sulphuretted hydrogen and substances such as carbon bisulphide, which yield sulphuretted hydrogen on being passed over heated platinum ; (2) substances which do not yield sulphuretted hydrogen under the above condition, but which are burnt to sulphuric acid. The sulphur impurities other than sulphuretted hydrogen are classed as sulphur compounds.

Without at present entering into a description of the continuous processes that have been brought forward for the removal of the impurities by liquid reagents in closed vessels, there may be said to be two systems whereby the carbon dioxide and the impurities

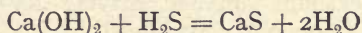
containing sulphur are removed—viz., purification by lime and purification by oxide of iron.

Purification by Lime.—Lime—quick or caustic lime—is calcium oxide, and is generally obtained by subjecting limestone, which is almost pure calcium carbonate, to a red heat, whereupon the calcium carbonate is decomposed, carbon dioxide gas being expelled and calcium oxide left as a residue.

It has been proved that dry calcium oxide will not combine to any appreciable extent with either carbon dioxide or sulphuretted hydrogen, at ordinary temperatures; but if the quicklime is slaked, with a slight excess of water, the calcium hydrate will rapidly absorb carbon dioxide, with the formation of calcium carbonate according to the equation—

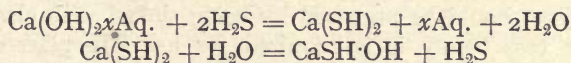


Calcium hydrate also absorbs sulphuretted hydrogen, with the formation of calcium sulphide in accordance with the equation—



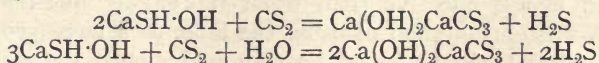
but the reaction is rather sluggish, owing to the sulphide caking and enclosing particles of unaltered hydrate.

With an excess of water in the calcium hydrate, calcium hydro-sulphide is formed, but this is rapidly decomposed into calcium hydroxy-hydrosulphide, a change which is accompanied by the evolution of heat.



Carbon bisulphide is not absorbed by either calcium oxide or calcium hydrate, and neither are the sulphide or hydrosulphide active materials in its elimination.

The active material for the absorption of carbon bisulphide is the hydroxy-hydrosulphide of calcium, which combines with the carbon bisulphide to form calcium thiocarbonate. This action is accompanied by the evolution of sulphuretted hydrogen according to the equation—



The reason of the occasional inactivity of the purifiers set aside for the elimination of carbon bisulphide, is that too much sulphuretted hydrogen has been passed into the lime, and that instead of

the active hydroxy-hydrosulphide, the inactive hydrosulphide has been formed.

The excess of sulphuretted hydrogen can be removed by breaking up the lime and exposing it to the air, or by allowing air to pass through the purifier.

It is well known that in lime purification carbon dioxide drives the sulphuretted hydrogen and sulphur compounds before it, decomposing both the calcium sulphides and the thiosulphates with the elimination of sulphuretted hydrogen and carbon bisulphide respectively, and the formation of calcium carbonate.

When the foul gas enters a clean purifier the combination of the lime with the carbon dioxide and sulphuretted hydrogen proceeds side by side, only the carbon bisulphide being driven forward, and this double action continues as long as there is left in the purifiers any uncombined lime.

But when the box has become fouled, then the carbon dioxide decomposes the calcium sulphide, driving forward the sulphuretted hydrogen as previously explained.

Cream or milk of lime was used in purifying in the early days of gas manufacture, and though this was thoroughly efficient, and is probably the most economical method of employing the lime, it has been generally discarded on account of the obnoxious character of the refuse material, "blue billy," as it was called, and the difficulty of getting rid of it.

The lime should be prepared by being slaked with clean water a day or two before it is required for use. If placed in the purifiers before this necessary interval has elapsed, it is liable to cake or become more compact than it otherwise would. On the other hand, hydrate of lime absorbs carbon dioxide from the atmosphere, and its purifying power is nullified in proportion to the extent of such absorption. It should not, therefore, be prepared for any great length of time before it is needed.

It is a mistake to place the prepared lime in the purifiers in a comparatively dry and almost powdery state. Lime used in this condition is less effective than when thoroughly moistened. It is also a wasteful method of using the lime, as a large proportion of the material will be found unspent and almost untouched by the impurities when the vessel requires to be changed. The finely divided lime is also more liable to cake than the other, and thus to increase the back pressure. When the production of gas

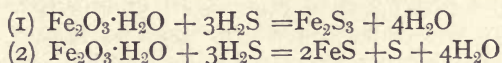
is great, as in the depth of winter, these disadvantages are strongly felt.

The lime should be well watered. A hose pipe or india-rubber tube, terminating in a copper spreader or rose, is useful for this purpose. It should then be passed through, by being thrown against, a screen made either of parallel steel rods $\frac{3}{8}$ in. thick and 1 in. apart, or of strong wire having 1 in. square meshes. This not only removes the stones or flints which are less or more present, but it gives a granular character to the prepared material, in which condition it best performs its work in the purifiers.

Mr. Hislop has a process of calcination in suitable kilns, by which the spent lime is converted into quicklime to an almost unlimited extent, and at considerably less cost than new lime. A nuisance is thus got rid of, and further economy in purification effected.

Purification by Oxide of Iron.—Oxide of iron possesses the property of combining with sulphuretted hydrogen, but it has no affinity for carbon dioxide and carbon bisulphide; hence when this oxide is used exclusively, the two latter-named impurities are still present in the gas as supplied from the holders.

The action of the sulphuretted hydrogen on the hydrated oxide of iron forms ferric sulphide, ferrous sulphide and water, according to the equations, thus—



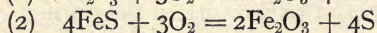
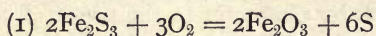
Although oxide of iron, pure and simple, has no affinity for carbon bisulphide and other sulpho-carbon compounds, from the observations made at the several Metropolitan gas-works by Mr. R. H. Patterson was deduced the interesting fact that the sulphur which is present in a state of minute division in the oxide of iron, after the latter has been in use for some time and frequently revived, possesses the power of arresting a portion of the carbon bisulphide.

The hydrated peroxide of iron may be either the natural oxide, bog-iron ore as it is called, found largely deposited in some of the bogs in Ireland and elsewhere, or the artificial oxide obtained as a waste product from various processes of the manufacturing chemist.

Oxide of iron possesses this advantage over lime: After it has been in the purifier, and has taken up its *quantum* of sulphuretted hydrogen, it can be revived either *in situ* or by exposure to the air.

Accordingly, when this material is revived by exposure, a floor is provided on which it can be spread out and turned over for revivification. At the Manchester Gas-Works, a horse and plough are employed for turning over the foul oxide.

When taken out of the purifier it is sulphide of iron, of a dense black; and after exposure it changes to its original reddish brown colour, oxygen having been taken up and sulphur deposited in the free state in the mass according to the equations—



Occasionally, oxide of iron becomes sluggish in its action. This may be due to several causes, namely (1) the oxide may be too dry; (2) it may have an acid reaction; or (3) it may be due to caking. Temperature, also, affects the oxide.

In order to overcome dryness, the gas may be allowed to enter at the top of the purifier and out at the bottom—the reverse of the usual procedure: the object being to allow the moisture to deposit on the top layer of oxide and on the underside of the cover, when the condensed products will soak through the mass to the bottom of the purifier, thus keeping the oxide in a moist state.

It is generally agreed that oxide of iron should be slightly alkaline, if its activity is to be retained unimpaired. No special provision, however, is necessary; the small percentage of ammonia in the gas that escapes removal in the washing plant is usually sufficient for this purpose.

The caking of oxide arises only with horizontal grids. The difficulty may be overcome by adopting the hurdle or other allied forms of grid.

When the sulphur is found in it to the extent of about 50 to 60 per cent. by weight (the proportion depending on the quality of the oxide), the material is sold to the manufacturing chemist, and replaced by fresh oxide.

In using fresh oxide of iron, it is necessary to exercise certain precautions. The foul material, on its exposure to the air for the first two or three times, absorbs oxygen so rapidly as often to generate very intense heat, the whole mass frequently becoming red hot. Should this occur in the purifiers, the danger is considerable, and the wood grids may be completely destroyed. Whenever, therefore, a purifier containing such new oxide has been

put out of action, it should be *emptied without delay*. The danger of ignition may be overcome by mixing the new oxide with a proportion of the spent.

Foul oxide should not be spread out immediately on being removed from the purifiers. If it is allowed to remain in the heap for a space of twelve to twenty-four hours, and then distributed over the floor, the revivification is more complete, whilst the liability to ignition is reduced.

Average Composition of the Richer Descriptions of Native Bog Ore for Purifying Purposes, dried at 212° Fahr. (King's Treatise.)

Ferric oxide	60 to 70 per cent.
Organic matter	15 to 25 „
Silica	4 to 6 „
Alumina	1 „

As generally used, the material contains 30 to 40 per cent. of water.

Weldon Mud.—As a substitute for oxide of iron for the removal of sulphuretted hydrogen, the bye-product from the manufacture of bleaching powder, commonly called Weldon mud, may be used.

The Weldon mud as taken from the bleach-works is unsuitable for use in a purifier owing to the superabundant amount of water contained in it, and also the presence of a large percentage of calcium chloride, which attracts more water owing to its deliquescent nature, and so forms a sloppy mixture in the purifiers.

To overcome this, the Weldon mud is washed until only a small percentage of calcium chloride is left, and then partially dried. The mud as then prepared for the purifiers contains about 50 per cent. of water, 30 per cent. of manganese dioxide, and 20 per cent. of a mixture chiefly composed of manganese monoxide, lime, calcium chloride, and silica.

The chief advantage claimed for Weldon mud over oxide of iron is its superior absorbent power. Like oxide of iron, it can be easily revived either *in situ* or in the ordinary manner.

Systems of Purification.—Lime alone, or lime and oxide of iron, when properly applied, are capable of freeing the gas entirely of the whole three impurities, carbon dioxide, sulphuretted hydrogen, and carbon bisulphide. This brings us to a consideration of the different systems whereby the purifying material is applied.

In works where there are no statutory restrictions as to the amount of sulphur impurities other than sulphuretted hydrogen in the purified gas, it is rarely that any special precautions are taken for the removal of these impurities.

There are other works, again, where the carbon dioxide is not removed from the gas, though, as has been previously stated, to the detriment of the illuminating power.

Beginning with the lowest degree of purification—viz., the removal of sulphuretted hydrogen alone, the method usually adopted is that of four vessels filled with oxide of iron, and worked on the rotation system, three vessels always "on," and one "off" for renewal.

For the removal of carbon dioxide and sulphuretted hydrogen there are two systems in vogue.

First, by the use of lime alone in four vessels worked on the rotation system; or, second, by the use of four vessels charged with oxide of iron for the removal of the sulphuretted hydrogen, followed by two vessels charged with lime for the removal of carbon dioxide.

Where it is necessary that the sulphur impurities should be removed as well as the carbon dioxide and sulphuretted hydrogen, the method of purifying expounded by the Referees in their report to the Board of Trade on sulphur purification at the Beckton Gas-Works, January 31, 1872, and also by Dr. Odling, somewhat more in detail, in his lecture on Sulphide of Carbon, delivered at the annual meeting of the British Association of Gas Managers, held in London in June, 1872, may be adopted.

To accomplish this perfect purification in accordance with the suggestions made by Dr. Odling, three sets of purifiers are required; the gas passing through the first set into the second, and on to the third, from which it makes its exit through the station-meter into the holders. The *modus operandi* is as follows:—

Let it be assumed that three sets of purifiers, consisting of four vessels each, are employed. Nine of these are constantly in action, three being at rest (one from each set), for the purpose of changing or revivifying the purifying material.

The first and second sets are charged with lime, the third set with oxide of iron.

Say the whole nine are newly charged. On the gas from the

scrubbers entering the first set, the lime is acted on by the carbon dioxide and sulphuretted hydrogen simultaneously, leaving the carbon bisulphide at the beginning of the process to pass unabsorbed. After they have worked for some time the sulphuretted hydrogen in the first set is gradually expelled by the incoming carbon dioxide, for which the lime has a stronger affinity. The second set is now being fouled with sulphuretted hydrogen, the lime being wholly or in part changed in character, having become calcium sulphide, in which state it has an affinity for, and consequently arrests, the carbon bisulphide; whilst the unabsorbed sulphuretted hydrogen passes on to be taken up by the oxide of iron with which the final set of purifiers is charged. By the application of the proper tests at the several sets of purifiers, the time for changing the material is ascertained.

The system adopted at the London Works, and known as the Beckton System, is probably the most perfect for the removal of all the impurities. It consists of four sets of vessels, each set being worked on the rotation system. The first set is filled with lime for the removal of carbon dioxide, the second set with oxide of iron for the removal of sulphuretted hydrogen, the third set with lime for the removal of carbon bisulphide, and the fourth set with lime for the final elimination of any sulphuretted hydrogen from the sulphide of lime boxes.

The foul gas, after it has passed through the first boxes, and whilst charged with sulphuretted hydrogen, is allowed to enter the third set of purifiers until the lime in these has become sufficiently sulphided for the removal of the carbon bisulphide, when it is made to enter the second set for the removal of the sulphuretted hydrogen, and then on to the third set for the removal of the carbon bisulphide. As has been previously explained, the formation of calcium thiocarbonate in the sulphide boxes is always accompanied by an evolution of sulphuretted hydrogen, which, in this case, passes on with the gas into the last set of boxes. These are never allowed to become more than slightly fouled before they are renewed; the half fouled material being transferred to either the first or third set for further use.

☞ The question of supplying gas entirely free from sulphur in any form is a formidable one for gas authorities; not so much because of the cost (though that is considerable) of erecting the additional sets of purifiers, as from the difficulty of providing the

necessary ground space for their erection. In new works about to be constructed the thing is easily arranged ; but in the majority of works already established it would not be easy to carry the system into effect.

As regards the question of cost, a careful estimate shows that to adopt the extended method of purifying as enunciated would entail an outlay of additional capital equivalent to close upon 2d. per 1000 cubic feet of gas sold.

Coal Liming.—Messrs R. O. Paterson and Twycross have patented a process for the liming of coal with the object of reducing the amount of the sulphur compounds, and increasing the yield of ammonia, as well as aiding purification.

The process consists in adding a regulated quantity of lime to, and distributed equally amongst, the coal.

The lime, in the state of fine powder, is applied to the coal by means of a special apparatus, and both are then steamed so as to moisten the lime, thus encasing the surface of the coal in a fine layer of lime.

The Use of Air in Purification.—By forcing in a measured quantity of air at the inlet to the purifiers, revivification of the oxide of iron *in situ* can be effected by adopting the reverse action in the flow of the gas.

The purifiers are thus made to continue in use for a greater length of time without changing, whilst it is remarkable that the oxide by this process can be charged with as much as 75 per cent. of free sulphur.

Purifiers with a proportionately large area in comparison with the make of gas are required to obtain the full advantage of this process.

In adopting the air process, two layers of oxide are preferable to one deep layer. Owing to the heat generated by chemical action, as well as to the deposition of the sulphur, a considerable increase or expansion in the bulk of the material takes place in the purifiers, and it is necessary, therefore, to allow ample room for the oxide to expand. A space of several inches should be allowed between the two layers, and the surface of the upper layer should be at least 3 in. below the top edge. Of course this applies only to horizontal grids, and not where " hurdle " or vertical grids are in use.

Reverse Action.—The essential feature of this system of purification *in situ* consists in admitting a measured quantity of air,

generally $2\frac{1}{2}$ per cent. of the volume of gas, to the inlet of the purifiers, by means of a blower or steam injector, and a wet meter.

The gas is admitted to a series of four purifiers, so arranged with centre or other valves to work them four on, that is to say, the gas passes through each of the purifiers in rotation, namely, one, two, three, four. When the gas in the second purifier shows a foul test, the valve is changed to work the last purifier in the series first in the order of—four, one, two, three. The next change is to bring number three purifier first, the rotation being three, four, one, two. The last change is to bring number two purifier first, the order then being two, three, four, one. In the next change the gas is back at its original sequence of one, two, three, four; thus—

1st rotation	I	2	3	4
2nd „	4	I	2	3
3rd „	3	4	I	2
4th „	2	3	4	I

Another system is that of changing the flow of gas to the purifiers periodically, say every 24 hours, instead of when the gas shows foul. The rotation in this system being: one, two, three, four; two, three, four, one; three, four, one, two; four, one, two, three; three, four, one, two; two, three, four, one; thus—

1st rotation	I	2	3	4
2nd „	2	3	4	I
3rd „	3	4	I	2
4th „	4	I	2	3
5th „	3	4	I	2
6th „	2	3	4	I

The principle of both methods, however, is the same, namely, the abstraction of the bulk of the impurities in the first purifier, thus allowing the oxygen to fulfil its function of revivification in the succeeding purifiers.

It is advisable to have catch boxes to the purifiers in the event of sudden fouling.

The Use of Pure Oxygen in Purification.—The chief objection to the use of air for revivifying the oxide of iron *in situ* is the importation of a considerable volume of the inert gas nitrogen into the gas, reducing the luminiferous value of the latter.

It is obvious that if pure oxygen were employed instead of atmospheric air, the objection stated would be overcome. The cost of producing oxygen, however, renders its use prohibitory.

Other Methods of Purification.—Continuous purification is the ideal of both chemists and gas engineers. Various attempts have been made to accomplish it, but hitherto without success. The processes suggested and tried are full of interest, and it is worth while referring to them.

The late R. H. Patterson patented a process of purifying by washing or scrubbing the gas in solutions of caustic soda and sodium sulphide, extracting the carbon dioxide and sulphur impurities, and so dispensing altogether with the ordinary lime and oxide of iron purifiers. The soda solutions, when saturated with the impurities, possess the important quality of being easily and perpetually revived or restored to their original state on the gas-works, whilst the whole of the sulphur is secured for sale. The plan, however, has not been tried on an adequately large scale.

Attempts have been made by Laming, Livesey, F. C. Hills, and others, to purify the gas in closed vessels by employing the ammonia found in the gas for arresting the other impurities. Unfortunately the loss of ammonia at each time of desulphurating the liquor, owing to its extreme volatility, prevented success in this direction under the conditions adopted.

Claus's Process.—This process of continuous purification in closed vessels, though not hitherto practically successful, is of such importance and promise as to merit a detailed description.

The crude ammoniacal liquor, consisting of ammonium sulphide and ammonium carbonate, is passed through a series of towers, wherein it is exposed to the action of carbon dioxide (obtained as described below), whereby the ammonium sulphide is decomposed, sulphuretted hydrogen being liberated, and ammonium carbonate remaining alone.

The sulphuretted hydrogen passes through and out of the towers in the opposite direction to that in which the crude liquor travels, and is disposed of in the manner described hereafter, whilst the ammonium carbonate solution passes forward into other towers in which it is heated to a temperature of 180° to 200° Fahr.

At this temperature the ammonium carbonate, of a strength

equal to 10 or 15 oz. liquor, loses two-thirds or three-fourths of its carbon dioxide, and a corresponding quantity of caustic ammonia remains in the liquor passing from these towers.

As only a portion of the carbon dioxide evolved in the heating vessel or towers is required for the above-mentioned decomposition of ammonium sulphide, the surplus is allowed to escape in a regulated quantity, and may be used for other purposes forming part of the process.

The sulphuretted hydrogen, after leaving the towers, is conveyed to a closed furnace charged with oxide of iron, where a low incandescent heat is generated and maintained by the admission of a regulated supply of air.

The oxide of iron, once heated, continues to absorb the sulphuretted hydrogen, which, owing to the continued admission of air, is evolved in the form of sulphur, in finely divided particles, which is carried off and caught in chambers, so that the oxide does not require revivification, and the same quantity, kept hot by continual working, goes on indefinitely decomposing the sulphuretted hydrogen sent through it.

The purified ammoniacal liquor is then passed down distilling towers, into which steam is admitted, driving off the ammonia gas at the top, which is passed through cooling chambers where any ammonium carbonate carried with it deposits in crystals.

Thence, as much of the ammonia gas as is required for the purposes of purification passes with the coal gas into a chamber, where they are allowed sufficient time to mix.

The gas is then passed through scrubbing towers, where all the impurities are washed out in the liquor, which may be obtained of 40 to 50 oz. strength if required.

Any surplus ammonia, being perfectly pure, can be used for making any of the salts of ammonia desired.

The liquor flowing from the bottom of the distilling towers contains ammonium sulphocyanide, and may be used over and over again in the scrubbers instead of water, until the sulphocyanide accumulates to such a strength as to make it marketably valuable for chemical manufacture.

A new process for the washing and purification of gas is that known as the "Burkheiser" system. The system is yet in its experimental stage, being tried in some places abroad.

The object of the inventor is to substitute for the ordinary

scrubbers and washers, purifying plant, and sulphate of ammonia plant, the "Burkheiser" patent purifiers and "Burkheiser" gas and air scrubbers. The process embodies the following series of operations:—

(1) The absorption of sulphuretted hydrogen by means of artificial or natural ferric hydrate; (2) The revivification of the fouled material, with the formation of sulphur dioxide. (3) The formation of ammonium bisulphite from the sulphur dioxide and a solution of ammonium sulphite; (4) The formation of ammonium sulphite by the taking up of ammonia by the solution of ammonium bisulphite; (5) The oxidation of ammonium sulphite to ammonium sulphate.

The inventor also claims, by a combination of his process and the contact process for the manufacture of sulphuric acid, to convert ammonia direct into ammonium sulphate.

Purifying House.—The house to contain the purifiers should be lofty and well ventilated, not only for the comfort of the workmen employed therein, but to lessen or entirely remove the risk of explosion from any leakage of gas that might occur. Efficient ventilation of the purifying house is best attained by having one side of the house entirely open, the roof being carried on braced girders supported at various points by cast-iron columns or steel

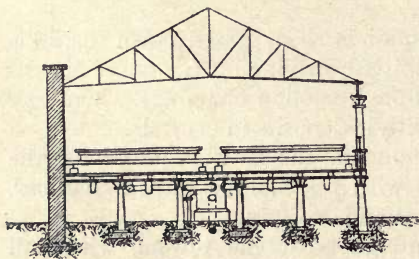


FIG. 87.

stanchions. The house should also be arranged with a view to future extension: but this, indeed, applies to every structure within a gas-works with its constantly growing business.

It is a convenient plan to build the house with a ground and upper floor, and to place the purifying vessels on the latter with the connections and centre or other valves underneath and fully exposed and accessible. The ground floor can thus be used for revivifying the oxide of iron, if that material is employed, or for other purposes (Figs. 87 to 92).

The vessels are discharged through an opening in the bottom of each, closed by a gas-tight lid, and the fresh material is raised

by means of an endless chain ladder, or other suitable elevating apparatus, to the floor above (Figs. 90 to 92).

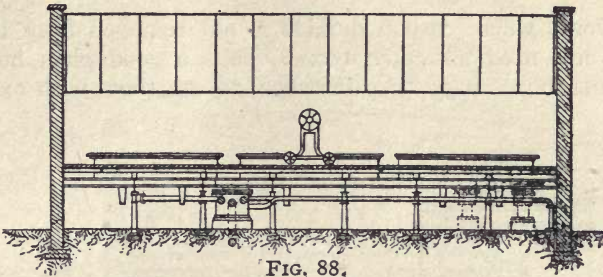


FIG. 88.

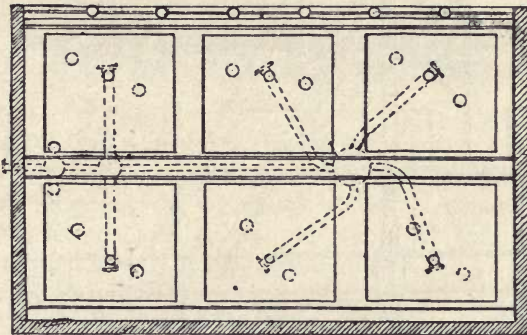


FIG. 89.

Purifiers.—The purifying vessels are almost invariably made of cast-iron (though we have seen purifying vessels made of wrought-iron plates riveted together, and also of ferro-concrete) with sheet-iron or steel plate covers secured with suitable fastenings to prevent their being lifted by the inflowing gas pressing on their under surface.

Malam's original arrangement of four in the set, with connections and a centre valve (Fig. 93), by which three of the vessels are kept in action and one out of use for renewal of the purifying material, is still generally adopted, and is the simplest and most convenient. In some works a second set of two purifiers is used in addition to the series of four, and these are connected together, and to the others, with single or four-way valves (Figs. 89 and 93). Under this arrangement the set of four is charged with oxide to arrest

the sulphuretted hydrogen, and the set of two with lime to take up the carbon dioxide, the gas passing through them in the order shown.

In works where carbon dioxide is not removed from the gas there is less need for catch boxes. It is a good plan, however, where such boxes have been installed, to use them with oxide, as

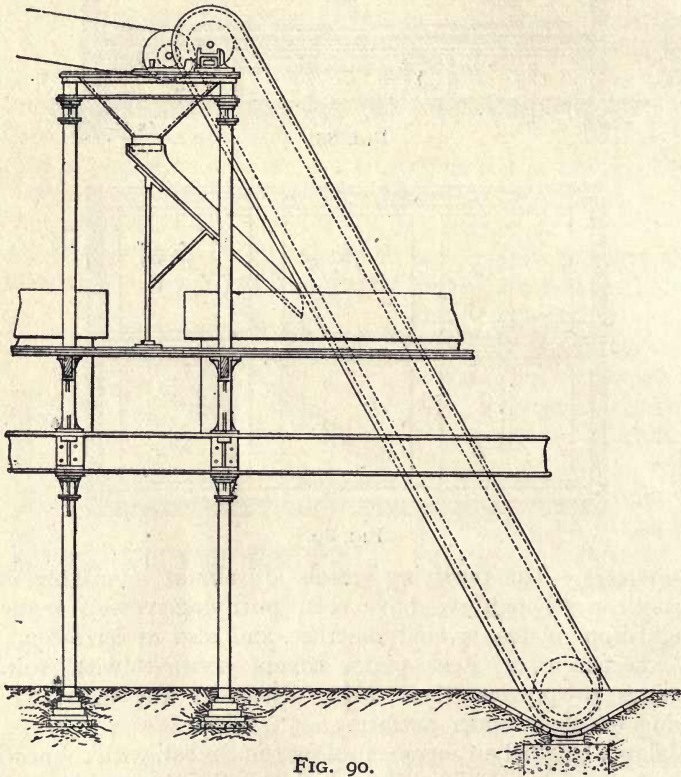


FIG. 90.

it tends to economy in working by allowing the oxide in the preceding boxes to take up the maximum quantity of sulphur.

In designing a set of purifiers, the engineer has to decide whether to have a ground-floor arrangement or to erect them on a superstructure of columns and girders (Figs. 91 and 92).

In coming to a decision, all the circumstances—financial and

economical—that are applicable to the particular works must be taken into account.

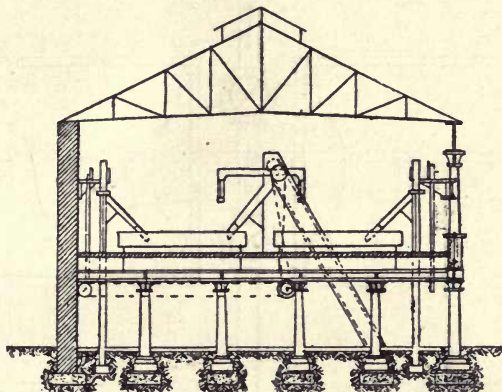


FIG. 91.

The first thing to consider is the available space. If the works is congested, there is no alternative, unless additional land is acquired, to adopting the overhead system. At another works the site may be spacious enough to allow of the ground-floor arrangement with a revivifying shed alongside.

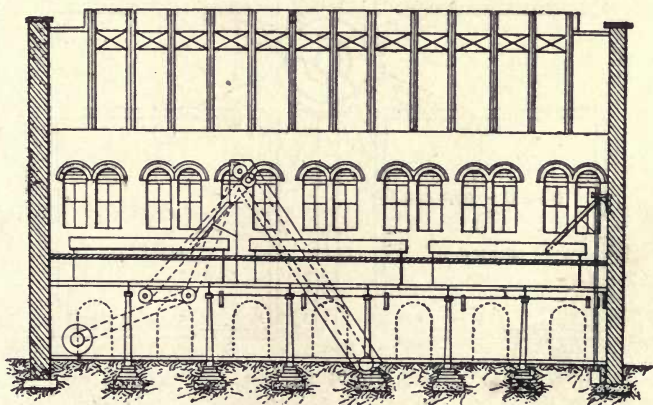


FIG. 92.

With the overhead system, elevating and conveying plant have to be provided. The capital cost of the elevated as compared

with the ground-floor position will range from 40 to 50 per cent. more.

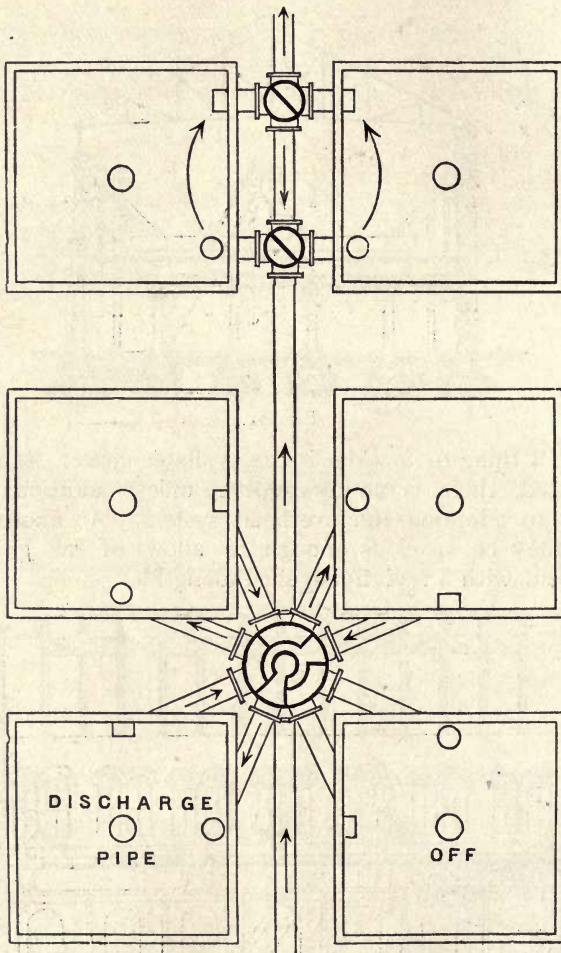


FIG. 93.

So far as labour saving is concerned, the overhead system has the advantage. The filling and emptying of the purifiers can be done in, roughly, one-third the time taken by the ground-floor

system. Furthermore, there is no need for a separate revivifying shed, this being on the floor underneath the purifiers, or on a floor above.

Until within recent years the water-lute purifier (Fig. 94) was the usual form, and in most works to-day this type of purifier is in use.

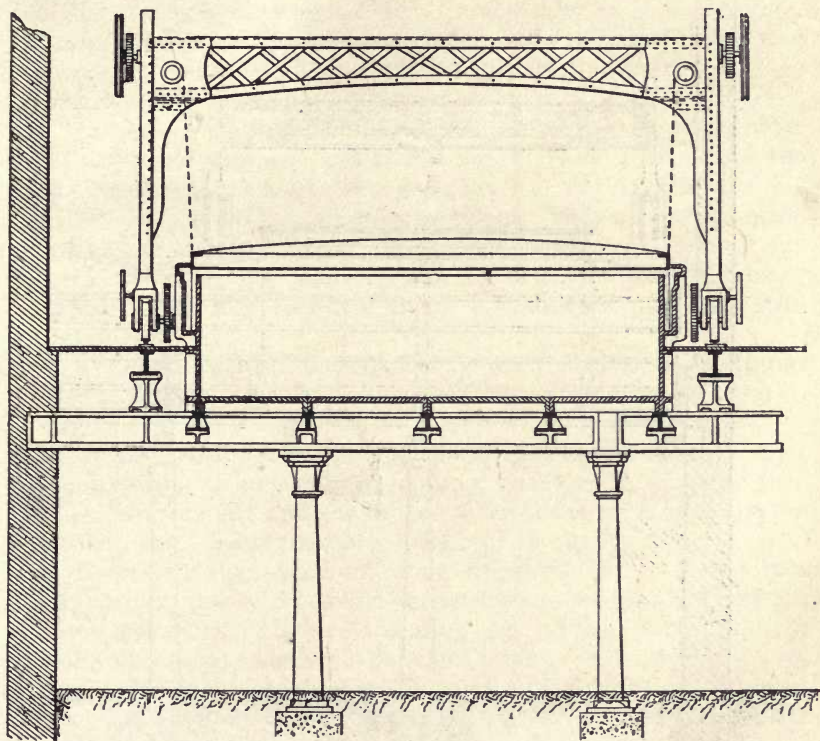


FIG. 94.

Luteless Purifiers.—The introduction of luteless purifiers, however, by Henry Green, of Preston, and the subsequent improvements that have been made, has led to a general adoption of this system of construction (Fig. 95).

The advantages which this system possesses over the water-lute type are many, not the least of which is the increase in the available purifying area.

The ordinary and best form is the square or oblong ; this shape is the cheapest, affords the largest area for the space occupied, and is also most convenient as regards the placing of the grids.

The purifiers are arranged either separate as in the case of the

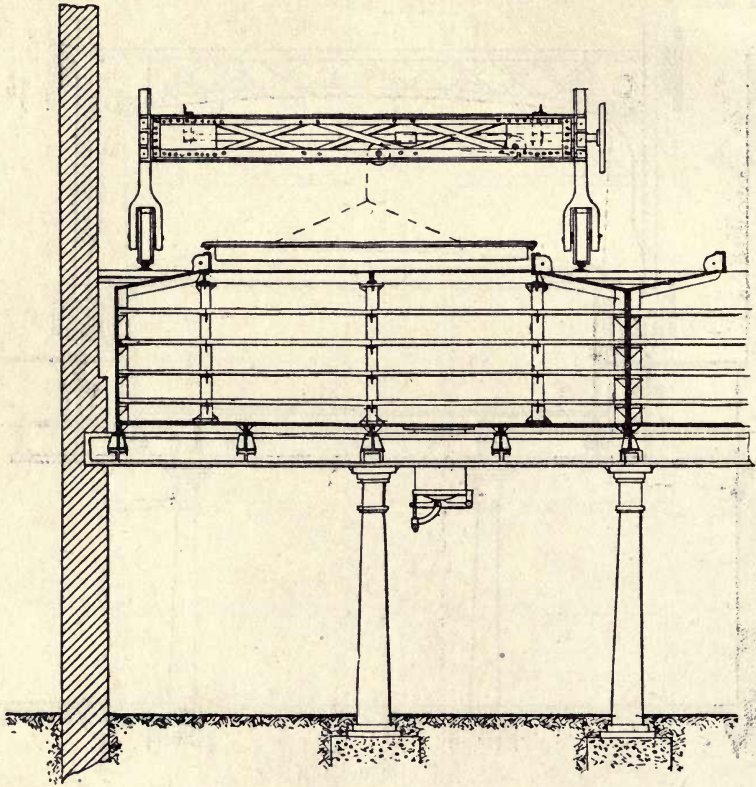


FIG. 95.

water-lute system, or continuous, with division plates. The latter arrangement is the more economical.

There is practically no limit to the length and breadth of which this type of purifier may be constructed ; the depth is usually from 4 ft. 6 in. to 6 ft.

The metal forming the plates should be $\frac{3}{4}$ in. in thickness and the flanges $3\frac{1}{4}$ in. by $\frac{7}{8}$ in., with bolt holes 6 in., apart and stiffening brackets midway between the bolt holes. The flanges of the top plates, in order to leave the top gangways clear of obstruction, should be internal, and the flanges to the side plates external. The position of the bottom plate flanges depends upon the situation of the purifiers, *i.e.* whether on a ground floor or superstructure. In the former case it is usual to have internal flanges and the bottom concreted level with the top of the flanges. With overhead purifiers it is usual to have the bottom flanges external.

Luteless Purifier Covers or Lids are constructed of an outer curb of angle steel with cross members of H or T steel and the whole covered with steel sheets generally $\frac{1}{4}$ in. in thickness, securely riveted to the curb and the cross members. They are usually made between 10 and 15 ft. square, there being a number of such covers to each purifier, determined by the size of the latter; each being provided with lugs to which chains are attached for raising and lowering.

The space between the lids and between the lids and the outer edge of the purifier is covered by cast-iron plate gangways 2 or 3 ft. wide.

To the lower side of the angle steel curb on the cover, various arrangements of india-rubber jointing, about $2\frac{1}{2}$ in. wide by $\frac{3}{4}$ in. thick, are secured; and the rubber, when the cover is down on the purifier, rests upon the planed edge of the gangway.

To prevent the cover from lifting when the gas is turned into the purifier, lugs and fastening arrangements are placed round the cover for securing same to the gangways. These flatten out the india-rubber and so secure a gas-tight joint.

The holding down catches, where no special automatic arrangement is used, are generally formed of eye-bolts which fit into slots made in the cover.

The better arrangement, however, and especially for large covers, are the automatic catches, which are all operated simultaneously, releasing the cover by one movement. The "Eclipse" patent fastener of Clapham Brothers and Milbourne's automatic rapid cover fastener are designed for this purpose.

Sieves, Trays, or Grids.—The arrangements inside the boxes for the purpose of supporting the grids depend upon the type of grid to be adopted. For horizontal wood grids, ribs are cast on the

inside plates of each purifier in either two or four tiers, and cast-iron standards are fixed inside the purifiers for the purpose of supporting the T-steel bearers on which the grids rest.

With vertical or hurdle grids it is usual to make provision for one or two tiers of ordinary grids on which the former rest.

For horizontal grids, round wrought-iron rods, $\frac{3}{8}$ of an inch thick, bound together with a framing of angle or flat iron, make an excellent grid, especially where lime is used; they are less suitable for oxide of iron, which destroys them by corrosion, though when made of the strength named, they last for many years. They possess a great advantage over most other grids in the smaller space which they occupy in the purifier and the larger purifying area obtained by their use. Perforated cast-iron and wood grids are suitable for either lime or oxide. The latter are usually made with strips of wood (yellow pine, pitch pine, or red deal, the prices being as 3, 2, 1) of any convenient length. The strips are $1\frac{7}{8}$ in. broad, $\frac{1}{2}$ in. thick, and slightly tapered, the outer pieces or frame being of harder timber (hickory, beech, oak, or ash), and $1\frac{1}{4}$ in. thick; the whole bound together with $\frac{3}{8}$ -in. bolts and nuts, having the heads, washers, and nuts countersunk in the side frames, and the holes plugged with wood or cement. The strips are kept $\frac{1}{2}$ in. to $\frac{5}{8}$ in. apart by pieces of wood of that thickness, and $1\frac{7}{8}$ in. square, put between them at the places where the bolts are inserted (Fig. 96).

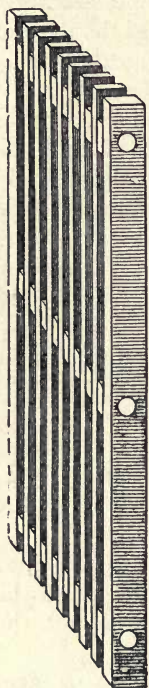


FIG. 96.

The "hurdle" form of grid is now being extensively used, the advantages claimed being that a larger quantity of purifying material can be utilized in the same area afforded by the horizontal grid; and also that the purifying material is suspended in thinner bulk, thus minimising the back pressure given by the plant.

The "Jäger," "Cutler," Spencer's "Hurdle" (Fig. 97), and the "Standard" of Kirkham, Hulett, & Chandler, rank foremost of the new forms.

Rule for the Size of Purifiers.—The capacity or purifying power of the vessels is determined more by their superficial area

than by their cubical volume. There is, however, a mutual relation between the two, as, when the depth is increased and fully utilized, the surface area has to be proportionately augmented, on account of the resistance offered by the deeper material to the flow of the gas. It is more strictly correct, then, to say that the superficial area, in proportion to the depth of the purifying material, is the gauge of the capacity or purifying power of the vessels; and the maximum hourly or

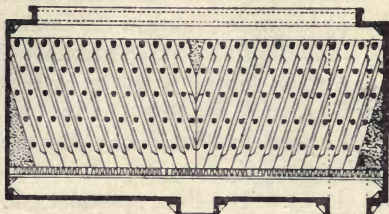


FIG. 97.

daily gas-make of which the works are capable should form the basis of any calculation to determine their size.

One of the chief conditions for securing satisfactory purification is the use of vessels of large area. If economy and efficiency are to be considered, *time* is an important element, and must not be disregarded. The mere passing of the gas through the purifying media is not sufficient in itself to insure good results; time, or, what is the same thing in this case, lengthened contact, is required for chemical affinity to operate.

Therefore, in determining the size of purifiers, where either lime or oxide of iron is intended to be used, it is of the utmost importance to provide a liberal superficial area, and to make ample allowance for increased gas-make.

One of the greatest sources of discomfort to a gas manager is having his purifiers so cramped and confined in their area as to be incapable of doing the work required in an efficient manner.

Where it is intended to have four purifiers, three always in action, the maximum daily (twenty-four hours) make of gas, expressed in thousands, multiplied by the constant 0.6, will give the superficial area in feet of each purifier.

Example.—Required the superficial area of each of the four purifiers in a works equal to the production of 500,000 cub. ft. of gas per diem of twenty-four hours.

$$500 \times 0.6 = 300 \text{ ft. superficial area of each purifier.}$$

$$\sqrt{300} = 17.3 \text{ (say 18) ft. side of square of purifier.}$$

For very small works where there is no exhauster, the constant 0.8 may be employed with advantage.

Water Lutes.—The evils of contracted area in purifiers are aggravated by having a shallow seal to the lids or covers and the hydraulic centre valve—if such be used.

In small works the lute should never be less than 12 in. deep by $4\frac{1}{2}$ in. wide; and in medium-sized and large works, from 18 to 30 in. in depth by 6 to 8 in. in width.

Ample depth of water lute is especially important where the back-pressure is increased by the use of telescopic holders.

Layers of Purifying Material.—In purifiers with horizontal grids charged with hydrate of lime, there may be two or four tiers of sieves. The lime spread upon their surface may be from 4 to 8 in. in depth.

When oxide of iron is used, the layers may be two in number and the material 15 to 20 in. deep on each.

It is a mistake to adopt the plan of placing either the lime or oxide in a single deep layer. The gas is apt to form passages through the deep material; whereas when there are two or more layers of less depth, it recovers itself and changes its course through each.

Apparatus for Raising the Lids or Covers.—For raising the lids or covers of water-luted purifiers various contrivances are employed, the most common being a double purchase crab, travelling on rails laid on either wooden beams or iron lattice girders, having their ends inserted in the walls of the building, or in the absence of walls, supported on pillars. Another arrangement consists of a traveller extending across the purifying house from wall to wall, traversing the length of the house on rails fixed on each side to a beam or girder supported by projecting corbels. On this again there is a lifting crab also on rails, and the gearing of both crab and traveller is actuated by chains from the floor of the house.

The lifting machine, sometimes called a "Goliath" (Figs. 94, 95, and 98), first constructed by Cockey & Sons, is a useful and compact contrivance for the same purpose. This consists of two standards, one on each side of the purifier, connected across the top by two girders a few inches apart. The standards, having grooved or flanged wheels or rollers attached, traverse the purifying house from one end to the other on rails on the floor. The covers are raised by means of two long vertical screws, with an eyelet-hole at the end of each, in which the hooks on the lid are inserted, and moved by a winch and cog-wheels put in motion by a handle

at one of the sides. When the apparatus is not in use, it can be wheeled out of the way, leaving the space above the purifiers, to the tie-rods or beams of the roof; entirely unobstructed. A somewhat similar traveller, in which hydraulic power is applied instead of the wheel gearing and screws, is sometimes employed for accomplishing the same object.

A compact and efficient lifting arrangement for lids of large size is that of the direct-acting hydraulic ram, the head of which is attached to the centre of the lid, and on the application of water pressure to the ram by means of a hand or steam pump, the lid is raised to the required height (Fig. 99).

By adopting the luteless system of purifier construction heavy machinery for raising the covers of large purifiers is

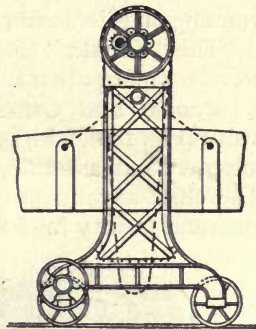


FIG. 98.

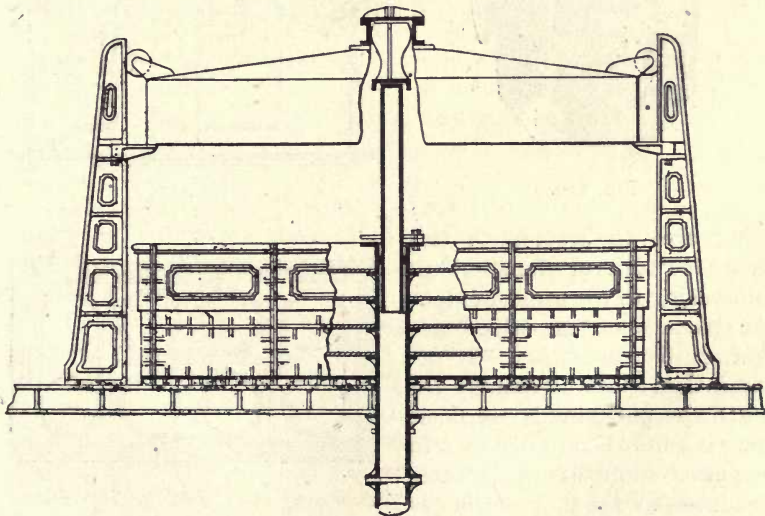


FIG. 99.

dispensed with, a simple arrangement of lifting gear only being required.

Various contrivances are employed, the most common being a

pulley-block with travelling carriage running on the bottom flange of a rolled-steel joist supported on steel stanchions.

Another arrangement is a light jib or double jib travelling crane running on rails fixed on the top plates or gangways of the purifiers.

The "Goliath" (Fig. 95) is also a useful and compact contrivance for the same purpose.

Centre and Other Change Valves.—The round dry centre valve (Fig. 100), with surface faced to fit gas-tight, is now extensively adopted, and, as a rule, is preferred to the old hydraulic centre valve. The chief advantages it possesses over the latter are the greater ease and facility in changing from one purifier to another, one man

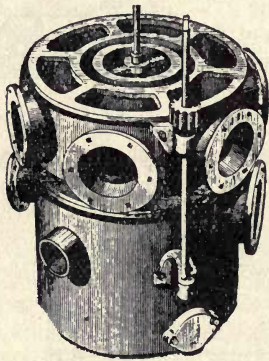


FIG. 100.

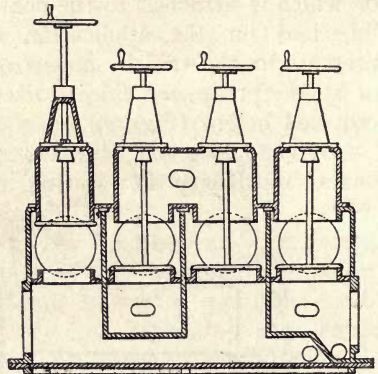


FIG. 101.

being able to accomplish this with a few turns of a handle, thus minimizing to the utmost extent the passage of unpurified gas during that operation. It occupies less space, is entirely beneath the purifying-house floor, and presents a dead resistance to pressure, admitting of greater steadiness in the flow of the gas where an exhauster is at work.

But it has its drawbacks. In the larger sizes especially it is liable to lose its tightness on the slightest disturbance of the foundation either by subsidence or the action of frost, and even by the weight and pressure of the connecting pipes. The Weck valve (Figs. 101 and 102), which

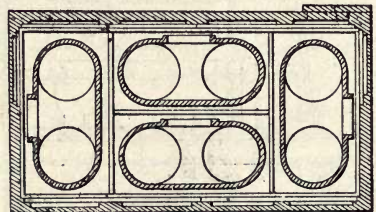


FIG. 102.

consists (for a set of four purifiers) of eight valves within a frame or box, is both handy and efficient, and for large connecting pipes is preferable to the foregoing.

Four-way valves are adopted by some managers in preference to the centre valve, their chief recommendation being that by their use the connections are simplified. The advantages which they possess over the ordinary single valve are more apparent. When the latter are employed, twelve are needed for a set of four purifiers and six for a set of two; whereas with the four-way valves only one-third that number is required.

The hydraulic valves, made specially for purifiers, by Samuel Cutler & Sons, and the "Eclipse" hydraulic centre valve of Clapham Bros., whilst possessing the simplicity in working of the dry-faced valve, have the further advantage of being perfectly gas-tight, no matter what the size of the valve may be. Both these valves are worked by the manipulation of a water supply.

The "Eclipse" hydraulic centre valve is cylindrical in form, with internal compartments formed by concentric and radial cast-iron plates. The water supply is under the control of a patent water-feed and draw-off valve.

By turning the index handle of the water valve to the different positions marked on the face, it is possible to work the purifiers with the following changes: First, any purifier alone; second, any two or three purifiers in juxtaposition to one another; or, third, all four purifiers on.

Connections.—With respect to the size of the connecting pipes, the rule is to make their internal diameter, *in inches*, equal, as nearly as possible, to the square root, *in feet*, of the area of the purifiers.

Thus, purifiers 10 ft. square, giving an area of 100 sq. ft., have connecting pipes 10 in. in diameter, and purifiers 16 ft. by 12 ft., having an area of 192 sq. ft., have their connecting pipes 14 in. in diameter. With the larger proportionate sizes of purifiers now being employed over those formerly erected, a deduction of $\frac{1}{8}$ may safely be made from the result obtained by the above rule. Thus (see rule on p. 169) a works capable of producing 500,000 cub. ft. of gas per day requires four purifiers, having each an area of 300 sq. ft. [$500 \times 0.6 = 300$], the square root being 17.3; deducting $\frac{1}{8}$, or 2.2, we have 15.1, or, say, 15 in., the diameter of the connecting pipes.

Within recent years there have been brought out two or three

patents, notably by C. & W. Walker and Willey & Co., whereby the connections between the purifiers are either considerably reduced or altogether dispensed with.

In Messrs. Walker's arrangement the connections, what few there are, may be in the form of a rectangular box passing beneath the gangways, on the sides of the purifier, or beneath the same, each purifier being worked by means of special disc-valves.

These are chiefly advantageous with the luteless type of purifiers, as in such cases advantage is taken of the several purifiers being in juxtaposition with each other.

Notes on Lime.—Limestone is calcium carbonate found in its natural state, from which the calcium oxide (quick or caustic lime) is produced by the expulsion of the carbon dioxide by means of heat in the lime kiln.

Quick or Caustic Lime (calcium oxide) is lime in the solid state before absorbing or being slaked with water.

Hydrate of Lime is a chemical compound of lime and water in the proportion of one part of water to three parts of lime.

Milk of Lime or Cream of Lime is a mixture or solution of hydrate of lime and water.

Quicklime nearly doubles in bulk on being slaked.

From 90 to 140 lbs. of quicklime, reduced to the hydrate, are required in the purification of the gas produced from one ton of cannel, and from 55 to 80 lbs. of that produced from one ton of coal.

1 bushel of quicklime weighs about	70 lbs.
1 cubic foot of	54 "
1 cubic yard of	1460 "
1 ton of	is equal to about 32 bushels.

The value of lime as a purifying agent is in inverse proportion to the amount of earthy or foreign matter it contains; that which leaves the smallest proportion of insoluble sediment on being dissolved in diluted acid is the best.

CLASSIFICATION

Of the best-known Limestones of this Country, in the order of their Purity, and which Order also expresses their Value for the purpose of Purifying Coal Gas. (Hughes.)

1. The white chalk limestone of Merstham, Dorking, Charlton, Erith, and other parts of the chalk range surrounding the Metropolis.

2. The grey chalk limestone, from the lower beds of chalk.
3. The blue beds of the upper and middle Oolites.
4. The lower white and grey limestones of the Oolites.
5. The most calcareous and crystalline beds of the carboniferous or mountain limestone, colours grey and bluish.
6. The magnesian limestone of Yorkshire and Derbyshire.
7. The white lias limestone.
8. The blue lias limestone.
9. The Silurian limestone of Wenlock, Dudley, etc., and the coralline limestones of Plymouth and the neighbourhood.

TABLE

Showing the Composition of Different Limestones and their Specific Gravity. (Government Commission.)

Quality of Limestone and Locality.		Carbonate of Lime.	Carbonate of Magnesia.	Silica (Flint).	Iron Alumina (Clay).	Water and Loss.	Specific Gravity (Dry).
Oolites.	Ancaster, Lincolnshire	93'59	2'90	—	0'80	2'71	2'182
	Bath Box, Wiltshire	94'52	2'50	—	1'20	1'78	1'839
	Portland, Dorsetshire	95'16	1'20	1'20	0'50	1'94	2'145
	Ketton, Rutlandshire	92'17	4'10	—	0'90	2'83	2'045
	Barnack, Northamptonshire	93'40	3'80	—	1'30	1'50	2'090
Limestone.	Chilmark, Wiltshire	79'00	3'70	10'40	2'00	4'20	2'481
	Ham Hill, Somersetshire	79'30	5'20	4'70	8'30	2'50	2'260
A trace of bitumen was observed in each of the above.							
Magnesian Limestone.	Bolsover, Derbyshire	51'10	40'20	3'60	1'80	3'30	2'316
	Huddlestone, Yorkshire	54'19	41'37	2'53	0'30	1'61	2'147
	Roche Abbey, Yorkshire	57'50	39'40	0'80	0'70	1'60	2'134
	Park Nook, Yorkshire	55'70	41'60	—	0'40	2'30	2'138

Other Analyses.

Quality of Limestone and Locality.	Carbonate of Lime.	Carbonate of Magnesia.	Silica (Flint).	Iron Alumina (Clay).	Water and Loss.	Analyst.	
Magnesian Limestone.	Denton, near York .	63·0	30·0	—	2·25	0·25	Holme
	Eldon	52·0	45·2	—	1·1	1·7	Davy
	Aycliffe	45·9	44·6	—	1·57	2·8	„
	Portishead, near Bristol	53·5	37·5	—	0·8	3·2	Gilby
	Four miles N.W. of Bristol	58·0	38·0	1·5	1·1	1·4	„

Quality of Limestone and Locality.	Carbonic Acid.	Lime.	Alumina.	Silica.	Bitumen.	Water and Loss.	Iron and Clay.	Magnesia.
Analyst : Clarke, Tennant.	{ Magnesian, of which York Minster is built }	47·00	33·24	—	—	—	0·40	19·36
		{ Carboniferous, White- ford, Flintshire . . }	40·10	49·65	8·80	0·60	0·60	0·25

Lime Burning.—This subject is not of absorbing interest to the gas manager in this country, because there is always an abundant supply of lime to be had for the ordering, without any need for concern as to how it is produced. But to those who undertake the management of gas-works in some places abroad, it is desirable that they should make themselves familiar with a process which they may have to practise as a matter of necessity or for the sake of economy.

Limestone or calcium carbonate, in some form or other, exists in almost every part of the globe, from the fat or rich qualities down to the lias or hydraulic kinds. These latter are not suitable for gas purification, as they contain an excess of earthy or clayey matter in their composition.

The substance existing in the limestone which gives it its peculiar character of hardness and durability, insomuch that it resists denuding atmospheric influences almost as effectually as granite and more so than most classes of sandstone, is carbon

dioxide. The chemical formula for limestone is CaCO_3 . The object of burning or calcining the limestone, as is well known, is to expel the water which is mechanically held in it, and the carbon dioxide, CO_2 . The quicklime or calcium oxide being left, its formula is therefore CaO . The equation representing the effects of the process of calcination is $\text{CaCO}_3 = \text{CaO} + \text{CO}_2$. Curiously enough, the water which is present in ordinary limestone when it is first broken in pieces, and not dried by exposure to the air, assists the calcination of the material by promoting the escape of the carbon dioxide.

The crudest method of burning lime, and that practised by half-civilized peoples, is to range the materials on the ground in alternate layers with coal, wood, turf, or other fuel, surrounding them with clay or clods of earth to retain the heat ; a firehole being left in the bottom, and an opening made in the apex of the heap to allow of the escape of the gas. Fire is then applied to the fuel, it is allowed to burn itself out, and the process is complete. This, as might be supposed, is the least economical plan to adopt ; the quantity of fuel required bearing an undue proportion to the bulk of lime produced.

Lime kilns are constructed in various forms ; but whatever form they take, they are resolvable into two classes—viz., tunnel kilns and flare kilns ; the former having the coal or other fuel and limestone arranged within them in alternate layers, and the latter being fired without allowing the fuel to come in contact with the lime. Either of these may be perpetual or draw kilns—that is to say, they may be kept constantly at work by removing the calcined lime from the drawhole at the bottom, and adding fresh material at the top ; or the fuel may be fired, and the charge allowed to burn itself out, and become cool before discharging the lime.

A small form of tunnel kiln is shown in Figs. 103 and 104. The lining is of fire-brick, 9 in. thick throughout ; but this does not always extend to the top, and in some examples the lining is entirely of gritstone a foot thick. Between the lining and the outer masonry, a cavity 2 in. wide is left—being filled in with ground stone, ashes, or other yielding material—to admit of the expansion of the lining by the heat without rending the structure.

In charging the kiln, a layer of brushwood, or other easily igniting fuel, is placed at the bottom to assist the kindling of the

coal at the beginning. Then comes a layer of coal about 4 or 6 in. thick. After that a layer of limestone 12 to 16 in. deep, in pieces ranging in weight from 2 to 20 lbs. ; the largest being placed in

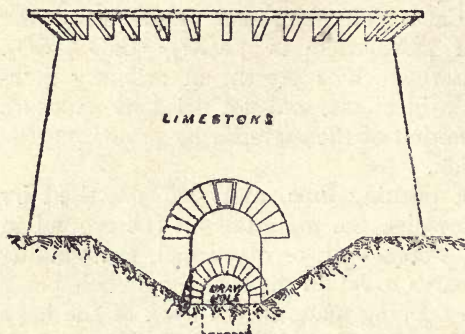


FIG. 103.—Elevation.

the centre, and so on. The stratification of the materials in alternate layers is continued till the kiln is completely filled, when the fire is lighted, and the burning or calcining process is begun. In the perpetual or draw kilns, where the operation is carried on continuously so long as the kiln lasts, the

burned lime is raked out through the draw-hole at the bottom. The mass gradually subsides, filling up the void, and fresh fuel and limestone are added at the top. The flare kiln, shown in Figs. 105 and 106, is the more cleanly of the two, the firing substance being kept apart from the lime ; but it is not as efficient and certain in its action as the tunnel kiln, where the material is placed in alternate layers.

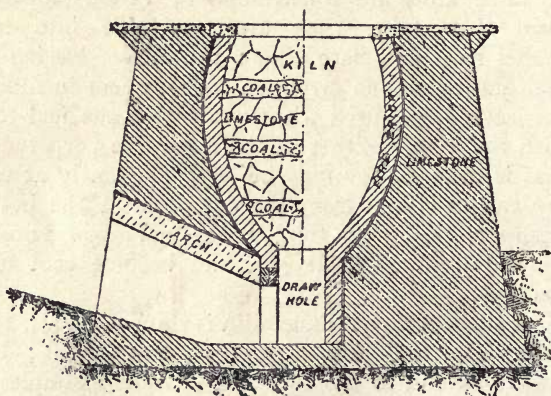


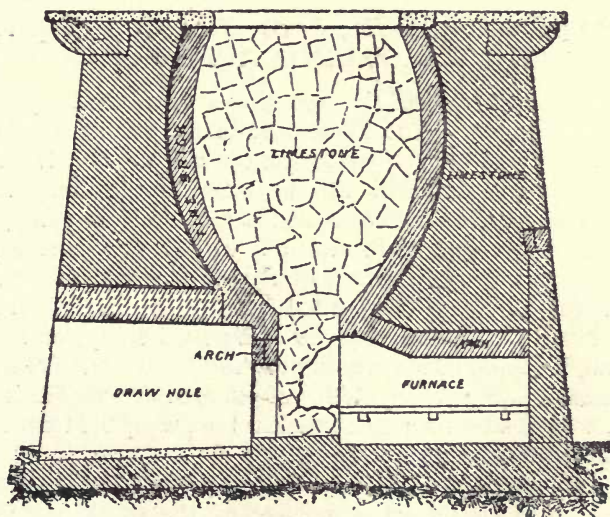
FIG. 104.—Section.

In course of burning, the stone is heated to redness ; and when the whole of the carbon dioxide has been expelled, the redness disappears, and the quicklime, or calcium oxide, is left in rich white floury lumps.



Elevation.

FIG. 105.



Section.

FIG. 106.

The proportion of coal used varies according to the obdurate nature of the limestone. In some instances one measure of coal serves for four of the stone, but in others it takes about 1 ton of coal to burn 2 tons of the stone. On the average, 3 bushels of lime are produced for each bushel of coal consumed. In the case of other fuels, a similar weight of gas-works coke, mixed with one-fourth small coal is needed, and of wood and turf 1 cub. ft. of limestone requires $1\frac{1}{2}$ cub. ft. of these in the burning.

The product known as "lime ashes" is the breeze of the kiln, and consists of small and dusty lime mixed with the ashes of the fuel.

In countries possessing a scanty supply of limestone, calcareous spar and oyster and other shells found on the sea coast are calcined into quicklime, which is produced as a fine flour.

It only remains to be said that the quicklime, on its removal from the kiln, is stored in sheds under protection from the weather. On its being slaked with water, it evolves much heat, crumbling or falling, and becomes calcium hydrate; its formula being CaOH_2O , in which condition it is ready for the purifiers.

THE STATION METER AND OTHER INDICATING AND RECORDING APPARATUS.

The most important of the recording appliances in a gas-works is the station meter. The house containing this should be conveniently situated on the works, and made sufficiently large to contain, if possible, in addition to the meters, the station governors, exhaust and pressure registers, and a range of pressure gauges. When thus arranged they are all within the purview, and immediately under the control, of the workman in charge. The meter house is susceptible of ornamentation, and should have a little bestowed upon it, besides being kept scrupulously clean. Above all, it should be well ventilated, and lighted from outside.

Station Meter.—The quantity of gas manufactured as it passes into the holders after its purification has been completed is measured and recorded by the station meter.

This is invariably of the "wet" description—that is to say, the measuring wheel is caused to revolve by the elastic force of the gas pressing upon the surface of a body of water, with which the vessel is charged up to a certain line.

In construction it differs slightly from the wet meters used by consumers, but its principle of action is identical with these.

The meter case, which is of cast-iron, is made either cylindrical (Fig. 107) or rectangular (Fig. 108); the former shape being generally adopted for sizes up to 20,000 cub. ft. per hour. When it is rectangular in form, the roof is composed of wrought-iron plates, usually No. 10 W.G.

The measuring wheel or drum is made of charcoal annealed tinned plates, riveted and soldered together in segments, and the shaft or axle is supported either by anti-friction wheels or by lubricated brass trunnion bearings.

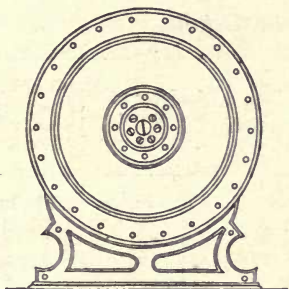


FIG. 107.

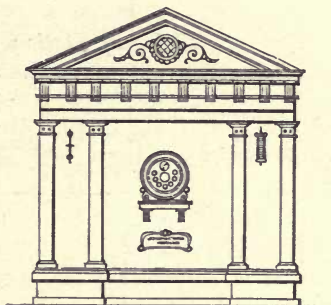


FIG. 108.

The registering mechanism consists of a series of enamelled dials, with wheel-work and pointers indicating from 100 to 100,000,000 cub. ft. at each of their revolutions. The dial figures, unlike those on consumers' meters, all run in the same direction.

An eight-day clock and tell-tale apparatus are placed in front, above the index. On a circular plate a graduated disc of card paper is fixed; and a lead-pencil attached to a rod, which again is attached to and actuated by the minute finger of the clock, pressing upon the paper, indicates the uniformity or otherwise of the gas production during each hour of the day and night.

The size or capacity of a station meter is designated by the quantity of gas in cubic feet which it is capable of passing per hour, the measuring wheel making 120 down to 100 revolutions, as a maximum, in that time—the number of revolutions depending on the size of the instrument. Thus, if the drum has a capacity of

60 cub. ft., $60 \times 100 = 6000$ cub. ft., the size of the meter. If the capacity be 200 cub. ft., then $200 \times 100 = 20,000$ cub. ft., the size of meter, and so on.

It is thus easy to determine the capacity of the wheel or drum required to measure any given production. Say the *maximum* hourly make of gas in a works is 30,000 cub. ft. ; then

$$\frac{30,000}{100} = 300 \text{ cub. ft.,}$$

the required capacity of the measuring wheel or drum. In all cases a reasonable margin in size should be allowed for growing production.

Table of Station Meter Details.

Quantity Measured per Hour.	Capacity per Revolution.	Number of Revolutions of Measuring Drum per Hour.	Pressure Absorbed in Actuating the Meter.	Diameter of Measuring Drum.	Depth or Length of Measuring Drum, minus Hollow Cover.
Cub. Ft.	Cub. Ft.		Inches.	Ft. In.	Ft. In.
600	5	120	$\frac{3}{8}$	2 6	1 3 $\frac{3}{4}$
900	7'5	120	$\frac{3}{8}$	2 10 $\frac{1}{2}$	1 8 $\frac{3}{4}$
1,200	10	120	$\frac{3}{8}$	3 0 $\frac{1}{2}$	2 0 $\frac{1}{2}$
1,500	12'5	120	$\frac{3}{8}$	3 5 $\frac{1}{2}$	2 0 $\frac{1}{2}$
1,800	15	120	$\frac{3}{8}$	3 5 $\frac{1}{2}$	2 5
2,400	20	120	$\frac{3}{8}$	3 6 $\frac{1}{2}$	2 10
3,000	25	120	$\frac{3}{8}$	4 0	3 0
3,600	30	120	$\frac{3}{8}$	4 0	3 5
4,800	48	100	$\frac{3}{8}$	4 3	4 2
6,000	60	100	$\frac{3}{8}$	4 7 $\frac{1}{2}$	4 4 $\frac{1}{2}$
7,200	72	100	$\frac{3}{8}$	4 11	4 6 $\frac{1}{2}$
9,600	96	100	$\frac{3}{8}$	5 6	4 11
12,000	120	100	$\frac{3}{8}$	5 8	5 6 $\frac{1}{2}$
15,000	150	100	$\frac{3}{8}$	6 8	6 3
20,000	200	100	$\frac{3}{8}$	8 0	6 3
25,000	250	100	$\frac{3}{8}$	8 0	7 0
30,000	300	100	$\frac{3}{8}$	8 1 $\frac{1}{2}$	8 1
40,000	400	100	$\frac{3}{8}$	9 6	8 5
50,000	500	100	$\frac{3}{8}$	10 3	9 3
60,000	600	100	$\frac{3}{8}$	11 6	10 2
80,000	800	100	$\frac{3}{8}$	12 10	11 7
100,000	1,000	100	$\frac{3}{8}$	15 4	12 6

When a meter wheel is driven beyond the speed above named, the friction is increased, more pressure is absorbed in working the wheel, and the registration is falsified.

The station meter should be placed perfectly level on a substantial foundation, with raised stone base.

It should be fitted with by-pass and hydraulic trap, with outlet cock ; shut-off valves ; adjustable overflow-pipe ; water-line gauge ; an ordinary pressure gauge each for the inlet and outlet pipes (Figs. 109 and 110), and differential pressure gauge (Fig. 111) ; a thermometer ; a filling tube and funnel, with stopcock ; and a flushing cock.

Rotary Meter.—A new departure in the construction of station meters is the inferential meter invented by Mr. T. Thorp, and known as the rotary meter.

In principle, the rotary meter is similar to the anemometer, but since with the anemometer only the approximate speed of wind and draughts is arrived at, much ingenuity on the part of the inventor was necessary before an instrument could be obtained whereby the flow of gas through the meter corresponded with the indicator of the same under varying conditions of flow.

The meter is in size only about twice the diameter of the gas main to which it is connected, and this constitutes its chief advantage. Further, it can be easily cleaned, and can be used in many situations where the size and cost of the ordinary station meter render the use of the latter inadmissible.

Pressure Gauges.—The ordinary pressure gauge (Figs. 109 and 110) has its tubes, which are of glass, charged with water to the zero line on the ivory or boxwood scale between. This is graduated into inches and tenths. It is made of any length as required, and the scale may be figured either in inches or tenths of an inch, as shown.

On the gauge being attached to the main or service pipe, either directly or by means of a short connecting tube, the difference between the two water levels represents the gas pressure in terms of a column of water.

A series of these gauges, to indicate the pressure existing between the different apparatus of the gas-works, should be fixed in some position convenient for frequent inspection.

King's gauge (Fig. 112) is constructed on the same principle as the above, but it indicates slighter variations of pressure.

It consists of two chambers connected to each other at the base. The chamber in which the gas enters is enclosed at the top, whilst the other chamber is open to the atmosphere and is provided with a counterbalanced metallic float suspended by a cord passing over a pulley.

A pointer is attached to the pulley shaft and traverses a semi-circular scale which is graduated into divisions of $\frac{1}{100}$ of an inch.

The apparatus is charged with water to a fixed level, and the pressure of the gas on entering the enclosed chamber depresses the water contained therein, causing it to rise in the second chamber, thus raising the metallic float and causing the pointer to indicate on the scale the variations of pressure.

The differential gauge (Fig. III) is commonly attached to the inlet and outlet pipes respectively of station meters; the indications of the instrument being the difference in pressure between the two, showing the pressure absorbed in actuating the meter.



FIG. 109.



FIG. 110.

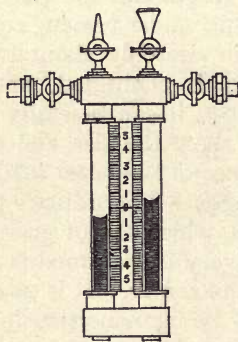


FIG. 111.



FIG. 112.

Coloured water for pressure gauges is made by infusing a little pounded cochineal in hot water. It is then filtered, and a few drops of nitric or hydrochloric acid added, to prevent the bright scarlet colour from fading.

The glass tubes of pressure gauges, when foul, may be cleansed with a weak solution of sulphuric acid in water.

Pressure and Exhaust Registers.—The principle of action of these instruments (Fig. 113), invented by Crosley, is the same as that of the foregoing, but they are made to *record* as well as *indicate* the pressure or exhaust, as the case may be.

This is accomplished by means of a float in water, to which a vertical spindle is attached, having a lead-pencil at the upper end, pressing upon a cylindrical graduated roll of paper upon

a drum, which is caused to revolve by clockwork once in twenty-four hours. The paper roll is renewed daily.

The exhaust register is connected to the mains on the works at a point between the hydraulic main and the exhauster, and the record shows whether, in the absence of the manager, the exhauster has been kept working with regularity.

The pressure register is attached to the street main beyond the governor, and records the various pressures maintained therein during the day and night.

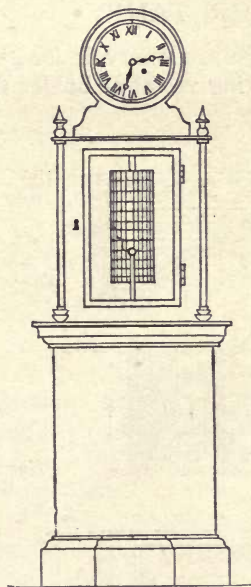


FIG. 113.

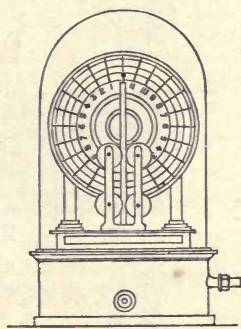


FIG. 114.

The difference between the exhaust and pressure registers is simply one of detail in construction; the zero line in the former being placed midway on the scale, and the spindle lengthened to correspond, whilst the area of the float is also increased. In the latter, the zero line is at the bottom.

Wright's pressure register (Fig. 114) is a combination of the King's gauge with a timepiece having a circular plate and paper disc instead of a dial. The twenty-four hours are printed on the

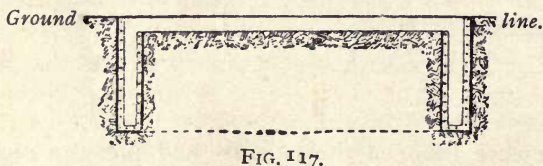
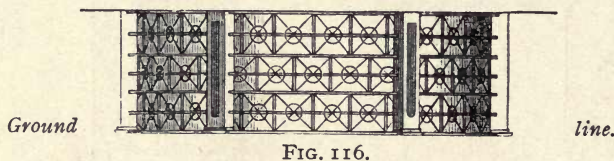
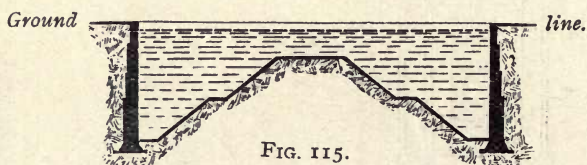
disc, and a pencil at the end of a rod actuated by the float, pressing upon the disc records the various pressures.

The recorders, on the float principle, of Mr. W. H. Cowan, James Milne and Son, and Mr. T. Thorp are useful adjuncts to pressure registration.

Hohmann and Maurer's dry pressure gauges and recorders, constructed on the principle of the aneroid barometer, and Bristol's pressure recorder, are handy and compact instruments for ordinary pressure purposes.

THE GASHOLDER TANK.

The tank is that portion of the storage reservoir for gas which contains the water in which the floating vessel or holder rises and descends (Figs. 115, 116, 117).



It may be constructed either wholly or partially under the ground level (Fig. 115), or (as in the case of iron and steel tanks) entirely above ground (Fig. 116).

The first thing to be done in determining the site of a tank, is to sink a well or shaft in the vicinity, or to make a number of borings on or near to the site, in order to ascertain the character

of the strata in which the excavation for the proposed tank has to be made. If the ground in the immediate neighbourhood is clear of other tanks or buildings, it is not a matter of serious concern to find that a bed of sand, full of water, has to be encountered. To overcome a difficulty of this kind in such circumstances is chiefly a question of pumping power. Piling also might be resorted to, and the free use of concrete, in case there is a possibility of the water being removed by pumping from underneath the tank at any future time. But, on the other hand, if there are adjacent structures which it is unwise to run the risk of damaging, then it is well to be chary about pumping the water from the underlying sand and gravel. In such event, it is almost a matter of certainty that the removal of the water, accompanied also by the removal of a large proportion of the sand along with it, would cause subsidence of the ground in the vicinity, with consequent, and possibly irreparable, damage to the structures thereon. The safer and more prudent thing to do in such a case is either to abandon the site for another, or, if that cannot well be done, to construct the tank either wholly or partially above ground, and of cast or wrought iron or steel plates.

Assuming that the site for a gasholder tank has been finally settled; that it has been decided the tank shall be constructed of masonry (which term includes stone, brick, and concrete, or a combination of these); that it has been ascertained by boring that water is present in objectionable abundance in the substrata to be pierced—the first thing to be done is to sink a well or sump, 3 to 4 ft. in diameter, at a convenient distance from the circumference of the proposed excavation. This should be lined with open unmortared brickwork (technically called “steining”), to allow of the free percolation of the water into the sump or well through the joints of the lining. Into this, when the sinker has reached the water-bearing strata, he conveys the suction pipe of the pump, puts the latter in operation, and clears out the inflowing water to enable him to proceed with his work. This well is carried down to a depth of 3 to 5 ft. (depending on the volume of water present) below the bottom of the intended excavation, and is then paved with bricks set in cement. If the strata are of uniformly open character—consisting, say, of a mixture of gravel and sand—one sump will be sufficient to clear the ground of water; otherwise, if it is not uniform, but barred by intervening

clayey deposits (not an unusual thing), and even by solid-bedded sand—for this sometimes is almost as impervious as clay—it may be necessary to drain the water to the sump, or even to put down two or more sumps outside the ground operated on. Duplicate pumps should be provided where the inflow of water is very great. With these arrangements completed, the work of excavating and building can be proceeded with unhindered by the presence of any undue quantity of water.

In the course of practice, the excavation for a tank, of which the writer was engineer, was chiefly through hard sandstone rock, the layers of which had been tilted up into almost the vertical position. This was fissured and cracked in all directions, and through the crannies water bubbled up in numberless springs. Although one side of the adjacent ground was at a lower level than the tank bottom, it was impossible, by any reasonable expedient, to draw off the water from the outside. Possibly, by sinking a shaft to a considerable depth, it might have been accomplished. But, considering the nature of the strata, that would have been costly; so other means were resorted to to overcome the difficulty. It is not an easy thing—in many cases it may be pronounced to be impossible—to choke out water from a tank from the inside. In puddling the bottom of the tank in question, and covering the puddle with a bed or layer of concrete, the springs were by no means closed; and though they were reduced in number, the flow of water was still quite as plentiful as before. Assuming that the pressure in these springs was sufficiently great to have overcome the pressure of the head of water in the tank when the latter was full, there would have been no objection to leaving them to flow unhindered. But that was a risk which it was not prudent to run. The head of water in the tank would probably have more than counterbalanced the pressure of the springs; and where water can enter, it can there as easily make its exit. The plan which in this case was adopted for making the tank water-tight, was to train or drain the different streams of inflowing water to one point, by cutting a trench round the side of the bottom where the springs occurred, and laying therein strong 3-in. drain-pipes, which in turn were carefully protected by a covering of strong concrete. The springs usually occur at, or near to, the base of the mound or dumping left in the tank bottom; so that it is easy to gather them together by a drain and convey all the water to one convenient point. There was now

only one stream of inflowing water to deal with; and at this point was placed a 3-in. cast-iron stand-pipe, 3 ft. in length, closed by a valve at its upper end, and the flanged foot secured by four Lewis bolts let into a base-stone 18 in. square and 9 in. thick, through the centre of which a hole was drilled. This stone was let into the floor slightly below the level of the concrete surface, and a cavity was left underneath it. From this stand-pipe the inflowing water was pumped to relieve the pressure on the bottom till the cement in which the stone was bedded had set hard. It should be mentioned that, in the side of the stand-pipe, at distances of 9 in. apart, there were $\frac{3}{4}$ -in. holes drilled. These were left open, to allow the water to issue from them without rising to the top. As the filling of the tank proceeded, these holes were each carefully plugged as the water rose above them; then the valve on the upper end of the stand-pipe being closed, the filling with water was completed—the tank proving to be perfectly water-tight.

Another method sometimes adopted, instead of using a stand-pipe as described, is to carry the drain right through the tank wall at its base, thus making an outside exit for the water. The stand-pipe, however, is preferable as being more self-contained and certain in its action.

It sometimes happens that, without previous indication of its presence, the pressure of surrounding water will, in the course of construction, blow a hole or holes in the tank bottom. If so, the best thing is to let it blow; let it have free vent until all is completed and the tank ready for water, then apply the stand-pipe as described.

In another instance, the line of circumference of a tank came close up to the side of a retaining wall bounding a considerable stream. In this case, the excavation having to be carried close up to the wall, the latter was laid bare for about 30 feet of its length; and as the cutting had to be taken about 6 ft. below the level of the water in the stream, the rush of water through the interstices of the wall would have been fatal to the operations. Accordingly, to shut out the water, a wall of wooden sheet-piling was constructed—a cofferdam, in fact—60 ft. in length. The wooden piles forming one side of it were shod with iron, and driven (most of them) 12 ft. into the bed of the stream. They were then bound together at the upper ends by a horizontal beam bolted thereto, and anchored at distances 10 ft. apart with

long bolts passing through the retaining wall. The space between the piling and the stone wall was 2 ft. in width, and was hand-dredged to a depth of 10 ft. below the water-level. This space was carefully filled in to above the stream-level with stiff clay puddle, well rammed down. The work was eminently successful; and it was found an easy matter to cope with any water from the stream that reached the excavation, either from beneath or from beyond the two ends of the cofferdam.

The presence of water in an excavation is not always objectionable, unless it be excessive in volume. For example, in excavating through stiff clay, it renders the work of the labourer much easier than if the ground is dry and hard. Those who have had experience in shifting boulder clay will readily endorse this view. Strata of this character are often so hard and parched and intractable as to require blasting to facilitate removal.

Avoid puddling a tank bottom in wet weather, especially if the bottom is in the form of a mound or cone. Uniformity of consistency in the puddle is of more importance here than against the outside of the walls, for the obvious reason that the bottom has to bear the pressure of the water when the tank is filled. If one portion is well consolidated and firm, and another soft and yielding, the concrete covering is liable to crack and split open, owing to the unequal sustenance. It is almost impossible to preserve this necessary uniformity with water coursing down the slope of the mound, the puddle becoming sodden and sloppy. The fact that equal sustenance is of such importance also proves the necessity of having the clay covering on the bottom uniform in thickness. The deeper excavation made to receive the horizontal portions of the inlet and outlet pipes should have a solid concrete filling, allowing for just a like thickness of puddle above them as over the other parts of the apron.

It is not a wise thing to test the tightness of a tank with water immediately on completion. Better wait till the holder is finished, in order to give the puddle and cement time to set before subjecting them to the heavy pressure of water. We have known several instances of the splitting of tanks due to this premature filling. Further, before filling a tank with water for the first time, the puddle and backing behind the wall should be carefully watered—by means of a hose-pipe, if possible—for several days before the filling is begun, and also during its progress. This promotes consolidation of the backing.

In excavated tanks, wherever the substratum is favourable, it is economical to leave a circular or conical mound in the centre. This is called the "dumpling" or "cone" (Fig. 115).

Tanks are occasionally formed by making a circular cutting in the ground, and erecting therein an iron or brick annular channel to contain the water, the intervening central space being also covered with water, but of less depth, depending on the extent to which the subsoil has been removed. This central space requires to be covered with a layer of concrete, and the surface rendered with Portland cement. These are called annular tanks. (See Fig. 117.)

Excavation for Tank.—The width of the excavation for a tank depends on the nature of the substrata encountered, whether clay, shale, gravel, sand, etc., unless a complete system of close-shoring by means of timber all round is adopted. The best method is to sink a trench 12 ft. wide all round the circumference, and close-timber both sides of the excavation. Where the ground is yielding and soft, or saturated with water, the vertical shoring-timbers may be 7 in. wide and 3 in. thick, the waling-pieces double, and 3 ft. apart, 11 in. by 3 in., and the struts 9 in. by 6 in., in cross section. This will afford substantial support.

Natural Slope or Angle of Repose of Earths with Horizontal Line. (Fig. 118.)

Sand, dry	average	37°	or	1'33	to	1
Sand, damp	"	21°	"	2'63	"	1
Shingle and gravel	"	40°	"	1'2	"	1
Clay, drained	"	45°	"	1'0	"	1
Clay, wet	"	16°	"	3'3	"	1
Earth, compact	"	48°	"	0'9	"	1
Peat or vegetable earth	"	28°	"	1'89	"	1

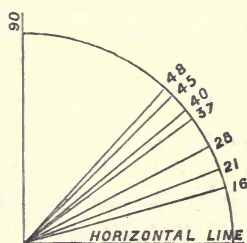


FIG. 118.

Weight of Various Earths and Rocks.

Per Cubic Yard.		Per Cubic Yard.	
Sand, dry	about 2430 lbs.	Marl	about 2900 lbs.
Sand, damp	" 3200 "	Shale	" 4370 "
Shingle and gravel	" 2850 "	Chalk	" 4000 "
Clay	" 3240 "	Sandstone	" 4250 "
Mud	" 2700 "	Slate	" 4860 "

Materials of which Tanks are Constructed.—Tanks are constructed of stone (either built up, or excavated from the solid rock), brick, concrete, cast or wrought iron, steel, or a combination of iron or steel with the other materials.

The kind of material employed is regulated, as a rule, by the character of the district where the gas-works are situated, and the nature of the ground whereon the erection is to be. If the neighbourhood abounds in stone, the probability is that that will be the cheapest, and will consequently be adopted in the construction of the tank. But even in districts where stone is plentiful, if this is of a hard nature, the expense of dressing is such as to make the tank more costly than if built of bricks, though the latter may have to be brought from a distance. In places distant from a supply of building material, and to which the latter has to be brought by conveyance, brick or concrete will generally be chosen as the most suitable.

On the other hand, where the ground is of such a character as would entail an extraordinary outlay in securing a good foundation, or where it is unsafe for a brick or stone structure; or, again, where the sinking of a tank is almost impossible, owing to the presence of a large body of inflowing water through the strata, as by the seaside, or contiguous to some rivers—the best class of tank to be adopted is one made either of cast or wrought iron, or steel plates bolted or riveted together, the cast-iron plate joints being either planed or made water-tight with rust cement.

It may happen that the ground is of such a nature as to render unsafe the construction even of an iron or steel tank upon it; or there may be a slope or embankment in dangerous proximity. In such cases recourse may be had to piling, to give it solidity and prevent movement.

We are not aware of any large gasholder tanks being constructed of reinforced concrete; but we have recently constructed a small tank, 60 ft. in diameter, with satisfactory results as to tightness, stability, and lessened cost, inasmuch as the wall is much thinner than would otherwise have been necessary. There is an opening for this class of structure in gas-works.

In the construction of a masonry tank the use of a trammel to ensure accuracy in the circle is indispensable. In Fig. 119 is shown a convenient form of this appliance.

When the tank is of large diameter, say 140 ft. and above, the movable arm of the trammel is necessarily long and heavy; and in such case the centre post may be a steel lattice girder stayed with wire guy ropes. The apparatus should remain in position and use until the tank coping is fixed. In addition to the trammel, wood templates 16 ft. long, made to the proper curve on their outer edge, should be provided, and frequently applied to the surface of the wall as it rises.

Masonry tanks, being porous, are generally built with a backing

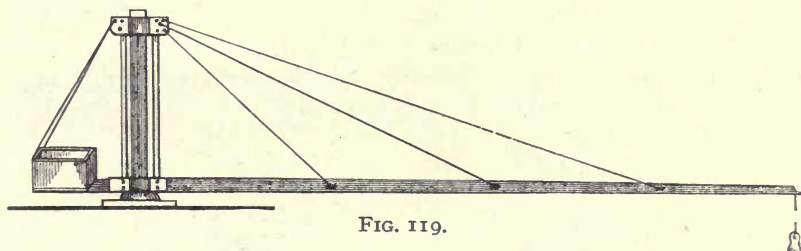


FIG. 119.

of clay puddle behind the walls and in the bottom; but the puddle can be dispensed with by lining the tank with a coat of neat Portland cement about 1 in. in thickness. Mortar composed of cement and clean sharp sand in equal proportions by measure makes a water-tight lining, provided it is carefully polished to a smooth face with a steel trowel.

A lining of $4\frac{1}{2}$ -in. brickwork, with a space between the tank wall and the lining, 1 in. wide, filled with neat cement or asphalt, is also occasionally adopted.

The walls of a tank so treated, being impervious to water, require to be made somewhat stronger, and the backing more carefully consolidated, than where puddle is employed, because there is no fluid pressure outside to balance the fluid pressure within the tank.

The weakest part of the masonry tank, as usually constructed, is that where the inlet and outlet pipes pass through the wall at the bottom. The instances of failure here are so numerous as to justify the plan, sometimes adopted, of placing the pipes in a recess built in the tank wall. The objection to this recess is that it breaks the circle of the wall, and consequently weakens its power of resistance to outside pressure. But continuity of the circle can

be secured by strutting the opening with a series of cast-iron struts as in Fig. 120.

Or the pipes can be made square in section, and built in with the wall, as in Fig. 121.

When a brick or stone tank built in blue lias lime mortar is of large dimensions, the walls may be strengthened at intervals of 2 or 3 ft. apart, by rings 2 or 3 ft. in width, of the brick or stone laid in Portland cement mortar.

Hoop-iron, or flat wrought-iron or steel rings, built at intervals into the masonry or concrete, are occasionally used for giving strength to the walls of a tank. When the diameter is great, and particularly in tanks where no puddle is employed, flat bar-iron or steel hoops, braced or tightened by screws or cotters, are also sometimes placed round the outside.

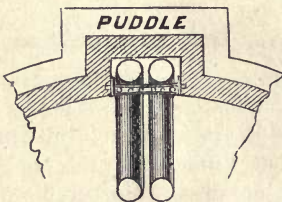


FIG. 120.

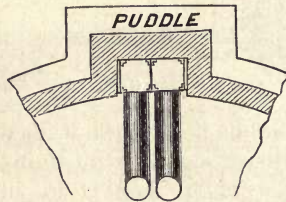


FIG. 121.

When from any cause it is found impracticable or undesirable to construct a masonry tank, whether of stone, brick, or concrete, with its coping on a level with the adjacent ground, circumstances may require that the raised portion of the wall should be strengthened, in addition to the support given by the earth backing, either by flat wrought-iron or steel rings built into it, or by outside wrought-iron or steel hoops. One such ring or hoop will suffice for every 4 ft. in height of the tank wall above the natural ground-level. The strength of the iron will, of course, be determined by the dimensions of the tank; but it may be stated, by way of guidance, that for a tank of 102 ft. in diameter the iron should be 5 in. wide and $\frac{3}{4}$ in. thick. The flat ring is made continuous throughout the circle by riveting, and the hoop by screw-bolts or cotters.

The bricks used in building a tank should be thoroughly well wetted before being laid, to cause the mortar to adhere.

In time of severe frost all brick, concrete, and stone work should cease.

To prevent injury in time of rain, and especially in winter when a sudden frost might supervene, the top of the new walling should be covered with weather boards.

Concrete.

	By measure.
Blue lias lime concrete (for foundations)—	
Gravel, shingle, broken stone, bricks, or old retorts, 1½ to 2 in. cube	6 parts.
Clean sharp sand	2 „
Blue lias or other hydraulic lime	1 part.
Portland cement concrete (for tank walls)—	
Gravel, shingle, broken stone, bricks, or old retorts, 1½ in. cube.	7 parts.
Clean sharp sand	2 „
Portland cement	1 part.

For preparing the concrete a platform, about 20 ft. square, of deals, should be laid on the ground to ensure the clean mixing of the materials. The measure for the material is simply a square box without top or bottom, and should contain, as a convenient quantity, about half-a-yard. It should be twice as many inches deep as the proportions of cement and ballast. For instance, if the cement is 1 in 8, it should be 16 in. deep. Inside, at 2 in. from the top, nail a lath all the way round; and after placing the measure at one end of the platform, fill the box with shingle or ballast to the level of the lath, and complete with cement, striking the cement level with a straight-edge. The box measure can then be lifted up and removed, when the cement will fall down over and among the aggregate, and the whole mass should be twice turned over *dry*. Water can then be added through a rose, and the whole turned twice over again. As little water should be added as possible, but enough to thoroughly moisten the whole mass. The concrete is then fit for use. In dry weather it is necessary to keep the work damp, as, if there is not sufficient water to enable the cement to set—about 11½ per cent.—the concrete will be useless. It is also important to thoroughly wet the previous work on which the fresh concrete is to be laid.

Concrete is best placed in position from barrows wheeled close up; it should then be well and solidly rammed down. To tip it from a height (as was formerly the practice) is objectionable, as tending to disintegrate the ingredients of which it is composed.

The Kind of Mortar Employed.—In the construction of brick or stone tanks, hydraulic mortar or cement mortar (either one or the other, or both) is invariably used. The following is their composition:—

Hydraulic Mortar.

	By Measure.
Best blue lias lime	1 part.
Clean sharp river sand	2 parts.
Or,	
Best blue lias lime	1 part.
Burnt clay	2½ parts.
Or,	
Best blue lias lime	1 part.
Puzzolana	1 „
Clean sharp sand	6 parts.

Cement Mortar.

Cement, Portland	1 part.
Clean sharp sand	3 parts.

The lime should be fresh burnt, and not more than sufficient of the mortar for a day's work prepared at once. The cement mortar should only be made as it is being used.

The characteristics of good Portland cement are thus succinctly stated by Mr. Faija: "In colour it should be of a dull bluish grey, and should have a clear, sharp, almost floury feel in the hand; it should weigh from 112 lbs. to 118 lbs. per striked bushel (87 to 92 lbs. per cub. ft.), and when moulded into a briquette, or small testing-block, and soaked in water for seven days, should be capable of resisting a tensile strain of from 300 to 400 lbs. per square inch. The cement should, during the process of setting, show neither expansion nor contraction."

Puddle.—For puddle, clay mixed with one-third sand, silt, or soil free from vegetable fibre, is preferable to pure clay, being firmer in texture and less liable to crack when dry. It should be prepared outside the trench, put in in thin layers as the wall

of the tank is built, kept moistened, trodden well in with the feet, and backed-up with earth carefully pounded. A cubic yard of puddle weighs about 2 tons.

Iron Tanks—In cast-iron tanks the flanges of the bottom plates should always be *inside*, whilst those for the sides may be *outside*, and the plates should break-joint with each other throughout.

In wrought-iron and steel plate tanks the horizontal and vertical seams are lap-jointed and double riveted with $\frac{3}{4}$ in. to 1 in. rivets. In large tanks, however, and where the plates exceed $\frac{1}{2}$ in. in thickness, the vertical seams are butt-jointed, with cover-plates.

Iron piers, or piers of brick, stone, or concrete, and built-up standards, are erected at equal distances apart round the outside of iron tanks, for the purpose of supporting the gasholder columns or standards.

Leakages of water from *iron or steel tanks* may often be greatly reduced or altogether stopped by emptying a bushel or two of horse dung into the water contiguous to the escape. A handful of fine iron filings sprinkled lightly over the dung will be found of advantage. By this simple expedient, very heavy escapes have frequently been reduced to a mere drip within the space of a few minutes.

Dry Wells, and Inlet and Outlet Pipes.—The dry or stand-pipe well is not necessarily the invariable accompaniment of a gas-holder tank. Some engineers prefer to dispense with it altogether.

Many of the largest tanks are made without dry wells, the inlet and outlet pipes being of such ample diameter as to admit of their examination and repair, if need be, from the inside.

The advantage supposed to be gained by providing a dry well is the facility which it affords of access to the inlet and outlet pipes, both vertical and horizontal, in case of fracture, without disturbing the puddle or other backing of the tank wall.

In small tanks it is not unusual to form a recess in the tank wall in which the inlet and outlet pipes are placed, and are thus accessible when the tank is emptied of water (Figs. 120 and 121).

The inlet and outlet pipes, especially when of wrought-iron or steel, should be securely anchored or bolted down to the stone or concrete base on which they rest within the tank. If this is not done, the water, by reason of its flotation power, is liable to raise them slightly, and so disturb and cause a leakage through or past the puddle or concrete in which the horizontal portions of the pipes are embedded.

Thickness of Tank Walls.—The walls of masonry tanks (brick, stone, and concrete) are never required to resist, unsupported, the pressure of the water acting upon their sides, but are generally built under the surface-level of the ground within the space of an excavation made for the purpose, and having a backing of earth carefully rammed all round them. If the upper portion of the tank is allowed to rise above the natural ground-level, a supporting embankment is raised behind the projecting portion. The earth backing offers a resistance to the pressure of the water within the tank greater than the combined weight of the wall and the cohesive nature of its component ingredients; and consequently in designing a tank wall this fact is allowed for, and a deduction made from the calculated unsupported thickness of the masonry.

In the well-known *Mémoire* by M. Arson, a translation of which, by Dr. Pole, is given in *King's Treatise* (vol. ii., p. 181 *et seq.*), the author investigates this subject with his usual ability. After some preliminary observations on the nature of the ground, and the choice and placing of material, he proceeds to a consideration of the forces and resistance in a gasholder tank of masonry, and deduces the formulæ as follows:—

As to the pressure of the water—

$$(1) \quad SD \frac{H^3}{6} = \text{the total force of the water.}$$

Then as to the threefold resistance to this force—

$$(1) \quad CD^1 \frac{H^2}{2} = \text{the resistance of the earth backing.}$$

$$(2) \quad \frac{PE^2D^1H}{2} = \text{the resistance of the weight of the masonry.}$$

$$(3) \quad KH^2E = \text{the resistance due to cohesion.}$$

Adding the combined resistance from the three sources together, we have—

$$CD^1 \frac{H^2}{2} + \frac{PE^2D^1H}{2} + KH^2E.$$

And to produce stability of the tank these must be greater than the effect of the pressure of the water—

$$SD \frac{H^3}{6}$$

where D = Internal diameter of the tank in feet.

E = Thickness of the wall (average) in feet.

D^1 = External diameter of the tank in feet.

E^1 = Thickness of wall at bottom in feet.

H = Height (or depth) of wall in feet.

S = Weight of a cubic foot of water.

C = Resistance of earth backing in lbs. per square foot.

P = Weight of a cubic foot of masonry.

K = Cohesive force per square foot.

Applying these formulæ to a tank actually constructed, let us see how they work out. Take a tank the finished dimensions of which are 122 ft. diameter and 24 ft. deep:—

D = 122 ft., internal diameter of tank.

E = $2\frac{1}{2}$ ft., average thickness of wall.

D^1 = 127 ft., external diameter.

E^1 = 3 ft., thickness of wall at bottom.

H = 24 ft., height or depth.

S = $62\frac{1}{2}$ lbs., weight of a cubic foot of water.

C = 1200 lbs., resistance of earth backing per square foot (average clay and earth).

P = 112 lbs., weight of a cubic foot of the masonry.

K = 31,680 lbs., cohesive force per square foot, bricks laid in 1 Portland cement to 3 sand, mortar.

Then—

$$(1) \quad SD \frac{H}{6} = 62.5 \times 122 \frac{24^3}{6} = 17,568,000 = \text{total force of the water in lbs.}$$

$$(1) \quad CD^1 \frac{H^2}{2} = 1200 \times 127 \frac{24^2}{2} = 43,891,200 = \text{resistance of earth backing.}$$

$$(2) \quad \frac{PE^2 D^1 H}{2} = \frac{112 \times 2.5^2 \times 127 \times 24}{2} = 1,066,800 = \text{resistance of weight of masonry.}$$

$$(3) \quad KH^2 E = 31,680 \times 24^2 \times 2.5 = 45,619,200 = \text{resistance due to cohesion.}$$

$$\underline{90,577,200} = \text{total resistance in lbs.}$$

Or more than five times the pressure of the water, which is a very ample margin for safety.

A modification of the foregoing calculation may be given, estimating, separately—

(1) The resistance of the masonry and backing to the outward pressure of the water.

(2) The cohesive resistance of the tank wall to the force tending to burst it open.

(1) The amount of outward pressure on a unit of length of wall will be $\frac{SH^2}{3}$; and the resistance due to the weight of masonry and the backing will be $PE^{12} + CH$, taking the thickness of the wall, 3 ft., at base. If these exceed the pressure, the wall will be stable, independent of any aid from the cohesion.

Then, taking the same example :—

$$\begin{array}{rcl} \frac{SH^2}{3} & = & \frac{62.5 \times 576}{3} = \underline{12,000} \\ PE^{12} & = & 112 \times 9 = 1008 \\ CH & = & 1200 \times 24 = \underline{28,800} \quad \underline{29,808} \end{array}$$

Showing a margin of safety nearly $2\frac{1}{2}$ times.

(2) The force tending to burst the tank increases with the depth. At the bottom of the tank wall the bursting force will be on a unit=SHD. This will be resisted by the cohesion of the two walls, which per unit of height will be $2KE^1$.

Then—

$$\begin{array}{rcl} SHD & = & 62.5 \times 24 \times 122 = \underline{183,000} \\ 2KE^1 & = & 31,680 \times 3 \times 2 = \underline{190,080} \end{array}$$

Showing that the cohesive force alone would be only barely sufficient to resist the bursting force of the water, the margin being far from a safe one; and that, too, although the thickest section of the wall has been taken.

Clearly, then, the chief element of resistance is the earth backing.

In the case of iron and steel tanks above ground, this latter calculation is the important one, as the structure depends on the cohesive resistance for its stability. The cohesive strength of cast-iron may be taken at 4000 lbs. per sectional square inch, its ultimate tenacity being 16,000 lbs. The safe cohesive strength of steel

plates may be taken at 15,680 lbs., and of wrought-iron plates at 10,000 lbs. per sectional square inch.

Cast-iron tanks require to be strengthened by wrought-iron or steel hoops round the outer circumference. A slight additional thickness beyond the calculated strength should be allowed for wrought-iron and steel tanks, owing to their greater liability to corrosion as compared with cast-iron.

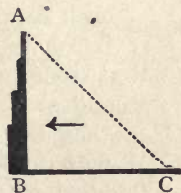
It has already been pointed out that the walls of brick tanks, which are porous in some degree, having a backing of clay puddle, are placed in equilibrium by the water on both sides, and therefore do not require to be quite as thick as those tanks with a lining of cement impermeable to water.

In the latter case, great care should be taken to see that the backing is thoroughly consolidated, so that the pressure of the water inside the tank may be transmitted thereto direct without danger of rupture to the masonry. Sand carefully punned and watered is the best backing for such tanks.

But, indeed, there should be equal care taken to insure consolidation of the backing in puddled tanks, because their immediate porosity is not always a dead certainty.

In the course of filling a masonry tank with water, it is well to give an occasional watering to the ground surface behind the wall all round.

The pressure of the water, which increases in proportion to the depth, may be represented by the triangle A B C, and therefore the thickness of the wall at the top would work out to nothing. It must not be overlooked, however, that the tank sides act as a retaining wall to the surrounding earth, both during construction and at any time afterwards when the water is withdrawn, and consequently the thickness should be graduated from the bottom or lower determined thickness to about $1\frac{1}{2}$, 2, or 3 bricks' width at the coping. The thickness of the lower section of the wall should be continued to slightly above the centre of pressure, or one-third the depth from the bottom.



In the example given above, the thickness of 3 ft. for the lower portion of the wall is much too thin for an ordinary retaining wall of that height (24 ft.); but it must be remembered that this apparent weakness is counterbalanced by the circular form of the structure, possessing as it does all the qualities of the arch, and

being built up, both wall and backing, gradually throughout the complete circle from base to coping.

Examples of Construction.

The following are examples of gasholder tanks actually constructed. They are intended to be suggestive rather than blindly followed. The engineer must bring his experience to bear and exercise his judgment, and take all the local circumstances into account, in settling his design.

It will be found advisable in practice, in some instances, to increase the strength of the footings and walls. A bed of concrete should be laid round the excavated circle, and the brick footings built upon it. This is especially necessary where the ground is of an unsatisfactory character.

BRICK TANKS.

Diameter, 62 ft. Depth, 14 ft.

Footings, 4 courses; width respectively $4\frac{1}{2}$, 4, $3\frac{1}{2}$, and 3 bricks.

Wall, thickness at base to height of 5 ft., $2\frac{1}{2}$ bricks; next 5 ft., 2 bricks; remaining 3 ft. to underneath coping, $1\frac{1}{2}$ bricks.

Coping stones, 1 ft. thick, dressed to the proper radius, and laid in cement.

Piers, 6, brought up from foundation, bound in with tank wall, each capped with a stone 3 ft. square, 10 in. thick, with 4 bolt-holes.

Rest stones, 12, 18 in. square, 8 in. thick, laid on footings.

Mound or cone left in bottom of tank, 8 ft. less in diameter than the latter, flagged round the base, other part pitched with random stones.

Puddled with clay two-thirds, intimately mixed with one-third sand; 2 ft. thick at bottom; the sides, 2 ft. at base to 1 ft. 6 in. at top.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sand.

Diameter, 102 ft. Depth, 24 ft.

Footings, 6 bricks wide at base, diminishing by offsets to the bottom of wall.

- Wall, thickness at base to 7 ft. in height, 4 bricks; next 7 ft., $3\frac{1}{2}$ bricks; next 5 ft., 3 bricks; and remaining 4 ft. to coping, $2\frac{1}{2}$ bricks thick.
- Coping of stone, 1 ft. thick.
- Piers, 12, carried up and built in with wall from foundation. Each capped with a stone 4 ft. square, 15 in. thick, with 4 bolt-holes.
- Rest stones, 24, 2 ft. 6 in. square, 12 in. thick, let 4 in. into bottom of wall, and resting on footings.
- Stones, 72 in number, 18 in. long, 12 in. by 12 in., built into tank wall, against which the channel guides are fastened.
- Puddled with clay, 2 ft. thick at bottom; the sides, 2 ft. 6 in. at base, tapering to 1 ft. 6 in. at top.
- Bottom, concreted over the puddle to the depth of 10 in.
- Centre pillar, 4 ft. square.
- Bricks, best hard-burnt stocks.
- Mortar, lias lime, mixed with two-thirds sharp river sand.
- Diameter, 154 ft. Depth, 40 ft. 6 in.
- Foundation, of concrete, 12 in. thick, 13 ft. wide under piers, and 11 ft. wide under walling.
- Wall, starts from concrete foundation without footings, 5 bricks thick for a height of 16 ft. 10 in.; next $4\frac{1}{2}$ bricks for 6 ft. 5 in. deep; next 4 bricks for 6 ft. 5 in.; next $3\frac{1}{2}$ bricks for 6 ft. 5 in., and 3 bricks the remaining height.
- Coping of stone, 12 in. by 2 ft. 3 in., in lengths not less than 4 ft. 6 in.
- Piers, 16 in number, 6 ft. square from bottom to top, capped with hard Yorkshire stones, 6 ft. square and 2 ft. thick, with 4 bolt-holes in each.
- Rest stones, 32, 4 ft. 10 in. by 2 ft. by 1 ft., built $4\frac{1}{2}$ in. in tank wall.
- Guide rail stones, 144 in number, 112 of which are 2 ft. by 1 ft. 9 in. by 1 ft., and the remaining 32 being 2 ft. by 1 ft. 9 in. by 1 ft. 6 in.
- Puddled with clay 24 in. thick over surface of mound in bottom, and behind tank wall.
- Brick apron, 2 ft. thick and 6 ft. wide, round bottom of tank wall inside, upon which the rest stones are set.
- Centre pillar of brick, 6 ft. square at bottom and 6 ft. 3 in. square at top, capped by a stone 12 in. thick.

Mortar, Portland cement, 1 part ; sand, 3 parts.

Bond, English ; alternate courses of headers and stretchers throughout.

Dry well, 10 ft. in diameter, 48 ft. 6 in. deep.

Diameter, 218 ft. Depth, 44 ft. 6 in.

Foundation of concrete 2 ft. thick, 9 ft. 5 in. wide, including apron.

Wall, thickness at base to 20 ft. in height, 5 bricks ; next 5 ft., $4\frac{1}{2}$ bricks ; next 5 ft., 4 bricks ; next 5 ft., $3\frac{1}{2}$ bricks ; next 5 ft., 3 bricks ; and the remaining portion, $2\frac{1}{2}$ bricks ; 7 circular bands of brickwork, 6 courses deep each, and extending through the full thickness of the wall, are built-in equidistantly in the height of the wall, set in Portland cement mortar, the intervening portions of the wall being set in hydraulic lime mortar all in English bond.

Coping of Yorkshire stone, 2 ft. 5 in. by 6 in., in 5 ft. lengths, projecting 1 in. over wall.

Piers, 24, each 7 ft. from inside tank wall to outside of pier, and 5 ft. 6 in. wide, side to side, capped with Bramley Fall stones, 7 ft. by 5 ft. 6 in. by 2 ft., having 7 bolt-holes in each.

Piers, intermediate, 24, each 3 ft. 10 in. square, capped with stones 4 ft. by 4 ft. by 6 in.

Rest blocks of concrete, 48, each 4 ft. 6 in. long by 2 ft. wide, and standing 6 in. above the concrete apron.

Guide rail stones, 288, each 18 in. by 12 in. by 12 in., projecting 1 in. from face of tank wall.

Puddled with clay, not less than 18 in. at any part.

Truncated surface of cone paved with stones.

Mortar, blue lias hydraulic lime, 1 part ; sand, 3 parts.

Cement mortar, Portland cement, 1 part ; sand, 3 parts.

Concrete, Portland cement, 1 part ; river ballast, 7 parts.

Shallow dry well, 12 ft. diameter, 26 ft. deep.

CONCRETE TANKS.

Diameter, 82 ft. Depth, 28 ft.

Wall, 3 ft. 8 in. thick at bottom, tapering on the outside to 2 ft. 4 in. at the top, built entirely of concrete, and rendered on inside with neat Portland cement $\frac{3}{4}$ in. thick.

Piers, 10, each 4 ft. by 3 ft. 8 in. of concrete.

Rest blocks of concrete $2\frac{1}{2}$ ft. long, 18 in. wide, 6 in. thick.

Backing composed of sand.

Cone, concreted over surface, 18 in. thick, and rendered with neat cement $\frac{3}{4}$ in. thick.

Centre pillar, 4 ft. square, 8 ft. high.

Concrete, Portland cement, 1 part; sand, gravel, old retorts, and clinkers, 5 parts.

Diameter, 184 ft. Depth, 47 ft.

Wall, 5 ft. thick at bottom, tapering on outside to 2 ft. 3 in. at top, built entirely of concrete, and rendered on inside with neat Portland cement $\frac{3}{4}$ in. thick.

Piers, 20, each 8 ft. thick, of concrete.

Rest blocks of concrete, 6 ft. long.

Puddle, none.

Cone, concreted over surface, 12 in. thick, and rendered with neat cement $\frac{3}{4}$ in. thick.

Centre pillar, hollow, external diameter, 14 ft.; internal ditto, 10 ft.

Concrete, Portland cement, 1 part; gravel, sand, ballast, burnt clay, old retorts, and clinkers, 7 parts.

Dry well, 10 ft. diameter, 53 ft. deep, built of concrete 2 ft. thick, and rendered outside with neat cement.

STONE TANK.

Diameter, 89 ft. Depth, 20 ft.

Footings, 2 courses. First course composed of stones at least 3 ft. 6 in. square and 9 in. thick; second course, 3 ft. square, 9 in. thick, breaking joint at least 1 ft. on vertical joint. |

Wall, to underneath coping, built of stones not less than 16 in. on the inner face, dressed to the proper radius; no stone having less than 10 in. of a square joint, nor less than 18 in. on the bed, and 5 in. thick. Walling carried out in horizontal courses throughout the circumference of the tank, and backed-up with good strong random. Two throughs to every superficial yard. Thickness of wall at base, random included, 2 ft. 8 in., gradually diminishing to 1 ft. 8 in. at top.

Coping of stones, 1 ft. 11 in. broad, 8 in. thick, and not less than 3 ft. 6 in. long, dressed to the proper radius, and laid in cement.

Piers, 9, bound-in and built-up along with the tank wall; a through of entire size every vertical yard, and capped with a solid cover 3 ft. 6 in. square, 15 in. thick, having 4 holes for foundation bolts of columns.

Rest or bearing stones, 18, throughs 2 ft. wide and 1 ft. thick built-in along with wall footings, and projecting 1 ft. 9 in. into the tank.

Mound or cone in bottom of tank, covered with puddle to the depth of 24 in., its base flagged with a course of yard flags 4 in. thick, the remainder pitched with dry rubble.

Pillar in centre of tank, capped with a solid stone 4 ft. square, 15 in. thick.

Mortar, lias lime, one-third; sharp clean sand, two-thirds.

STEEL TANKS.

Diameter, 72 ft. Depth, 18 ft. 9 in.

Plates, mild steel, bottom or floor plates $\frac{1}{4}$ in. thick; sides, four rings; bottom ring, $\frac{5}{16}$ in.; second ring, $\frac{5}{16}$ in.; and two top rows, $\frac{1}{4}$ in.

Curbs, bottom curb securing sides and bottom, of angle-steel, 4 in. by 4 in. by $\frac{1}{2}$ in. Top curb, 5 in. by 4 in. by $\frac{1}{2}$ in.

Guides, 16 in number, 6 in. by 3 in. by $\frac{3}{8}$ in. channel-steel.

Lap of plates, horizontal lap $2\frac{1}{4}$ in., $\frac{3}{4}$ in. rivets, 2 in. pitch.

Vertical joints to overlap $3\frac{5}{8}$ in., and to be double riveted.

Diameter, 102 ft. Depth, 20 ft. 3 in.

Plates, mild steel, bottom or floor plates. Outer row, $\frac{7}{16}$ in.

Thick; inner rows, $\frac{3}{8}$ in. thick. Sides, five rings; bottom ring, $\frac{1}{2}$ in. thick; next two rings, $\frac{7}{16}$ in.; top rings, $\frac{3}{8}$ in. thick.

Curbs, bottom curb securing sides and bottom, of angle-steel, 4 in. by 4 in. by $\frac{5}{8}$ in. Top curb, $3\frac{1}{2}$ in. by $3\frac{1}{2}$ in. by $\frac{5}{8}$ in. angle-steel. Top of tank finished with a $\frac{1}{2}$ in. steel plate riveted to standards and top curb, and curved to radius of tank.

Guide bars, 24 in number, 6 in. by 3 in. by 3 in. by $\frac{3}{8}$ in. channel-steel.

Lap of plates, $2\frac{1}{4}$ in., $\frac{3}{4}$ in. rivets, 2 in. pitch. Vertical joints to overlap $4\frac{1}{2}$ in., and to be double riveted.

Diameter, 140 ft. Depth, 26 ft. 9 in.

Plates, mild steel, bottom or floor plates. Outer row, $\frac{5}{8}$ in. thick; inner rows, $\frac{3}{8}$ in. thick. Sides, six rings; bottom ring, $\frac{3}{4}$ in. thick; second ring, $\frac{5}{8}$ in. thick; third ring, $\frac{1}{2}$ in. thick; fourth ring, $\frac{7}{16}$ in. thick; two top rings, $\frac{3}{8}$ in. thick each.

Curbs, bottom curb securing sides and bottom, of angle-steel, 5 in. by 5 in. by $\frac{5}{8}$ in. Top curb, 5 in. by 5 in. by $\frac{3}{8}$ in. angle-steel. Three intermediate curbs or belts of angle-steel, the top belt 5 in. by 3 in. by $\frac{3}{8}$ in., the two lower ones 5 in. by 3 in. by $\frac{1}{2}$ in. Top of tank finished with a platform formed with the top curb, an outer row of $3\frac{1}{2}$ in. by 3 in. by $\frac{3}{8}$ in. angle-steel, and $\frac{1}{4}$ in. chequered plate, the whole secured to standards and to intermediate brackets bolted to the side of tank.

Tank guides, 32 in number. Main guides, $6\frac{1}{4}$ in. by $\frac{5}{8}$ in. channel-steel; intermediate guides, 6 in. by 3 in. by $\frac{1}{2}$ in. channel-steel. All plates lap-jointed $2\frac{1}{4}$ in. riveted with $\frac{3}{4}$ in. rivets, except vertical joints of side plates, three top rows of which lap $4\frac{1}{2}$ in., and double riveted with $\frac{3}{4}$ in. rivets, next two rows lap $4\frac{5}{8}$ in., and double riveted with $\frac{7}{8}$ in. rivets. The vertical joints of bottom row of plates covered with a cover plate 9 in. by $\frac{7}{8}$ in. double riveted on both sides of joint with $\frac{7}{8}$ in. rivets.

ANNULAR OR RING TANKS.

Wrought-Iron.

Diameter, 127 ft. Depth, 20 ft. 8 in.

Annular space, 3 ft. 9 in. wide.

Plates, bottom or ring plates $\frac{1}{2}$ in. thick; sides 5 rows deep; first and second row of plates from bottom $\frac{1}{2}$ in. thick; third and fourth rows $\frac{7}{16}$ in. thick, and the fifth or top row $\frac{3}{8}$ in. thick; lap of plates, 3 in.; the top of inner row of plates being 8 in. lower than the outer row; angle-iron curbs in bottom, 4 in. by 4 in., by $\frac{5}{8}$ in. thick; the $\frac{1}{2}$ in. and $\frac{7}{16}$ in. plates riveted with $\frac{7}{8}$ in. rivets, $2\frac{1}{2}$ in. apart, and the $\frac{3}{8}$ in. plates by $\frac{3}{4}$ in. rivets, 2 in. apart,

Curbs, top outer curb of angle-iron 5 in. by 5 in. by $\frac{1}{2}$ in. ; top inner curb of angle-iron 3 in. by 3 in. by $\frac{1}{2}$ in. ; both riveted with $\frac{3}{4}$ in. rivets, 6 in. apart.

Standards, 18, box form, 15 in. by 9 in., of $\frac{3}{8}$ in. plates on three sides, 3 in. by 3 in. by $\frac{1}{2}$ in. angle-iron to secure the same to side sheets, and extending round the bottom of the standard at its lower end, and 5 in. by 5 in. by $\frac{5}{8}$ in. angle-iron round the top to form a base for the columns, all riveted at 6 in. apart with $\frac{3}{4}$ in. rivets. Two of these standards form the inlet and outlet pipes, for which purpose they are continued under the annular space and up the inside of the inner ring of side sheets, and riveted with $\frac{3}{4}$ in. rivets as before, but only 2 in. apart.

THE GASHOLDER.

The holder or floating vessel (Fig. 122) is the storage reservoir for the gas, and it serves the all-important purpose of equalizing the distribution of the gas under pressure, and ensures an unbroken continuity of supply so long as any gas remains in it. In form it is invariably cylindrical like a beaker, inverted, and works freely up and down in the tank. To keep it in the true vertical position, carriages are fixed on the top and bottom of the vessel, and these carry rollers which work in or against guide-rails attached to the tank sides and to the columns or standards.

The holder may be either single (Fig. 122) or telescopic (Fig. 123) in two or more lifts. When it is made in the telescopic form, its capacity is nearly double or treble or quadruple (as the case may be) the capacity of the single-lift holder for equal dimensions of tank. Ground space and capital are thus economized by its adoption.

Telescopic holders require great care in construction and working—first, to ensure accuracy in the “cupping” of the water-lute or seal (composed of cup and grip), and, second, to prevent the water in the lute from freezing, which endangers the action of the vessel, or causes distortion, and imperils the lighting of the district.

Holders, whether single or telescopic, are counterbalanced or not, as is found desirable or necessary. Counterbalance weights are not required where an exhauster on the one hand and a governor

on the other are employed, as is the case in all but the very smallest works. In the latter, when the diameter and depth of the holder nearly approximate, it will generally be found of advantage to reduce the pressure by counterbalancing.

The crown or roof of a holder may be either trussed (Fig. 122) or untrussed (Fig. 123). In the latter case the top curb, being without radiating struts, requires to be made sufficiently strong to resist the pressure of the gas exerted on the underside of the roof which tends to distort the curb. A framework of wood or iron is required to be erected within the tank to support the untrussed roof when the holder is empty of gas and resting on the landing stones.

The usual rise given to the roof or crown of a holder is 5 per cent. or one-twentieth of the diameter.

The trussing of a holder is in principle precisely similar to that of the roof of a building. It consists of a crown plate with king post or centre pillar, having the main T-rafters radiating therefrom to the

top curb, usually angle-steel of strong section, these being braced with main and secondary tie-rods and struts; secondary rafters extending from the curb to about two-thirds of the radius, and all braced together with angle or flat steel purlins; the whole when complete somewhat resembling a spider's web. Opposite each column, and intermediately, are vertical stays reaching from the top to the bottom curb and secured thereto.

The top and bottom curbs of a holder are its most important members, and should be carefully designed, both as regards their strength and form, to resist the strains to which they are subjected.

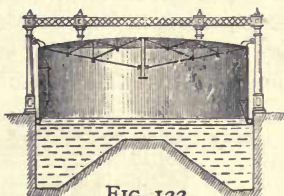


FIG. 122.

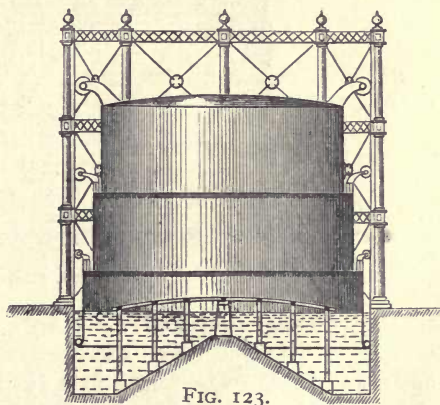


FIG. 123.

The lower guide-framing of a holder consists of a series of channel-irons secured by Lewis bolts to the sides of the tank, one in a vertical line with each column or standard, and one intermediately, in which the rollers, held by carriages attached to the bottom curb, revolve. In the case of telescopic holders, each outer lift also carries channel guides attached to the curbs, top and bottom, to receive the rollers of the corresponding inner lifts.

The upper guide-framing may either be composed of cast-iron columns or wrought-iron or steel standards, with back and front members braced together by lattice bars, and having a channel or tee-iron guide in front, within or upon which the guide rollers

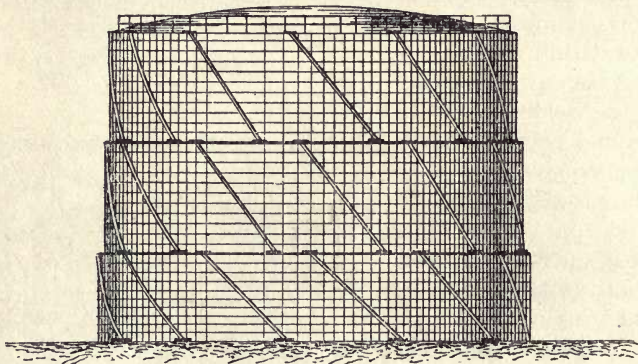


FIG. 124.

revolve. Tangential rollers are also sometimes applied to vessels of large size. The roller carriages are attached to the top curb and roof plates (which are made thicker at these points), and, in the case of telescopic holders, to the top of the grip.

The cast-iron columns or wrought-iron or steel standards are braced together by a series of wrought-iron or steel girders at the upper end (Fig. 122), and also intermediately in the case of telescopic holders (Fig. 123). Diagonal wind ties of round or flat wrought-iron are also employed to give rigidity to the framing when the columns or standards are of considerable height (Fig. 123).

Gasholders with the upper Guide-Framing either partially or wholly dispensed with.—Sir George Livesey first introduced at Rotherhithe the method of carrying the upper lift of a three-lift holder beyond the guide-framing, the only additions made

in this case being the replacing of the channel guides with H-iron to furnish paths for the combined radial and tangential rollers on the grips of the middle and outer lifts. He further extended this principle at East Greenwich, where the two upper lifts of the large holders rise above the guide-framing.

The spiral-guided gas-holder (Fig. 124) in which the elevated guide framing is dispensed with is the invention of Mr. W. Gadd; it was first erected at Northwich, Cheshire, in 1890, and is now being largely adopted.

Various improvements have been made on the original construction, principally in connection with the guiding arrangement.

In the Northwich gas-holder the guide rails and rollers were fixed to the side sheeting inside the holder. This has been superseded by outside rails and rollers; and the rails instead of being attached to the side sheets, are fixed to one continuous diagonal plate, thus forming a perfectly level and true course.

The rollers are arranged on the dips of each lift and round the tank wall radially with the side of the vessel; and as they work in the guide rails, which are attached to the diagonal plate, the floating vessel rises and descends in the tank with a helical or screw-like motion.

This type of gasholder, if properly constructed, has proved itself, beyond doubt, to be a safe structure even under the most inclement conditions. There is less liability to oscillation and tilting than with the ordinary type, owing to the construction of the

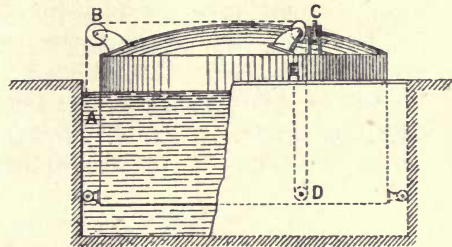


FIG. 125.

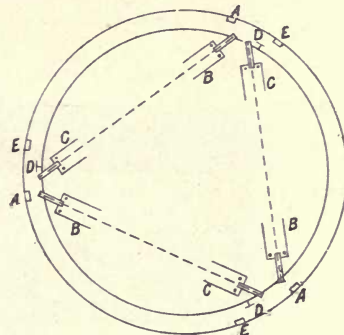


FIG. 126.

guides and rollers. Attention, however, should be given to the efficient lubrication of the roller bearings. Any want of care in this direction is liable to cause the holder to bind.

Mr. E. Lloyd Pease in his ingenious arrangement of wire ropes and pulleys also dispenses with the upper guide-framing. Figs. 125 and 126 show the principle of the arrangement when adapted to a single-lift holder.

As will be seen, three ropes at least are required. These are made of galvanized steel-wire, varying in size from half an inch upwards, according to the size of the holder. Each rope is

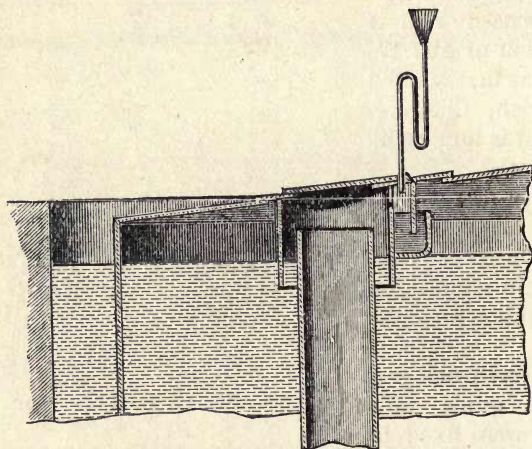


FIG. 127.

fastened, as shown, to brackets A and E on the tank, and passes over the pulleys B C D carried on the holder. The pulleys are grooved so that the rope cannot slip out of place, and small springs are used to keep the ropes at an even tension. The ropes act independently of each other, so that in case of a failure only one rope is affected.

Sir George Livesey's Hydraulic Seal (Fig. 127), for attaching to the underside of the roof of a gasholder over the inlet and outlet pipes, is an ingenious device for allowing access to the pipes without having to discharge the gas contained in the crown.

Precautions to be observed in the Working of Gas-holders.—Telescopic holders are liable in winter to be thrown out

of order by the freezing of the water in the cup between the lifts. When the lower lift is down, the upper lift in its progress downward rolls the ice and snow in the lute into lumps, often, if not removed, throwing the vessel out of the plumb, and even fracturing the columns. Great care should therefore be taken to keep the water-lute clear; and where steam can be readily applied, it is of the utmost service in accomplishing this object in time of frost. Appliances of various kinds have been devised for preventing the freezing of the water in gasholder tanks and cups, by admitting steam or hot water at intervals round the circumference of the vessel.

Another important precaution is to keep the top or crown of the holder, whether single or telescopic, clear of snow, especially when the latter is drifting. Nothing will sooner break down a holder and its guide-framing than allowing a mass of snow to collect and lie on one side of the roof.

The oscillation of a telescopic holder during strong winds is greater when uncupped than when the lifts are joined. Its liability to damage from wind is also greater when uncupped, even although less surface is presented to the wind's action.

The sheeting of a holder, being thin and the portion most liable to wear out by oxidation, should be coated outside at least once a year with good oxide of iron or other suitable paint. All rust should be removed before laying on the paint, and for this purpose the sheets should be scrubbed with a brush made of short steel wires. For removing tar a steel scraper may be employed. If coating with tar be preferred to paint, the following recipe will be found useful:—

1 gallon of tar.
 $\frac{1}{2}$ lb. of slaked lime.
 $\frac{1}{2}$ lb. of pitch.
 $\frac{1}{2}$ lb. of tallow.
 $\frac{1}{2}$ pint of coal naphtha.

Dissolve the pitch and mix the lime in the tar by heating them in a boiler, being careful not to boil them; ladle out the hot liquid into a bucket, and then add the tallow and the naphtha. Stir the mixture occasionally, and with a brush paint it on the holder before it grows cold.

It happens not unfrequently that the roof of a gasholder becomes pitted with small pinholes, from which there is a considerable and constant escape of gas. This may arise from the inferiority of the metal in the first instance, or from allowing the sheets to become oxidized before fixing; or it may be due to neglect to paint the vessel when in use. In districts where there are numerous chemical works, the impurities in the atmosphere affect the sheets in this manner. The leaks may be stopped by coating the roof with hot tar, and riddling dry sand or cement over it through a sieve, at the same time rubbing the mixture well in with a stiff brush.

To ascertain, by the following Table, the Pressure which a Gasholder will give, the Diameter and Weight being known.

RULE.—Divide the weight in lbs. of the gasholder by the weight given opposite to the diameter.

EXAMPLE.—What pressure will a gasholder give whose weight is 32,075 lbs., and diameter 56 feet ?

$$32,075 \div 1283 = \frac{25}{10}, \text{ maximum pressure of gasholder.}$$

The figures given in the following table are based on the weight of a cubic foot of water—viz., 62.5 lbs.; a column of water $\frac{1}{10}$ in. high, with an area of 1 sq. ft., being 0.52083 lbs., or the 120th part.

Thus, if the area of the holder in feet (obtained by squaring the diameter and multiplying by 0.7854) be multiplied by 62.5, the weight of a cubic foot of water in lbs., and divided by 120, the number of 10ths of an inch in a foot, the product will be the weight of the holder in lbs. for each 10th of an inch maximum pressure.

Or thus: The area of a circle is to the square of its diameter as 0.7854 is to 1; hence the weight of a gasholder in lbs., to give $\frac{1}{10}$ of an inch pressure, is to the square of its diameter in feet as 0.52083 \times 0.7854 is to unity; or, which is the same thing, as 0.4091 is to unity. So to ascertain the weight of a holder, say, 100 ft. diameter, giving a maximum pressure of $\frac{25}{10}$ —

$$100^2 \times 35 \times 0.4091 = 143,185 \text{ lbs., weight of gasholder.}$$

TABLE OF THE WEIGHTS OF GASHOLDERS

In pounds for every One-Tenth of an Inch Maximum Pressure, and from 20 to 200 Feet in Diameter.

Diameter of Gas-holder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.
20	164	53	1149	86	8026	119	5798
21	181	54	1193	87	8097	120	5891
22	198	55	1238	88	8168	121	5990
23	217	56	1283	89	8241	122	6089
24	236	57	1329	90	8314	123	6189
25	256	58	1376	91	8388	124	6290
26	277	59	1424	92	8463	125	6392
27	298	60	1473	93	8538	126	6495
28	321	61	1522	94	8615	127	6598
29	344	62	1573	95	8692	128	6703
30	368	63	1624	96	8770	129	6808
31	393	64	1676	97	8849	130	6914
32	419	65	1729	98	8929	131	7021
33	446	66	1782	99	4010	132	7128
34	473	67	1837	100	4091	133	7237
35	501	68	1892	101	4173	134	7346
36	530	69	1948	102	4256	135	7456
37	560	70	2005	103	4340	136	7567
38	591	71	2062	104	4425	137	7678
39	622	72	2121	105	4510	138	7791
40	655	73	2180	106	4597	139	7904
41	688	74	2240	107	4684	140	8018
42	722	75	2301	108	4772	141	8133
43	757	76	2363	109	4861	142	8249
44	792	77	2426	110	4950	143	8366
45	828	78	2489	111	5041	144	8483
46	866	79	2553	112	5132	145	8601
47	904	80	2618	113	5224	146	8720
48	943	81	2684	114	5317	147	8840
49	982	82	2751	115	5410	148	8961
50	1023	83	2818	116	5505	149	9083
51	1064	84	2887	117	5600	150	9205
52	1106	85	2956	118	5696	200	16,364

To ascertain the Weight of a Gasholder by the above Table, the Diameter and Maximum Pressure being known.

RULE.—Multiply the number of lbs. standing opposite to the diameter by the pressure in tenths of an inch.

EXAMPLE.—What is the weight of a gasholder 78 ft. in diameter, giving a maximum pressure of $\frac{32}{10}$ ths ?

$$2489 \times 32 = 79,648 \text{ lbs., weight of gasholder.}$$

Gasholder Capacity.—The holder or holders should be of capacity sufficient to contain at least the twenty-four hours' maximum production of gas. An excess in capacity, though not absolutely necessary, is found advantageous in point of convenience and economy, where the rate of consumption is liable to fluctuations by the non-lighting of the public lamps during the hours of moonlight, and where, as in manufacturing towns and districts, the large manufactories, generally the heaviest gas consumers, being closed on Saturday nights and Sundays, the production for these two days (unless Sunday labour is partially avoided) is greatly in excess of the consumption.

There can be no doubt, also, that abundant gasholder capacity tends to convenience, and, what is of greater importance, to economy in gas manufacture, especially when, as is now frequently the case, a setting of eight and nine through retorts, heated by one furnace, embraces as many as 16 or 18 mouthpieces. Unless the storage capacity is very ample, it is a matter of difficulty either to start or to let down so many mouthpieces at once.

DIMENSIONS OF THE PRINCIPAL MATERIALS IN GASHOLDERS IN ACTUAL WORKING.

Single Gasholder.

Diameter, 35 ft. Depth, 12 ft.

Roof sheets, No. 15 B. wire gauge.

Side sheets, No. 16 B. wire gauge.

Crown plate, 3 ft. 6 in. diam., $\frac{3}{8}$ in. thick.

4 main and 4 secondary bars, of 3 in. T-iron.

Top and bottom curbs, of 3 in. angle-iron.

4 columns, 13 ft. 6 in. long; diam. at base, 6 in.; at top,
5½ in.

4 holding-down bolts to each column, 4 ft. long, 1 in. round iron.

Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 40 ft. Depth, 15 ft.

Crown plate, 3 ft. 5 in. diam., $\frac{3}{8}$ in. thick.

Roof sheets, No 14 B. wire gauge.

Side sheets, top and bottom tiers, No. 14 B. wire gauge ; all the rest, No. 15 B. wire gauge.

Rivets for sheets, $\frac{1}{4}$ in. diam., 1 in. apart, centre to centre.

Rivets for top curb, $\frac{1}{2}$ in. diam., $1\frac{1}{2}$ in. apart, centre to centre.

Rivets for bottom curb, $\frac{1}{2}$ in. diam., 6 in. apart, centre to centre.

Centre pipe of cast-iron, 6 ft. long, 4 in. diam.

Truss cup, cast-iron, 2 ft. 6 in. diam.

12 main bars, T-iron, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in.

4 vertical stays, T-iron, 3 by $2\frac{1}{2}$ by $\frac{3}{8}$ in.

Top curb, angle-iron, 3 by 3 by $\frac{3}{8}$ in.

Bottom curb, angle-iron, 3 by 3 by $\frac{3}{8}$ in.

4 columns, 17 ft. long ; diam. at base, 9 in. ; diam. at top, 7 in.

3 holding-down bolts to each column, 7 ft. long each, $1\frac{1}{4}$ in. diam.

Girders of T-iron, 3 by 4 by $\frac{1}{2}$ in., trussed.

Balance-weights, 40 cwt. ; $\frac{1}{2}$ -in. chains.

Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 44 ft. 6 in. Depth, 20 ft.

Rise of crown, 1 ft. 9 in.

Crown plate, 3 ft. 6 in. diam., $\frac{3}{8}$ in. thick.

Roof-sheets, inner and outer circles, No. 12 B. wire gauge ; all the rest, No. 14.

Side sheets, top and bottom tiers, No. 12 B. wire gauge ; the rest, No. 17.

Rivets for Nos. 12 and 14 sheets, $\frac{5}{16}$ in. diam. ; for No. 16 sheets, $\frac{1}{4}$ in. diam.

5 main and 5 secondary bearing bars, of T-iron, 3 by 3 by $\frac{3}{8}$ in.

5 columns, 22 ft. long, 7 in. diam. at base, $5\frac{3}{4}$ in. diam. at top ; metal $\frac{1}{16}$ thick.

4 holding-down bolts, 16 ft. long, $1\frac{1}{4}$ in. square-iron.

Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 50 ft. Depth, 16 ft.

Rise of crown, 2 ft. 6 in.

Crown plate, 3 ft. diam., $\frac{1}{4}$ in. thick.

Roof sheets, inner and outer circles, No 12 B. wire gauge ; all the others, No. 14.

Side sheets, top and bottom tiers, No. 14 B. wire gauge ; the others, No. 16.

Rivets, $\frac{1}{4}$ in. diam., 1 in. apart, centres.

Rivets for joining sheets to angle-iron, $\frac{3}{8}$ in. diam., $1\frac{1}{2}$ in. apart, centres.

Rivets for bottom curb, $\frac{1}{2}$ in. diam., 9 in. apart, centres.

10 main and 10 secondary rafters, of T-iron, 3 by 3 by $\frac{3}{8}$ in.

Top curb, of angle-iron, 2 by 3 by $\frac{3}{8}$ in.

Bottom curb, two rings of angle-iron, 3 by 3 by $\frac{3}{8}$ in., 6 in. apart, with flat bar of iron, 6 in. wide and $\frac{1}{2}$ in. thick, between them.

Centre strut, cast-iron pipe, 9 ft. long, 6 in. external diam., $\frac{3}{4}$ in. thick ; bearing flanges, 13 in. diam., $1\frac{1}{4}$ in. thick ; outer ring of cup strengthened by a ring of S C and crown-iron, 2 by 1 in., shrunk on hot.

10 vertical ribs, T-iron, 3 by 3 by $\frac{3}{8}$ in., secured to top and bottom curbs and to side sheets.

5 columns, 18 ft. long ; diam. at base, 7 in. ; diam. at top, 5 in. ; metal, $\frac{3}{4}$ in. thick.

Suspension chains, $\frac{1}{2}$ in. short link, tested to 5 tons.

Inlet and outlet pipes, 10 in. diam.

Single Gasholder.

Diameter, 50 ft. Depth, 20 ft.

Rise of crown, 12 in.

Roof sheets, No. 14 B. wire gauge.

Side sheets, No. 15 B. wire gauge.

Rivets, 1 in. apart, centres.

Top and bottom curbs, 3 in. angle-iron.

6 vertical bars.

6 columns, 22 ft. long, cast in two lengths each ; 12 in. diam. at base, 6 in. diam. at top.

Inlet pipe and outlet pipes, 10 in. diam.

Single Gasholder.

Diameter, 60 ft. Depth, 17 ft.

Rise of crown, 3 ft.

Crown plate, 4 ft. diam., $\frac{1}{2}$ in. thick.

Roof sheets, inner and outer circles, No. 13 B. wire gauge ;
the rest, No. 14.

Side sheets, top and bottom tiers, No. 14 B. wire gauge ; the
rest, No. 15.

Top curb, 4 by 4 by $\frac{7}{16}$ in. angle-iron.

Bottom curb, two bars of 3 by 3 by $\frac{3}{8}$ in. angle-iron, placed
back to back, and bar of flat-iron riveted to the bottom
with $\frac{3}{8}$ in. rivets.

16 vertical bars, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in. T-iron, riveted to top and
bottom curbs and to side sheets.

8 columns, 18 ft. long ; diam. at base, $6\frac{3}{8}$ in. ; at top, $5\frac{1}{2}$ in. ;
metal, $\frac{3}{4}$ in. thick.

Inlet and outlet pipes, 12 in. diam.

Single Gasholder.

Diameter, 60 ft. Depth, 18 ft.

Roof sheets, inner and outer circles, No. 13 B. wire gauge ;
the others, No. 14.

Side sheets, top and bottom tiers, No. 14 B. wire gauge ; the
others, No. 15.

Top curb, 4 by 4 by $\frac{1}{2}$ in. angle-iron.

Bottom curb, formed of two bars of angle-iron, 4 by 4 by $\frac{1}{2}$ in.,
riveted back to back with $\frac{1}{2}$ in. rivets, 12 in. apart, centres.

14 vertical bars, 4 by 3 by $\frac{1}{2}$ in. T-iron.

7 columns, 19 ft. 6 in. long each.

Inlet and outlet pipes, 12 in. diam.

Single Gasholder.

Diameter, 81 ft. 8 in. Depth, 20 ft. 6 in.

Rise of crown, 3 ft.

Crown plate, 4 ft. diam., $\frac{1}{2}$ in. thick.

Roof sheets, inner and outer circles, No. 10 ; all the rest, No.
14 B. wire gauge.

Side sheets, top and bottom tiers, No. 14 ; all the rest, No. 16
B. wire gauge.

Rivets, $\frac{1}{4}$ in. diam., 1 in. apart, centres.

16 main rafters, 5 by 3 by $\frac{1}{2}$ in. T-iron.

16 secondary rafters, 4 by $\frac{1}{2}$ in. flat-iron, placed on edge.

Centre strut cast-iron pipe, 9 ft. long, 7 in. external diam., 1 in. thick; flanges, 13 in. diam., $1\frac{1}{4}$ in. thick; cup strengthened by a hoop, 2 by 1 in. S C iron, shrunk on hot.

Tension rods, long Queen bolts, short Queen bolts, long suspenders, short suspenders, 16 in number each, of $1\frac{3}{4}$ in., $1\frac{1}{2}$ in., $1\frac{1}{4}$ in., 1 in., and $\frac{7}{8}$ in. round-iron respectively.

Top curb, of angle-iron, 4 by 4 by $\frac{1}{2}$ in.

Bottom curb, of angle-iron, 4 by 4 by $\frac{1}{2}$ in., with bar of flat-iron, 6 by $\frac{1}{2}$ in. between, and riveted with $\frac{5}{8}$ in. rivets, 12 in. apart.

12 vertical bars, 4 by 3 by $\frac{1}{2}$ in. T-iron.

Inlet and outlet pipes, 14 in. diam.

Single Gasholder.

Diameter, 87 ft. Depth, 20 ft.

Rise of crown, 4 ft.

2 crown plates, 4 ft. diam., $\frac{1}{2}$ in. thick.

Roof sheets, inner and outer circles, No. 12; the rest, No. 14

B. wire gauge, except 9 sheets upon which the sliding carriages are fixed, No. 7 B. wire gauge.

Side sheets, top and bottom tiers, No. 12; all the remainder,

No. 14 B. wire gauge.

Rivets, $\frac{5}{16}$ in. diam., 1 in. apart, centres.

Centre pipe of wrought-iron, 12 ft. long, 12 in. diameter.

Truss cup, wrought-iron, 3 ft. diam., $\frac{3}{4}$ in. thick.

18 main bars, T-iron, 4 by 3 by $\frac{1}{2}$ in.

18 secondary bars, T-iron, 3 by 3 by $\frac{1}{2}$ in.

9 rings or purlins of bracket bars, the middle purlin of angle iron $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ in., the remainder of flat-iron, 2 by $\frac{1}{2}$ in., secured to main and secondary bars with $\frac{5}{8}$ in. bolts.

18 principal tension rods, $1\frac{1}{4}$ in. diam.

36 diagonal tension rods, $\frac{7}{8}$ in. diam.

36 truss bars; 18 of $1\frac{1}{2}$ in. diam., 18 of $1\frac{1}{4}$ in. diam.

Top curb, 2 rings of angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{3}{8}$ in.

Bottom curb, 2 rings of angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{3}{8}$ in.

18 vertical truss bars, T-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ in.

9 columns, 22 ft. long each, 14 in. diam. at base, 11 in. at top.

4 holding-down bolts, 8 ft. long, $1\frac{1}{2}$ in. diam.

Inlet and outlet pipes, 16 in. diam.

Single Gasholder.

Diameter, 100 ft. Depth, 20 ft.

Rise of crown, 5 ft.

2 crown plates, 5 ft. diam., $\frac{5}{8}$ in. thick.

Roof sheets, inner and outer circles, No. 10; the remainder,

No. 12 B. wire gauge, except carriage sheets, $\frac{1}{4}$ in. thick.

Side sheets, top and bottom tiers, No. 9; the remainder, No. 12 B. wire gauge.

Rivets, $\frac{5}{16}$ in. diam., 1 in. apart, centres.

Centre pipe of wrought-iron, 14 ft. long, 24 in. diam., $\frac{5}{16}$ in. thick.

18 main and 18 secondary bars.

Top curb, 2 rings of angle-iron, 4 by 4 by $\frac{7}{16}$ in.

Bottom curb, 2 rings of angle-iron, 4 by 4 by $\frac{7}{16}$ in., and a flat bar of wrought-iron, 6 by $\frac{3}{8}$ in.

18 vertical bars, T-iron, 4 by 4 by $\frac{3}{8}$ in.

9 columns, 24 ft. long, 24 in. diam. at base, 18 in. diam. at top, $1\frac{1}{4}$ to 1 in. metals.

4 holding-down bolts, 8 ft. long, $1\frac{1}{2}$ in. diam.

Inlet and outlet pipes, 18 in. diam.

Single Gasholder.

Diameter, 110 ft. Depth, 26 ft.

Rise of crown, 5 ft. 6 in.

Crown plates, 4 ft. diam.; $\frac{3}{8}$ in. thick.

Roof sheets, row next centre and outer row next curb, $\frac{1}{4}$ in. thick; second row from centre, $\frac{1}{8}$ in. thick; and second row next curb, $\frac{3}{16}$ in. thick; the remainder, No. 12 B. wire gauge.

Side sheets, top and bottom rows, $\frac{1}{2}$ in. thick; next row to each, $\frac{3}{16}$ in. thick; the remainder, No. 12 B. wire gauge.

Rivets, $\frac{1}{4}$ in. and $\frac{3}{16}$ in. plates, $\frac{3}{8}$ in. rivets, 2 in. centres; the $\frac{1}{8}$ in. and No. 12 B. wire gauge sheets, $\frac{5}{16}$ in. rivets $1\frac{1}{2}$ in. centres; $\frac{1}{4}$ in. plates and curb, $\frac{5}{8}$ in. rivets, 2 in. centres.

Top curb of 2 angle-irons, 5 by 4 by $\frac{1}{2}$ in.

Bottom curb of 2 angle-irons, 4 by 4 by $\frac{1}{2}$ in.

Vertical stays, 14, of 2 angle-irons 3 by 3 by $\frac{1}{2}$ in., and a piece of timber 12 in. by 4 in. bolted between.

Centre pipe of $\frac{1}{4}$ in. plate, 2 ft. diam.

Main rafters, 28, of T-iron 5 by 3 by $\frac{1}{2}$ in.

Purlins, of T-iron 3 by 4 by $\frac{1}{2}$ in., and remainder of angle-iron 3 by 3 by $\frac{3}{8}$ in.

Struts, 3, on main rafters $1\frac{1}{2}$ and $1\frac{1}{4}$ in. diam.

Tie-rod, principal $1\frac{5}{8}$ in. diam., second $1\frac{1}{2}$ in. diam., and third 1 in. diam.

Columns, 14, of cast-iron 1 ft. 6 in. in diam. at bottom, 1 ft. 2 in. at top; metal $\frac{7}{8}$ in. at bottom, diminishing to $\frac{5}{8}$ in. thick at top.

Holding-down bolts, 4, $1\frac{1}{2}$ in. diam., 20 ft. long.

Lattice girders, 14, 1 ft. 6 in. deep, of two frames of angle-iron, 3 by 3 by $\frac{1}{2}$ in., and braces $2\frac{1}{2}$ by $\frac{1}{4}$ in. riveted between, top and bottom of girder covered with a plate 10 in. wide by $\frac{3}{8}$ in. thick.

Inlet and outlet pipes, 20 in. diam.

Single Gasholder.

Diameter, 142 ft. Depth, 55 ft.

Roof, without trussing or framework.

Roof sheets, first, or outside circle, 3 ft. long, $\frac{3}{8}$ in. thick; rivets, $\frac{5}{8}$ in. diam., $2\frac{1}{2}$ in. apart, centres. Second circle, 3 ft. long, $\frac{1}{4}$ in. thick; rivets, $\frac{9}{16}$ in. diam., $2\frac{1}{2}$ in. apart, centres; centre sheets, forming a circle, 30 ft. diam., $\frac{1}{4}$ in. thick, butted and riveted to each other by lapping pieces, $3\frac{1}{2}$ in. wide; rivets, $\frac{9}{16}$ in. diam.; remainder of roof sheets, 5 ft. long, $\frac{3}{16}$ in. (No. 7 B. wire gauge) thick; rivets, $\frac{3}{8}$ in. diam., $1\frac{1}{4}$ in. apart, centres.

Side sheets, top and bottom tiers, $\frac{1}{4}$ in. thick; rivets, $\frac{1}{2}$ in. diam., $1\frac{1}{2}$ in. apart, centres. Intervening side sheets, No. 10 B. wire gauge; rivets, $\frac{3}{8}$ in. diam., $1\frac{1}{4}$ in. apart, centres.

Top curb, a circular chamber or girder, in section nearly rectangular; outer depth, 18 in.; inner depth, $19\frac{1}{4}$ in.; width, 2 ft. 6 in.; constructed of 4 by 4 by $\frac{1}{2}$ in. angle-iron.

Bottom curb, formed of two circles of $\frac{3}{8}$ in. boiler plates, 12 in. wide, each riveted to a circle of angle iron, 4 by 4 by $\frac{1}{2}$ in.

32 vertical stays, three sides of a rectangular figure, 12 in. wide, 10 in. deep; formed of four angle-irons 3 by 3 by $\frac{3}{8}$ in. and $\frac{1}{4}$ in. boiler-plate.

16 columns ; diam. at base, 3 ft. ; at top, 2 ft. 3 in. ; metal, $\frac{7}{8}$ in. to $\frac{3}{4}$ in. thick.
 4 holding-down bolts, 10 ft. long, $2\frac{1}{4}$ in. round-iron.
 Inlet and outlet pipes, 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter of outer lift, $44\frac{1}{2}$ ft. Depth, 16 ft.
 Diameter of inner lift, 43 ft. Depth, 16 ft.
 Rise of crown, 1 ft. 9 in.
 Crown plate, 3 ft. 6 in. diam., $\frac{3}{8}$ in. thick.
 Roof-sheets, inner and outer circles, No. 12 ; all the rest, No. 14 B. wire gauge.
 Side sheets in both lifts, top and bottom tiers, No. 12 ; all the rest No. 16 B. wire gauge.
 Rivets for Nos. 12 and 14 sheets, $\frac{5}{16}$ in. diam. ; for No. 16 sheets, $\frac{1}{4}$ in. diam.
 Cup, inner lift, formed by 2 rings of $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{5}{16}$ in. angle-iron, connected together with No. 8 plates, with side of No. 10 plate, and a ring $1\frac{1}{4}$ by $\frac{1}{2}$ in. half-round iron, riveted round.
 Grip, outer lift, the counterpart of the cup inverted.
 Main-bearing bars, T-iron, 3 by 3 by $\frac{1}{2}$ in.
 Secondary bearing bars, T-iron, 3 by 3 by $\frac{3}{8}$ in.
 6 vertical bars, inner lift, T-iron, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in.
 6 vertical bars, outer lift, T-iron, $2\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{3}{8}$ in.
 Bottom curb, angle-iron, double, 3 by 3 by $\frac{3}{8}$ in.
 6 columns, 12 in. diam. at base, 10 in. at top ; metal, 1 in. to $\frac{3}{4}$ in. thick.
 Inlet and outlet pipes, 10 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 87 ft. Depth, 20 ft.
 Diameter, inner lift, 85 ft. Depth, $20\frac{1}{2}$ ft.
 Rise of crown, 4 ft.
 2 crown plates, 4 ft. diam., $\frac{1}{2}$ in. thick.
 Roof sheets, inner and outer circles, No. 12 ; the rest, No. 14 B. wire gauge, except 9 sheets upon which the carriages are fixed, No. 7 B. wire gauge.
 Side sheets, top and bottom tiers, both lifts, No. 12 ; all the rest, No. 14 B. wire gauge.

- Rivets, $\frac{5}{16}$ in. diam., 1 in. apart, centres.
 Hydraulic cup and dip, 7 in. wide, 16 in. deep.
 Centre pipe of wrought-iron, 12 ft. long, 12 in. diam.
 Truss cup, wrought-iron, 3 ft. diam., $\frac{3}{4}$ in. thick.
 18 main bars, T-iron, 4 by 3 by $\frac{1}{2}$ in.
 18 secondary bars, T-iron, 3 by 3 by $\frac{1}{2}$ in.
 9 rings or purlins of bracket bars, the middle purlin of angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ in., the remainder of flat-iron, 2 by $\frac{1}{2}$ in., secured to main and secondary bars with $\frac{5}{8}$ in. bolts.
 18 principal tension rods, $1\frac{1}{4}$ in. diam.
 36 diagonal tension rods, $\frac{7}{8}$ in. diam.
 36 truss bars; 18 of $1\frac{1}{2}$ in. diam., 18 of $1\frac{1}{4}$ in. diam.
 Bottom curb, 2 rings of angle-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{3}{8}$ in.
 18 vertical truss bars, T-iron, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ in.
 9 columns, 41 ft. long, 30 in. diam. at base, 20 in. at top, $1\frac{1}{8}$ to $\frac{7}{8}$ in. metal, cast in 4 lengths.
 4 holding-down bolts, 8 ft. long, $1\frac{1}{2}$ in. diam.
 Inlet and outlet pipes, 18 in. diam.

Two-lift Telescopic Gasholder.

- Diameter, outer lift, 100 ft. Depth, 22 ft.
 Diameter, inner lift, 98 ft. Depth, 22 ft.
 Roof sheets, No. 11 B. wire gauge.
 Side sheets, top tier, to be No. 11; all the others, No. 12 B. wire gauge.
 Rivets, $\frac{1}{4}$ in. diam., 1 in. apart, centres.
 Hydraulic joint, 8 in. wide, 15 in. deep, No. 10 B. wire gauge; top edge of cup and bottom edge and dip bound by half-round iron 2 by 1 in. thick.
 Bottom curb, angle-iron, 4 by 1 in. at the root, and ring of bar-iron 4 by 1 in.
 12 columns, 24 in. diam. at base, 16 in. at top; metal, $1\frac{1}{2}$ to 1 in. thick.
 4 holding-down bolts, 10 ft. long, 2 in. square-iron.
 Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

- Diameter, outer lift, 102 ft. Depth, 22 ft.
 Diameter, inner lift, 100 ft. Depth, $22\frac{1}{2}$ ft.

Rise of crown, 4 ft.

Crown plate, 5 ft. diam., $\frac{5}{8}$ in. thick.

Roof sheets, first ring next centre, No. 9; next and outer rings, No. 11; all the rest, No. 12 B. wire gauge.

Side sheets, outer lift, top and bottom tiers, No. 11; all the rest, No. 13 B. wire gauge. Inner lift, top and bottom tiers, No. 13; all the rest, No. 17 B. wire gauge.

Cup and grip, 8 in. wide, 15 in. deep, of angle-iron 3 by 3 by $\frac{3}{8}$ in. plate, No. 7 B. wire gauge; edges stiffened with $1\frac{1}{2}$ by $\frac{3}{4}$ in. half-round iron; $\frac{1}{4}$ in. rivets, 6 in. apart.

10 columns, 18 in. diam. at base, 14 in. at top; metal, $1\frac{1}{4}$ to $\frac{3}{4}$ in. thick, cast in 4 lengths.

4 holding-down bolts, 8 ft. long, 2 in. square wrought-iron.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 112 ft. Depth, 26 ft.

Diameter, inner lift, 110 ft. Depth, 26 ft.

Rise of crown, 6 ft.

Roof trussed.

Roof sheets, centre plate, $\frac{1}{2}$ in. thick; next row, $\frac{1}{4}$ in.; next $\frac{3}{16}$ in.; outer row, $\frac{1}{4}$ in.; next, $\frac{3}{16}$ in.; and the intermediate 7 rows, $\frac{1}{8}$ in. thick.

Side sheets, $\frac{3}{16}$ in. thick, top and bottom rows; remainder, No. 12 B. wire gauge; the cup, 8 in. by 18 in., is formed of 2 rings of 3 by 3 by $\frac{3}{8}$ in. angle-iron, bottom and sides being $\frac{1}{4}$ in. plate, having 2 by 1 in. half-round bead at edge of plate.

Top curb, of 2 rings of angle-iron, 5 by $3\frac{1}{2}$ by $\frac{1}{2}$ in.

Bottom curb, of 2 rings of angle-iron, 5 by 3 by $\frac{1}{2}$ in., placed 9 in. apart, between which bottom roller carriages are secured.

Vertical stays, inner lift, 28, 14 of which are of 2 angle-irons 3 by 3 by $\frac{1}{2}$ in. riveted on each side to a web-plate 9 in. wide and $\frac{1}{4}$ in. thick; the remaining 14 being of T-iron 5 by $3\frac{1}{2}$ in. by $\frac{1}{2}$ in., trussed with three struts and a tie-rod.

Outer lift has 28 vertical stays of $\frac{3}{8}$ in. guard-iron 5 in. wide, against which the guide pieces on the cup slide.

Centre column, 17 ft. 6 in. long and 2 ft. diam. of wrought-iron plates $\frac{3}{8}$ in. thick, $\frac{3}{4}$ in. rivets, $2\frac{1}{2}$ in. pitch; this is secured

to the under crown plate, which is 4ft. in diam., by a ring of angle-iron 5 by 4 by $\frac{1}{2}$ in. and $\frac{3}{4}$ in. rivets; at the lower end of the column are 2 rings of angle-iron, 5 by 4 by $\frac{3}{4}$ in., placed $3\frac{1}{2}$ in. apart to form a jaw to receive ends of tension rods.

Main rafters, 14, of T-iron, 4 by 5 by $\frac{1}{2}$ in., trussed with 6 wrought-iron struts $1\frac{1}{2}$, $1\frac{1}{2}$, and $1\frac{3}{4}$ in. diam., and a $1\frac{1}{2}$ in. diam. tension rod. 14 main tie-rods of $1\frac{3}{4}$ in. round-iron, extending from curb to bottom of centre column, and suspended in two places from the main rafters with $\frac{1}{2}$ in. round rods; the main tie-rods and the tension rods have each a wrought-iron coupling box with right and left hand threads.

Secondary rafters, 14, T-iron, 3 by 5 by $\frac{1}{2}$ in., trussed as above, with four struts $1\frac{1}{2}$ and $1\frac{1}{2}$ in. diam., tension rod $1\frac{1}{4}$ in. diam. with coupling box. These rafters extend from curb to within 21 ft. of the centre of holder, the inner ends being secured to a main brace bar or purlin.

Purlins, 7 rows between side and centre. The main purlin mentioned above is $4\frac{1}{2}$ by $4\frac{1}{2}$ by $\frac{9}{16}$ in.; the one next curb, 4 by 3 by $\frac{1}{2}$ in.; and the remainder, 3 by 3 by $\frac{3}{8}$ in., all of T-iron.

Columns, 14, of cast-iron, 2 ft. 6 in. diam. at bottom, 2 ft. at top, and 55 ft. 8 in. high, surmounted with a large ball 30 in. diam., with spiked finial.

Girders, 2 rows, each 2 ft. deep and 10 in. wide, of 4 angle-irons 3 by 3 by $\frac{3}{8}$ in., with plate 10 by $\frac{3}{8}$ in. top and bottom; diagonal braces 3 by $\frac{3}{8}$ in., at the intersection of which is a cast-iron spiked ball in two halves, 17 in. diam. across spikes.

Holding-down bolts, 4, 2 in. diam., 11 ft. 6 in. long.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 120 ft. Depth, 24 ft.

Diameter, inner lift, 118 ft. Depth, 24 ft.

Rise of crown, 6 ft.

Roof untrussed, resting when down on timber framing in tank.

Roof sheets, first or outside rows, $\frac{3}{8}$ in. thick; second row, $\frac{1}{4}$ in.; third row, $\frac{3}{16}$ in.; fourth row, No. 8 B. wire gauge; crown plates, $\frac{1}{4}$ in. thick and 6 ft. in diam.; inside row, next crown plate, $\frac{3}{16}$ in.; next, No. 8 B. wire gauge; and the remaining 10 rows of intermediate sheets, No. 11 B. wire gauge.

Side sheets, inner lift, 12 courses high; top and bottom course, $\frac{1}{4}$ in. thick; second course at top, $\frac{3}{16}$ in.; and the remainder, No. 12 B. wire gauge.

Side sheets, outer lift, 12 courses high; top and bottom course, $\frac{1}{4}$ in. thick; second course at bottom, $\frac{3}{16}$ in.; and the remainder No. 12 B. wire gauge. The thicker sheets in both inner and outer lift riveted together with $\frac{3}{8}$ in. rivets, $1\frac{1}{4}$ in. apart, centres, and the others with $\frac{5}{16}$ in. rivets, $1\frac{1}{8}$ in. apart, centres.

Top curb, of 2 angle-irons, one at junction of roof with side sheets, 5 by 5 by $\frac{5}{8}$ in., and the other at the inner edge of outer row of sheets, 4 by 4 by $\frac{1}{2}$ in.; the two stiffened by gusset-pieces springing from the vertical stays.

Bottom curb, of two 5 by 4 by $\frac{5}{8}$ in. angle-irons, riveted to the outside of the lower row of sheets, with $\frac{3}{8}$ in. rivets, 6 in. apart. Between these two curbs, which are placed 2 in. apart, are fixed the 28 guide carriages and rollers.

Cup and grip formed of rolled channel-iron 8 by $3\frac{1}{2}$ by $\frac{1}{2}$ in. riveted to the side sheets and rising and dip plates, with $\frac{1}{2}$ in. rivets 4 in. apart. A half-round bead 2 by $\frac{5}{8}$ in. being riveted to edge of rising plates, which are $\frac{3}{8}$ in. thick and 18 in. deep.

Vertical stays, 28, formed of two 4 by 4 by $\frac{1}{2}$ in. angle-irons and a web-plate between, $\frac{3}{8}$ in. thick and 9 in. wide, secured with $\frac{3}{8}$ in. rivets, 6 in. apart; at the upper end of these is attached a gusset-plate with angle-iron edges 3 by 3 by $\frac{3}{8}$ in., extending to the inner angle-iron curb of roof, to which and the outer curb it is riveted.

Standards, 14, in the form of the letter T, 4 ft. 2 in. by 3 ft. at bottom, tapering to 1 ft. 9 in. each way at the top; each standard 51 ft. high. Between the angle-iron framework of the standards is cast-iron trellis work, 1 in. thick, on one of its sides, and wrought-iron lattice work on the other; the standards are secured to cast-iron hollow base-plates

6 in. deep ; 4 holding-down bolts to each standard, 11 ft. 6 in. long, $2\frac{1}{4}$ in. diam.

Lattice girders, 2 rows in the height ; first or lower row, 27 in. deep ; top row, 30 in. deep ; formed of 4 angle-irons, 3 by 3 by $\frac{1}{2}$ in., wrought-iron tension bars, 3 by $\frac{1}{2}$ in., and cast-iron struts.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 151 ft. 6 in. Depth, 40 ft.

Diameter, inner lift, 149 ft. Depth, 40 ft. 3 in.

Crown, trussed, rise 8 ft.

Roof sheets, outer row, $\frac{5}{16}$ in. ; next row, $\frac{3}{16}$ in. ; and the remainder No. 10 B. wire gauge, two centre plates $\frac{3}{4}$ in. thick and 4 ft. 6 in. diam.

Side sheets, top and bottom rows in both lifts $\frac{1}{4}$ in. thick, the remainder No. 11 B. wire gauge, $\frac{1}{4}$ in. rivets, 1 in. centre ; cup and grip 10 in. wide and 20 in. deep, Piggott's form ; plates $\frac{3}{8}$ in. thick, strengthened at edges with bead-iron.

Top curb, of 2 rings of angle-iron, 5 by 5 by $\frac{1}{2}$ in., placed one above the other ; the lower one is secured to a flat bar 10 in. wide and $\frac{1}{2}$ in. thick, which is again connected by straps 4 in. wide and $\frac{1}{2}$ in. thick to the top row of sheets.

Bottom curb, of 2 rings of angle-iron, 5 by 4 by $\frac{5}{8}$ in., riveted to the outside of the bottom row of sheets with $\frac{5}{8}$ in. rivets.

Between these two rings are fixed the bottom guide roller carriages.

Vertical stays, 32 in. top lift of H-iron 12 in. deep, and 32 in. bottom lift, of channel-iron 8 by $2\frac{1}{2}$ by $\frac{1}{2}$ in., attached to sheets, cups, and curbs with $\frac{5}{8}$ in. bolts in upper lift, and $\frac{5}{8}$ in. screwed pins in lower lift.

Centre column, 3 ft. 6 in. diam., 22 ft. long, of plates $\frac{7}{16}$ in. thick.

Roof framing, 24 main radial T-iron bars 6 by 4 by $\frac{1}{2}$ in. curved to roof, each with a main tension rod 2 in. in diam. at curb, and reduced to $1\frac{1}{2}$ in. at the foot of centre column, and having a coupling box with right and left hand threads,

4 struts and 4 tension rods form the bracing to each main bar, the former of cross-iron 4 by $4\frac{1}{2}$ by $\frac{3}{4}$ in. placed vertically, and the latter of 1, $1\frac{1}{8}$, $1\frac{1}{4}$, and $1\frac{3}{8}$ in. round-iron placed diagonally, the strongest section being nearest the centre column; 48 secondary radial bars of 4 by $\frac{1}{2}$ in. flat-iron, that is, 2 equidistant between the main radial bars, and extending from top curb towards centre, a distance of 26 ft., and then for a further distance of 16 ft., in direction of the centre, another bar of the same dimensions is fixed. 17 rings or rows of purlins, divided equally from curb to centre, are fixed between main and secondary bars; the first row from centre being of 6 by $\frac{1}{2}$ in. flat-iron; next 4 rows of angle-iron, $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{1}{4}$ in.; next row of angle-iron, 2 by 2 by $\frac{1}{4}$ in.; next row of T-iron, 3 by 6 by $\frac{1}{2}$ in.; next two rows, which are subdivided in length by the secondary radial bars above mentioned, are of angle-iron $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{1}{4}$ in.; next row extending from main bar to main bar is of I-iron 3 by 6 by $\frac{1}{2}$ in.; next two rows are divided in 3 lengths between main bars by the two secondary bars, and are of $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{1}{4}$ in. angle-iron; next row extending from main to main is of T-iron, 4 by 6 by $\frac{1}{2}$ in.; next row divided in 3 lengths as before of $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{1}{4}$ in. angle-iron, and the remaining two rows divided in 3 as before of 2 by 2 by $\frac{1}{4}$ in. angle-iron; 3 bars of flat-iron $2\frac{1}{2}$ by $\frac{3}{8}$ in. cross diagonally in each bay formed by the two main bars.

Columns, 16, of cast-iron, 83 ft. high, 3 ft. in diam. at base, and 2 ft. 8 in. at top, metal 1 in. thick; cast-iron channel guide up the column, 5 by 3 in. inside measure, weighing 56 lbs. per foot.

Girders, 16, at top 4 ft. deep, 7 in. wide, of 4 angle-irons 3 by 3 by $\frac{3}{8}$ in. and a top and bottom plate 7 in. wide by $\frac{3}{8}$ in. thick; diagonal brace bars 4 by $\frac{3}{8}$ in.; 16 intermediate girders 3 ft. 6 in. deep, 6 in. wide, of 4 angle-irons $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in., and top and bottom plates 6 in. wide by $\frac{3}{8}$ in. thick; diagonal brace bars 3 by $\frac{3}{8}$ in.; at the intersection of the brace bars a cast-iron star 12 in. in diam. is riveted.

Holding-down bolts, 4, 2 in. square and 14 ft. long.

Capacity 1,400,000 cub. ft.

Inlet and outlet pipes, 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 197 ft. 6 in. Depth, 36 ft.

Diameter, inner lift, 195 ft. Depth, 36 ft.

Crown, untrussed, rise 10 ft.

Roof sheets, centre plate $\frac{1}{4}$ in. thick, 6 ft. diam.; row next centre of No. 7 B. wire gauge; row next curb, $\frac{1}{2}$ in. thick; next row, $\frac{5}{16}$ in. thick; third row, No. 7 B. wire gauge; and the remaining rows of No. 11 B. wire gauge.

Side sheets, of inner lift in 18 rows; top row, $\frac{1}{2}$ in.; bottom row forming cup, $\frac{3}{8}$ in.; second row from top and bottom $\frac{1}{4}$ in.; third row from top and bottom of No. 7 B. wire gauge; and the 12 intermediate rows of sheets of No. 11 B. wire gauge in thickness. Those of outer lift in 18 rows; top row forming cup, $\frac{1}{4}$ in.; bottom row, $\frac{5}{16}$ in.; second from top, No. 9 B. wire gauge; second from bottom, $\frac{3}{16}$ in.; third from bottom, No. 9 B. wire gauge; and the 13 intermediate rows of No. 11 B. wire gauge in thickness.

Cup and grip, 10 in. wide, 18 in. deep, of channel-iron, 10 by $3\frac{1}{2}$ by $\frac{1}{2}$ in., rising and dip plates, $\frac{3}{8}$ in. thick, with $2\frac{1}{2}$ by $\frac{3}{4}$ in. bead riveted to edges.

Top curb of 2 angle-iron rings; outer one, 6 by 6 by $\frac{3}{4}$ in.; inner one, 5 by 5 by $\frac{5}{8}$ in., both double riveted to top and side sheets, with $\frac{3}{4}$ in. rivets, 2 in. apart, centre to centre.

Bottom curb, of 2 angle-iron rings, 6 by 5 by $\frac{5}{8}$ in., riveted to side sheets, with $\frac{5}{8}$ in. rivets, 6 in. apart.

Vertical stays, 44, in upper lift of H-iron, 8 by 5 by 5 by $\frac{7}{16}$ in., secured to top and bottom rows of sheets and the outer angle-iron curb, but not to the intermediate sheets, except just at the centre, where there are two clips, 6 in. wide by $\frac{5}{16}$ in. thick, to which the sheet is riveted. Gusset pieces, 44, of 2 angle-iron frames, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in., riveted to a $\frac{7}{16}$ in. web-plate placed between them and riveted together, and to the vertical stays, outer row of top sheets, and inner angle-iron curb with $\frac{5}{8}$ in. rivets, 4 in. pitch. Vertical stays to lower or outer lift, 44, of channel-iron, 8 by $2\frac{1}{2}$ by $\frac{1}{2}$ in., riveted to bottom curb, and to the sheets half-way up, with four $\frac{3}{4}$ in. rivets, countersunk heads in the channel, and bolted to the channel-iron of grip with two $\frac{7}{8}$ in. bolts.

Guide wheels, 22, at top lift of malleable cast-iron, 24 in. diameter, with steel axles or pins, mounted on wrought-

iron carriages, 44 fixed under cup of upper lift, 22 on grip, and 44 on bottom curb of outer lift, all of malleable cast-iron, having steel pins and wrought-iron carriages.

Columns, 22, of cast-iron, 3 ft. diam. at bottom, and 2 ft. 6 in. at top, mounted on ornamental base 4 ft. square and 9 ft. 9 in. high; two entablatures and ornamental cap; 4 holding-down bolts to each column, $2\frac{1}{4}$ in. diam.

Girders, upper tier, 3 ft. 6 in. deep; lower tier, 3 ft. deep, of two frames of angle-iron, 4 by 4 by $\frac{7}{16}$ in., with lattice bars 4 by $\frac{5}{8}$ in. riveted between them; the top, bottom, and ends of girders covered with a $\frac{3}{8}$ in. plate 9 in. wide; rivets, $\frac{3}{4}$ in., 4 in. apart, centres; at the intersection of the diagonal braces with each other are fixed plates, 12 in. diam. and $\frac{3}{8}$ in. thick.

Quality of iron, plate, angle, and T-iron of best South Staffordshire brands, the channel and H-iron of the best Belgian; the sheets of the very best South Staffordshire, equal to B. B. H. best.

Rivets, all sizes, of the best soft charcoal-iron. Those for the No. 11 B. wire gauge sheets, of No. 3 B. wire gauge in diam. and 1 in. pitch; and those for No. 7 B. wire gauge sheets, with $\frac{3}{8}$ in. rivets, $1\frac{1}{4}$ in. apart, centres.

Capacity, 2 million cub. ft.

Inlet and outlet pipes, 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 200 ft. Depth, 25 ft. 3 in.

Diameter, inner lift, 198 ft. Depth, 25 ft. 9 in.

Roof, untrussed, and flat.

Roof sheets, centre plate, $\frac{3}{4}$ in.; row next centre plate, $\frac{1}{2}$ in.; next row, $\frac{1}{3}$ in.; outer row next curb, $\frac{1}{2}$ in.; second row, $\frac{1}{4}$ in.; and the whole of the remaining rows, $\frac{1}{8}$ in. thick.

Side sheets, outer lift, bottom row, $\frac{1}{4}$ in.; next $\frac{3}{16}$ in.; top row, $\frac{3}{16}$ in.; intermediate rows all $\frac{1}{8}$ in. thick; inner lift, bottom and top rows, $\frac{3}{16}$ in. thick; remainder, $\frac{1}{8}$ in. thick.

Top curb is a box girder 3 ft. by 2 ft. of $\frac{3}{4}$ in. plates and $4\frac{1}{2}$ by $4\frac{1}{2}$ by $\frac{1}{2}$ in. angle-irons in the inside corners, riveted together.

Bottom curb, of 2 angle-irons, $4\frac{1}{2}$ by $4\frac{1}{2}$ by $\frac{1}{2}$ in. riveted to a

$\frac{3}{4}$ in. plate 8 in. wide ; the whole riveted to the lower sheet of holder.

Cup and grip formed of channel-iron 8 by 3 by 3 by $\frac{5}{8}$ in. thick ; rising and dip plates $\frac{3}{8}$ in. thick and 15 in. deep ; a $1\frac{1}{2}$ in. half-round-iron bead is riveted to edge of rising plate.

Columns, 28, 52 ft. long, 3 ft. diam. at bottom, and 2 ft. 4 in. diam. at top ; metal $1\frac{1}{4}$ in thick at bottom and 1 in. at top.

Capacity, $1\frac{1}{2}$ million cub. ft.

Inlet and outlet pipes, 30 in. diam.

Three-lift Telescopic Gasholder.

Diameter, outer lift, 214 ft. Depth, 53 ft.

Diameter, middle lift, 211 ft. Depth, 53 ft. 3 in.

Diameter, inner lift, 208 ft. Depth, 53 ft. 6 in.

Rise of crown, 14 ft.

Roof untrussed.


Roof sheets, outer row forming part of curb, $\frac{3}{4}$ in. thick of steel plates 3 ft. wide ; next row, No. 7 B. wire gauge ; then another row of No. 9 B. wire gauge ; the remainder being all of No. 10 B. wire gauge ; these latter riveted with $\frac{5}{16}$ in. rivets, 1 in. pitch ; the No. 7 B. wire gauge sheets riveted to the $\frac{3}{4}$ in. steel curb plate by $\frac{3}{4}$ in. rivets, $2\frac{1}{2}$ in. pitch.

Side sheets of No. 11 B. wire gauge, secured to each other with $\frac{5}{16}$ in. rivets, 1 in. pitch ; lap of sheets, $1\frac{1}{4}$ in. ; the bottom and top rows of sheets in outer lift are $\frac{1}{4}$ and $\frac{3}{16}$ in. thick respectively ; in the middle lift $\frac{3}{16}$ in. and in the top lift $\frac{3}{16}$ and $\frac{1}{4}$ in. respectively, being riveted to the other sheeting with $\frac{3}{8}$ in. rivets, $1\frac{1}{4}$ in. pitch, $1\frac{3}{8}$ in. lap. Piggott's cup and dip, the former of $\frac{7}{16}$ in. plate, and the latter of $\frac{3}{8}$ in. plate, secured to adjoining sheets with $\frac{5}{8}$ in. rivets $1\frac{3}{4}$ in. pitch 2 in. lap ; cup and dip 12 in. wide and 21 in. deep ; edge of cup and dip stiffened by a $2\frac{1}{2}$ by $\frac{5}{8}$ in. flat-iron.

Top curb, formed by two $\frac{3}{4}$ in. steel plates, one forming the outer row of sheets on the crown being 36 in. wide, the other forming top row of sheets on the side 12 in. wide ; these are joined together at the angle with a 5 by 5 by $\frac{3}{4}$ in.

angle-steel curb, and further stiffened at the inner edge of the crown plate with a 6 by 3 by $\frac{1}{2}$ in. angle-steel, all riveted together with $\frac{7}{8}$ in. and 1 in. steel rivets, 4 in. pitch.

Bottom curb, formed by a plate $\frac{5}{8}$ in. thick and 15 in. wide, secured at right angles to the lower rows of sheets to a 6 by 3 by $\frac{1}{2}$ in. angle-iron with $\frac{3}{4}$ in. rivets, $5\frac{1}{2}$ in. pitch; another angle-iron of the same dimensions being placed 1 ft. 5 in. higher, forming a space in which are fixed the bottom roller carriages.

Vertical stays, 48, on lower and middle lifts are made of No. 10 B. wire gauge sheets bent in the form thus  8 by $4\frac{1}{2}$ in., riveted to the outside of the sheets, and on the inside opposite these are 8 by $3\frac{1}{4}$ by $\frac{1}{2}$ in. channel-irons, placed between two 4 by 3 by $\frac{1}{4}$ in. angle-irons, which are riveted through the sheets to the outside stays. The top or inner lift is stiffened by No. 8 B. wire gauge sheets of the same form as above, but 12 by 9 in., placed inside only.

Standards, 24, in the form of the letter H, 20 by 16 in. and 158 ft. 6 in. high above coping of tank, of wrought-iron formed of four 3 by 3 by $\frac{3}{8}$ in. angle-irons. $\frac{3}{8}$ in. web-plate, and $\frac{1}{2}$ in. inside and outside plates, having 5 tiers of struts from standard to standard, and 10 sets of diagonal braces. Two channel-irons 8 by 3 by $\frac{1}{2}$ in., riveted to each other back to back and to the standards, form the guides upon which the radial and tangential rollers work; the bottoms of standards are fastened to triangular-shaped cast-iron base-plates, each secured to the tank with three $2\frac{1}{2}$ in. bolts.

Capacity, $5\frac{1}{2}$ million cub. ft.

Inlet and outlet pipes, 36 in. diam.

GOVERNORS.

An unnecessarily high pressure of gas in the mains and service pipes is synonymous with a heavy leakage account. Ordinary valves are powerless to effect the desired pressure regulation, however well they may be attended to. No gas-works, therefore, whatever its size, should be without a station governor to control the initial pressure. When properly constructed it accomplishes this important object perfectly, however much the consumption

on the one side and the density of the gas on the other may vary.

The construction of the governor is of the most simple character, consisting of a small cast-iron water-tank, through the bottom of which the gas from the regular holder enters, and makes its exit by means of a stand-pipe rising above the water-level. This pipe may be either annular or rectangular in form. In the former case the gas enters by way of the central opening, and makes its exit by the annular space. In the latter arrangement the pipe is divided into two by a mid-feather, one division being the inlet and the other the outlet for the gas; the inlet division of the pipe occupying the central position in the tank. Within the tank is a floating bell or gasholder made of tinned sheet-iron, from the crown of which a conical or parabolic-shaped valve is suspended by an eye-bolt. It is the raising and lowering of this valve within the inlet gas aperture, by reason of the gas exerting a pressure of greater or less force (according as the consumption varies) on the inner surface of the floating bell, that accomplishes the necessary regulation.

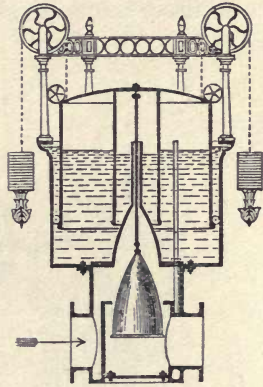


FIG. 128.

Various forms of valves have been devised with the object of allowing a gradual inflow and outflow of gas to and from the bell, namely (1) the conical or parabolic-shaped valve; (2) by a cylindrical seating with tapered perforations in which the valve moves; (3) by a plain seating with a hollow cylindrical perforated valve.

The conical valve for increasing or diminishing the area of the gas apertures has generally given place to that in the form of a parabola, the latter requiring a shorter range to produce the necessary effect, and being more delicate and certain in its action. The parabola should be made twice its diameter in length, and of weight sufficient to resist, without oscillation or blinking, whatever pressure may be exerted against it by the inflowing gas.

The holder may be balanced or buoyed up either by means of an air chamber within itself, placed round its lower curb (Fig. 132), or counterbalanced by chains and weights (Fig. 129), or it may be balanced as in Fig. 130.

The needed pressure is obtained (1) by placing cast-iron or lead weights on the crown of the holder; (2) by allowing water to flow from a feed-pipe into a tank, formed by continuing the sides of the holder a few inches above the crown; or (3) by air pressure or gas pressure from a distance.

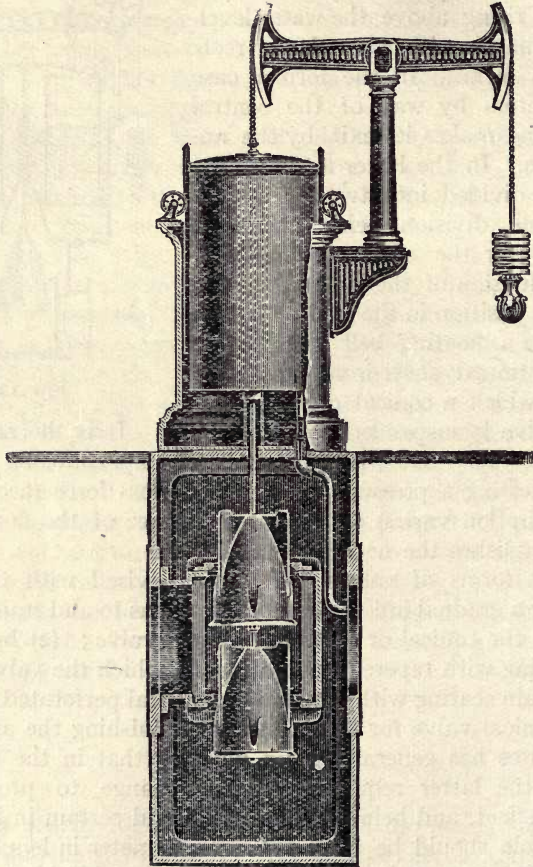


FIG. 129.

The method of weighting by water is preferable to the others, as the pressure can be applied or removed in a more gradual manner, the opening of the supply and discharge taps being regulated as desired.

A recent form of governor, by J. & J. Braddock, is shown in Fig. 129. The governor is of the counterbalance type and is specially suitable to meet the conditions of limited ground space. The two valves are arranged on the one spindle.

Another form of governor, by J. & J. Braddock, is shown in Fig. 130, which, amongst other advantages, occupies small space,

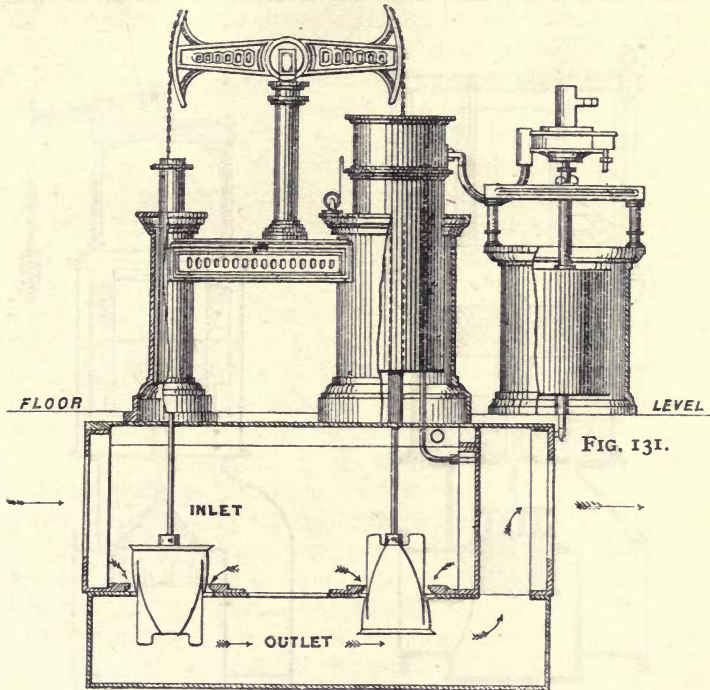


FIG. 130.

inasmuch as the usual large bell and tank are materially reduced in size. The governor has a chamber divided into two compartments, forming inlet and outlet. The two valves are connected together, counterbalance each other, and act in opposite directions. A pressure-controlling tube, open at both ends, is fitted in the top of the outlet chamber, so as to admit gas from the outlet into the bell, above the water level. As the consumption of gas decreases the pressure in the outlet chamber increases and the bell is raised,

so diminishing or shutting off, as required, the supply of gas. As the consumption of gas increases, the action is reversed.

The governor can be fitted with self-loading apparatus (Fig. 131) which automatically changes the outlet pressure, according to the demand for gas.

The governor of W. & B. Cowan is shown in Fig. 132, the adjusted pressure being maintained under all variations of draught or changes

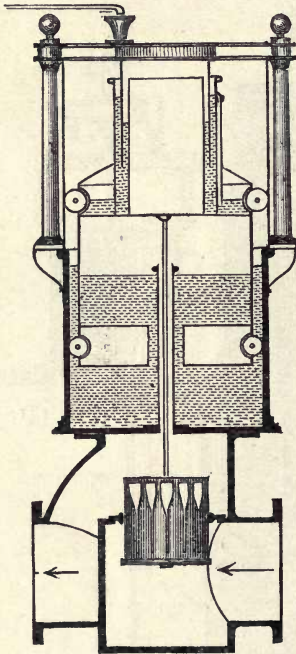


FIG. 132.

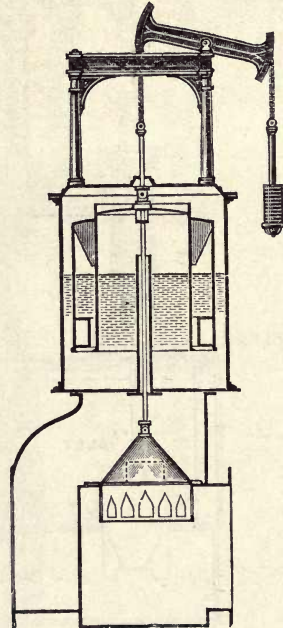


FIG. 133.

at the inlet. They have also invented an "Automatic Pressure Changer" and electric self-loading apparatus, both ingenious instruments for raising and reducing the pressure automatically at any given time, thus dispensing with the attendant.

Parkinson's equilibrium double cone governor is fitted with six columns and girders and is specially adapted for high pressures: the pressure being applied either by means of weights or water.

Peebles' governor (Fig. 133) is a compact and efficient apparatus,

with the bell enclosed, so obviating the possibility of the bell being tilted.

The inlet pressure is admitted to the top of the valve and to the underside of the central bell of equal diameter, so as to put the valve in perfect equilibrium. The governing power is obtained by the outlet pressure acting upon the interior of a concentric bell, and the area of the underside of the valve. This area gives the governor power to respond to the slightest change in the outlet pressure.

The same firm have invented a governor with double balanced valves and a large single bell. Also mercurial governors of the constant-pressure type, suitable for high or low pressures according to the seal, and to act either as station governors or district governors, particularly the latter; the method of loading being either by means of weights or air pressure from a distance.

In winter time the water in a governor tank is liable to freeze, particularly if the house containing it is in an exposed situation. A very efficient and simple remedy for this is provided by the steam stove. This is merely a cast-iron cylinder or pipe in the form of a pedestal, 2 ft. 6 in. to 3 ft. in height, and 10 or 12 in. in diameter, having a base, and an ornamental top or covering brightened by being ground and polished. The stove is placed on end on the floor of the governor room, in any convenient part, and a steam pipe about $\frac{3}{4}$ in. in diameter, with stopcock, is inserted through the bottom, in which is another stopcock for letting off the water of condensation. In time of frost, by means of this stove the atmosphere of the room can be maintained at an equable temperature, at a minimum expense. A piece of ordinary cast-iron pipe can be adapted to the purpose; on the other hand, the stove is susceptible of any amount of ornamentation.

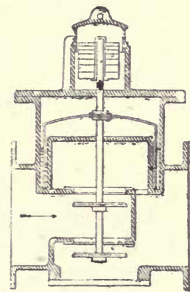


FIG. 134.

District or Differential Governors.—Gas pressure varies according to the elevation, increasing and decreasing at the rate of about $\frac{1}{10}$ of an inch for each 10 ft. of rise and fall respectively. It is thus obvious that if the pressure in the lower mains is sufficient, that in the higher mains (assuming them to be connected throughout) must be in excess.

For the supply of gas to varying levels, therefore, separate

leading mains, with a station governor upon each, are highly advantageous, and should be employed wherever practicable.

District or differential governors, for the automatic regulation of the pressure in the mains at high altitudes considerably removed from the gas-works, are also of the utmost utility. These are produced both in the wet and dry form by most makers of gas apparatus. Fig. 134 shows Peebles' mercurial governor suitable for underground mains. The loading is effected by the weights placed in the small chamber above the governor and covered by a cap, fixed with a bayonet joint.

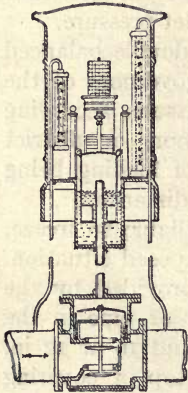


FIG. 135.

The same governor may be loaded by air pressure controlled from a distance (Fig. 135). The arrangement consists of a cast-iron pillar box, which may be fixed (say) at the side of the pavement, and containing a small air bell to which a float is attached, working in a tank partly filled with water. Weights are placed on top of the air bell and the compressed air is carried by a small pipe to the top of the governor bell.

Inlet and outlet pressure gauges are fitted, and a recording pressure gauge either for the day or week.

By doubling the amount of pressure, the consumption of gas is increased by one-half. Leakage from a pipe is, of course, increased in the same ratio—*i.e.* in the proportion of the square root of the pressure.

MAIN PIPES.

The leakage which arises in the distribution of gas is largely due to defective and badly jointed main pipes. Hence it is of the first importance to ensure that the pipes employed for that purpose are made of a good quality of metal, close in texture, free from defects of every kind, and as equal as possible in their sectional thickness.

To secure these three latter conditions, all cast-iron pipes 5 in. internal diameter and upwards should be cast vertically in dry sand moulds. Smaller sizes are usually cast in green sand and

in inclined moulds. The pipes should be tested by hydrostatic pressure equal to at least 75 lbs. on the square inch (173 ft. head of water), either at the place of manufacture or on the gas-works; and whilst under pressure they should be smartly rapped with a 3-lb. hammer from end to end. This will often reveal faults, such as sandy, porous, and blown places, not otherwise discernible. Rapping the pipes whilst on the ground will also indicate their character. If the sound emitted is clear and bell-like, the pipe may be considered free from defects. On the other hand, if dull

TABLE.

CAST-IRON GAS PIPES, WITH OPEN JOINTS.

The weight of the socket, and bead on spigot, is equal to 9-10ths of a lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Length of Socket, inside measure.	Length of Pipe, not including Socket.	Weight per Pipe, inclusive of Socket and Bead.
Inches.	Inches.	Inches.	Fect.	Cwts. qrs. lbs.
1	5-16ths	2½	6	0 1 0
1½	5-16ths	2½	6	0 1 10
2	5-16ths	3	6	0 1 22
2½	3-8ths	3	6	0 2 17
3	3-8ths	3	9	1 0 11
4	3-8ths	4	9	1 1 19
5	7-16ths	4	9	2 0 7
6	7-16ths	4	9	2 1 21
7	5-10ths	4	9	3 0 27
8	5-10ths	4	9	3 2 19
9	5-10ths	4½	9	4 0 11
10	9-16ths	4½	9	5 0 16
11	9-16ths	4½	9	5 2 14
12	5-8ths	4½	12	8 3 16
13	5-8ths	4½	12	9 2 12
14	5-8ths	4½	12	10 1 8
15	5-8ths	4½	12	11 0 4
16	11-16ths	4½	12	12 3 24
17	11-16ths	4½	12	13 2 24
18	11-16ths	4½	12	14 2 0
19	3-4ths	4½	12	16 2 24
20	3-4ths	4½	12	17 2 8
21	3-4ths	5	12	18 1 20
22	13-16ths	5	12	20 3 20
23	13-16ths	5	12	21 3 8
24	7-8ths	5	12	24 2 8
30	1	5	12	35 0 0
36	1½th	6	12	47 0 16
42	1¾ths	6	12	57 3 16
48	1½th	6	12	69 2 0

and leaden, it is cracked or otherwise imperfect. All pipes that do not stand the tests should be rejected.

The metal of pipes, whilst compact and close, should not be excessively brittle and splintery, but such as may be readily chipped and drilled.

Cast-iron pipes below 3 in. diameter are 6 ft. long; 3 in. to

TABLE.

CAST-IRON GAS PIPES, WITH TURNED AND BORED JOINTS, HAVING A RECESS IN FRONT FOR LEAD.

The weight of the socket and thickened spigot is equal to $1\frac{1}{10}$ lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Length of Socket, inside measure.	Length of Pipe, not including Socket.	Weight per Pipe, inclusive of Socket and thickened Spigot.
Inches.	Inches.	Inches.	Feet.	Cwt. qrs. lbs.
1	5-16ths	2½	6	0 1 1
1½	5-16ths	2½	6	0 1 12
2	5-16ths	3	6	0 1 24
2½	3-8ths	3	6	0 2 19
3	3-8ths	3½	9	1 0 14
4	3-8ths	4	9	1 1 22
5	7-16ths	4	9	2 0 13
6	7-16ths	4½	9	2 1 27
7	5-10ths	4½	9	3 1 8
8	5-10ths	4½	9	3 3 0
9	5-10ths	4½	9	4 0 23
10	9-16ths	4½	9	5 1 0
11	9-16ths	4½	9	5 3 1
12	5-8ths	4½	12	9 0 4
13	5-8ths	4½	12	9 3 0
14	5-8ths	4½	12	10 1 24
15	5-8ths	5	12	11 0 24
16	11-16ths	5	12	13 0 16
17	11-16ths	5½	12	13 3 20
18	11-16ths	5½	12	14 2 24
19	3-4ths	5½	12	16 3 24
20	3-4ths	5½	12	17 3 12
21	3-4ths	5½	12	18 2 24
22	13-16ths	5½	12	21 1 0
23	13-16ths	5½	12	22 0 20
24	7-8ths	5½	12	24 3 24
30	1	5½	12	35 2 4
36	1½th	6	12	47 3 16
42	1¾ths	6	12	58 3 4
48	1½th	6	12	70 2 8

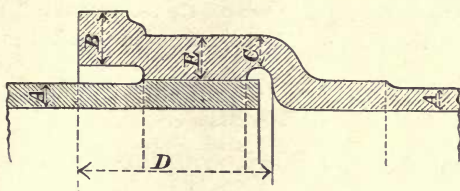


FIG. 136.

TABLE.

Dimensions of the Sockets of Turned and Bored Cast-Iron Gas Pipes, with a recess in front. (Fig. 136.)

Diameter of Pipe.	A	B	C	D	E
Inches.	Inches.	In.	In.	In.	In.
2	5-16ths	1 $\frac{3}{8}$	3	3 $\frac{1}{2}$	2
2 $\frac{1}{2}$	3-8ths	1 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	2 $\frac{1}{2}$
3	3-8ths	1 $\frac{3}{8}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3
3 $\frac{1}{2}$	3-8ths	1	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$
4	3-8ths	1 $\frac{1}{8}$	4	4	4
5	7-16ths	1 $\frac{1}{2}$	4	4	5
6	7-16ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	6
7	5-10ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	7
8	5-10ths	1 $\frac{3}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	8
9	5-10ths	1 $\frac{3}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	9
10	9-16ths	1 $\frac{7}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	10
11	9-16ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	11
12	5-8ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	12
13	5-8ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	13
14	5-8ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	14
15	5-8ths	1 $\frac{1}{8}$	5	5	15
16	11-16ths	1 $\frac{1}{2}$	5	5	16
17	11-16ths	1 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	17
18	11-16ths	1 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	18
20	3-4ths	1 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	20

TABLE.

Dimensions of the Sockets of Turned and Bored Cast-Iron Gas Pipes, without a Recess in Front. (Fig. 137.)

Diam. of Pipe.	A	B	C	D
Inches.	Inches.	Inches.	Inches.	Inches.
2	5-16ths	1 $\frac{3}{8}$	3	3
2 $\frac{1}{2}$	3-8ths	1 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$
3	3-8ths	1	3 $\frac{1}{2}$	3 $\frac{1}{2}$
3 $\frac{1}{2}$	3-8ths	1 $\frac{1}{8}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$
4	3-8ths	1 $\frac{1}{4}$	4	4
5	7-16ths	1 $\frac{3}{8}$	4	4
6	7-16ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
7	5-10ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
8	5-10ths	1 $\frac{3}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
9	5-10ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
10	9-16ths	1 $\frac{3}{4}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
11	9-16ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
12	5-8ths	1 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
13	5-8ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
14	5-8ths	1 $\frac{1}{8}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$
15	5-8ths	2	5	5
16	11-16ths	2	5	5
17	11-16ths	2 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$
18	11-16ths	2 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$
20	3-4ths	2 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$

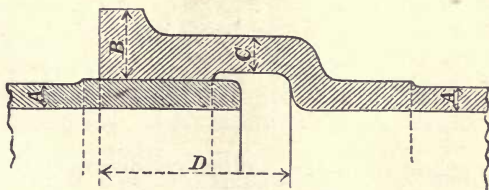


FIG. 137.

11 in. diameter, 9 ft. long; when 12 in. diameter and upwards they may be either 9 ft. or 12 ft. long. The socket is not included in these lengths.

TABLE.

CAST-IRON GAS PIPES, WITH FLANGE JOINTS.

The weight of the flanges is equal to 1 lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Flanges.				Length of Pipe outside the Flanges.	Weight per Pipe inclusive of the Flanges.
		Diameter across Flanges.	Thickness of Metal.	Number of Bolt Holes.	Diameter, centre to centre, of Bolt Holes.		
1	Inches. 5-16ths	Inches. 4	Inches. $1\frac{7}{16}$	3	Inches. $2\frac{3}{8}$	Feet. 6	Cwts. qrs. lbs. 0 1 0
1½	5-16ths	4½	$1\frac{7}{8}$	3	$3\frac{3}{8}$	6	0 1 11
2	5-16ths	6	$1\frac{1}{2}$	4	4½	6	0 1 22
2½	3-8ths	7¼	$1\frac{9}{16}$	4	5¼	6	0 2 18
3	3-8ths	7½	$1\frac{11}{16}$	4	5½	9	1 0 11
4	3-8ths	9	$1\frac{13}{16}$	4	7	9	1 1 22
5	7-16ths	10¼	$1\frac{1}{2}$	4	8¼	9	2 0 10
6	7-16ths	11½	$1\frac{3}{4}$	4	9½	9	2 1 24
7	5-10ths	13	$1\frac{5}{8}$	4	11	9	3 1 5
8	5-10ths	14½	$1\frac{7}{8}$	6	12	9	3 2 25
9	5-10ths	16	$1\frac{9}{8}$	6	13½	9	4 0 17
10	9-16ths	17¼	$1\frac{11}{8}$	6	14¾	9	5 0 22
11	9-16ths	18½	$1\frac{13}{8}$	6	15¾	9	5 2 20
12	5-8ths	19½	$1\frac{1}{2}$	6	16½	12	8 3 24
13	5-8ths	20½	$1\frac{3}{4}$	6	17½	12	9 2 20
14	5-8ths	21½	1	8	18½	12	10 1 16
15	5-8ths	22½	1	8	19½	12	11 0 12
16	11-16ths	24	$1\frac{1}{8}$	8	21	12	13 0 8
17	11-16ths	25	$1\frac{1}{8}$	8	22	12	13 3 8
18	11-16ths	26	$1\frac{1}{8}$	10	23	12	14 2 12
19	3-4ths	27	$1\frac{1}{8}$	10	24	12	16 3 12
20	3-4ths	28	$1\frac{1}{8}$	10	24½	12	17 2 24
21	3-4ths	29	$1\frac{1}{8}$	10	25½	12	18 2 8
22	13-16ths	30	$1\frac{3}{8}$	10	26½	12	21 0 8
23	13-16ths	31	$1\frac{1}{2}$	10	27½	12	22 0 0
24	7-8ths	32	$1\frac{1}{2}$	12	28½	12	24 3 0
30	1	38	$1\frac{1}{2}$	14	34½	12	35 1 0
36	1¼th	45	$1\frac{1}{2}$	13	41½	12	47 2 0
42	1¾ths	51	$1\frac{1}{2}$	20	47½	12	58 1 8
48	1½th	57	$1\frac{1}{2}$	24	53½	12	70 0 4

Cast-iron, in cooling from the molten condition, shrinks $\frac{1}{8}$ of an inch per foot.

Formula for calculating the weight of cast-iron pipes—

$$W = 2.45 (D^2 - d^2).$$

Where D = outside diameter of pipe in inches.

d = inside diameter of pipe in inches.

W = weight of a lineal foot of pipe in lbs.

It is usual to pay for any overweight in the pipes beyond the weight specified, not exceeding 4 per cent.

For the smaller sizes of pipes up to 8 in. diameter, the open jointing space is $\frac{3}{8}$ in., and for larger diameters $\frac{1}{2}$ in. wide all round. The following are the usual depths of the socket, inside measure, for the various sizes of open-jointed gas-pipes, plugged with yarn and lead :—

Diameter.	Depth of Socket.
Up to 3 inches	3 inches.
4 to 8 "	4 " "
9 to 20 "	4½ " "
21 to 30 "	5 " "
32 " and upwards	6 " "

When the turned and bored joint, on being tested, is found gas-tight, it is not necessary to fill the recess with lead. The usual filling material adopted under such circumstances is Portland or Roman cement. These cements, if kneaded with warm water, set quickly ; with cold water, not so soon.

Main Pipe Joints.—A host of joints for main pipes have been invented from time to time, which, though theoretically good, have not all proved satisfactory in practice. The classes of joint generally in use are the turned and bored, and the open joint. The ball and socket joint is employed under exceptional circumstances, as when the main has to be laid in the bed of a river or harbour, or across a narrow arm of the sea.

A difference of opinion exists among engineers as to which form of joint is best—the turned and bored, or the open joint filled with lead, rust cement, or other substance, metallic or otherwise. We, who have had large experience in both, and under most circumstances, prefer the turned and bored, alike for ease in adjustment, economy, and efficiency.

In districts where the ground is extensively undermined and liable to subsidence, the vulcanized india-rubber joint (which is virtually an open joint) is the most suitable (Fig. 141).

Special pipes, such as bends, tees, and junctions, are, for convenience sake, made with open joints (Fig. 144).

The turned and bored joint is shown in Fig. 138.

There is no difficulty in swinging round ordinary curves with a line of mains jointed in this manner; but when the radius of the curve is short, an occasional yarn and lead joint is required.

In specifying for pipes with these joints, care should be taken that the bored and turned surfaces are not made with too much taper; indeed, the nearer the surfaces approach to parallel lines without being absolutely parallel, the better they will fit.

The socket may either be bored flush up to the face, as in Fig. 137, or it may have a recess in front, as in Figs. 136 and 138. The latter is to be preferred, as it can be supplemented with lead or other filling should the turned joint prove defective.

Two examples of the open joint are given in Figs. 139 and 140.

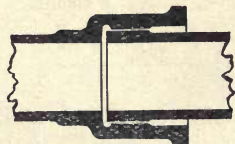


FIG. 138.

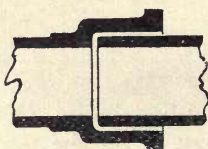


FIG. 139.

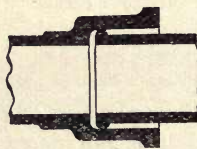


FIG. 140.

The india-rubber joint (Fig. 141) is formed by passing a vulcanized ring of that material round the spigot end of the pipe, which is specially cast with a groove and bead to suit this description of joint. When the pipe end is pushed forward into the socket, the ring is compressed or flattened, and butts against the raised bead. No other packing is necessary, so that it is an expeditious method of jointing, whilst the vulcanized india-rubber, unaffected by the presence of gas or moisture, is practically indestructible. The other advantages of this joint have already been referred to.

The ball and socket joint is shown in Fig. 142. This particular form is the invention of Mr. J. Z. Kay, and has been successfully employed for main pipes crossing through rivers and harbours where the ordinary rigid joint is inapplicable. The lead is first run in and caulked; and the connected pipes, being like a chain, can be paid out of a lighter or other vessel, when they will find their own bed in the river bottom.

The expansion joint (Fig. 143) is useful in all cases where a line of main is exposed to varying temperatures, as in pipes

placed against a wall or alongside a bridge, or in an open trench or channel.

Mill-board or engine-board, coated with red or white lead, makes a good and durable joint for flanges not under water.

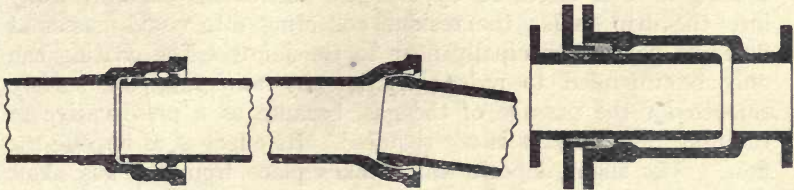


FIG. 141.

FIG. 142.

FIG. 143.

A combination of asbestos and india-rubber woven sheeting makes a superior flange joint, especially for steam purposes, as these substances resist the action of both heat and moisture. To prevent adherence to the iron (in the case of blank-flange and manhole joints that require to be frequently broken), the flange should be rubbed over with powdered black lead before placing the cover.

Metallic rings are best for flange joints. These may be made with $\frac{1}{4}$ in. or $\frac{3}{8}$ in. lead pipe, with the ends soldered evenly together; the ring is then covered with flax, and well smeared with red lead or paint. The pipe must not be beaten flat, but left round, with a few gimlet holes bored in it to allow of the exit of the air, so that when the joint is screwed up it may bed into any irregularities in the surfaces. The remaining space between the flanges is filled with rust or other cement.

Flange pipes can be jointed without the interposition of any packing material, by having the flanges faced in a lathe. In such case the surfaces are merely coated with white lead paint, and the joint tightened up.

Bolts used for jointing flanges, etc., should have a gummet of flax or tow, smeared with red or white lead, placed round their neck and behind the washer at the nut end, to bed under the head and nut when screwed up.

Red and white lead should always be mixed with boiled linseed oil. Other oil can be made to answer, but not nearly so well.

The bends, tees, junction pipes, and other irregulars required in the distributing department, are shown in Fig. 144.

Gas pipes should be free from excrescences, and moderately smooth on their inner surface.

They are better not coated internally with any kind of substance soluble in naphtha or other hydrocarbon liquid. Such coating is soon dissolved by the gas, and drains partially away into the drip wells; the residue collecting into viscid masses at different points, principally near to the joints. The coating can only be intended to reduce friction by rendering the surface smooth for the passage of the gas, because as a preservative to the iron, internally, it is not required. Its effect is to impede the flow. The slight deposit which takes place from the gas alone soon gives the metal a smooth coating. These objections do not, of course, apply to the internal coating of water pipes.

It is only for appearance sake, as a rule, that a covering of this description can be recommended for the outside of cast-iron pipes. It often serves only to hide defects in the casting.

The reddish brown oxide covering which cast-iron pipes acquire in a short time, when laid in ordinary soil, is one of the best preservatives of the metal. This covering is impervious to moisture, its effect being to arrest further corrosive action.

There are, however, circumstances where it is desirable and necessary to coat pipes externally,—as for example, when they are of wrought-iron, and when, though of cast-iron, they are to be laid in soils intermixed with engine ashes, furnace slag, vitrified cinders, clinker, dross, scoria, or chemical refuse of any kind.

Wrought-Iron and Steel Main Pipes.—Of recent years wrought-iron and steel main pipes have been largely adopted.

The advantage that wrought-iron and steel possess over cast-iron is due, primarily, to their much higher tensile strength and greater ductility; hence the tubes may be made thinner.

This advantage is also accompanied by economy in the cost of laying and subsequent maintenance; the former being due to the long lengths obtainable (40 ft.) and the consequent fewness of joints, and the latter to the absence of breakage. A further advantage is that the smaller sizes of these mains can be bent *in situ*; thus minimizing the use of special bends.

Since the advent of the Mannesmann weldless steel tube, first made on the Continent, and now in this country, the use of this type of tubing has made rapid progress, especially in the direction of high-pressure distribution.

This tubing is made with a number of different joints ; Fig. 145 shows the ordinary joint, corresponding to the open joint in cast-iron pipes. The rigid joint is used (Fig. 146) where the main is subject to vibration, or the ground liable to subsidence.

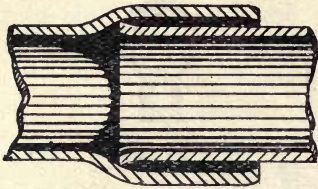


FIG. 145.

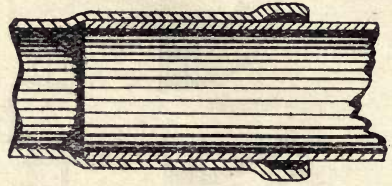


FIG. 146.

The socket in the rigid joint is expanded in two stages, the inner portion being of diameter sufficient only to take the spigot, and the outer portion, which is of larger diameter, is utilized for the jointing material.

The object of this joint is to make the tube a homogeneous length ; the jointing material serving only to prevent leakage, whilst the vibration is transmitted direct from pipe to pipe.

An improved form of rigid joint has been devised in which the spigot, so far as it enters the inner sleeve, is slightly expanded so as to form a shoulder, which, pressing on the packing, prevents drawing.

The jointing is effected in the same way as with cast-iron pipes.

Wrought-iron and steel mains are also made lap-welded and riveted, and with flanged or screwed and socketed joints.

Thickness and Weight of Wrought-Iron Main Pipes.

Diameter Inside.	Thickness.	Weight per Foot.
Inches.	Inches.	Pounds.
3	$\frac{3}{8}$ full.	6
3½	$\frac{3}{8}$ "	7
4	$\frac{1}{2}$ "	9
5	$\frac{1}{2}$ "	10½
6	$\frac{1}{2}$ "	13
7	$\frac{1}{2}$ bare.	18
8	$\frac{1}{2}$ "	20
9	$\frac{1}{2}$ "	24½
10	$\frac{1}{2}$ "	28
12	$\frac{1}{2}$ "	33
14	$\frac{1}{2}$ "	43
16	$\frac{1}{2}$ "	50

Mannesmann Tubes with Ordinary Joints.

Internal diameter of Tube	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"	7"	8"	9"	10"	11"	12"
Thickness of Tube I. W. G.	II	II	II	3 7/8"	4 1/8"	4 3/8"	5 1/8"	6 3/8"	7"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"
Internal diam. of Socket	2 1/8"	2 3/8"	3 1/8"	3 7/8"	4 1/8"	4 3/8"	5 1/8"	6 3/8"	7"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"
Packing Space	3/8"	1/2"	5/8"	3/4"	1"	1 1/8"	1 1/4"	1 1/2"	1 3/4"	1 7/8"	2"	2 1/8"	2 3/8"	2 7/8"
Depth of Joint	3 1/8"	3 3/8"	3 5/8"	3 7/8"	4 1/8"	4 3/8"	5 1/8"	6 3/8"	7"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"
Approx. Weight per foot without coating and wrapping—in pounds	2'13	2'65	3'33	4'6	5'82	6'9	8'8	11'7	14'6	18'3	24'1	29'4	31'15	34'25
Approx. Weight per foot including coating and wrapping—in pounds	2'43	3'03	3'81	5'15	6'45	7'6	9'65	12'7	15'75	19'6	25'7	31'3	33'35	36'75

Mannesmann Tubes with Rigid Joints.

Internal diameter of Tube	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"	7"	8"	9"	10"	11"	12"
Thickness of Tube I. W. G.	II	II	II	5 1/8"	6"	7 1/8"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"	13 1/8"	14 1/8"	15 1/8"
Length of Socket	3"	4"	5"	5 1/8"	6"	7 1/8"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"	13 1/8"	14 1/8"	15 1/8"
Length of Faucet	1 1/4"	1 1/2"	1 3/4"	1 7/8"	2"	2 1/8"	2 3/8"	2 7/8"	3"	3 1/8"	3 3/8"	3 7/8"	4 1/8"	4 3/8"
Diameter of Faucet at lip	2 1/8"	2 3/8"	3 1/8"	3 3/8"	4 1/8"	4 3/8"	5 1/8"	6 3/8"	7"	8 1/8"	9 1/8"	10 1/8"	11 1/8"	12 1/8"
Packing Space	3/8"	1/2"	5/8"	3/4"	1"	1 1/8"	1 1/4"	1 1/2"	1 3/4"	1 7/8"	2"	2 1/8"	2 3/8"	2 7/8"

The smaller sizes, 3 in., 3½ in., and 4 in. diameter, have screwed ends and sockets. The larger diameters may be either screwed, socketed or plain. In the latter case the "Kimberley" collar (Fig. 147) is employed for connecting them; this is also made of wrought-iron.

Weight of Lead required for Jointing Wrought-Iron Main Pipes with the "Kimberley" Collar.

Internal Diameter of Pipe.	Depth of Lead on each side of Collar.	Weight of Lead.	Internal Diameter of Pipe.	Depth of Lead on each side of Collar.	Weight of Lead.
Inches.	Inches.	Pounds.	Inches.	Inches.	Pounds.
5	1¼	8¾	10	1¼	16½
6	1¼	10	11	1¼	18
7	1¼	11¾	12	1¼	20
8	1¼	13½	14	2	26
9	1¼	15	16	2	30

All wrought-iron and steel mains should be protected on the outside with some form of impervious covering to prevent corrosion.

The connection of branch pipes to these is a matter that has claimed special attention on account of the thinness of the metal. Various connections have been devised chiefly by the use of clamps or clips.

An ingenious device is the "expansion nipple," patented by Woodall & Parkinson. This consists of a short length of steel tube of the barrel nipple type, and has an internal annular bead at the lower end about $\frac{1}{16}$ in. in thickness. The lower end is screwed into the main, which is drilled and tapped in the usual way. A tapered mandrel is drawn through the nipple and expands the annular bead, thus

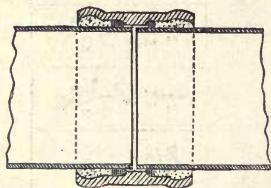


FIG. 147.

riveting the nipple on the inside of the main. An expansion nipple and ferrule have also been devised for high-pressure tapping.

The Laying of Main Pipes.—Special care is needed in the laying of main pipes. As a general rule the covering of soil over them should be at least 21 in. deep, to protect them from

breakage by steam rollers, the influences of heavy traffic and low and varying temperatures.

The risk of breakage by steam rollers does not apply to steel mains; hence the excavations need not be quite as deep. The covering, however, excepting under special circumstances, should not be less than 18 in.

The excavation to receive the pipes should not be unnecessarily wide, as the less filling up that is required the better, not to mention the saving in cost.

The bottom of the trench on which the pipes rest should be even and firm, and if not so, then thoroughly consolidated by punning. The soil should be scooped out at the various points in the trench bottom where the sockets come, so that the body of the pipe may lie solid throughout its length. In cases where this cannot well be done, resort may be had to underpinning.

Each pipe should be laid with the proper inclination or fall, and securely jointed; all joints being proved either with gas or air under high pressure while the trench is open.

In roads or footpaths made with ashes or chemical refuse, the pipes should be carefully embedded in good common soil obtained for the purpose, or puddled round with clay—especially protecting the upper side with a thick covering.

It is worse than useless to place *clay only underneath* the pipe. When so placed, it serves to receive and retain the water, which, percolating through the material forming the ground, is charged with acid bisulphides and other deleterious compounds. The metal of the pipe thus lying, as it were, in a bath of acidulous liquid, is destroyed sooner than it would be if no clay were present. The protection afforded by the clay should therefore be complete, all round the pipe, and particularly over its upper surface.

In refilling the trench, the soil should be shovelled in in layers, and rammed firmly and equally all round and above the pipes.

Gas pipes laid through arable land do it no harm, but rather good, inasmuch as they help to drain the land. The joints should be perfect, however, as the escape of any gas is fatal to vegetable life.

When laying pipes with bored and turned joints, the spigot and socket ends, after being cleaned with cotton waste, are coated with thick paint composed with one part each white and red

lead mixed with boiled linseed oil. The end is then inserted and driven home with a mallet, or, should the pipe be large, with a swing block. Or another pipe swung from the shear-legs may be used. In this case a wood shield should be laid against the socket to take the force of the blow.

In driving the pipes, they will sometimes be found to spring back at every stroke. This may be due either to the surfaces being made too conical, in which case it is difficult to ensure a good joint; or there is a slight ridge or roughness on the inner edge of the bored part of the socket. Chip off with a sharp chisel.

Red lead sets sooner and harder than white, and the following reason is given for preferring the white to the red for joints: When any expansion or contraction takes place in the pipes, the red lead is liable to crack, and so cause a leakage; whereas the white lead is more tractable, and better adapts itself to the varying circumstances. An equal mixture of the two is preferable.

In placing pipes with open joints, twined gasket is caulked in all round so as to fill nearly half the length of the open space. A roll of tough plastic clay is then passed round and pressed against the socket face, and through a lip on the upper side molten lead is poured till the remaining space is filled. On the lead being set up with a blunt caulking tool and hammer, the joint is complete.

The ladle should contain sufficient molten lead to fill the joint at one pouring, otherwise the adhesion of the metal throughout will not be perfect.

Molten lead, when heated to redness, will fly when poured upon a wet or damp surface.

Mains in level ground should be laid with a slight inclination, say 1 ft. in 400 yds., and at each lowest point a syphon or drip-well (Fig. 148), of cast-iron, should be placed underneath, and connected by a tube to the pipe to receive the liquid arising from condensation. Another form of syphon, with sockets to receive the main pipes, is shown in Fig. 149. In all cases where a main dips, a syphon is required at the place where the dip is reversed.

The liquor from these receptacles is pumped out periodically into a cask on wheels, and deposited in the tar well on the gas-works.

In laying down mains in lieu of others of a smaller size, the

difference in value between the two sizes of pipes only should be charged to capital account.

For pipes $1\frac{1}{2}$ to 8 in. in diameter the lead is assumed to be about $\frac{3}{8}$ in. thick; and in pipes 9 in. in diameter and upwards, $\frac{1}{2}$ in. thick.

In place of molten lead, lead wool, rust cement, and a mixture of beeswax and tallow are used for jointing mains.

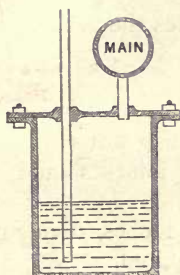


FIG. 148.

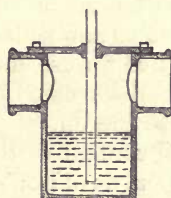


FIG. 149.

TABLE.

Giving the Weight of Lead in Pounds required for Jointing Cast-Iron Mains.

Diameter of Pipe in Inches.	Depth of Lead in Inches.	Weight of Lead in Pounds.	Diameter of Pipe in Inches.	Depth of Lead in Inches.	Weight of Lead in Pounds.
$1\frac{1}{2}$	$\frac{1}{8}$	$1\frac{1}{4}$	11	$2\frac{1}{2}$	$16\frac{1}{2}$
2	$\frac{1}{8}$	$1\frac{3}{4}$	12	$2\frac{3}{8}$	$18\frac{1}{2}$
$2\frac{1}{2}$	$\frac{1}{8}$	$2\frac{1}{4}$	13	$2\frac{3}{8}$	21
3	$\frac{1}{8}$	$2\frac{3}{4}$	14	$2\frac{3}{8}$	$23\frac{1}{2}$
4	$\frac{1}{8}$	4	15	$2\frac{3}{8}$	26
5	$\frac{1}{8}$	$5\frac{1}{2}$	16	$2\frac{3}{8}$	$28\frac{1}{2}$
6	2	7	17	$2\frac{3}{8}$	31
7	2	$8\frac{3}{4}$	18	$2\frac{3}{8}$	$32\frac{1}{2}$
8	$2\frac{1}{8}$	$10\frac{1}{2}$	19	$2\frac{3}{8}$	34
9	2	$12\frac{1}{4}$	20	2	$35\frac{1}{2}$
10	$2\frac{1}{8}$	$14\frac{1}{2}$	24	3	48

Iron or Rust Cements for Flange and Open Socket Joints.

- (1) 1 lb. of clean iron borings, pounded fine in a mortar.
- 2 oz. sal ammoniac (muriate of ammonia) in powder.
- 1 oz. flowers of sulphur.

Mix the whole together by pounding, and keep dry. For use, mix one part with twenty of iron borings pounded, adding water to the consistency of mortar.

- (2) 98 parts fine iron borings.
 1 part flowers of sulphur.
 1 part sal ammoniac.

Mix, and when required for use, dissolve in boiling water. This cement sets quickly.

If required to set slowly, which makes the better joint—

- (3) 197 parts iron borings.
 1 part flowers of sulphur.
 2 parts sal ammoniac.

When required for use, mix with boiling water.

The iron borings used for making joints should be perfectly free from grease and oil.

The cubical content of the joint in inches, divided by 5, gives the weight in pounds of iron cement required.

Lead-Wool.—The advantage of this joint depends more on the skill of the workman than on the material used.

It is invariably employed in the jointing of steel mains owing to the sockets being able to withstand the caulking strain.

In caulking with lead-wool, a 4-lb. hammer is usually employed, the object being to caulk the lead strand by strand as tightly as possible.

Appliances used in Mainlaying.—In beginning to lay an extensive length of main pipes, considerable delay, and consequent loss, is often experienced at first, owing to a want of foresight in providing beforehand the necessary men, tools, and other appliances required. The following is an enumeration of what is necessary to be provided, varying according to the peculiarities of the district and the extent of the work to be done:—

One or two skilled mainlayers.

A number of labourers according to the extent of the work.

A pavior and his labourer. A night watchman.

A pick and spade (and a tool, if clay) for each labourer.

A supply of picks, pick handles, and wedges should be kept in stock, to replace broken ones.

A screen for separating stones and soil.

Shear-legs or tripod; or, what is better, if the mains are of

large diameter, a movable pipe-layer, supported on wheels, running on rails laid alongside of the trench.

Blocks, tackle, and ropes or chain.

A chain or clip to encircle the pipes.

Eight hand-spikes of wood, for moving the pipes about.

Two pieces of 2 or 3 in. wrought-iron tube (according to the size of the main), on which to roll the pipe previous to lowering it to its place in the trench.

Two or four long iron bars, and two short ones.

Two planks for long and strong leverage.

Red and white lead, mixed with boiled oil, if turned and bored joints.

Some cotton waste and old cards to clean the joints, if turned and bored. A supply of spun yarn and lead or lead-wool.

A wooden mallet for driving small bored and turned pipes.

Two or four oak blocks, strengthened with bolts or hoops, to lay against the pipe sockets when driving.

A 3 or 4 in. cast-iron pipe, to swing with a rope or chain from centre of shear-legs when driving, or a wooden spring block if preferred.

Wood plugs for the various sizes of pipes and branches.

India-rubber cloth bags for plugging the mains. (Fig. 150.)

A lead pot and two ladles.

Chisels and caulking tools.

Tarred rope for trying the joints and pipes.

A coke fire-grate for melting the lead and for use by the night watchman.

Three setts, with handles, for cutting any pipes required.

Two large hammers, 7 lbs. weight, and several smaller ones, 1½, 2, and 3 lbs. each.

A 4-lb. hammer for lead-wool, and suitable caulking tools.

Screwing tackle.

Some fine flax for indifferent joints.

A few casks of cement.

A bogie or hand-drag, and two or three hand-barrows.

Portable bench, with vice attached.

Covered hand-cart, under lock and key.

A supply of good soil for bedding the pipes, and to prevent the contact of ashes, if such should be present in the cutting.

A spirit-level and a straight-edge 10 or 14 ft. long.

A supply of planking to cover up any part of the trench temporarily.

A box for the night watchman.

Two red signal lamps to warn passengers of the open trench during the dark hours.

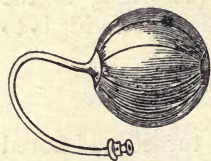


FIG. 150.

Two stand-pipes for the signal lights.

Apparatus for proving the mains for leakage before filling up the trench.

Look up beforehand what bends, tees, thimbles, flanges, drip-wells, and other special castings will be required in the course of the work, and have them ready when needed.

In enlarging or replacing pipes, many services require to be coupled-up and renewed, and in that case service layers and tools should be in readiness.

EXPLOSIONS IN MAIN PIPES.

In the laying of large main pipes, due care and diligence should be exercised by the skilled and responsible officials in charge of such work. Calamitous explosions have occurred owing to neglect in these particulars.

Such an explosion took place in London in 1862, and again in 1880; and one in Manchester in 1873, when a large cast-iron syphon well was being attached to a main.

Coal gas when unmixed with air or oxygen, as is well known, is perfectly inexplusive, and is even incombustible. It is only when the gas comes in contact with the oxygen of the air, as at the burner for example, that it can be ignited; combustion being in fact the union in the presence of heat of the hydrogen and carbon of the gas with atmospheric oxygen.

Explosions of the kind referred to are produced by a mixture of gas and air in certain proportions. The explosive force of a compound of this character is greatest when gas is mixed with eight times its bulk of air.

Under ordinary circumstances it is impossible for air to become mixed with the gas in the street mains. This can only occur when a main is in course of being laid, or when a fresh junction is being made with an existing main.

In the case of the London explosions referred to, a new main

was being laid. In order to allow of this being done, the gas was either wholly or partially shut off at the junction with the live main. Probably the gas was only partially excluded; and the limited quantity entering would, by the operation of the law of the diffusion of gases, gradually mix with the air existing in the new length of main, till the latter became charged throughout its course with a dangerously explosive compound. On the application of a light, either accidentally or from intention, the mixture was ignited, with disastrous consequences to life and property.

It is not necessary that there should be the presence of actual flame to cause ignition. Dr. Frankland and other authorities have demonstrated the fact, well known to most gas engineers, that explosive mixtures of coal gas and air may be inflamed by a spark struck from stone or metal; that ignition may be caused by a spark produced from the hammer and chisel of a workman, or even from the tramp of a horse upon the stone pavement.

There is no absolute necessity that the gas should be excluded from such an extent of main pipes in course of being laid as to incur the risk of accident; because the main for a short space from the point where the junction is being made can readily be closed by the ordinary india-rubber valves. When the main is of such large diameter as to preclude the possibility of a valve of this kind being used, the utmost precaution is necessary to ensure the expulsion of the air before a light is applied to test the soundness of the joints.

Under any circumstances, the application of a light is objectionable and unnecessary, as the joints can be proved when the main is under pressure by brushing them over with a solution of soap in water.

TESTING OF GAS MAINS IN THE GROUND.

The reduction of the loss of gas by leakage during recent years is remarkable. It is safe to estimate that thirty years ago, the unaccounted-for gas averaged 16 per cent. of the gas produced. At the present time the average is only 7 per cent. This reduction is largely due to the closer attention that is given to the pressures by day and night; to the use of governors in street

lighting; and to the better supervision that is exercised in the laying of mains and service pipes.

It may be stated as a salutary rule that, under modern prevailing conditions, $\frac{3}{16}$ is a reasonable maximum initial pressure during the hours of heaviest consumption. When there is found to be a necessity for more, the trunk mains, or some of the most contracted mains branching therefrom, should be replaced by larger ones, or boosting must be resorted to.

Considerable expense must be incurred in any systematic attempt to reduce leakage; but wherever in a district the unaccounted-for gas exceeds 10 per cent. of the make, the expenditure is not only justifiable on

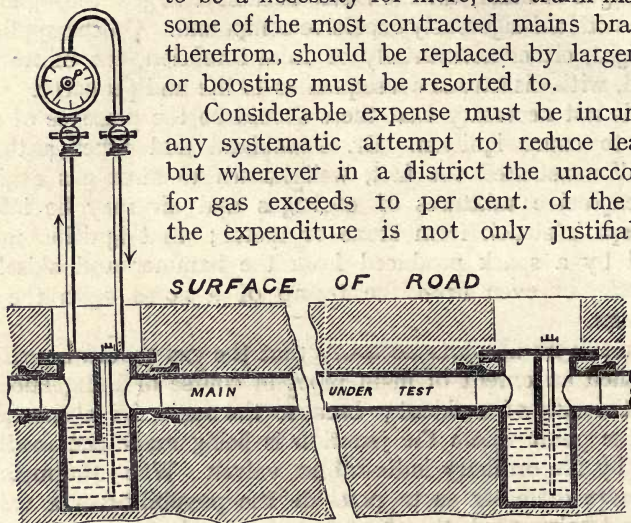


FIG. 151.

sanitary and other grounds, but is eventually found to be a good and profitable investment.

Various appliances have been devised for testing gas mains in the ground. Brothers' apparatus consists simply of two 30-light meters, one of which registers the passage of gas in the usual way, and the other is made to act as an exhaustor, either by continuing the spindle of the drum through the casing and attaching a handle to it, or by means of a small wheel geared into a larger one on the periphery of the drum—the former being actuated by a handle from the outside. The main having been severed, and the two ends carefully plugged, the exhaustor inlet is connected to the live main, and the meter outlet to the dead section of main; the exhaustor and meter also being joined. On the exhaustor being gently turned, gas is drawn from the live main and forced through the meter into the length of main under test, and thus the

amount of loss in a certain time, and under a given pressure, is indicated.

The great cost is in cutting the pipes, reinstating them, and finding the exact locality of the escape. To obviate the necessity of severing the pipes, a suggestion was made at the meeting of the Manchester District Institution of Gas Engineers, in November 1879, that water valves or traps, which would also answer the purpose of drip-wells, might be permanently placed at intervals in the line of mains. These traps, having a diaphragm extending to within a regulated distance of the bottom, on being charged with water would form a hydraulic valve, shutting off the gas from any section of main as desired, and enabling a test to be made without difficulty and at reduced expense.

Acting on this suggestion, Mr. J. H. Lyon has introduced an improved syphon box or hydraulic valve, for attaching to mains, and by means of a leakage indicator affixed to stand-pipes on each side of the box or valve, the quantity of gas escaping is readily ascertained. (See Fig. 151.)

ELECTROLYSIS OF MAIN AND SERVICE PIPES.

Since the introduction of electric lighting and traction, a new danger to the distributing mains and other pipes of gas undertakings has arisen—viz., electrolysis.

For the protection of metallic substances buried in the streets, the Board of Trade has issued certain regulations; but there is a difference of opinion as to whether these regulations are sufficiently stringent or not.

Experiments show that quite small potential differences between iron surfaces, buried in damp soil especially, if soluble chlorides are present, may bring about considerable electrolytic corrosion in short periods of time, and that there is no absolute security in the limit of $1\frac{1}{2}$ volts as imposed by the Board of Trade Regulations.

It is essential that managers of gas undertakings should make a careful inspection of their mains and services whenever opportunity occurs, and note if any corrosion is taking place. This is especially necessary at points nearest to the electrical generating stations, which are known as "danger areas."

Electrolytic troubles due to electric lighting systems, whilst of importance, are less so than in the case of electric traction. They will be due to leakage from badly insulated cables, and to the fact that in a three or five wire system the middle conductor is earthed.

Whenever electric lighting or traction is introduced within the district of any gas undertaking, every endeavour should be made to secure the utmost protection for the mains and service pipes from damage likely to be caused through electrolytic action or direct fusion.

The electric cables and the rails should be as far distant as possible from the mains and other pipes; and, where the former cross the latter, the mains and pipes should be protected by some insulating material.

It is well understood that it is not at the point where the electric current *enters* a pipe that the damage is done, but where it *leaves* the pipe. The necessity, however, for protecting the pipe at the initial point is evident, in order to obviate or diminish the risk of currents entering.

No danger of electrolysis arises through vagabond currents from the return current in electric tramways, provided the gas or water pipes are 3 ft. distant from the rails. This has been proved by investigation and from actual experiment.

An effort should be made to obtain the insertion in the Order of any Electric Lighting or Tramway Company, of protective clauses including the following provisions:—

1. Where the distance from the upper side of any main or service pipe belonging to the Gas Company (or local gas authority) to the lowest part of the cable or rail of the Electric Cable or Tramway Company is less than 2 ft., such main or pipe shall be lowered by the Gas Company (or local gas authority) at the expense of the Electric Lighting or Tramway Company, so as to leave a distance of not less than 2 ft. between the upper side of such main or pipe and the lowest part of such cable or rail.
2. At any point or points where the cables or rails cross a main or pipe, the Electric Lighting or Tramway Company shall, at their own expense, lay and maintain underneath each cable or rail, and immediately over such main or pipe, a bed of asphalt or other insulating material, not less than

2 ft. wide by 6 in. thick, and of a length extending 2 ft. beyond such main or pipe on each side thereof.

3. If it is proved that any injury or damage to any main or pipe or apparatus belonging to the Gas Company (or local gas authority), or any loss of gas, shall have resulted from electrolytic action caused by any currents generated or used for the purposes of electric lighting or traction, nothing in the Board of Trade Regulations or this Order shall relieve the Electric Lighting or Tramway Company (or local authority) from any liability to make compensation for such injury, damage, or loss.

It is claimed that the jute cloth covering usually employed as a protection from corrosion to steel mains is a non-conductor of electricity, and that as a consequence mains so covered are immune from the danger of electrolysis and fusion. Sufficient data, however, on this point, are not as yet available to prove the accuracy of the contention.

TABLE

Showing the Average Cost per Yard of Laying Cast-Iron Mains, 9 feet long each, with Turned and Bored Joints, and with Lead Joints, including the Total Expenses of Material (Pipes excepted) Excavating, Reinstiting, and Maintaining the Ground for Six Months after Completion. Average Depth from the surface of the Ground to the Upper Side of the Pipe, 1 foot 9 inches.

Diameter in Inches.	2.		3.		4.		5.		6.	
	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
In ordinary ballast	s. d. 0 8	s. d. 1 0	s. d. 0 9	s. d. 1 2	s. d. 1 3	s. d. 1 7	s. d. 1 6	s. d. 2 0	s. d. 1 7	s. d. 2 2
In roads macadamized with Welsh or limestone	0 11	1 3	1 0	1 6	1 7	1 11	1 9	2 4	1 11	2 6
In ordinary paved streets	1 0	1 4	1 1	1 6	1 8	2 0	2 1	2 7	2 3	2 10
In bituminized streets	3 2	3 6	3 3	3 6	4 2	5 0	5 3	6 0	5 7	6 2
In footpaths made with sand or ashes	0 6	0 11	0 7	1 0	0 8	1 3	1 4	1 10	1 5	2 0
In footpaths flagged	0 8	1 0	0 9	1 1	0 10	1 3	1 6	2 0	1 7	2 2
In footpaths asphalted	1 10	2 2	2 0	2 2	2 8	2 7	2 10	3 4	2 11	3 6

Diameter in Inches.	7.		8.		9.		10.		11.		12.	
	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
In ordinary ballast	s. d. 1 10	s. d. 2 6	s. d. 2 1	s. d. 2 10	s. d. 2 2	s. d. 3 0	s. d. 2 6	s. d. 3 6	s. d. 2 8	s. d. 3 10	s. d. 2 11	s. d. 4 2
In roads macadamized with Welsh or limestone	2 2	2 10	2 5	3 2	2 6	3 4	2 10	3 10	3 1	4 3	3 4	4 7
In ordinary paved streets	2 5	3 1	2 8	3 5	2 9	3 7	3 1	4 1	3 4	4 6	3 7	4 10
In bituminized streets	5 10	6 9	6 1	7 2	6 2	7 6	6 6	8 0	6 8	8 4	7 11	9 8
In footpaths made with sand or ashes	1 7	2 3	1 11	2 8	2 0	2 10	2 4	3 4	2 6	3 8	2 9	4 0
In footpaths flagged	1 10	2 6	2 1	2 10	2 2	3 0	2 6	3 6	2 8	3 10	2 11	4 2
In footpaths asphalted	3 2	3 10	3 5	4 3	3 6	4 4	3 10	4 10	4 0	5 2	4 4	5 7

TABLE Showing Average Cost per Yard of Laying Cast-Iron Mains—continued.

Diameter in Inches.	13.		14.		15.		16.		17.		18.	
	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
In ordinary ballast	s. d.	3 3	s. d.	3 5	s. d.	3 9	s. d.	4 4	s. d.	4 8	s. d.	5 0
In roads macadamized with Welsh or limestone	s. d.	3 8	s. d.	3 10	s. d.	4 2	s. d.	4 9	s. d.	5 2	s. d.	5 6
In ordinary paved streets	s. d.	3 11	s. d.	4 1	s. d.	4 5	s. d.	5 0	s. d.	5 4	s. d.	5 8
In bituminized streets	s. d.	8 3	s. d.	8 5	s. d.	9 0	s. d.	9 8	s. d.	10 2	s. d.	10 6
In footpaths made with sand or ashes	s. d.	3 0	s. d.	3 5	s. d.	3 7	s. d.	4 2	s. d.	4 6	s. d.	5 0
In footpaths flagged	s. d.	3 3	s. d.	3 5	s. d.	3 9	s. d.	4 4	s. d.	4 8	s. d.	5 0
In footpaths asphalted	s. d.	4 9	s. d.	5 0	s. d.	5 3	s. d.	5 10	s. d.	6 2	s. d.	6 6

Diameter in Inches.	19.		20.		21.		22.		23.		24.	
	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
In ordinary ballast	s. d.	5 8	s. d.	6 3	s. d.	6 8	s. d.	7 1	s. d.	7 4	s. d.	7 7
In roads macadamized with Welsh or limestone	s. d.	6 2	s. d.	6 9	s. d.	7 2	s. d.	7 7	s. d.	7 10	s. d.	8 1
In ordinary paved streets	s. d.	6 4	s. d.	7 0	s. d.	7 5	s. d.	7 10	s. d.	8 1	s. d.	8 4
In bituminized streets	s. d.	11 10	s. d.	12 6	s. d.	13 0	s. d.	13 6	s. d.	13 8	s. d.	14 0
In footpaths made with sand or ashes	s. d.	5 6	s. d.	6 0	s. d.	6 6	s. d.	6 10	s. d.	7 2	s. d.	7 4
In footpaths flagged	s. d.	5 8	s. d.	6 3	s. d.	6 8	s. d.	7 1	s. d.	7 4	s. d.	7 7
In footpaths asphalted	s. d.	7 2	s. d.	7 9	s. d.	8 2	s. d.	8 7	s. d.	8 10	s. d.	9 1

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 2, 3, and 4 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	2.			3.			4.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	25	26	25	41	42	41	53	54	54
Cost per yard at £4 0 0 per ton.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	0 11	0 11	0 11	1 6	1 6	1 6	1 11	1 11	1 11
4 5 0	0 11	1 0	0 11	1 7	1 7	1 7	2 0	2 1	2 1
4 7 6	1 0	1 0	1 0	1 7	1 8	1 7	2 1	2 1	2 1
4 10 0	1 0	1 1	1 0	1 8	1 8	1 8	2 2	2 2	2 2
4 12 6	1 0	1 1	1 0	1 8	1 9	1 8	2 2	2 3	2 3
4 15 0	1 1	1 1	1 1	1 9	1 9	1 9	2 3	2 3	2 3
4 17 6	1 1	1 2	1 1	1 9	1 10	1 9	2 4	2 4	2 4
5 0 0	1 1	1 2	1 1	1 10	1 11	1 10	2 4	2 5	2 5
5 2 6	1 2	1 2	1 2	1 11	1 11	1 11	2 5	2 6	2 6
5 5 0	1 2	1 3	1 2	1 11	2 0	1 11	2 6	2 6	2 6
5 7 6	1 2	1 3	1 2	2 0	2 0	2 0	2 7	2 7	2 7
5 10 0	1 3	1 3	1 3	2 0	2 1	2 0	2 7	2 8	2 8
5 12 6	1 3	1 4	1 3	2 1	2 1	2 1	2 8	2 9	2 9
5 15 0	1 3	1 4	1 3	2 1	2 2	2 1	2 9	2 9	2 9
5 17 6	1 4	1 4	1 4	2 2	2 2	2 2	2 9	2 10	2 10
6 0 0	1 4	1 5	1 4	2 2	2 3	2 2	2 10	2 11	2 11
6 2 6	1 4	1 5	1 4	2 3	2 3	2 3	2 11	2 11	2 11
6 5 0	1 5	1 5	1 5	2 3	2 4	2 3	2 11	3 0	3 0
6 7 6	1 5	1 6	1 5	2 4	2 5	2 4	3 0	3 1	3 1
6 10 0	1 5	1 6	1 5	2 5	2 5	2 5	3 1	3 2	3 2
6 12 6	1 6	1 6	1 6	2 5	2 6	2 5	3 2	3 2	3 2
6 15 0	1 6	1 7	1 6	2 6	2 6	2 6	3 2	3 3	3 3
6 17 6	1 6	1 7	1 6	2 6	2 7	2 6	3 3	3 4	3 4
7 0 0	1 7	1 8	1 7	2 7	2 8	2 7	3 4	3 5	3 5
7 2 6	1 7	1 8	1 7	2 7	2 8	2 7	3 4	3 5	3 5
7 5 0	1 7	1 8	1 7	2 8	2 9	2 8	3 5	3 6	3 6
7 7 6	1 8	1 9	1 8	2 8	2 9	2 8	3 6	3 7	3 7
7 10 0	1 8	1 9	1 8	2 9	2 10	2 9	3 7	3 7	3 7
7 12 6	1 8	1 9	1 8	2 9	2 10	2 9	3 7	3 8	3 7
7 15 0	1 9	1 10	1 9	2 10	2 11	2 10	3 8	3 9	3 9
7 17 6	1 9	1 10	1 9	2 11	2 11	2 11	3 9	3 10	3 10
8 0 0	1 9	1 10	1 9	2 11	3 0	2 11	3 9	3 10	3 10
8 2 6	1 10	1 11	1 10	3 0	3 1	3 0	3 10	3 11	3 11
8 5 0	1 10	1 11	1 10	3 0	3 1	3 0	3 11	4 0	4 0
8 7 6	1 10	1 11	1 10	3 1	3 2	3 1	4 0	4 0	4 0
8 10 0	1 11	2 0	1 11	3 1	3 2	3 1	4 0	4 1	4 1
8 12 6	1 11	2 0	1 11	3 2	3 3	3 2	4 1	4 2	4 2
8 15 0	1 11	2 0	1 11	3 2	3 3	3 2	4 2	4 3	4 3
8 17 6	2 0	2 1	2 0	3 3	3 4	3 3	4 2	4 3	4 3
9 0 0	2 0	2 1	2 0	3 4	3 5	3 4	4 3	4 4	4 4
9 2 6	2 0	2 1	2 0	3 4	3 5	3 4	4 4	4 5	4 5
9 5 0	2 1	2 2	2 1	3 5	3 6	3 5	4 5	4 6	4 6
9 7 6	2 1	2 2	2 1	3 5	3 6	3 5	4 5	4 6	4 6
9 10 0	2 1	2 2	2 1	3 6	3 7	3 6	4 6	4 7	4 7
9 12 6	2 2	2 3	2 2	3 6	3 7	3 6	4 7	4 8	4 8
9 15 0	2 2	2 3	2 2	3 7	3 8	3 7	4 7	4 8	4 8
9 17 6	2 2	2 4	2 2	3 7	3 8	3 7	4 8	4 9	4 9
10 0 0	2 2	2 4	2 2	3 8	3 9	3 8	4 9	4 10	4 10

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 5, 6, and 7 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	5.			6.			7.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	77	79	78	91	93	93	121	124	123
Cost per yard at £4 0 0 per ton.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	2 9	2 10	2 9	3 3	3 4	3 3	4 4	4 5	4 5
4 5 0	2 10	2 11	2 10	3 4	3 5	3 5	4 5	4 7	4 6
4 7 6	2 11	3 0	3 0	3 5	3 6	3 6	4 7	4 8	4 8
4 10 0	3 0	3 1	3 1	3 6	3 7	3 7	4 9	4 10	4 10
4 12 6	3 1	3 2	3 2	3 8	3 9	3 8	4 10	5 0	4 11
4 15 0	3 2	3 3	3 3	3 9	3 10	3 10	5 0	5 1	5 1
4 17 6	3 3	3 4	3 4	3 10	3 11	3 11	5 2	5 3	5 3
5 0 0	3 4	3 5	3 5	4 0	4 1	4 0	5 4	5 5	5 4
5 2 6	3 5	3 6	3 6	4 1	4 2	4 1	5 5	5 6	5 6
5 5 0	3 6	3 7	3 7	4 2	4 3	4 3	5 6	5 8	5 8
5 7 6	3 7	3 8	3 8	4 3	4 4	4 4	5 8	5 10	5 11
5 10 0	3 8	3 9	3 9	4 4	4 5	4 5	5 10	5 11	5 9
5 12 6	3 9	3 10	3 10	4 6	4 7	4 6	5 11	6 1	6 0
5 15 0	3 10	4 0	3 11	4 7	4 8	4 7	6 1	6 3	6 2
5 17 6	3 11	4 1	4 0	4 8	4 9	4 9	6 2	6 4	6 4
6 0 0	4 0	4 2	4 1	4 9	4 11	4 10	6 4	6 6	6 5
6 2 6	4 1	4 3	4 2	4 10	5 0	4 11	6 6	6 8	6 7
6 5 0	4 2	4 4	4 3	5 0	5 1	5 0	6 7	6 9	6 9
6 7 6	4 3	4 5	4 4	5 1	5 2	5 2	6 9	6 11	6 10
6 10 0	4 4	4 6	4 5	5 2	5 3	5 3	6 11	7 1	7 0
6 12 6	4 4	4 7	4 6	5 3	5 5	5 4	7 0	7 2	7 2
6 15 0	4 7	4 8	4 7	5 4	5 6	5 5	7 2	7 4	7 3
6 17 6	4 8	4 9	4 8	5 6	5 7	5 7	7 4	7 6	7 5
7 0 0	4 9	4 10	4 9	5 7	5 9	5 8	7 5	7 7	7 7
7 2 6	4 10	4 11	4 10	5 8	5 10	5 9	7 7	7 9	7 8
7 5 0	4 11	5 0	5 0	5 9	5 11	5 10	7 8	7 11	7 10
7 7 6	5 0	5 1	5 1	5 11	6 0	5 11	7 10	8 0	8 0
7 10 0	5 1	5 2	5 2	6 0	6 1	6 1	8 0	8 2	8 1
7 12 6	5 2	5 3	5 3	6 1	6 3	6 2	8 1	8 4	8 3
7 15 0	5 3	5 5	5 4	6 2	6 4	6 3	8 3	8 5	8 4
7 17 6	5 4	5 6	5 5	6 3	6 5	6 4	8 4	8 7	8 6
8 0 0	5 5	5 7	5 6	6 5	6 6	6 6	8 6	8 9	8 8
8 2 6	5 6	5 8	5 7	6 6	6 8	6 7	8 8	8 10	8 9
8 5 0	5 7	5 9	5 8	6 7	6 9	6 8	8 9	9 0	8 11
8 7 6	5 8	5 10	5 9	6 8	6 10	6 9	8 11	9 2	9 1
8 10 0	5 9	5 11	5 10	6 10	6 11	6 10	9 1	9 3	9 2
8 12 6	5 10	6 0	5 11	6 11	7 0	7 0	9 2	9 5	9 4
8 15 0	5 11	6 1	6 0	7 0	7 2	7 1	9 4	9 7	9 6
8 17 6	6 0	6 2	6 1	7 1	7 3	7 2	9 5	9 8	9 7
9 0 0	6 1	6 3	6 2	7 3	7 4	7 3	9 7	9 10	9 9
9 2 6	6 2	6 4	6 3	7 4	7 6	7 5	9 9	10 0	9 10
9 5 0	6 3	6 5	6 4	7 5	7 7	7 6	9 10	10 1	10 0
9 7 6	6 4	6 6	6 5	7 6	7 8	7 7	10 0	10 3	10 2
9 10 0	6 5	6 7	6 6	7 7	7 9	7 8	10 2	10 5	10 4
9 12 6	6 6	6 8	6 7	7 9	7 10	7 10	10 3	10 6	10 5
9 15 0	6 7	6 9	6 8	7 10	8 0	7 11	10 5	10 8	10 7
9 17 6	6 8	6 10	6 9	7 11	8 1	8 0	10 6	10 10	10 8
10 0 0	6 9	6 11	6 11	8 0	8 2	8 1	10 8	10 11	10 10
	6 11	7 1	7 0	8 2	8 4	8 3	10 10	11 1	11 0

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 8, 9, and 10 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	8.			9.			10.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per Yard in lbs.	137	140	139	153	157	155	192	196	194
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	4 11	5 0	5 0	5 6	5 7	5 6	6 10	7 0	6 11
4 2 6 "	5 1	5 2	5 1	5 8	5 9	5 9	7 1	7 3	7 2
4 5 0 "	5 2	5 4	5 3	5 10	6 0	5 11	7 3	7 5	7 4
4 7 6 "	5 4	5 6	5 5	6 0	6 2	6 1	7 6	7 8	7 7
4 10 0 "	5 6	5 8	5 7	6 2	6 4	6 3	7 9	7 11	7 10
4 12 6 "	5 8	5 9	5 9	6 4	6 6	6 5	7 11	8 1	8 0
4 15 0 "	5 10	5 11	5 11	6 6	6 8	6 7	8 2	8 4	8 3
4 17 6 "	6 0	6 1	6 1	6 8	6 10	6 9	8 4	8 6	8 5
5 0 0 "	6 1	6 3	6 2	6 10	7 0	6 11	8 7	8 9	8 8
5 2 6 "	6 3	6 5	6 4	7 0	7 2	7 1	8 9	9 0	8 11
5 5 0 "	6 5	6 7	6 6	7 2	7 4	7 3	9 0	9 2	9 1
5 7 6 "	6 7	6 -9	6 8	7 4	7 6	7 5	9 3	9 5	9 4
5 10 0 "	6 8	6 11	6 10	7 6	7 9	7 7	9 5	9 8	9 6
5 12 6 "	6 11	7 0	7 0	7 8	7 11	7 9	9 8	9 10	9 9
5 15 0 "	7 0	7 2	7 2	7 10	8 1	7 11	9 10	10 1	10 0
5 17 6 "	7 2	7 4	7 3	8 0	8 3	8 2	10 1	10 3	10 2
6 0 0 "	7 4	7 6	7 5	8 2	8 5	8 4	10 3	10 6	10 5
6 2 6 "	7 6	7 8	7 7	8 4	8 7	8 6	10 6	10 9	10 7
6 5 0 "	7 8	7 10	7 9	8 6	8 9	8 8	10 9	10 11	10 10
6 7 6 "	7 10	8 0	7 11	8 8	8 11	8 10	10 11	11 2	11 1
6 10 0 "	7 11	8 2	8 1	8 10	9 1	9 0	11 2	11 5	11 3
6 12 6 "	8 1	8 3	8 3	9 1	9 3	9 2	11 4	11 7	11 6
6 15 0 "	8 3	8 5	8 5	9 3	9 6	9 4	11 7	11 10	11 8
6 17 6 "	8 5	8 7	8 6	9 5	9 8	9 6	11 9	12 0	11 11
7 0 0 "	8 7	8 9	8 8	9 7	9 10	9 8	12 0	12 3	12 1
7 2 6 "	8 9	8 11	8 10	9 9	10 0	9 10	12 3	12 6	12 4
7 5 0 "	8 10	9 1	9 0	9 11	10 2	10 0	12 5	12 8	12 6
7 7 6 "	9 0	9 3	9 2	10 1	10 4	10 2	12 8	12 11	12 9
7 10 0 "	9 2	9 5	9 4	10 3	10 6	10 5	12 10	13 2	13 0
7 12 6 "	9 4	9 6	9 6	10 5	10 8	10 7	13 1	13 4	13 2
7 15 0 "	9 6	9 8	9 7	10 7	10 10	10 9	13 4	13 7	13 5
7 17 6 "	9 8	9 10	9 9	10 9	11 0	10 11	13 6	13 9	13 7
8 0 0 "	9 9	10 0	9 11	10 11	11 3	11 1	13 9	14 0	13 10
8 2 6 "	9 11	10 2	10 1	11 1	11 5	11 3	13 11	14 3	14 0
8 5 0 "	10 1	10 4	10 3	11 3	11 7	11 5	14 2	14 5	14 3
8 7 6 "	10 3	10 6	10 5	11 5	11 9	11 7	14 4	14 8	14 6
8 10 0 "	10 5	10 8	10 7	11 7	11 11	11 9	14 7	14 11	14 8
8 12 6 "	10 7	10 9	10 8	11 9	12 1	11 11	14 9	15 1	14 11
8 15 0 "	10 8	10 11	10 10	11 11	12 3	12 1	15 0	15 4	15 2
8 17 6 "	10 10	11 1	11 0	12 1	12 5	12 3	15 2	15 6	15 4
9 0 0 "	11 0	11 3	11 2	12 3	12 7	12 5	15 5	15 9	15 7
9 2 6 "	11 2	11 5	11 4	12 5	12 9	12 8	15 7	16 0	15 9
9 5 0 "	11 4	11 7	11 6	12 8	13 0	12 10	15 10	16 2	16 0
9 7 6 "	11 6	11 9	11 8	12 10	13 2	13 0	16 0	16 5	16 2
9 10 0 "	11 7	11 11	11 9	13 0	13 4	13 2	16 3	16 8	16 5
9 12 6 "	11 9	12 0	11 11	13 2	13 6	13 4	16 5	16 10	16 8
9 15 0 "	11 11	12 2	12 1	13 4	13 8	13 6	16 8	17 1	16 10
9 17 6 "	12 1	12 4	12 3	13 6	13 10	13 8	16 10	17 3	17 1
10 0 0 "	12 3	12 6	12 5	13 8	14 0	13 10	17 2	17 6	17 3

TABLE

Giving Weight and Cost per yard of Cast-Iron Main Gas Pipes, 11, 12, and 13 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	11.			12.			13.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	210	215	212	249	253	251	269	273	271
Cost per yard at £4 0 0 per ton	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	7 6	7 8	7 7	8 11	9 0	9 0	9 7	9 9	9 8
4 5 0	7 9	7 11	7 10	9 2	9 4	9 3	9 11	10 1	10 0
4 7 6	8 0	8 2	8 0	9 5	9 7	9 6	10 3	10 4	10 3
4 10 0	8 2	8 5	8 3	9 9	9 11	9 10	10 6	10 8	10 7
4 12 6	8 5	8 8	8 6	10 0	10 2	10 1	10 10	11 0	10 11
4 15 0	8 8	8 11	8 9	10 3	10 5	10 4	11 1	11 3	11 2
4 17 6	8 11	9 1	9 0	10 6	10 9	10 8	11 5	11 7	11 6
5 0 0	9 2	9 4	9 3	10 10	11 0	10 11	11 9	11 11	11 10
5 2 6	9 4	9 7	9 5	11 1	11 4	11 3	12 0	12 2	12 1
5 5 0	9 7	9 10	9 8	11 4	11 7	11 6	12 4	12 6	12 5
5 7 6	9 10	10 1	9 11	11 7	11 10	11 9	12 7	12 10	12 8
5 10 0	10 1	10 4	10 2	11 11	12 2	12 0	12 11	13 1	13 0
5 12 6	10 4	10 7	10 5	12 2	12 5	12 4	13 3	13 5	13 4
5 15 0	10 7	10 10	10 8	12 5	12 8	12 7	13 6	13 9	13 7
5 17 6	10 10	11 1	10 10	12 9	13 0	12 11	13 10	14 0	13 11
6 0 0	11 0	11 3	11 1	13 1	13 3	13 2	14 1	14 4	14 3
6 2 6	11 3	11 6	11 4	13 4	13 7	13 5	14 5	14 8	14 6
6 5 0	11 6	11 9	11 7	13 7	13 10	13 9	14 9	14 11	14 10
6 7 6	11 9	12 0	11 10	13 11	14 1	14 0	15 0	15 3	15 2
6 10 0	11 11	12 3	12 1	14 2	14 5	14 3	15 4	15 6	15 5
6 12 6	12 3	12 6	12 4	14 5	14 8	14 7	15 7	15 10	15 9
6 15 0	12 5	12 8	12 6	14 9	15 0	14 10	15 11	16 2	16 0
6 17 6	12 8	13 0	12 9	15 0	15 3	15 2	16 3	16 5	16 4
7 0 0	12 11	13 2	13 0	15 3	15 6	15 5	16 6	16 9	16 8
7 2 6	13 2	13 5	13 3	15 7	15 10	15 8	16 10	17 1	16 11
7 5 0	13 5	13 8	13 6	15 10	16 1	16 0	17 1	17 4	17 3
7 7 6	13 7	13 10	13 9	16 1	16 5	16 3	17 5	17 8	17 7
7 10 0	13 10	14 2	14 0	16 5	16 8	16 6	17 9	18 0	17 10
7 12 6	14 2	14 5	14 2	16 8	16 11	16 10	18 0	18 3	18 2
7 15 0	14 4	14 8	14 5	16 11	17 3	17 1	18 4	18 7	18 5
7 17 6	14 6	14 11	14 8	17 3	17 6	17 4	18 7	18 11	18 9
8 0 0	14 9	15 1	14 11	17 6	17 9	17 8	18 11	19 2	19 1
8 2 6	15 0	15 4	15 2	17 10	18 1	17 11	19 3	19 6	19 4
8 5 0	15 3	15 7	15 4	18 1	18 4	18 2	19 6	19 10	19 8
8 7 6	15 6	15 10	15 7	18 4	18 7	18 5	19 10	20 1	20 0
8 10 0	15 8	16 1	15 10	18 8	18 11	18 9	20 1	20 5	20 3
8 12 6	15 11	16 4	16 1	18 11	19 2	19 0	20 5	20 9	20 7
8 15 0	16 2	16 7	16 4	19 2	19 6	19 4	20 9	21 0	20 10
8 17 6	16 5	16 10	16 7	19 6	19 9	19 7	21 0	21 4	21 2
9 0 0	16 8	17 0	16 9	19 9	20 1	19 11	21 4	21 8	21 6
9 2 6	16 10	17 3	17 0	20 0	20 4	20 2	21 7	21 11	21 9
9 5 0	17 1	17 6	17 3	20 4	20 7	20 5	21 11	22 3	22 1
9 7 6	17 4	17 9	17 6	20 7	20 11	20 9	22 3	22 7	22 5
9 10 0	17 7	18 0	17 9	20 10	21 2	21 0	22 6	22 10	22 8
9 12 6	17 10	18 3	18 0	21 2	21 6	21 4	22 10	23 2	23 0
9 15 0	18 1	18 6	18 3	21 5	21 9	21 7	23 1	23 6	23 4
9 17 6	18 3	18 9	18 6	21 8	22 0	21 10	23 5	23 9	23 7
10 0 0	18 6	19 0	18 8	22 0	22 4	22 2	24 0	24 4	24 2
	18 9	19 2	18 11	22 3	22 7	22 5	24 0	24 5	24 2

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 14, 15, and 16 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in inches.	14.			15.			16.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	289	293	291	309	314	311	363	338	366
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0	10 4	10 6	10 5	11 0	11 3	11 1	13 0	13 2	13 1
4 2 6	10 8	10 9	10 9	11 5	11 7	11 5	13 4	13 7	13 6
4 5 0	11 0	11 1	11 1	11 9	11 11	11 10	13 9	14 0	13 11
4 7 6	11 3	11 5	11 4	12 1	12 3	12 2	14 2	14 5	14 4
4 10 0	11 7	11 9	11 8	12 5	12 7	12 6	14 7	14 9	14 8
4 12 6	11 11	12 1	12 0	12 9	13 0	12 10	15 0	15 2	15 1
4 15 0	12 3	12 5	12 4	13 1	13 4	13 2	15 5	15 7	15 6
4 17 6	12 7	12 9	12 8	13 5	13 8	13 6	15 10	16 0	15 11
5 0 0	12 11	13 1	13 0	13 10	14 0	13 11	16 2	16 5	16 4
5 2 6	13 3	13 5	13 4	14 2	14 4	14 3	16 7	16 10	16 9
5 5 0	13 7	13 9	13 8	14 6	14 9	14 7	17 0	17 3	17 2
5 7 6	13 10	14 1	14 0	14 10	15 1	14 11	17 5	17 8	17 7
5 10 0	14 2	14 5	14 3	15 2	15 5	15 3	17 10	18 1	18 0
5 12 6	14 6	14 9	14 7	15 6	15 9	15 7	18 3	18 6	18 5
5 15 0	14 10	15 0	14 11	15 10	16 1	15 11	18 8	18 11	18 9
5 17 6	15 2	15 4	15 3	16 3	16 6	16 4	19 0	19 4	19 2
6 0 0	15 6	15 8	15 7	16 7	16 10	16 8	19 5	19 8	19 7
6 2 6	15 10	16 0	15 11	16 11	17 2	17 0	19 10	20 2	20 0
6 5 0	16 1	16 4	16 3	17 3	17 6	17 4	20 3	20 6	20 5
6 7 6	16 5	16 8	16 7	17 7	17 10	17 8	20 8	20 11	20 10
6 10 0	16 9	17 0	16 11	17 11	18 3	18 0	21 1	21 4	21 3
6 12 6	17 1	17 4	17 3	18 3	18 7	18 5	21 6	21 9	21 8
6 15 0	17 5	17 8	17 6	18 7	18 11	18 9	21 10	22 2	22 1
6 17 6	17 9	18 0	17 10	19 0	19 3	19 1	22 3	22 7	22 6
7 0 0	18 1	18 4	18 2	19 4	19 7	19 5	22 8	23 0	22 10
7 2 6	18 5	18 8	18 6	19 8	20 0	19 9	23 1	23 5	23 3
7 5 0	18 8	18 11	18 10	20 0	20 4	20 1	23 6	23 10	23 8
7 7 6	19 0	19 4	19 2	20 4	20 8	20 6	23 11	24 3	24 1
7 10 0	19 4	19 7	19 6	20 8	21 0	20 10	24 4	24 8	24 6
7 12 6	19 8	19 11	19 10	21 0	21 5	21 2	24 9	25 1	24 11
7 15 0	20 0	20 3	20 2	21 4	21 9	21 6	25 1	25 5	25 4
7 17 6	20 4	20 7	20 6	21 9	22 1	21 10	25 6	25 11	25 9
8 0 0	20 8	20 11	20 9	22 1	22 5	22 2	25 11	26 3	26 2
8 2 6	21 0	21 3	21 1	22 5	22 9	22 7	26 4	26 8	26 7
8 5 0	21 3	21 7	21 5	22 9	23 2	22 11	26 9	27 1	26 11
8 7 6	21 7	21 11	21 9	23 1	23 6	23 3	27 2	27 6	27 4
8 10 0	21 11	22 3	22 1	23 5	23 10	23 7	27 6	27 11	27 9
8 12 6	22 3	22 7	22 5	23 10	24 2	23 11	27 11	28 4	28 2
8 15 0	22 7	22 11	22 9	24 2	24 6	24 3	28 4	28 9	28 7
8 17 6	22 11	23 3	23 1	24 6	24 10	24 8	28 9	29 2	29 0
9 0 0	23 3	23 6	23 4	24 10	25 3	25 0	29 2	29 7	29 5
9 2 6	23 7	23 10	23 9	25 2	25 7	25 4	29 7	30 0	29 10
9 5 0	23 10	24 2	24 0	25 6	25 11	25 8	30 0	30 5	30 3
9 7 6	24 2	24 6	24 4	25 10	26 3	26 0	30 5	30 10	30 8
9 10 0	24 6	24 10	24 8	26 2	26 7	26 4	30 9	31 2	31 0
9 12 6	24 10	25 2	25 0	26 7	27 0	26 9	31 2	31 8	31 5
9 15 0	25 2	25 6	25 4	26 11	27 4	27 1	31 7	32 0	31 10
9 17 6	25 6	25 10	25 8	27 3	27 8	27 5	32 0	32 5	32 3
10 0 0	25 10	26 2	26 0	27 7	28 0	27 9	32 5	32 10	32 8

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 17, 18, and 19 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	17.			18.			19.		
	Open.	F. & B.	Flnge	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	384	390	387	403	412	409	468	475	472
Cost per yard at £4 0 0 per ton.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	13 8	13 11	13 10	14 6	14 8	14 7	16 8	16 11	16 10
4 5 0	14 2	14 4	14 3	14 11	15 2	15 1	17 3	17 6	17 5
4 7 6	14 7	14 9	14 8	15 5	15 7	15 6	17 9	18 0	17 11
4 10 0	15 0	15 3	15 1	15 10	16 1	16 0	18 3	18 7	18 5
4 12 6	15 5	15 8	15 6	16 4	16 7	16 5	18 10	19 1	18 11
4 15 0	15 10	16 1	15 11	16 9	17 0	16 11	19 4	19 7	19 6
4 17 6	16 3	16 6	16 5	17 2	17 6	17 4	19 10	20 2	20 0
5 0 0	16 9	17 0	16 9	17 8	17 11	17 10	20 4	20 8	20 7
5 2 6	17 2	17 5	17 3	18 1	18 5	18 3	20 11	21 2	21 1
5 5 0	17 7	17 10	17 9	18 7	18 10	18 9	21 5	21 9	21 7
5 7 6	18 0	18 3	18 2	19 0	19 4	19 2	21 11	22 3	22 1
5 10 0	18 5	18 9	18 7	19 6	19 9	19 8	22 6	22 10	22 8
5 12 6	18 10	19 2	19 0	19 11	20 3	20 1	23 0	23 4	23 2
5 15 0	19 3	19 7	19 5	20 5	20 8	20 6	23 6	23 10	23 8
5 17 6	19 8	20 0	19 10	20 10	21 2	21 0	24 0	24 5	24 3
6 0 0	20 2	20 5	20 4	21 4	21 7	21 5	24 7	24 11	24 9
6 2 6	20 7	20 11	20 9	21 9	22 1	21 11	25 1	25 5	25 3
6 5 0	21 0	21 4	21 2	22 2	22 6	22 4	25 7	26 0	25 10
6 7 6	21 5	21 9	21 7	22 8	23 0	22 10	26 1	26 6	26 4
6 10 0	21 10	22 2	22 0	23 1	23 5	23 3	26 8	27 0	26 10
6 12 6	22 3	22 7	22 5	23 7	23 11	23 9	27 2	27 7	27 5
6 15 0	22 9	23 1	22 11	24 0	24 4	24 2	27 8	28 1	27 11
6 17 6	23 2	23 6	23 4	24 5	24 10	24 8	28 2	28 7	28 5
7 0 0	23 7	23 11	23 9	24 11	25 3	25 1	28 7	29 2	29 0
7 2 6	24 0	24 4	24 2	25 4	25 9	25 7	29 3	29 8	29 6
7 5 0	24 5	24 10	24 7	25 10	26 3	26 0	29 9	30 3	30 0
7 7 6	24 10	25 3	25 0	26 3	26 8	26 6	30 3	30 9	30 7
7 10 0	25 3	25 8	25 6	26 9	27 2	26 11	30 10	31 3	31 1
7 12 6	25 8	26 1	25 11	27 2	27 7	27 5	31 4	31 10	31 8
7 15 0	26 2	26 7	26 4	27 8	28 1	27 10	31 10	32 4	32 2
7 17 6	26 7	27 0	26 9	28 1	28 6	28 3	32 4	32 10	32 8
8 0 0	27 0	27 5	27 2	28 7	29 0	28 9	32 11	33 5	33 2
8 2 6	27 5	27 10	27 8	29 0	29 5	29 2	33 5	33 11	33 8
8 5 0	27 10	28 4	28 1	29 5	29 11	29 8	33 11	34 6	34 3
8 7 6	28 3	28 9	28 6	29 11	30 4	30 1	34 6	35 0	34 9
8 10 0	28 8	29 2	28 11	30 4	30 10	30 7	35 0	35 6	35 4
8 12 6	29 2	29 7	29 4	30 10	31 3	31 0	35 6	36 0	35 10
8 15 0	29 7	30 0	29 10	31 3	31 8	31 6	36 1	36 7	36 4
8 17 6	30 0	30 5	30 3	31 8	32 2	31 11	36 7	37 1	36 10
9 0 0	30 5	30 11	30 8	32 2	32 8	32 5	37 1	37 8	37 5
9 2 6	30 10	31 4	31 1	32 7	33 1	32 10	37 7	38 2	37 11
9 5 0	31 3	31 9	31 6	33 1	33 7	33 4	38 2	38 8	38 5
9 7 6	31 8	32 2	31 11	33 6	34 0	33 9	38 8	39 3	39 0
9 10 0	32 1	32 8	32 5	34 0	34 6	34 3	39 2	39 9	39 6
9 12 6	32 7	33 1	32 10	34 5	34 11	34 8	39 8	40 3	40 0
9 15 0	33 0	33 6	33 3	34 11	35 5	35 2	40 3	40 10	40 7
9 17 6	33 5	33 11	33 8	35 4	35 10	35 7	40 9	41 4	41 1
10 0 0	33 10	34 5	34 1	35 10	36 4	36 1	41 3	41 11	41 7
	34 3	34 10	34 7	36 3	36 9	36 6	41 9	42 5	42 2

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 20, 21, and 22 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	20.			21.			22.		
	Open.	T. & B.	Flnge.	Open.	T. & D.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	492	500	496	516	524	520	530	595	590
Cost per yard at £4 0 0 per ton.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	17 7	17 10	17 8	18 5	18 8	18 7	20 11	21 8	21 1
4 5 0	18 1	18 5	18 3	19 0	19 4	19 2	21 7	21 11	21 9
4 7 6	18 8	19 0	18 10	19 7	19 11	19 9	22 3	22 7	22 5
4 10 0	19 3	19 6	19 5	20 2	20 6	20 4	22 11	23 3	23 1
4 12 6	19 9	20 0	19 11	20 9	21 1	20 11	23 6	23 11	23 8
4 15 0	20 4	20 8	20 6	21 4	21 8	21 6	24 2	24 7	24 4
4 17 6	20 10	21 2	21 0	21 10	22 3	22 1	24 10	25 3	25 0
5 0 0	21 5	21 9	21 7	22 6	22 10	22 8	25 6	25 11	25 8
5 2 6	21 11	22 4	22 2	23 0	23 5	23 2	26 2	26 7	26 4
5 5 0	22 6	22 11	22 8	23 7	24 0	23 9	26 10	27 3	27 0
5 7 6	23 1	23 5	23 3	24 2	24 7	24 4	27 5	27 11	27 8
5 10 0	23 7	24 0	23 10	24 9	25 2	25 0	28 1	28 7	28 4
5 12 6	24 2	24 7	24 4	25 4	25 9	25 6	28 9	29 3	29 0
5 15 0	24 9	25 1	24 11	25 11	26 4	26 1	29 5	29 11	29 8
6 0 0	25 3	25 8	25 5	26 6	26 11	26 8	30 1	30 6	30 3
6 2 6	25 10	26 3	26 0	27 1	27 6	27 3	30 9	31 3	30 11
6 5 0	26 4	26 9	26 7	27 8	28 1	27 10	31 5	31 10	31 7
6 7 6	26 11	27 4	27 2	28 3	28 8	28 5	32 0	32 6	32 3
6 10 0	27 5	27 11	27 8	28 0	29 3	29 0	32 8	33 2	32 11
6 12 6	28 0	28 6	28 3	29 4	29 10	29 7	33 4	33 10	33 7
6 15 0	28 7	29 0	28 9	29 11	30 5	30 2	34 0	34 6	34 3
6 17 6	29 1	29 7	29 4	30 6	31 0	30 9	34 8	35 2	34 11
7 0 0	29 8	30 1	29 11	31 1	31 7	31 4	35 4	35 10	35 7
7 2 6	30 2	30 8	30 5	31 8	32 2	31 11	36 0	36 6	36 3
7 5 0	30 9	31 3	31 0	32 3	32 9	32 6	36 7	37 2	36 10
7 7 6	31 4	31 10	31 7	32 10	33 4	33 1	37 3	37 10	37 6
7 10 0	31 10	32 4	32 1	33 5	33 11	33 8	37 11	38 6	38 2
7 12 6	32 5	32 11	32 8	34 0	34 6	34 3	38 7	39 2	38 10
7 15 0	32 11	33 6	33 2	34 7	35 1	34 10	39 3	39 10	39 6
8 0 0	33 6	34 0	33 9	35 2	35 8	35 5	39 11	40 6	40 2
8 2 6	34 0	34 7	34 4	35 8	36 3	36 0	40 6	41 2	40 10
8 5 0	34 7	35 2	34 11	36 3	36 10	36 7	41 2	41 10	41 6
8 7 6	35 2	35 8	35 5	36 10	37 5	37 2	41 10	42 6	42 2
8 10 0	35 8	36 3	36 0	37 5	38 0	37 9	42 6	43 2	42 10
8 12 6	36 3	36 10	36 6	38 0	38 7	38 4	43 2	43 10	43 5
8 15 0	36 9	37 5	37 1	38 7	39 2	38 11	43 10	44 6	44 1
8 17 6	37 4	37 11	37 8	39 2	39 9	39 5	44 6	45 2	44 9
9 0 0	37 11	38 6	38 2	39 9	40 4	40 0	45 2	45 10	45 5
9 2 6	38 5	39 1	38 9	40 4	40 11	40 7	45 9	46 6	46 1
9 5 0	39 0	39 7	39 4	40 11	41 6	41 2	46 5	47 2	46 9
9 7 6	39 6	40 2	39 10	41 5	42 1	41 9	47 1	47 10	47 5
9 10 0	40 1	40 9	40 5	42 0	42 8	42 4	47 9	48 6	48 1
9 12 6	40 7	41 3	40 11	42 7	43 3	42 11	48 5	49 2	48 9
9 15 0	41 2	41 10	41 6	43 2	43 10	43 6	49 1	49 10	49 5
9 17 6	41 9	42 5	42 1	43 9	44 5	44 1	49 8	50 5	50 0
10 0 0	42 3	43 0	42 8	44 4	45 0	44 8	50 4	51 1	50 8
	42 10	43 6	43 2	44 11	45 7	45 3	51 0	51 9	51 4
	43 5	44 1	43 9	45 6	46 2	45 10	51 8	52 5	52 0
	43 11	44 8	44 3	46 1	46 9	46 5	52 4	53 1	52 8

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 23, 24, and 30 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	23.			24.			30.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	611	621	616	688	699	693	980	995	997
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	21 10	22 2	22 0	24 7	24 11	24 9	35 0	35 6	35 3
4 2 6 "	22 6	22 10	22 8	25 4	25 9	25 6	36 1	36 8	36 4
4 5 0 "	23 2	23 7	23 4	26 1	26 6	26 3	37 2	37 9	37 5
4 7 6 "	23 10	24 3	24 1	26 11	27 4	27 1	38 3	38 10	38 7
4 10 0 "	24 6	24 11	24 9	27 8	28 1	27 10	39 4	40 0	39 8
4 12 6 "	25 3	25 8	25 5	28 5	28 10	28 7	40 6	41 1	40 9
4 15 0 "	25 11	26 4	26 1	29 2	29 8	29 5	41 7	42 2	41 10
4 17 6 "	26 7	27 0	26 10	29 11	30 5	30 2	42 8	43 4	43 0
5 0 0 "	27 3	27 9	27 6	30 8	31 2	30 11	43 9	44 5	44 1
5 2 6 "	28 0	28 5	28 2	31 6	32 0	31 9	44 10	45 6	45 2
5 5 0 "	28 8	29 1	28 10	32 3	32 9	32 6	45 11	46 8	46 3
5 7 6 "	29 4	29 10	29 7	33 0	33 7	33 3	47 0	47 9	47 4
5 10 0 "	30 0	30 6	30 3	33 9	34 4	34 0	48 1	48 10	48 5
5 12 6 "	30 8	31 2	30 11	34 7	35 1	34 10	49 3	50 0	49 7
5 15 0 "	31 4	31 10	31 7	35 4	35 11	35 7	50 4	51 1	50 8
5 17 6 "	32 1	32 7	32 4	36 1	36 8	36 4	51 5	52 2	51 9
6 0 0 "	32 9	33 3	33 0	36 10	37 5	37 1	52 6	53 4	52 10
6 2 6 "	33 5	34 0	33 8	37 8	38 3	37 11	53 7	54 5	54 0
6 5 0 "	34 1	34 8	34 4	38 5	39 0	38 8	54 8	55 6	55 1
6 7 6 "	34 9	35 4	35 1	39 2	39 9	39 5	55 9	56 8	56 2
6 10 0 "	35 5	36 0	35 9	39 11	40 7	40 2	56 10	57 9	57 3
6 12 6 "	36 2	36 9	36 5	40 8	41 4	41 0	58 0	58 10	58 5
6 15 0 "	36 10	37 5	37 1	41 5	42 1	41 9	59 1	59 11	59 6
6 17 6 "	37 6	38 1	37 10	42 3	42 11	42 6	60 2	61 0	60 7
7 0 0 "	38 2	38 10	38 6	43 0	43 8	43 4	61 3	62 2	61 8
7 2 6 "	38 10	39 6	39 2	43 9	44 6	44 1	62 4	63 3	62 9
7 5 0 "	39 6	40 2	39 10	44 6	45 3	44 10	63 5	64 5	63 11
7 7 6 "	40 3	40 11	40 7	45 4	46 0	45 7	64 6	65 6	65 0
7 10 0 "	40 11	41 7	41 3	46 1	46 10	46 5	65 7	66 7	66 1
7 12 6 "	41 7	42 3	41 11	46 10	47 7	47 2	66 9	67 8	67 2
7 15 0 "	42 3	42 11	42 7	47 7	48 4	47 11	67 10	68 10	68 3
7 17 6 "	42 11	43 8	43 4	48 5	49 2	48 9	68 11	69 11	69 5
8 0 0 "	43 8	44 4	44 0	49 2	49 11	49 6	70 0	71 0	70 6
8 2 6 "	44 4	45 1	44 8	49 11	50 9	50 3	71 1	72 1	71 7
8 5 0 "	45 0	45 9	45 4	50 8	51 6	51 0	72 2	73 3	72 8
8 7 6 "	45 8	46 5	46 1	51 5	52 3	51 10	73 3	74 4	73 10
8 10 0 "	46 4	47 1	46 9	52 2	53 0	52 7	74 4	75 6	74 11
8 12 6 "	47 0	47 10	47 5	53 0	53 10	53 4	75 6	76 8	76 0
8 15 0 "	47 9	48 6	48 2	53 9	54 7	54 2	76 7	77 9	77 1
8 17 6 "	48 5	49 3	48 10	54 6	55 5	54 11	77 8	78 10	78 3
9 0 0 "	49 1	49 11	49 6	55 3	56 2	55 8	78 9	79 11	79 4
9 2 6 "	49 9	50 7	50 2	56 1	56 11	56 6	79 10	81 1	80 5
9 5 0 "	50 5	51 3	50 10	56 10	57 9	57 3	80 11	82 2	81 6
9 7 6 "	51 2	52 0	51 7	57 7	58 6	58 0	82 0	83 3	82 7
9 10 0 "	51 10	52 8	52 3	58 4	59 3	58 9	83 1	84 5	83 8
9 12 6 "	52 6	53 4	52 11	59 2	60 1	59 7	84 2	85 6	84 10
9 15 0 "	53 2	54 1	53 7	59 11	60 10	60 4	85 4	86 7	85 11
9 17 6 "	53 10	54 9	54 4	60 8	61 8	61 1	86 5	87 9	87 0
10 0 0 "	54 7	55 5	55 0	61 5	62 5	61 10	87 6	88 10	88 1

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 36, 42, and 48 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	36.			42.			48.		
	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	1920	1941	1930	1621	1646	1638	1946	1976	1961
Cost per yard at £4 0 0 per ton.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
4 2 6	47 2	47 11	47 6	57 11	53 9	58 4	69 6	70 7	70 0
4 5 0	48 7	49 5	49 0	59 8	60 7	60 2	71 8	72 9	72 3
4 7 6	50 1	50 11	50 5	61 6	62 5	61 11	73 10	75 0	74 5
4 10 0	51 7	52 5	51 11	63 4	64 4	63 9	75 11	77 2	76 7
4 12 6	53 0	53 10	53 5	65 1	66 2	65 7	78 2	79 5	78 9
4 15 0	54 6	55 4	54 11	66 11	68 0	67 5	80 4	81 7	81 0
4 17 6	56 0	56 10	56 5	68 9	69 10	69 3	82 6	83 10	83 2
5 0 0	57 5	58 4	57 11	70 7	71 8	71 1	84 8	86 0	85 4
5 2 6	58 11	59 10	59 4	72 4	73 6	72 11	86 10	88 2	87 6
5 5 0	60 4	61 4	60 10	74 2	75 4	74 9	89 1	90 5	89 9
5 7 6	61 10	62 10	62 4	76 0	77 2	76 6	91 3	92 7	91 11
5 10 0	63 4	64 4	63 10	77 10	79 0	78 4	93 5	94 10	94 1
5 12 6	64 10	65 10	65 4	79 7	80 10	80 2	95 7	97 0	96 8
5 15 0	66 4	67 4	66 10	81 5	82 8	82 0	97 9	99 3	98 6
5 17 6	67 9	68 10	68 3	83 3	84 6	83 10	99 11	101 5	100 8
6 0 0	69 3	70 4	69 9	85 0	86 4	85 8	102 1	103 8	102 10
6 2 6	70 8	71 10	71 3	86 10	88 2	87 6	104 3	105 10	105 1
6 5 0	72 2	73 4	72 9	88 8	89 0	89 3	106 5	108 0	107 8
6 7 6	73 8	74 10	74 2	90 5	91 10	91 1	108 7	110 3	109 5
6 10 0	75 2	76 4	75 8	92 3	93 8	92 11	110 8	112 6	111 7
6 12 6	76 7	77 10	77 2	94 1	95 6	94 9	112 11	114 8	113 10
6 15 0	78 1	79 3	78 8	95 11	97 4	96 8	115 1	116 11	116 0
6 17 6	79 7	80 10	80 2	97 8	99 2	98 5	117 3	119 1	118 2
7 0 0	81 0	82 4	81 8	99 6	101 0	100 3	119 5	121 4	120 6
7 2 6	82 6	83 10	83 1	101 4	102 10	102 1	121 7	123 6	122 4
7 5 0	84 0	85 4	84 7	103 1	104 9	103 11	123 10	125 8	124 7
7 7 6	85 5	86 10	86 1	104 11	106 6	105 8	126 0	127 11	126 10
7 10 0	86 11	88 4	87 7	106 9	108 5	107 6	128 2	130 1	129 1
7 12 6	88 5	89 9	89 1	108 6	110 3	109 4	130 4	132 4	131 2
7 15 0	89 10	91 4	90 6	110 4	112 1	111 2	132 6	134 6	133 4
7 17 6	91 4	92 9	92 0	112 2	113 11	113 0	134 8	136 9	135 8
8 0 0	92 10	94 3	93 6	114 0	115 9	114 10	136 10	138 11	137 11
8 2 6	94 3	95 9	95 0	115 9	117 7	116 8	139 0	141 2	140 1
8 5 0	95 9	97 3	96 6	117 7	119 5	118 6	141 2	143 4	142 9
8 7 6	97 3	98 9	97 11	119 5	121 3	120 3	143 4	145 7	144 5
8 10 0	98 9	100 3	99 5	121 3	123 1	122 2	145 6	147 9	146 8
8 12 6	100 2	101 9	100 11	123 0	124 11	123 11	147 8	149 11	148 10
8 15 0	101 8	103 3	102 5	124 10	126 9	125 9	149 10	152 1	151 0
8 17 6	103 1	104 9	103 11	126 8	128 7	127 7	152 0	154 4	153 2
9 0 0	104 7	106 3	105 5	128 6	130 5	129 5	154 2	156 6	155 5
9 2 6	106 1	107 9	106 10	130 3	132 3	131 3	156 4	158 7	157 7
9 5 0	107 7	109 3	108 4	132 1	134 1	133 1	158 7	160 11	159 9
9 7 6	109 0	110 9	109 10	133 10	135 11	134 10	160 8	163 2	161 11
9 10 0	110 6	112 3	111 4	135 8	137 9	136 8	162 11	165 4	164 1
9 12 6	111 11	113 9	112 10	137 6	139 7	138 6	165 1	167 7	166 4
9 15 0	113 5	115 3	114 4	139 4	141 5	140 4	167 3	169 9	168 6
9 17 6	114 11	116 9	115 9	141 1	143 3	142 2	169 5	172 0	170 8
10 0 0	116 5	118 3	117 3	142 11	144 1	144 0	171 7	174 2	172 10
	117 10	119 9	118 9	144 9	146 11	145 10	173 9	176 5	175 11

TABLE
Showing the Discharge of Gas in Cubic Feet per Hour. Specific Gravity 0.420. Pressure, 1 inch.
 (Clegg, 4th Ed., p. 304.)

Length of Pipes in Yards.	DIAMETER OF PIPES IN INCHES.														
	2.	3.	4.	5.	6.	7.	8.	9.	10.	12.	14.	16.	18.	20.	22.
20	7,253	21,262	28,965	38,168	50,519	65,475	84,758	107,950	124,362	150,681	201,986	235,440	272,467	300,664	
30	5,941	18,192	25,758	36,969	41,334	53,970	73,288	96,579	124,362	184,774	179,252	214,920	272,467	300,664	
40	1,859	5,127	7,417	10,689	14,968	21,027	30,758	41,334	53,970	84,758	107,950	150,681	201,986	235,440	
50	1,066	3,244	4,652	6,521	9,483	13,534	19,051	26,611	37,967	53,970	73,288	106,464	148,375	184,774	
100	1,177	3,244	4,652	6,521	9,483	13,534	19,051	26,611	37,967	53,970	73,288	106,464	148,375	184,774	
150	961	2,653	3,721	5,242	7,417	10,689	15,479	21,886	30,758	43,379	60,803	87,145	122,714	164,700	
200	863	2,284	3,284	4,708	6,521	9,483	13,534	19,051	26,611	37,967	53,970	73,288	106,464	148,375	
250	745	1,957	2,825	4,013	5,621	8,164	12,039	16,846	23,220	32,845	46,461	68,266	97,785	134,200	
300	679	1,871	2,721	3,844	5,242	7,417	10,689	15,479	21,886	30,758	43,379	60,803	87,145	122,714	
400	589	1,615	2,325	3,325	4,604	6,521	9,483	13,534	19,051	26,611	37,967	53,970	73,288	106,464	
500	529	1,433	2,060	2,980	4,129	5,816	8,268	11,836	16,846	23,220	32,845	46,461	68,266	97,785	
600	480	1,324	1,924	2,721	3,844	5,242	7,417	10,689	15,479	21,886	30,758	43,379	60,803	87,145	
700	442	1,227	1,765	2,505	3,505	4,807	6,521	9,483	13,534	19,051	26,611	37,967	53,970	73,288	
800	400	1,142	1,584	2,265	3,265	4,463	6,268	9,051	12,846	17,846	24,846	34,846	49,846	70,846	
900	360	1,081	1,481	2,003	2,847	3,966	5,526	7,839	10,926	15,026	20,846	29,286	40,926	58,426	
1,000	320	1,020	1,381	1,905	2,678	3,733	5,186	7,286	10,286	14,286	19,886	27,886	38,886	55,886	
1,760	260	850	1,176	1,676	2,374	3,416	4,716	6,416	8,965	12,197	17,010	24,688	36,250	50,803	
2,640	200	700	1,026	1,426	2,026	2,825	3,925	5,225	7,225	10,225	14,225	20,225	29,225	41,512	
3,620	150	550	826	1,126	1,526	2,126	2,925	4,025	5,525	7,525	10,525	14,525	20,525	29,525	
5,280	100	400	626	876	1,226	1,726	2,425	3,325	4,525	6,225	8,725	12,225	17,225	24,225	
7,040	70	300	476	676	926	1,276	1,776	2,475	3,375	4,675	6,475	9,075	12,575	17,575	
8,800	50	200	326	476	676	926	1,276	1,776	2,475	3,375	4,675	6,475	9,075	12,575	
10,000	40	150	226	326	476	676	926	1,276	1,776	2,475	3,375	4,675	6,475	9,075	

TABLES

Of the Discharge of Gas, in Cubic Feet per hour, through Pipes of various Diameters and Lengths at different Pressures.

By THOMAS G. BARLOW. Extended by THOMAS NEWBIGGING.

(The specific gravity of the gas is taken at 0.4, air being 1.)

The tables are calculated according to the formula given by Dr. Pole in his valuable article¹ "On the Motion of Fluids in Pipes."

Q = quantity of gas in cubic feet per hour.

l = length of pipe in yards.

d = diameter of pipe in inches.

h = pressure in inches of water.

s = specific gravity of gas, air being 1.

$$Q = 1350 d^2 \sqrt{\frac{hd}{sl}}$$

—i.e., multiply the pressure in inches of water by the diameter of the pipe, also in inches. Divide the product by the specific gravity of the gas multiplied by the length of the pipe in yards. Extract the square root of the quotient, which root, multiplied by the constant quantity 1350, and the square of the diameter of the pipe in inches, gives the number of cubic feet discharged in one hour.

EXAMPLE.—It is required to find the number of cubic feet of gas of the specific gravity of 0.400, which will be discharged in one hour from a pipe 8 in. in diameter and 1250 yards in length, under a pressure of $\frac{16}{10}$, or $1\frac{1}{2}$ in. head of water.

Thus— $(hd) = 8 \times 1.5 = 12$.

$\left(\sqrt{\frac{hd}{sl}} = \sqrt{\frac{12}{0.4 \times 1250}} = \sqrt{0.024} \right)$, the square root being = 0.1549.

$\left(1350 d^2 \sqrt{\frac{hd}{sl}} \right) = 1350 \times 64 \times 0.1549 = 13,383$ cub. ft. = Q .

Recent research work by Professor Unwin on the discharge of gas in pipes revealed the fact that Dr. Pole's formula is not strictly accurate.

¹ See *King's Treatise*, vol. ii., p. 374 et seq.

It is well known that Dr. Pole in computing his formula assumed an average coefficient of friction of 0.006, whereas Professor Unwin has determined that different diameters of pipes have varying coefficients of friction.

The following table gives the coefficient of friction based on the formula, $\mu = 0.0044 \left(1 + \frac{1}{7d} \right)$, where d is the diameter of the pipe in feet, deduced by Professor Unwin.

Diameter of Main.	Coefficient of Friction.	Diameter of Main.	Coefficient of Friction.
2	0.0082	14	0.0049
2.5	0.0074	15	0.0049
3	0.0069	16	0.0049
4	0.0063	18	0.0048
5	0.0059	20	0.0048
6	0.0057	22	0.0047
7	0.0055	24	0.0047
8	0.0053	26	0.0047
9	0.0052	28	0.0047
10	0.0051	30	0.0047
12	0.0050	36	0.0044

The difference in the discharge by adopting the new values of friction is, however, not of sufficient importance to annul the values as determined by Dr. Pole. When it is remembered that no theoretical calculation can be strictly accurate under the varying conditions of gas supply, Dr. Pole's formula may be accepted for all practical purposes.

Diameter of Pipe, 0.5 Inch.

Length in yards.	10.	20.	30.	50.	75.	100.	150.
Quantity delivered with 0.1 in. pressure.	37.7	26.7	21.7	16.8	13.8	11.9	9.7
0.2 "	53.4	37.7	30.6	23.8	19.5	16.8	13.8
0.3 "	65.2	46.3	37.7	29.1	23.8	20.7	16.8
0.4 "	75.2	53.3	43.2	33.7	27.5	23.8	19.5
0.5 "	84.3	59.4	48.6	37.4	30.7	26.7	21.7
0.6 "	92.1	65.1	53.3	41.1	33.7	29.0	23.8
0.8 "	106.7	75.4	61.4	47.5	38.8	33.7	27.4
1.0 "	119.1	84.3	68.8	53.3	43.2	37.7	30.8
1.2 "	130.6	92.1	75.2	58.3	47.5	41.1	33.7
1.5 "	146.1	103.2	84.3	65.1	53.3	45.9	37.8
1.8 "	159.9	113.0	92.1	71.5	58.3	50.6	41.1
2.0 "	168.7	119.1	97.2	75.2	61.4	53.3	43.5
2.5 "	188.6	133.3	108.5	84.3	68.8	59.4	48.6

Diameter of Pipe, 0.75 Inch.

Length in yards.	10.	20.	30.	50.	75.	100.	150.
Quantity delivered with 0.1 in. pressure.	104.3	73.8	60.0	46.6	37.9	32.9	26.9
0.2 "	147.5	104.3	84.9	65.8	53.7	46.6	37.9
0.3 "	179.9	126.8	104.3	80.9	65.8	57.0	46.6
0.4 "	207.3	146.5	119.9	93.2	75.9	65.8	53.8
0.5 "	232.3	164.0	133.6	103.2	84.2	73.8	60.0
0.6 "	254.3	179.9	146.5	113.9	92.6	79.7	65.3
0.8 "	293.8	207.3	169.3	131.3	107.0	92.6	75.9
1.0 "	328.8	232.3	189.8	146.5	119.9	103.2	84.3
1.2 "	359.9	254.3	207.3	160.9	131.3	113.9	92.6
1.5 "	402.4	284.0	232.3	179.9	146.5	126.8	103.2
1.8 "	441.1	311.3	254.3	192.2	160.9	138.9	113.9
2.0 "	464.7	328.8	268.0	207.3	169.3	146.5	119.9
2.5 "	519.4	367.5	299.9	232.2	189.8	164.0	133.6

Diameter of Pipe, 1 Inch.

Length in yards.	10.	20.	30.	50.	75.	100.	150.
Quantity delivered with 0.1 in. pressure.	214.0	151.0	124.0	95.0	78.0	67.0	55.0
0.2 "	302.0	214.0	175.0	135.0	110.0	95.0	78.0
0.3 "	368.5	260.5	214.0	165.0	135.0	117.0	95.0
0.4 "	426.6	301.0	245.7	190.0	156.0	135.0	110.0
0.5 "	476.5	337.5	274.0	213.3	172.8	151.0	123.0
0.6 "	522.4	368.5	301.0	233.5	190.3	164.7	135.0
0.8 "	603.4	426.6	348.3	270.0	220.0	190.3	155.2
1.0 "	675.0	476.5	388.8	301.0	245.7	213.3	172.8
1.2 "	738.4	522.4	426.6	329.4	270.0	233.5	190.3
1.5 "	826.2	584.5	476.5	368.5	301.0	260.5	213.3
1.8 "	904.5	639.9	522.4	405.0	329.4	286.2	233.5
2.0 "	954.4	675.0	550.8	426.6	348.3	301.0	245.7
2.5 "	1,066.5	754.6	615.6	476.5	388.8	337.5	274.0

Diameter of Pipe, 1.25 Inches.

Length in yards.	25.	50.	75.	100.	150.	200.	300.
Quantity delivered with 0.1 in. pressure.	236.0	167.0	137.0	118.0	96.0	84.0	68.0
0.2 "	333.0	236.0	192.0	167.0	137.0	118.0	96.0
0.3 "	407.1	289.0	236.0	205.0	167.0	144.0	118.0
0.4 "	470.3	333.2	272.1	236.0	192.0	167.0	137.0
0.5 "	527.3	371.2	303.7	263.6	215.1	187.0	152.0
0.6 "	575.8	407.1	333.2	286.8	235.8	203.9	166.6
0.8 "	666.5	470.3	383.9	333.2	272.1	235.8	192.3
1.0 "	744.6	527.3	430.3	371.2	303.7	263.6	215.1
1.2 "	816.3	575.8	470.3	407.1	333.2	286.8	235.8
1.5 "	913.3	645.4	527.3	455.6	371.2	322.7	263.6
1.8 "	999.8	706.4	575.8	499.9	407.1	352.2	286.8
2.0 "	1,054.6	744.6	607.5	527.3	430.3	371.2	303.7
2.5 "	1,179.1	833.2	679.2	588.5	480.9	415.5	339.6

Diameter of Pipe, 1.5 Inches.

Length in yards.	25.	50.	75.	100.	150.	200.	300.
Quantity delivered with 0.1 in. pressure.	374.0	264.0	215.0	187.0	152.0	132.0	107.0
0.2 "	528.0	374.0	304.0	264.0	215.0	187.0	152.0
0.3 "	643.9	458.0	374.0	322.0	264.0	229.0	187.0
0.4 "	741.1	525.4	423.2	374.0	304.0	264.0	215.0
0.5 "	829.2	586.2	479.9	413.1	339.5	295.0	239.0
0.6 "	911.2	643.9	525.4	455.6	370.5	321.9	261.2
0.8 "	1,050.9	741.1	607.5	525.4	428.2	370.5	303.7
1.0 "	1,175.5	829.2	677.3	586.2	479.9	413.1	339.5
1.2 "	1,237.9	911.2	741.1	643.9	525.4	455.6	370.5
1.5 "	1,439.7	1,017.5	829.2	719.8	586.2	507.2	413.1
1.8 "	1,576.4	1,114.7	911.2	789.1	643.9	555.8	455.6
2.0 "	1,661.5	1,175.5	959.8	829.2	677.3	586.2	479.9
2.5 "	1,858.9	1,315.2	1,072.2	929.4	759.3	656.1	534.6

Diameter of Pipe, 2 Inches.

Length in yards.	50.	75.	100.	150.	200.	300.	500.
Quantity delivered with 0.1 in. pressure.	540	441	381	311	270	220	170
0.2 "	763	623	540	441	381	311	241
0.3 "	934	763	665	540	468	381	296
0.4 "	1,080	880	761	623	540	441	341
0.5 "	1,204	983	853	697	604	492	381
0.6 "	1,318	1,080	934	761	659	540	416
0.8 "	1,523	1,242	1,080	880	761	621	481
1.0 "	1,706	1,393	1,204	983	853	697	540
1.2 "	1,868	1,523	1,318	1,080	934	761	589
1.5 "	2,090	1,706	1,474	1,204	1,042	853	659
1.8 "	2,290	1,868	1,620	1,318	1,145	934	724
2.0 "	2,414	1,971	1,706	1,393	1,204	983	761
2.5 "	2,700	2,203	1,906	1,555	1,350	1,102	853

Diameter of Pipe, 2.5 Inches.

Length in yards.	50.	75.	100.	150.	200.	300.	500.
Quantity delivered with 0.1 in. pressure.	943	770	667	545	471	335	298
0.2 "	1,355	1,090	943	770	667	545	421
0.3 "	1,628	1,335	1,172	943	819	667	516
0.4 "	1,862	1,540	1,333	1,090	943	770	596
0.5 "	2,109	1,721	1,485	1,215	1,055	861	667
0.6 "	2,303	1,882	1,628	1,333	1,148	943	791
0.8 "	2,666	2,177	1,832	1,540	1,333	1,088	844
1.0 "	2,978	2,430	2,109	1,721	1,485	1,215	943
1.2 "	3,265	2,666	2,303	1,882	1,628	1,333	1,029
1.5 "	3,653	2,978	2,582	2,109	1,823	1,485	1,148
1.8 "	3,999	3,265	2,827	2,303	2,000	1,628	1,266
2.0 "	4,219	3,443	2,978	2,430	2,109	1,721	1,333
2.5 "	4,717	3,848	3,333	2,717	2,354	1,924	1,485

Diameter of Pipe, 3 Inches.

Length in yards.	100.	150.	250.	500.	750.	1000.	1250.
Quantity delivered with 0.1 in. pressure.	1,054	859	666	471	384	333	298
0.2 "	1,440	1,214	942	666	543	471	375
0.3 "	1,823	1,487	1,153	815	666	576	529
0.4 "	2,102	1,713	1,332	942	768	666	596
0.5 "	2,345	1,920	1,482	1,054	859	744	666
0.6 "	2,576	2,102	1,628	1,152	942	815	739
0.8 "	2,965	2,430	1,882	1,324	1,081	942	845
1.0 "	3,317	2,709	2,102	1,482	1,215	1,052	942
1.2 "	3,645	2,965	2,296	1,628	1,324	1,152	1,030
1.5 "	4,070	3,317	2,576	1,823	1,482	1,288	1,152
1.8 "	4,459	3,645	2,819	1,993	1,628	1,409	1,262
2.0 "	4,702	3,839	2,965	2,102	1,713	1,432	1,324
2.5 "	5,261	4,289	3,317	2,345	1,920	1,652	1,482

Diameter of Pipe, 4 Inches.

Length in yards.	100.	250.	500.	750.	1000.	1250.	1500.
Quantity delivered with 0.1 in. pressure.	2,160	1,366	966	788	683	611	557
0.2 "	3,054	1,932	1,366	1,114	966	864	788
0.3 "	3,737	2,366	1,673	1,366	1,183	1,058	966
0.4 "	4,320	2,722	1,932	1,576	1,366	1,222	1,114
0.5 "	4,817	3,046	2,160	1,761	1,526	1,366	1,245
0.6 "	5,270	3,346	2,354	1,932	1,672	1,496	1,366
0.8 "	6,091	3,845	2,722	2,225	1,932	1,728	1,576
1.0 "	6,826	4,320	3,046	2,484	2,160	1,932	1,761
1.2 "	7,474	4,730	3,346	2,722	2,354	2,115	1,922
1.5 "	8,359	5,270	3,737	3,046	2,635	2,354	2,160
1.8 "	9,158	5,789	4,082	3,346	2,894	2,592	2,354
2.0 "	9,655	6,091	4,320	3,521	3,046	2,722	2,484
2.5 "	10,800	6,826	4,817	3,931	3,413	3,046	2,786

Diameter of Pipe, 5 Inches.

Length in yards.	100.	250.	500.	750.	1000.	1250.	1500.
Quantity delivered with 0·1 in. pressure.	3,540	2,245	1,587	1,296	1,122	1,000	910
0·2 "	5,005	3,174	2,245	1,832	1,587	1,414	1,296
0·3 "	6,514	3,888	2,748	2,245	1,943	1,732	1,575
0·4 "	7,526	4,759	3,174	2,592	2,245	2,000	1,820
0·5 "	8,438	5,333	3,773	2,888	2,508	2,236	1,934
0·6 "	9,214	5,839	4,118	3,174	2,743	2,449	2,245
0·8 "	10,665	6,750	4,759	3,881	3,174	2,828	2,596
1·0 "	11,914	7,526	5,333	4,354	3,773	3,174	2,877
1·2 "	13,061	8,235	5,839	4,759	4,118	3,679	3,375
1·5 "	14,614	9,214	6,514	5,333	4,590	4,118	3,540
1·8 "	15,998	10,125	7,156	5,839	5,063	4,523	4,118
2·0 "	16,875	10,665	7,526	6,143	5,333	4,759	4,354
2·5 "	18,866	11,914	8,438	6,885	5,940	5,333	4,860

Diameter of Pipe, 6 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	3,770	2,660	2,170	1,830	1,680	1,530	1,420
0·2 "	5,320	3,770	3,130	2,660	2,370	2,170	2,010
0·3 "	6,530	4,620	3,770	3,270	2,920	2,660	2,460
0·4 "	7,540	5,320	4,340	3,770	3,360	3,060	2,840
0·5 "	8,408	5,970	4,860	4,210	3,770	3,430	3,180
0·6 "	9,185	6,512	5,320	4,620	4,130	3,770	3,460
0·8 "	10,643	7,528	6,124	5,320	4,740	4,340	4,020
1·0 "	11,858	8,408	6,853	5,929	5,320	4,860	4,500
1·2 "	13,025	9,185	7,528	6,512	5,832	5,297	4,923
1·5 "	14,580	10,303	8,408	7,290	6,512	5,970	5,500
1·8 "	15,941	11,275	9,185	7,970	7,139	6,512	6,026
2·0 "	16,816	11,858	9,720	8,408	7,528	6,853	6,360
2·5 "	18,808	13,268	10,838	9,330	8,408	7,679	7,096

Diameter of Pipe, 7 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	5,560	3,920	3,200	2,780	2,470	2,270	2,100
0·2 "	7,840	5,560	4,510	3,920	3,500	3,200	2,960
0·3 "	9,600	6,800	5,560	4,800	4,300	3,920	3,640
0·4 "	11,120	7,840	6,400	5,560	4,940	4,540	4,200
0·5 "	12,370	8,750	7,180	6,200	5,560	5,060	4,680
0·6 "	13,554	9,585	7,840	6,800	6,080	5,560	5,130
0·8 "	15,611	11,047	8,996	7,840	7,020	6,400	5,930
1·0 "	17,463	12,370	10,054	8,732	7,840	7,180	6,610
1·2 "	19,170	13,554	11,047	9,585	8,533	7,805	7,210
1·5 "	21,433	15,148	12,370	10,716	9,585	8,750	8,120
1·8 "	23,477	16,597	13,554	11,709	10,452	9,855	8,864
2·0 "	24,740	17,463	14,288	12,370	11,047	10,054	9,360
2·5 "	27,651	19,567	15,942	13,825	12,370	11,292	10,452

Diameter of Pipe, 8 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0.1 in. pressure.	7,760	5,470	4,470	3,880	3,460	3,160	2,920
0.2 "	10,940	7,760	6,310	5,470	4,880	4,470	4,130
0.3 "	13,400	9,450	7,760	6,700	5,980	5,470	5,050
0.4 "	15,520	10,940	8,940	7,760	6,920	6,320	5,840
0.5 "	17,280	12,200	9,900	8,640	7,760	7,020	6,520
0.6 "	18,922	13,383	10,940	9,450	8,480	7,760	7,150
0.8 "	21,851	15,379	12,614	10,940	9,780	8,940	8,260
1.0 "	24,365	17,280	14,083	12,182	10,940	9,900	9,237
1.2 "	26,767	18,922	15,379	13,383	11,923	10,886	10,109
1.5 "	29,894	21,082	17,280	14,947	13,383	12,200	11,300
1.8 "	32,746	23,155	18,922	16,330	14,602	13,383	12,355
2.0 "	34,560	24,365	19,872	17,280	15,379	14,083	13,040
2.5 "	38,621	27,302	22,291	19,267	17,280	15,725	14,602

Diameter of Pipe, 9 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0.1 in. pressure.	10,400	7,380	6,350	5,200	4,650	4,250	3,950
0.2 "	14,760	10,400	8,500	7,380	6,480	6,000	5,620
0.3 "	18,000	12,780	10,400	9,000	8,300	7,380	6,800
0.4 "	20,800	14,760	12,700	10,400	9,300	8,500	7,900
0.5 "	23,182	16,500	13,420	11,900	10,400	9,680	8,800
0.6 "	25,369	17,933	14,760	12,780	11,400	10,400	9,650
0.8 "	29,306	20,667	16,938	14,760	13,100	12,000	11,050
1.0 "	32,805	23,182	18,918	16,403	14,760	13,420	12,380
1.2 "	35,867	25,369	20,667	17,933	16,064	14,653	13,559
1.5 "	40,131	28,409	23,182	20,011	17,933	16,500	15,200
1.8 "	43,959	31,055	25,369	21,979	19,683	17,933	16,621
2.0 "	46,364	32,805	26,681	23,182	20,667	18,918	17,600
2.5 "	51,332	36,632	29,853	25,916	23,182	21,105	19,574

Diameter of Pipe, 10 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0.1 in. pressure.	9,560	7,800	6,750	6,050	5,520	5,100	4,780
0.2 "	13,500	11,040	9,560	8,520	7,800	7,300	6,750
0.3 "	16,500	13,500	11,700	10,520	9,560	8,850	8,259
0.4 "	19,120	15,600	13,500	12,100	11,040	10,200	9,560
0.5 "	21,300	17,400	15,050	13,500	12,380	11,400	10,650
0.6 "	23,355	19,120	16,500	14,800	13,500	12,500	11,650
0.8 "	27,000	22,005	19,120	17,050	15,600	14,400	13,500
1.0 "	30,105	24,570	21,330	19,120	17,400	16,150	15,050
1.2 "	32,940	27,000	23,355	20,911	19,035	17,550	16,578
1.5 "	36,855	30,105	26,055	23,355	21,300	19,600	18,500
1.8 "	40,500	32,940	28,620	25,515	23,355	21,600	20,250
2.0 "	42,660	34,830	30,105	27,000	24,570	22,800	21,300
2.5 "	47,655	38,880	33,750	30,105	27,540	25,501	23,760

Diameter of Pipe, 12 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	15,100	12,300	10,700	9,550	8,700	8,050	7,550
0·2 "	21,400	17,400	15,100	13,450	12,300	11,850	10,700
0·3 "	26,100	21,400	19,500	16,500	15,100	13,880	13,050
0·4 "	30,200	24,600	21,400	19,100	17,400	16,100	15,100
0·5 "	33,600	27,500	23,800	21,400	19,440	18,050	16,800
0·6 "	36,741	30,200	26,100	23,300	21,400	19,800	19,500
0·8 "	42,573	34,603	30,200	26,900	24,600	22,700	21,400
1·0 "	47,433	38,880	33,631	30,200	27,500	25,450	23,800
1·2 "	52,099	42,573	36,741	32,853	30,112	27,799	26,049
1·5 "	58,320	47,433	41,212	36,741	33,600	31,250	29,250
1·8 "	63,763	52,099	45,100	40,396	36,741	34,020	31,881
2·0 "	67,262	54,820	47,433	42,573	38,880	36,100	33,600
2·5 "	75,232	61,430	53,071	47,433	43,351	40,240	37,519

Diameter of Pipe, 14 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	22,100	18,100	15,600	13,950	12,750	11,800	11,050
0·2 "	31,200	25,500	22,100	19,800	18,100	16,700	15,600
0·3 "	38,400	31,200	27,100	24,250	22,100	20,500	19,200
0·4 "	44,200	36,200	31,200	27,900	25,500	23,600	22,100
0·5 "	49,400	40,400	35,000	31,200	28,500	26,460	24,700
0·6 "	54,216	44,200	38,400	34,300	31,200	28,900	27,100
0·8 "	62,445	51,067	44,200	39,600	36,200	33,400	31,200
1·0 "	69,854	57,153	49,480	44,200	40,400	37,300	35,000
1·2 "	76,681	62,445	54,216	48,421	44,188	40,986	38,340
1·5 "	85,730	69,854	60,593	54,216	49,400	45,700	42,600
1·8 "	93,906	76,681	66,414	59,270	54,216	50,009	46,834
2·0 "	98,960	80,703	69,854	62,445	57,153	52,920	49,400
2·5 "	110,602	90,228	78,268	69,854	63,768	59,005	55,301

Diameter of Pipe, 15 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	26,300	21,400	18,600	16,600	15,200	14,000	13,150
0·2 "	37,200	30,400	26,300	23,500	21,400	19,900	18,600
0·3 "	45,500	37,200	32,250	28,750	26,300	24,300	22,750
0·4 "	52,600	42,800	37,200	33,200	30,400	28,000	26,300
0·5 "	58,700	48,000	41,600	37,200	34,000	31,400	29,350
0·6 "	64,395	52,600	45,500	40,700	37,200	34,450	32,250
0·8 "	74,115	60,750	52,600	47,000	42,800	39,800	37,200
1·0 "	82,923	67,736	58,623	52,600	48,000	44,400	41,600
1·2 "	91,125	74,115	64,395	57,408	52,548	48,600	45,562
1·5 "	101,756	82,923	71,983	64,395	58,700	54,300	50,800
1·8 "	111,476	91,125	78,914	70,470	64,395	59,535	55,586
2·0 "	117,551	95,985	82,923	74,115	67,736	62,800	58,700
2·5 "	131,523	107,223	92,947	82,923	75,937	70,166	65,610

Diameter of Pipe, 16 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	31,000	25,250	21,850	19,550	17,850	16,550	15,500
0·2 "	43,700	35,700	31,000	27,700	25,250	23,400	21,850
0·3 "	53,600	43,700	38,100	34,000	31,000	28,700	26,800
0·4 "	62,000	50,500	43,700	39,100	35,700	33,100	31,000
0·5 "	69,120	56,600	49,000	43,700	39,900	37,150	34,560
0·6 "	75,686	62,000	53,600	47,900	43,700	38,100	40,700
0·8 "	87,402	71,193	62,000	55,400	50,500	46,800	43,700
1·0 "	97,459	79,488	69,120	62,000	56,600	52,400	49,000
1·2 "	107,066	87,402	75,686	67,703	61,516	57,024	53,533
1·5 "	119,577	97,459	84,326	75,686	69,120	63,900	60,100
1·8 "	130,982	107,066	92,620	82,944	75,686	70,087	65,318
2·0 "	138,240	112,665	97,459	87,402	79,488	74,300	69,120
2·5 "	154,483	126,144	109,209	97,459	89,164	82,598	77,068

Diameter of Pipe, 18 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	41,400	33,800	29,400	23,900	20,700	18,400	16,900
0·2 "	58,800	47,800	41,400	33,800	29,400	26,200	23,900
0·3 "	71,800	58,800	50,800	41,400	35,900	32,100	29,400
0·4 "	82,800	67,600	58,800	47,800	41,400	36,800	33,800
0·5 "	92,600	75,700	65,600	53,500	46,300	41,400	37,850
0·6 "	101,476	82,800	71,800	58,800	50,800	45,400	41,400
0·8 "	117,223	95,790	82,800	67,600	58,800	52,300	47,800
1·0 "	131,220	106,725	92,728	75,700	65,600	58,800	53,500
1·2 "	143,467	117,223	101,476	82,668	71,733	64,254	58,611
1·5 "	161,400	131,220	113,636	92,728	80,000	71,800	65,600
1·8 "	175,834	143,467	124,221	101,476	87,917	78,732	71,733
2·0 "	185,457	151,340	131,220	106,725	92,728	82,800	75,700
2·5 "	207,327	169,273	146,529	119,410	103,663	92,728	84,500

Diameter of Pipe, 20 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	54,000	44,000	38,250	31,200	27,000	24,200	22,000
0·2 "	76,500	62,400	54,000	44,000	38,250	34,200	31,200
0·3 "	93,500	76,500	66,100	54,000	46,750	41,800	38,250
0·4 "	108,000	88,000	76,500	62,400	54,000	48,400	44,000
0·5 "	120,500	98,800	85,300	69,800	62,250	54,000	49,400
0·6 "	131,760	108,000	93,500	76,500	66,100	59,100	54,000
0·8 "	152,280	124,200	108,000	88,000	76,500	68,400	62,400
1·0 "	170,640	139,320	120,420	98,800	85,300	76,500	69,800
1·2 "	186,840	152,280	131,760	108,000	93,420	83,646	76,140
1·5 "	208,980	170,640	147,420	120,420	102,300	93,500	85,300
1·8 "	228,960	186,840	162,000	131,760	114,480	102,060	93,420
2·0 "	241,380	197,100	170,640	139,320	120,420	108,000	98,800
2·5 "	270,000	220,320	190,620	155,520	135,000	120,420	110,200

Diameter of Pipe, 22 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	68,600	56,000	48,400	39,600	84,300	30,700	28,000
0·2 "	96,800	79,200	68,600	56,000	48,000	43,400	39,600
0·3 "	118,800	96,800	84,000	68,600	59,400	53,300	48,400
0·4 "	137,200	112,000	96,800	79,200	68,600	61,400	56,000
0·5 "	153,500	122,500	108,200	88,600	76,800	68,400	61,200
0·6 "	168,577	137,200	118,800	96,800	84,000	75,000	68,600
0·8 "	193,406	158,122	137,200	112,000	96,800	86,500	79,200
1·0 "	216,275	176,418	152,895	122,500	108,200	96,800	88,600
1·2 "	237,184	193,406	168,577	136,560	118,265	105,850	96,703
1·5 "	265,280	216,275	187,525	152,895	132,000	118,800	108,200
1·8 "	290,697	237,184	203,860	168,577	145,054	130,026	118,265
2·0 "	306,444	249,598	216,275	176,418	152,895	137,200	122,500
2·5 "	342,381	279,655	242,280	197,326	171,190	152,895	140,000

Diameter of Pipe, 24 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	84,000	68,600	59,500	48,500	42,000	37,500	34,300
0·2 "	119,000	97,000	84,000	68,600	59,500	53,400	48,500
0·3 "	145,500	119,000	103,000	84,000	72,700	65,200	59,500
0·4 "	168,000	137,200	119,000	97,000	84,000	75,000	68,600
0·5 "	187,500	155,000	135,600	108,600	93,800	84,000	77,500
0·6 "	208,396	168,000	145,000	119,000	103,000	92,000	84,000
0·8 "	240,900	196,655	168,000	137,200	119,000	106,000	97,000
1·0 "	269,049	219,283	189,734	155,000	135,600	119,000	108,600
1·2 "	294,710	240,900	208,396	170,294	146,966	131,414	120,450
1·5 "	329,702	269,049	233,280	189,734	163,000	145,500	135,600
1·8 "	360,806	294,710	255,052	208,396	180,403	161,585	146,966
2·0 "	380,946	311,040	269,049	219,283	189,734	168,000	155,000
2·5 "	425,347	347,587	300,931	245,721	212,284	189,734	172,000

Diameter of Pipe, 26 Inches.

Length in yards.	750.	1000.	1500.	2000.	2500.	3000.	4000.
Quantity delivered with 0·1 in. pressure.	85,000	73,500	60,000	52,000	46,500	42,500	36,750
0·2 "	120,000	104,000	85,000	73,500	65,800	60,000	52,000
0·3 "	147,000	127,000	104,000	90,000	80,600	73,500	63,500
0·4 "	170,000	147,000	120,000	104,000	93,000	85,000	73,500
0·5 "	189,000	165,000	134,000	116,000	104,000	94,500	82,500
0·6 "	208,000	180,000	147,000	127,000	114,000	104,000	90,000
0·8 "	240,013	208,000	170,000	147,000	132,000	120,000	104,000
1·0 "	268,304	232,621	189,000	165,000	147,000	134,000	116,000
1·2 "	293,857	254,615	208,072	179,782	160,617	146,928	126,851
1·5 "	328,536	284,731	232,621	201,000	180,000	165,000	142,000
1·8 "	360,385	312,109	254,615	220,666	197,121	179,782	156,054
2·0 "	379,641	328,536	268,304	232,621	208,000	189,000	165,000
2·5 "	424,359	367,777	300,245	260,091	232,621	213,000	184,000
3·0 "	465,334	402,456	328,536	284,731	254,615	232,621	201,000

Diameter of Pipe, 28 Inches.

Length in yards.	1000.	1500.	2000.	2500.	3000.	4000.	5000.
Quantity delivered with 0.5 in. pressure.	198,000	161,000	140,000	125,000	114,500	99,000	88,600
0.6 "	216,866	176,752	153,362	136,533	124,891	107,956	96,314
0.8 "	249,782	204,271	176,752	157,701	143,942	124,891	111,978
1.0 "	280,000	229,000	198,000	177,000	161,000	140,000	125,000
1.2 "	306,724	249,782	216,866	193,687	176,752	153,362	136,533
1.5 "	342,921	280,000	241,000	216,000	198,000	171,000	153,500
1.8 "	375,626	308,724	265,658	237,081	216,866	187,336	167,227
2.0 "	395,841	322,812	280,000	250,000	229,000	198,000	177,200
2.5 "	442,411	360,914	313,074	280,000	255,000	222,000	198,000
3.0 "	484,747	395,841	342,921	306,724	280,000	241,000	216,000

Diameter of Pipe, 30 Inches.

Length in yards.	1000.	2000.	3000.	4000.	5000.	7500.	10000.
Quantity delivered with 0.5 in. pressure.	234,000	166,000	135,000	117,000	105,000	86,000	74,500
0.6 "	257,580	182,250	148,230	128,790	115,182	94,041	81,405
0.8 "	296,460	210,195	171,315	148,230	132,435	108,135	94,041
1.0 "	332,000	234,000	192,000	166,000	149,000	121,500	105,000
1.2 "	364,500	257,580	210,195	182,250	162,810	132,435	115,182
1.5 "	407,025	287,000	234,000	203,000	182,000	149,000	128,500
1.8 "	445,905	315,657	257,580	222,345	199,260	162,810	140,940
2.0 "	470,205	331,695	270,000	234,000	210,000	172,000	149,000
2.5 "	526,095	371,790	303,750	263,000	234,000	192,000	166,000
3.0 "	575,910	407,025	331,695	287,955	257,000	210,000	182,000
4.0 "	664,605	470,205	383,940	331,695	298,000	243,000	210,000

Diameter of Pipe, 36 Inches.

Length in yards.	1000.	2000.	3000.	4000.	5000.	7500.	10000.
Quantity delivered with 0.5 in. pressure.	370,915	262,440	213,451	185,457	165,862	135,419	117,223
0.6 "	405,907	286,934	234,446	202,953	181,783	148,366	127,720
0.8 "	468,892	330,674	271,013	234,446	209,952	171,235	148,366
1.0 "	530,000	370,000	303,000	265,000	234,000	192,000	166,000
1.2 "	573,868	405,907	330,674	286,934	257,016	209,952	181,783
1.5 "	642,103	456,000	372,000	322,000	288,000	234,900	204,000
1.8 "	703,339	496,886	405,907	351,669	314,928	257,016	222,199
2.0 "	741,830	524,880	423,000	372,000	332,000	271,000	234,000
2.5 "	829,310	586,116	477,640	416,000	372,000	303,000	265,000
3.0 "	908,042	642,103	524,880	454,546	407,000	332,000	288,000
4.0 "	1,049,760	742,180	605,361	524,880	468,892	384,000	332,000

The foregoing tables are calculated upon the basis of the specific gravity of the gas being 0.400. The quantity of gas of any other specific gravity discharged may be ascertained by multiplying the quantity indicated in the table by 0.6325 (the square root of 0.400), and dividing by the square root of the specific gravity of the other gas.

TABLE.

Square Root of Pressures, rising by Tenths of an Inch, from One-tenth to Four Inches.

Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.
0·1	0·3162	1·5	1·2251	2·8	1·6733
0·2	0·4472	1·6	1·2649	2·9	1·7029
0·3	0·5477	1·7	1·3038	3·0	1·7320
0·4	0·6324	1·8	1·3416	3·1	1·7606
0·5	0·7071	1·9	1·3784	3·2	1·7888
0·6	0·7745	2·0	1·4142	3·3	1·8165
0·7	0·8366	2·1	1·4491	3·4	1·8439
0·8	0·8944	2·2	1·4832	3·5	1·8708
0·9	0·9487	2·3	1·5165	3·6	1·8973
1·0	1·0000	2·4	1·5491	3·7	1·9235
1·1	1·0488	2·5	1·5811	3·8	1·9493
1·2	1·0954	2·6	1·6123	3·9	1·9748
1·3	1·1401	2·7	1·6431	4·0	2·0000
1·4	1·1832				

Should it be required to find the pressure in inches of water to discharge a certain quantity of gas of given specific gravity in an hour, through a pipe the dimensions of which are known, the formula is—

$$h = \frac{Q^2 s l}{(1350)^2 d^5}$$

—*i.e.*, multiply the square of the number of cubic feet of gas to be discharged in one hour by the specific gravity of the gas, and by the length of the pipe in yards; divide the product by the square of the constant number 1350, multiplied by the diameter in inches raised to the fifth power, and the quotient is the pressure.

EXAMPLE.—It is required to find the pressure in inches of water to discharge in an hour 12,000 cub. ft. of gas, specific gravity 0·5, through a pipe 8 in. in diameter and 1900 yards long. Then—

$$\frac{Q^2 \times s \times l}{1350^2 \times d^5} = \frac{144,000,000 \times 0\cdot5 \times 1900}{1,822,500 \times 32,768} \times \frac{136,800,000,000}{59,719,680,000} = \begin{cases} 2\cdot3 \text{ in.,} \\ \text{nearly.} \end{cases}$$

If the diameter of a pipe is required which will discharge a given quantity of gas under a given pressure, we have the formula—

$$d = \sqrt[5]{\frac{Q^2 s l}{(1350)^2 h}}$$

This can be easily calculated by a table of logarithms—thus :

$$\log. d = \frac{1}{5} (2 \log. Q + \log. s + \log. l - 2 \log. 1350 - \log. h.)$$

EXAMPLE.—It is required to find the diameter of a pipe 1240 yds. long, to discharge 48,000 cub. ft. of gas, of the specific gravity 0.4, in one hour, with a pressure of 2 in. Then—

2 log. Q	= 2 log. 48,000			= 9.3624824
log. s	= log. 0.4			= 1.6020600
log. l	= log. 1240			= 3.0934217
				12.0579641
2 log. 1350	= 6.2606676	}	. . . . .	= 6.5616976
log. h = log. 2	= 0.3010300			
				5) 5.4962665
log. d				= 1.0992533

Therefore $d = 13$ in.

The following axioms are worth remembering :—

1. The discharge of gas will be doubled when the length of the pipe is only $\frac{1}{4}$ of any of the lengths given in the tables.
2. The discharge of gas will be only $\frac{1}{2}$ when the length of the pipe is four times greater than the lengths given in the tables.
3. The discharge of gas will be doubled by the application of four times the pressure.

Handy Rule for finding (approximately) the Content of a Pipe in Gallons and Cubic Feet.

RULE.—Multiply the square of the diameter of the pipe in inches by the length in yards, and divide by 10 for gallons and by 60 for cubic feet.

EXAMPLE—A pipe is 6 in. diameter and 400 yds. long, what is the content ? then—

$$6^2 \times 400 \begin{array}{l} \div 10 = 1440 \text{ gals.} \\ \div 60 = 240 \text{ cub. ft.} \end{array}$$

SERVICE PIPES AND FITTINGS.

In the term service pipes are included all pipes branching out of the mains to consumers' meters, and for the supply of public and private lamps.

Leakage or unaccounted-for gas is due more to defects in service pipes than to all the other causes combined. The leaks are chiefly caused in the pipe by corrosion, or at its junction with the main. Such being the case, it is clear that the utmost care should be devoted to the habilitation and maintenance of this portion of the distributory plant.

Service pipes are of cast-iron, wrought-iron, steel and lead. The use of cast-iron pipes for this purpose is, as a general rule, confined to the supply of gas to large establishments, where the diameter of the pipe required exceeds 2 in. The smaller sizes of cast-iron are too fragile to bear the overhead traffic, and the number of joints is objectionable. Such services as are of less bore than 3 in. are usually of wrought-iron or lead.

Wrought-iron pipes or tubes are chiefly employed for services. They can be obtained of any convenient length, and are easily and expeditiously fixed.

Wrought-iron tubes and fittings, such as tees, bends, elbows, ferrules, sockets, etc., should be perfectly cylindrical, with no ribs or flat places, and internally as smooth as possible. The welding should be scarcely discernible from the other parts, and the screw should be equally deep throughout the thread.

In laying wrought-iron pipes, the coupling or socket at the end, and which is supplied along with the pipe, should always be removed, the thread painted with red or white lead paint, and then replaced.

Lead pipes have their advantages, though they require more care in laying; and to prevent their sagging in the ground, wood lags have to be placed underneath them throughout their length.

On the other hand, they can be laid with fewer joints; the only jointing places being the connections with the main and the meter, unless the premises to be supplied is beyond the ordinary distance from the main. When taken up, also, to be renewed the old metal is of more value than old iron.

All service pipes, whether of wrought-iron or lead, when laid

in the ground, should be protected from the oxidizing influences of the soil, moisture, and air, by being encased in a U-shaped or V-shaped channel of wood or other material, filled, after the pipe has been laid therein, with a mixture of hot pitch and tar. This prolongs their life indefinitely, and prevents leakage, and consequently is well worth the trifling extra cost and trouble entailed.

It is not possible always to see whether a wrought-iron service pipe is worn out or not, unless it is taken up out of the ground. The under part of the pipe will often be found completely oxidized when the upper surface is sound and good. The rust forms a shell which crumbles on being disturbed, but when untouched is sufficient to prevent the immediate escape of gas.

The tinning or galvanizing of the surface of wrought-iron pipes adds greatly to their durability in sandy soil impregnated with saline matter.

Various processes have been devised for covering iron with a thin layer of oxide to protect it from corrosion either in the soil or when exposed to the atmosphere, and they are peculiarly valuable when applied to wrought-iron tubes and fittings.

Mains should be drilled, not cut with a chisel, for the insertion of service pipes. The full sectional thickness of the metal is thus preserved, and the hole is a true circle in form.

Several makers supply drilling apparatus which secures immunity from leakage in attaching the service pipe to the main, and it is easily applied and used.

All service pipes should, if possible, be laid with a slight fall to the main to admit of the condensed moisture draining away thereto. When the pipe is of great length, and a continuous inclination to the main is impracticable, a small drip-well, commonly called a bottle-syphon (Fig. 30, on p. 295), should be attached at the lowest point.

The service cleansers of D. Hulett & Co. (Fig. 152), of W. & B. Cowan (Fig. 153), and of Hutchinson Bros. (Fig. 154), are exceedingly useful for removing water and other obstructions from service pipes.

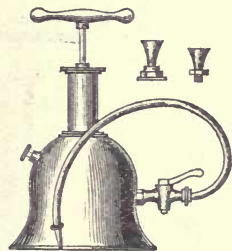


FIG. 152.

All abrupt angles, such as square elbows, whether in mains, services, or internal fittings, owing to the resistance they offer to the regular and even flow of the gas, act as condensers, and diminish the available pressure. Their use should, therefore, be discarded wherever practicable; bends or round elbows being much more preferable. For the same reason the internal surface of pipes should be as smooth as possible. No pipe should be put

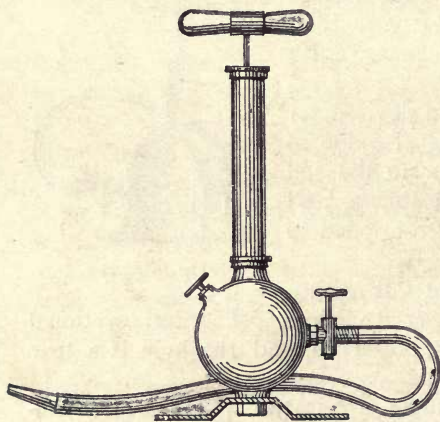


FIG. 153.

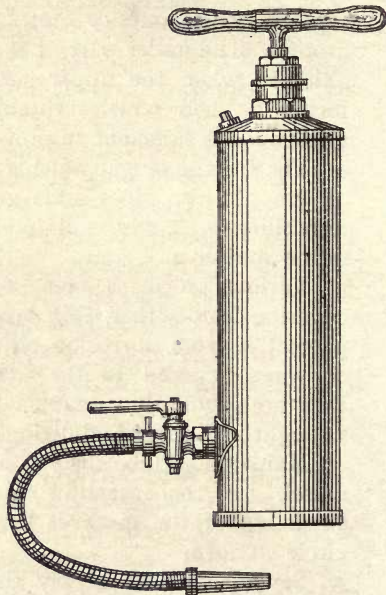


FIG. 154.

in use without careful examination and the removal of all existing roughnesses.

2-in. cast-iron pipes as mains,
 $\frac{1}{2}$ -in. wrought-iron pipes as services, and
 $\frac{1}{4}$ -in. lead or composition pipes for internal supply, should be utterly abandoned.

The first are a grievous source of direct leakage, owing to breakages at their junction with the service pipes; the whole three, if used to any great extent, entail high initial pressure, which is synonymous with a heavy leakage account.

If the distance from the main to the meter does not exceed

30 yds., the following sizes of service pipes will supply the number of lights named:—

1 to 9 lights (consuming, say, 4 cub. ft. per hour each)		$\frac{3}{4}$ in.
10	15	1
16	20	$1\frac{1}{4}$
30	50	$1\frac{1}{2}$
60	80	2
90	120	$2\frac{1}{2}$
130	150	3
200	300	4
	400	5
	500	6
	600	6
	700	7
	1000	8

The above sizes allow for partial contraction of the area of the pipe by corrosion or deposition.

TABLE.

*Weight per Foot of Wrought-Iron Tubing
For Gas, Water, and Steam.*

GAS.		WATER.			STEAM.		
Internal Diameter.	Weight per Foot.	Internal Diameter.	Weight per Foot.		Internal Diameter.	Weight per Foot.	
Inches.	Lbs. Ozs.	Inches.	Lbs.	Ozs.	Inches.	Lbs.	Ozs.
$\frac{1}{2}$	0 14 $\frac{1}{2}$	$\frac{1}{2}$	0	15	$\frac{1}{2}$	0	15 $\frac{1}{2}$
$\frac{3}{4}$	1 5 $\frac{1}{2}$	$\frac{3}{4}$	1	7 $\frac{1}{2}$	$\frac{3}{4}$	1	8
1	1 15	1	2	1	1	2	3 $\frac{1}{2}$
$1\frac{1}{4}$	2 10	$1\frac{1}{4}$	2	14	$1\frac{1}{4}$	3	4
$1\frac{1}{2}$	3 2 $\frac{1}{2}$	$1\frac{1}{2}$	3	9	$1\frac{1}{2}$	4	0
2	4 6 $\frac{1}{2}$	2	4	14	2	5	8
$2\frac{1}{2}$	5 10 $\frac{1}{2}$	$2\frac{1}{2}$	6	4	$2\frac{1}{2}$	7	0

Uniformity in the screws or threads of service pipes and fittings is greatly to be desired, a large proportion of the leakage being due to the want of this. The screwed joint may be too slack, in

TABLE.

Weight of Wrought-Iron Gas Tubes and Fittings.

Internal Diameter Inches.	Tubes.							Fittings.					
	Weight per 100 feet.			Weight per 1000 feet.				Weight of 10 Elbows.		Weight of 10 Tees.		Weight of 10 Crosses.	
	Cwts.	Qrs.	Lbs.	Tons.	Cwts.	Qrs.	Lbs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.
$\frac{1}{8}$	0	1	0	0	2	2	0	1	1	1	0	1	8
$\frac{1}{4}$	0	1	14	0	3	3	0	1	7	1	8	1	14
$\frac{3}{8}$	0	2	6	0	5	2	4	1	13	2	4	2	8
$\frac{1}{2}$	0	3	6 $\frac{1}{2}$	0	8	0	9 $\frac{1}{2}$	2	15	3	0	3	4
$\frac{5}{8}$	1	0	22 $\frac{1}{2}$	0	12	0	1	4	6	5	4	5	11
1	1	2	26	0	17	1	8	6	4	7	10	9	2
1 $\frac{1}{8}$	2	1	11	1	3	1	26	10	10	12	15	14	11
1 $\frac{1}{4}$	2	3	7	1	8	0	14	15	8	16	7	18	10
1 $\frac{3}{8}$	3	0	12	1	11	0	8	15	12	20	0	21	4
2	3	3	21	1	19	1	14	22	6	27	0	31	4
2 $\frac{1}{8}$	4	0	26	2	2	1	8	30	2	32	8	41	4
2 $\frac{1}{4}$	5	0	5	2	10	1	22	46	2	50	15	51	4
2 $\frac{3}{8}$	5	1	19	2	14	0	22	55	10	68	8	80	10
3	6	0	20	3	1	3	4	73	8	85	5	88	12
3 $\frac{1}{8}$	7	1	14	3	13	3	0	101	0	121	0	129	0
4	8	2	0	4	5	0	0	126	0	144	0	158	0

TABLE.

Pitch of the Whitworth Taps and Dies for Gas Tubing.

Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch.	Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch.
$\frac{1}{8}$	0'385	28	2	2'347	11
$\frac{1}{4}$	0'520	19	2 $\frac{1}{8}$	2'467	11
$\frac{3}{8}$	0'665	19	2 $\frac{1}{4}$	2'587	11
$\frac{1}{2}$	0'882	14	2 $\frac{3}{8}$	2'794	11
$\frac{5}{8}$	1'034	14	2 $\frac{1}{2}$	3'001	11
1	1'302	11	2 $\frac{5}{8}$	3'124	11
1 $\frac{1}{8}$	1'492	11	2 $\frac{3}{4}$	3'247	11
1 $\frac{1}{4}$	1'650	11	2 $\frac{7}{8}$	3'367	11
1 $\frac{3}{8}$	1'745	11	3	3'485	11
1 $\frac{1}{2}$	1'882	11	3 $\frac{1}{8}$	3'698	11
1 $\frac{3}{4}$	2'021	11	3 $\frac{1}{4}$	3'912	11
2	2'047	11	3 $\frac{3}{8}$	4'125	11
2 $\frac{1}{8}$	2'245	11	4	4'339	11

which case leakage often follows ; on the other hand, when a socket is too small to receive the screwed end of a pipe, instead

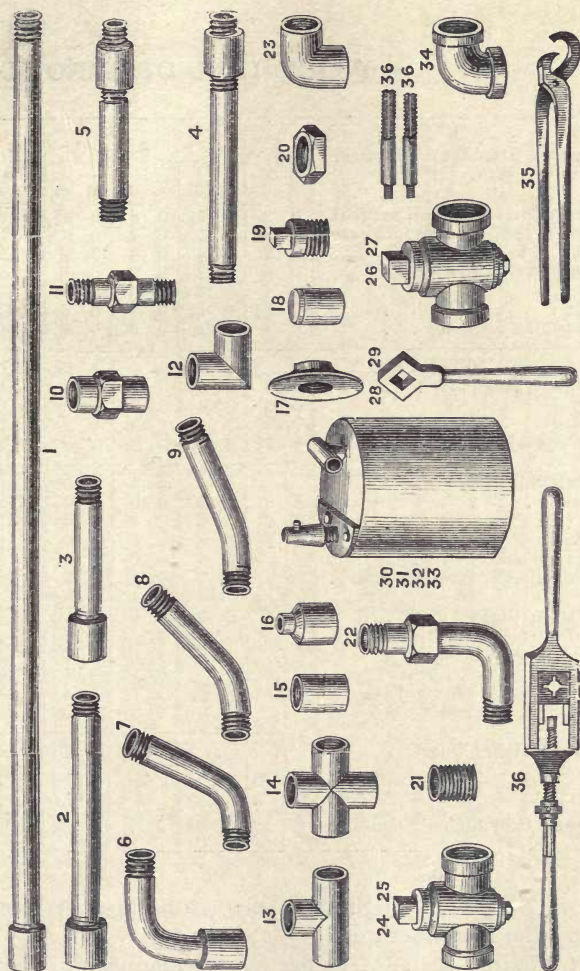


FIG. 155.

of running the tap into the one, or the dies over the other, careless workmen are often content to let the joint pass, provided they can succeed in getting a single thread to bite. The natural settlement

of the ground, the traffic over the surface, or the first keen frost, disjoins the connection, and an escape follows.

PRICE LIST OF WROUGHT-

No.	INTERNAL DIAMETER. INCHES.	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1
		s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1	Tubes, 2 to 14 feet long, per foot	0 2	0 2½	0 3	0 4½	0 6	0 8½
2	Pieces, 12 to 23½ inches long, each	0 4	0 5	0 7	0 9	1 0	1 4
3	Do. 3 to 11½ " "	0 2	0 3	0 4	0 6	0 8	0 11
4	Longscrews, 12 to 23½ " "	0 5	0 7	0 9	0 11	1 2	1 6
5	" 3 to 11½ " "	0 4	0 5	0 6	0 8	0 10	1 0
6	Bends	0 5½	0 6½	0 7	0 8	0 11	1 3
789	Springs, not Socketed	0 4	0 5	0 6	0 7	0 9	0 11
10 11	Socket Union (10), Pipe Do. (11)	..	2 0	2 6	3 0	4 0	5 6
12	Elbows, Wrought-Iron	0 6	0 6½	0 7	0 8	0 10	1 2
13	Tees "	0 6	0 6½	0 7	0 9	1 0	1 3
14	Crosses "	0 10	1 0	1 0	1 5	1 9	2 3
15	Plain Sockets "	0 1½	0 1½	0 2	0 3	0 3½	0 4
16	Diminished Sockets . . . . .	..	0 3	0 4	0 5	0 6	0 7
17	Flanges	0 8	0 9	0 10	1 0	1 2	1 4
18 19	Caps (18), Plugs (19)	0 2	0 3	0 3	0 4	0 5	0 6
20 21	Backnuts (20), Nipples (21)	0 1	0 2	0 2	0 3	0 3½	0 4
22	Union Bends . . . . .	..	2 6	3 0	3 9	5 0	6 3
23	Round Elbows, Wrought-Iron	0 7	0 7	0 8	0 9	1 0	1 4
24	Iron Main Cocks	2 3	2 3	2 9	3 6	4 6	6 6
25	Do. with Brass Plugs . . . . .	..	..	4 6	5 6	7 6	10 6
26	Round Way Iron Cocks . . . . .	..	..	3 6	4 0	5 6	7 6
27	Do. with Brass Plugs . . . . .	..	..	5 0	6 6	9 0	13 0
28	Cock Spanners, Wrought-Iron . . . . .	..	..	1 0	1 4	1 8	2 0
29	Do. Malleable Cast-Iron . . . . .	..	..	0 7	0 8	0 10	1 2
30	Syphon Boxes, 1 Quart . . . . .	..	..	..	11 0	12 0	13 0
31	Do. 2 " . . . . .	..	..	..	..	16 0	17 0
32	Do. 3 " . . . . .	..	..	..	..	20 0	22 0
33	Do. 4 " . . . . .	..	..	..	..	21 0	23 0
34	Malleable Cast Round Elbows	0 6	0 6½	0 7	0 8	0 10	1 2

(35) Tongs or Nippers, (36) Stocks, Dies, and Taps, at prices as quoted by the manufacturer.

If tubes are required to be of longer length than 14 ft., they are charged at the next higher rate.

Tubes of intermediate diameters charged at the price of the next larger size.

IRON TUBING AND FITTINGS, ETC.

1½	1½	1¾	2	2¼	2½	2¾	3	3½	4
s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
0 11	1 2	1 6	1 9	2 7	3 3	4 0	4 6	5 6	7 0
1 8	2 0	2 6	3 0	4 6	6 3	7 6	9 0	11 6	14 6
1 1	1 4	2 0	2 3	4 0	4 9	6 0	7 0	8 0	9 0
2 0	2 6	3 3	4 0	5 6	7 0	8 6	10 0	12 6	15 6
1 3	2 0	2 6	3 0	4 6	5 6	6 6	7 6	8 6	10 0
1 9	2 3	3 3	4 3	6 6	10 0	12 0	16 0	25 0	32 6
1 4	1 8	2 6	3 3	5 6	7 6	10 0	12 0	19 0	26 0
6 9	8 0	9 0	10 0	12 0	14 0	16 0	18 0	22 0	28 0
1 9	2 3	3 0	3 6	5 6	8 6	11 0	14 0	22 0	28 0
1 9	2 6	3 0	3 9	6 0	9 6	12 6	16 6	24 0	30 0
3 0	3 6	4 6	5 3	10 6	16 0	21 0	30 0	42 0	50 0
0 6	0 7	0 9	1 0	1 6	2 6	3 0	3 6	5 0	6 0
0 9	0 11	1 1	1 3	2 0	3 0	4 0	5 0	7 0	9 0
1 6	1 9	2 0	2 6	3 9	5 0	6 9	8 6	10 0	11 6
0 8	0 10	1 0	1 3	2 0	2 6	3 6	4 9	7 0	10 0
0 6	0 8	0 10	1 0	1 9	2 3	3 0	3 6	4 6	5 6
8 6	10 0	11 6	15 6	16 0	19 0	22 0	25 0	30 0	36 0
1 11	2 6	3 4	3 10	6 6	10 0	13 0	16 0	25 0	32 0
8 6	11 0	14 0	18 0	27 0	36 0	44 0	50 0	75 0	90 0
15 0	19 6	25 0	32 0	47 0	60 0	90 0	110 0	140 0	190 0
10 0	13 0	17 6	22 0	38 0	54 0	62 0	70 0	100 0	160 0
19 0	28 0	36 0	42 0	60 0	85 0	105 0	120 0	180 0	280 0
2 4	3 0	3 6	4 0	4 9	6 0	7 6	9 0	12 0	14 0
1 8	2 2	2 9	3 3	4 9	6 0	7 6	9 0	12 0	14 0
14 0	15 0	15 6	16 0	18 0	30 0	35 0	40 0	50 0	60 0
18 0	19 0	21 0	23 0	25 0	30 0	35 0	40 0	50 0	60 0
24 0	25 0	26 6	28 0	32 0	35 0	40 0	45 0	54 0	66 0
25 0	27 0	29 0	31 0	34 0	38 0	42 0	47 0	54 0	66 0
1 9	2 3	3 0	3 6	5 6	9 0	12 0	15 0	30 0	40 0

Springs ; if socketed, sockets added at list prices.

Discount { Gas tubes and fittings, per cent.
 Galvanized " "
 Steam and water " "
 Galvanized " "

Iron Cocks over 2 in. at special discounts.

HIGH PRESSURE DISTRIBUTION.

The distribution of gas at a higher pressure than was formerly required has become essential.

The necessity for higher pressures, due chiefly to the general adoption of the incandescent burner, has led to the boosting up of the pressure beyond what is usually given by the gasholders.

An increase in the consumption of gas, inadequate delivering capacities of existing mains, and the centralization of manufacturing works, are also amongst the factors that have brought into prominence the question of the best means of economically distributing gas under the new conditions.

Generally speaking, a shortage of pressure is found in outlying districts, due to the restricted size of the mains, and also to the trunk mains from which the smaller mains take their supply, being over-taxed by the consumption *en route*.

High pressure distribution offers a solution, other than increasing the size of the mains generally, for many of the difficulties connected with inadequate pressure, but at the same time it is not a system that should be adopted indiscriminately.

A special study of the prevailing conditions of supply is necessary, and whether the existing mains could be utilized, or whether new mains would have to be laid.

The ideal conditions for high pressure distribution may be summarized as follows:—

(1) The supply of gas to a district where the pressure in the existing mains is inadequate; (2) supplying gas from the works to outlying gasholders, and (3) reinforcing the pressure in trunk mains.

But in order to obtain the full advantage of the system, without any attendant disadvantages, care must be taken to see that the jointing of the old mains, and the attachment of the service pipes thereto, are in perfect condition, and if they are not so, to put them in such condition. Any neglect in these respects will inevitably result in an increase in the loss by leakage.

In all cases, excepting where gas is supplied to gasholders, it is necessary to employ district governors to regulate the supply from the high to the low pressure main; or a service pipe may be taken direct from the high pressure main, and a service governor applied to reduce the pressure to suit requirements of consumers on the route of the high pressure main.

Compression of the gas is best obtained by means of blowers, reciprocating compressors, or rotary exhausters of modified design.

Various firms make a speciality of compressors of these types.

The Bryan Donkin Co., Ltd., have introduced a rotary compressor (Fig. 156) which retains the advantages of the exhauster, though specially designed for high pressure work.

The compressor is made both in the single and double stage according to the pressure required, and may be driven by steam, gas engine, or electric motor.

The main difference in design from their ordinary exhauster is that the central block, which ordinarily serves to guide the

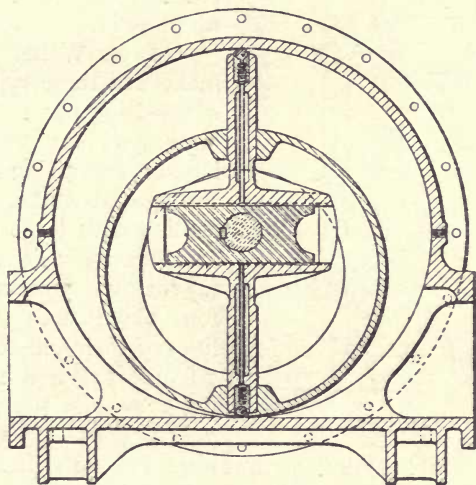


FIG. 156.

motion of the slide, is mounted on a revolving steel shaft, which acts as the driving member of the machine. The cast-iron drum, which in the exhauster drives the slides round, in the case of the compressor is driven round by the slides which constitute the pistons of the machine.

A simple arrangement of plant (Fig. 157), where only a moderate increase of pressure is required, is made by the same firm.

It consists of a small pressure blower driven by a gas or steam engine, which raises the pressure in the distributing mains that are directly connected to the outlet of the compressor.

A district governor is fixed on the outlet main which regulates

the pressure maintained on the district. The arrangement can be controlled from the works.

A compressor of the same type can be utilized for fixing at some point in the district to meet the conditions of an over-taxed trunk main that is supplying mains of a smaller diameter.

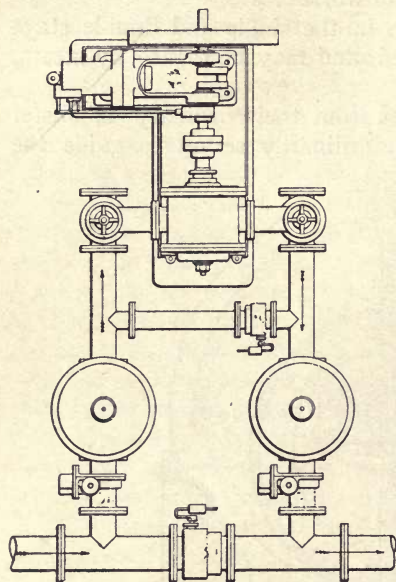


FIG. 157.

The compressor draws the gas from the trunk main and raises the pressure before distributing the gas to the smaller mains.

This type of pressure-raising plant is suitable for pressures up to 36 in.

George Waller & Son are makers of three types of pressure-raising plant—namely, (1) high speed high pressure boosting fans for raising the pressure throughout a district, and for dealing with large volumes at comparatively light pressures; (2) rotary compressor, three or four blade types, built on the lines of their exhausters (Figs. 70 and 71) and modified to work against pressures up to 7 lbs. per square inch; (3)

reciprocating double-acting compressors for high pressure transmission from 7 lbs. up to 50 lbs. per square inch.

The reciprocating compressor may be belt-driven from gas engine, steam engine, or electric motor, or arranged tandem with steam cylinder direct acting, as may be most convenient.

The rotary compressor of James Milne & Son (Fig. 158) is designed for pressures up to $3\frac{1}{2}$ lbs. per square inch; the usual driving power being by means of a gas engine, though any other means of drive may be adopted.

A steam driven reciprocating compressor, with automatic speed regulation controlled by the gas delivery pressure, is also made by them for delivery pressures of 5 lbs. and upwards.

The centrifugal type of booster made by the Sturtevant Engineering Co., and driven by their gearless steam turbine, is

also an efficient apparatus where only moderate pressures have to be dealt with. The machines are built in sizes having outputs ranging from 20,000 to 500,000 cub. ft. per hour, and are capable of raising the pressure from the normal up to 20 in.

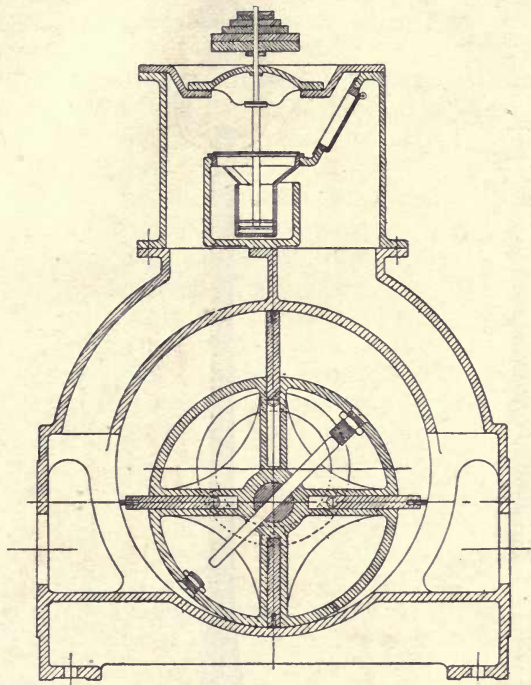


FIG. 158.

A rotary type of machine is also made by them for pressures up to 2 or 3 lbs. per square inch.

PUBLIC LIGHTING.

There are at present three systems applicable to the illumination of public thoroughfares—namely: (1) low pressure, (2) self-intensifying high power, and (3) high pressure.

The height of a lamp pillar for low pressure lamps should not be less than 10 feet from the surface of the ground.

For high pressure lighting the height of the pillar ranges from 14 feet upwards according to local circumstances.

A $\frac{3}{8}$ -in. or even a $\frac{1}{2}$ -in. lead pipe is not suitable for placing in the interior of a lamp column. In cold districts, in winter, the

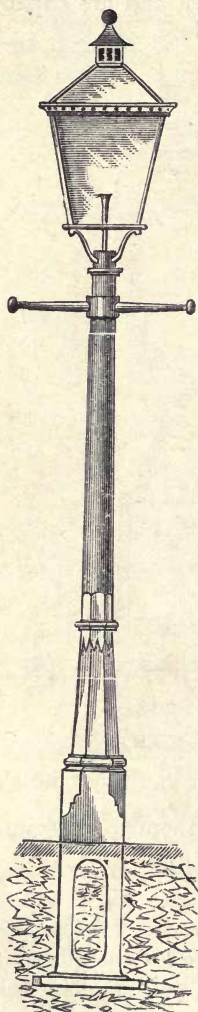


FIG. 159.



FIG. 160.

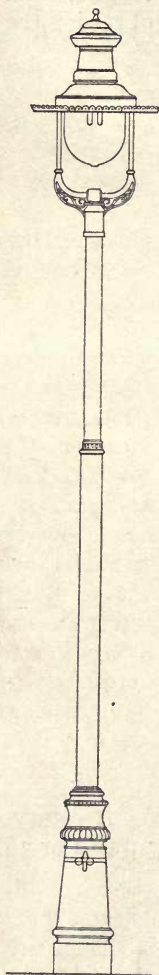


FIG. 161.

condensed moisture in a pipe of this small bore becomes frozen, filling up the entire length with solid ice in a very short time. This

is probably due to the wavy irregularities in the pipe preventing the water from draining rapidly away.

Galvanized wrought-iron pipe is best for lamp columns and for placing against a wall for the supply of a bracket lamp, and $\frac{1}{2}$ in. is the smallest size that should be used. In situations exposed to cutting winds, and where the frost is keen, $\frac{3}{4}$ -in. wrought-iron pipes are best.

If the service pipe at the entrance of the base of a lamp column has not very ample fall to the main, the water of condensation, unable to drain quickly away, will inevitably be frozen at that point during frost, and, by accretion, will eventually interrupt the passage of the gas.

It is not unusual to find one half the public lights in some districts extinguished at night when a severe frost prevails. This is simply due to mismanagement, as it would not occur if attention were paid to the matters indicated above.

The supply of gas to public lamps is usually fixed at 4 cub. ft. per hour. A regulator to each lamp secures the necessary supply of gas to which the burner

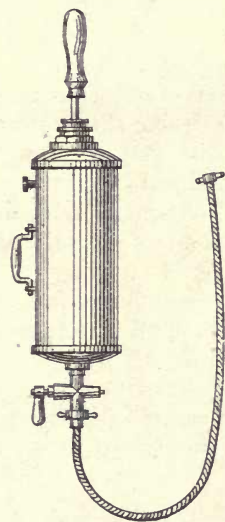


FIG. 162.

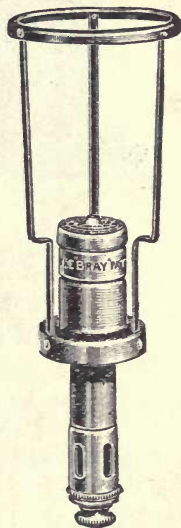


FIG. 163.

is regulated. Borradaile's, Peebles', Wright's "Precision," and Simmance-Abady lamp governors are well known and efficient types of governors for this purpose.

Various service and lamp clearers are to be had for the purpose of clearing out obstructions from services and fittings.

Hutchinson Brothers' service cleanser (Fig. 162) is a handy instrument for this purpose.

Satisfactory public lighting, as between gas companies and local authorities, is best secured by the adoption of a good average meter system, and the application of a governor to every lamp.

The incandescent burner may be said to have revolutionized street lighting. Since Welsbach introduced his burner, continuous progress has been made, not only by the Welsbach Co., but by numerous other makers.

The burners of the Welsbach Co., Wm. Sugg & Co., the Anti-vibration Incandescent Lighting Co., and Geo. Bray & Co., are typical of the low pressure class, both upright and inverted.

Fig. 163 is an illustration of the Bray "1907" S.L. burner.

It is constructed of a tube having a series of fine slits instead of the usual wire gauze, through which the mixture of gas and air passes. The burners are made in shapes and sizes to suit all conditions.

The upright incandescent burner is being gradually superseded by the inverted form.

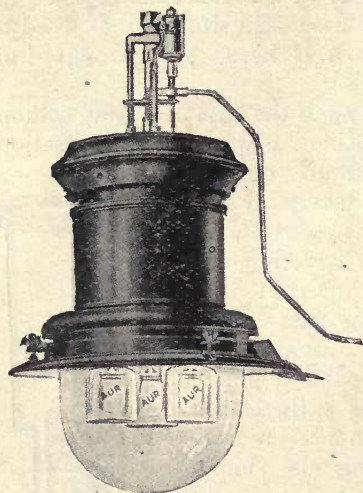


FIG. 164.

The efficiency of the latter, due to the facilities for superheating the gas and air supply, is often as much as 40 candles per cub. ft. A further advantage is that a shadowless light is obtained, as there is no framework or gallery below the burner.

Typical of the high power system are the lamps of the Welsbach Light Company, Wm. Sugg & Co., the "Graetzin," Moffat's, A. E. Podmore, the Bland Light Syndicate, and the New Inverted Incandescent Gas Lamp Co.

The Welsbach lamp (Fig. 164) is made with steel or copper casing, and built in four sizes—namely: 1500, 1000, 600, and 300 candle power. The first is of the four-burner, and the second and third of the three-burner class, whilst the last is constructed with one burner.

The "1912" lamp (Fig. 160) of William Sugg & Co. is a good example of modern low pressure lighting. The burners are of the horizontal type, so arranged to superheat the mixture of gas and air. All the adjustments are outside the lamp and away

from the heated products of combustion. An atmospheric flash-light burner is attached which lights the mantles; its consumption is 1 cub. ft. of gas in 12 hours.

The Bland lamp (Fig. 165) is constructed of copper and fitted with a Bland inverted burner. The gas supply is taken up one of the astragals to the top of the reflector, where the gas and air supplies are adjusted. A 3-light Bland street lamp is also made.

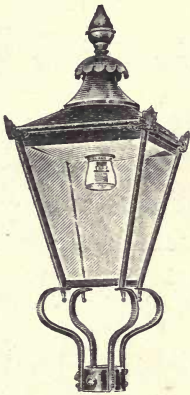


FIG. 165.

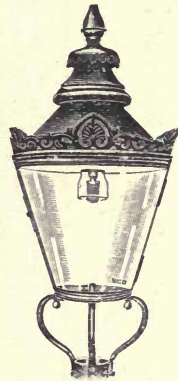


FIG. 166.

Fig. 166 illustrates the one light circular lamp of the New Inverted Incandescent Gas Lamp Co. Two, three, and four-light lamps with burners to pass $3\frac{1}{2}$ to 4 cub. ft. per hour are also made.

High Pressure Lighting.—There can be no doubt that the present systems of high pressure lighting are a great advance on the low pressure. Whether the efficiency of 60 candles per cubic foot can be still further improved upon will depend on research. We believe it will.

Amongst the systems in use in this country are the James Keith and Blackman Co., the Welsbach Light Co., Wm. Sugg & Co., the "Pintsch," "Graetzin," and the "Selas" of Bever and Wolff. All these necessitate some form of compressing plant to increase the pressure of the gas from the normal of say, 3 in. to a pressure of 54 ins., or higher if necessary, and also special mains, preferably of steel.

TABLE

Showing the Consumption of Gas by One Burner per Month, and for the Twelve Months, during the Average Hours of Burning from Sunset throughout the Year.

Month.	Average Time of Sunset.		Mean Duration of Hours of Burning.		Number of Hours of Night per Month.	Consumption of Gas by One Burner per Month, and for the whole Year. Pub'ic Street Lamps assumed to be Lighted from Sunset to Sunrise, and Private Lamps from Sunset until Nine o'Clock.									
	h.	m.	h.	m.		8 Cubic Feet per Hour.		4 Cubic Feet per Hour.		4½ Cubic Feet per Hour.		5 Cubic Feet per Hour.			
						Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.		
January.	4	13	16	31	512	c. ft. 1536	c. ft. 445	c. ft. 1792	c. ft. 519	c. ft. 2048	c. ft. 594	c. ft. 2304	c. ft. 668		
February.	5	7	14	41	411	1293	325	1438	350	1644	436	1850	742		
March.	6	6	12	19	382	1146	270	1337	315	1528	360	1719	490		
April.	6	57	9	50	295	885	185	1032	216	1180	246	1327	405		
May.	7	46	7	48	242	726	115	847	134	968	154	1089	277		
June.	8	16	6	30	195	585	..	683	..	780	..	878	173		
July.	8	2	7	0	217	651	..	760	..	868	..	976	..		
August.	7	16	9	54	307	921	162	1074	190	1228	216	1382	242		
September.	6	30	11	30	345	1035	240	1207	280	1380	320	1552	360		
October.	5	21	13	35	421	1263	340	1474	396	1684	453	1895	509		
November.	4	25	15	46	473	1419	413	1655	481	1892	550	2128	619		
December.	3	49	17	0	527	1581	483	1845	564	2108	644	2372	725		
Total for the year.	4327	12,981	2979	15,144	3475	17,308	3973	19,472	4468	21,635	4960

TABLE

Showing the Number of Hours during which Gas is usually Burned in each Month, Quarter, and Year, according to the Times of Lighting and Extinguishing.

Times of Lighting and Extinguishing.	Lady-Day Quarter.		Midsummer Quarter.			Michaelmas Quarter.			Christmas Quarter.			Lady-Day.	Midsummer.	Michaelmas.	Christmas.	Total of Year.*		
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.						December.	
If lighted at dusk and extinguished at—																		
6 p.m.	65	33	4	4	..	..	..	2	2	31	62	80	102	..	2	173	277
7 "	96	61	31	28	..	..	14	22	14	62	92	111	188	4	36	265	493
8 "	127	89	62	58	4	..	40	52	52	93	122	142	278	32	92	367	759	
9 "	158	117	93	88	29	8	71	82	82	124	152	173	368	95	166	449	1078	
10 "	189	145	124	88	60	38	102	112	112	155	182	204	458	186	258	541	1443	
11 "	220	173	155	118	91	68	133	142	142	186	212	235	548	277	350	633	1808	
12 "	251	201	186	148	122	98	164	172	172	217	242	266	638	368	442	725	2173	
All night . . .	512	411	382	295	242	195	307	345	345	421	473	527	1305	732	869	1421	4327	
Lighted at—																		
4 a.m. till daylight	137	98	71	28	2	..	16	48	48	80	110	137	306	30	64	327	727	
5 " " "	105	70	40	3	..	..	..	18	18	49	80	106	216	8	18	235	472
6 " " "	75	42	9	..	..	..	..	..	..	18	50	75	126	..	..	143	269
7 " " "	44	14	..	..	..	..	..	..	..	..	20	44	68	..	..	64	122

* A deduction of one-sixth may be made for moonlight nights; and in the case of private lamps not being lighted on Sundays, deduct one-seventh.

In the Keith-Blackman system the pressure is obtained in a variety of ways—namely, by (1) rotary blower, (2) electric motor, (3) water motor, and (4) belt drive (Fig. 167), all of which are

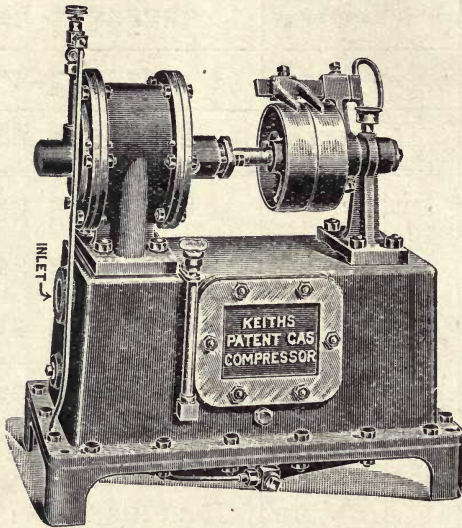


FIG. 167.

capable of compressing the gas up to a pressure of 5 lbs. per square inch.

The high pressure lamps are made in various sizes, and, with an average quality of gas, have an efficiency of 60 candles per cub. ft. working at a pressure of 2 to 3 lbs. per square inch. The lamps range in candle power from 60 to 4500. Fig. 168 is an illustration of a 3000-candle power suspension lamp with octagonal opal reflector and ornamental frieze, and fitted with horizontal injectors and adjustment screws below the reflector.

For busy and congested thoroughfares, the lamps may be suspended on a wire or wires across the streets (Fig. 169) and fitted with raising, lowering and traversing gear.

When the lamp requires attention for renewals or cleaning, it is disconnected automatically, drawn by means of a winch to the side of the street, and lowered. On the lamp being raised and placed back in position, the gas connection is again automatically

made. The lamp is also fitted with a device to prevent escape of gas during disconnection, and also an arrangement for removing any condensation without taking the lamp down.

The most recent advance in street lighting by Keith, Blackman & Co. is the "silica cup system," whereby the usual

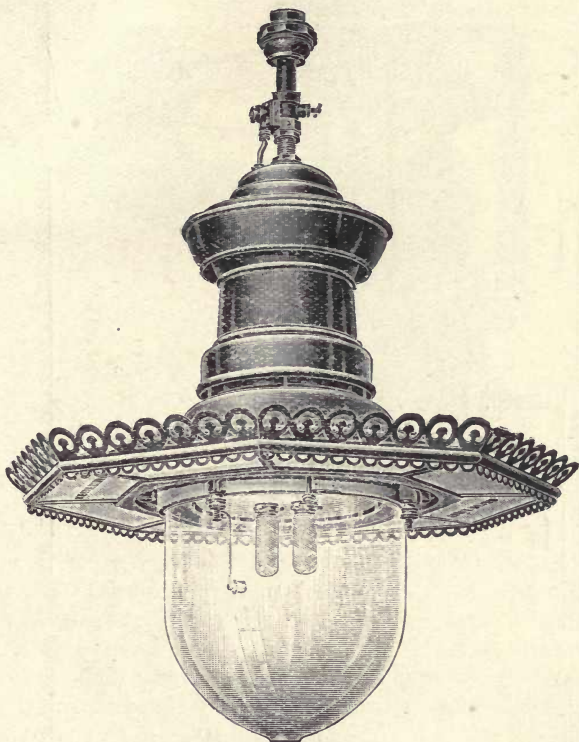


FIG. 168.

secondary air supply and the large glass globes are dispensed with; each inverted mantle being enclosed within a silica cup. Should experience warrant their utility, the item of maintenance will be materially reduced.

The Pharos-Welsbach system consists of either the application of high pressure gas or high pressure air. The advantage claimed

for the latter is that there is no alteration required to the existing

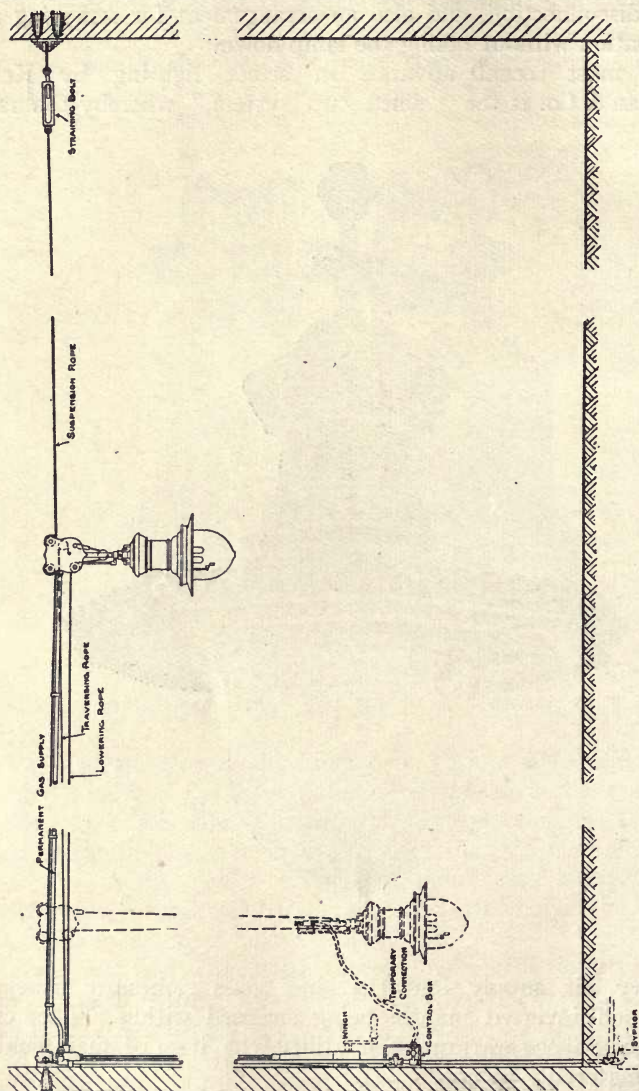


FIG. 169.

low pressure supply, excepting the installation of a governor to regulate the consumption.

The compressor (Fig. 170), for either gas or air, is a rotary blower of special design, and the suction and compression are obtained without any pulsating effect. Any drive may be arranged for.

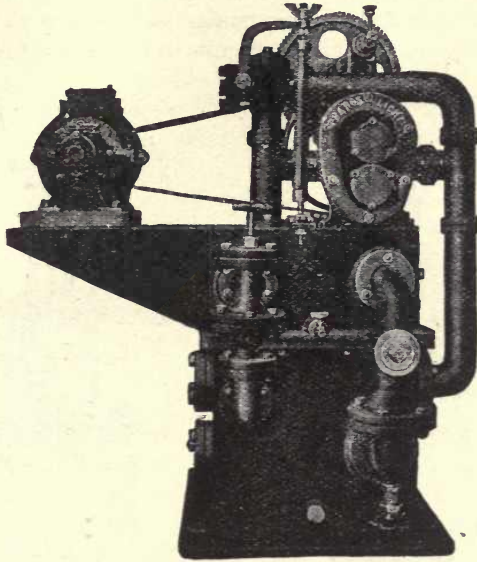


FIG. 170.

In the Pharos-Welsbach gas lamp (Fig. 171) the principle of preheating is carried out to a very large extent, although to prevent too high a temperature in the mixing tube, and to cut off cold secondary air, the lamp is so constructed as to heat only the primary air. This is attained by a corrugated sheet which absorbs the heat from the waste gases, the radiation from which is utilized to preheat the air as drawn into the lamp.

The air lamp (Fig. 172) is similar in construction, but instead of high pressure gas, high pressure air is applied. The air is drawn into the compressing apparatus and supplied through a special service to the burners, and when these are reached, the compressed air mixes with the gas supplied at about 3 in. pressure, and is delivered at a pressure of 55 in. in scientifically economical proportions.

With all high pressure installations it is an advantage to have

a small single low pressure lamp attached to each column, so that when the light is extinguished at midnight, the small burner may be brought into use.

A novelty in high pressure lighting is the "Selas" system, in which both gas and air are compressed before passing to the burner at a pressure that can be regulated to suit requirements.

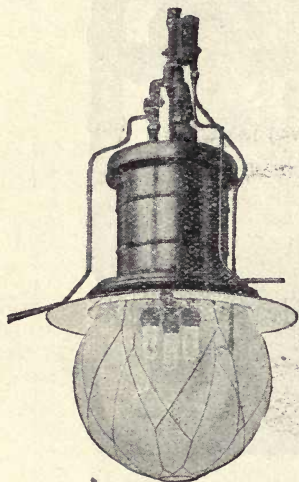


FIG. 171.

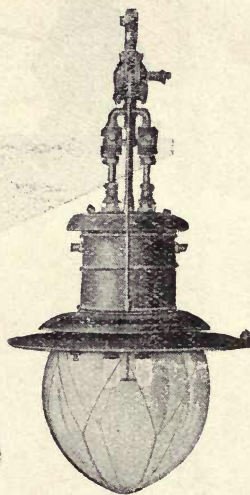


FIG. 172.

Apart from lighting there is a wide field open for the use of high pressure gas for manufacturing purposes.

The supply of gas at high pressure to public lamps and consumers has led to the necessity for meters suitable for the correct registration under such pressures.

According to Boyle's law, the volume of a gas varies inversely with the pressure, hence a given volume of gas supplied at a high pressure would be something more if measured at the ordinary pressure.

The high pressure meter of Parkinson and W. & B. Cowan, Ltd., has been designed to overcome this recording difficulty. It consists of a patent compensating index with variable gearing, controlled by an aneroid which is acted on by the pressure of the gas, and gives a proportionately increased movement with an increase of pressure.

In this device, the registration indicates the volume at normal pressure, whatever the actual pressure is, provided that it does not exceed the limit for which the meter is made.

Among the devices which have been proposed for a new system of rating is one that records the time during which the gas is being consumed in a lamp—public or private.

The apparatus (the invention of Mr. J. G. Newbigging and Mr. F. Thorp) consists of a clockwork movement in combination with a means for automatically starting and stopping the recorder.

The dial of the apparatus, which is about 3 in. in diameter, is graduated in hours. Two pointers are used, the larger one making one revolution in 100 hours, and the smaller one in 1000 hours. A very long main spring is employed, so that re-winding is only required after 500 hours of actual working.

With regard to the lighting of street lamps, there are four systems at present in use, namely, (1) by means of a by-pass, (2) torch, (3) flashlight arrangement, and (4) automatic device for both lighting and extinguishing.

In the first system a small pilot light is constantly burning, and the lamp is lit from this source, on the gas tap being turned on by the lamplighter.

The improvements made on the ordinary torch to suit the conditions of the incandescent burner are numerous, and are extensively adopted. The Simmance-Abady torch consists of two wells, one containing a colza oil burner and the second a supply of benzolene. A pneumatic tube communicates with the latter and causes a stream of benzolene vapour which is ignited by the colza oil burner.

The carbide torch, in which a supply of carbide is generated to acetylene, is also a useful and handy appliance for the same purpose.

The flashlight arrangement is intended to supersede the by-pass. It consists of a tube connected to the gas supply and terminating near the burners. The gas, being turned on, issues from the tube and is ignited by a torch and produces a flashlight to the burners. The flashlight is extinguished after it has served its purpose of lighting.

Automatic lighting and extinguishing apparatus are being tried by several municipalities and gas companies.

The lighting and extinguishing are achieved in the devices of Alder and Mackay, the "Broadberry" and the "Bamag" by

increasing the pressure for a short period on the mains; and by clockwork devices in the "Gunfire," "Horstmann," "Simplex," and "Dacolight" controllers.

TABLE

Giving the Pressure per Square Inch of Columns of Water varying in Height from $\frac{1}{2}$ Inch to 12 Feet.

A column of water 33.9 feet high = 14.7 lbs. per square inch.

Column of Water.		Pressure per Square Inch.		Column of Water.		Pressure per Square Inch.		Column of Water.		Pressure per Square Inch.	
Ft.	Ins.	Lbs.	Ozs.	Ft.	Ins.	Lbs.	Ozs.	Ft.	Ins.	Lbs.	Ozs.
0	$\frac{1}{2}$	0	0.29	0	11 $\frac{1}{2}$	0	6.65	6	6	2	13.09
0	$\frac{3}{4}$	0	0.43	1	0	0	6.94	6	9	2	14.83
0	1	0	0.58	1	3	0	8.67	7	0	3	2.56
0	1 $\frac{1}{2}$	0	0.87	1	6	0	10.41	7	3	3	2.30
0	2	0	1.16	1	9	0	12.14	7	6	3	4.03
0	2 $\frac{1}{2}$	0	1.45	2	0	0	13.87	7	9	3	5.77
0	3	0	1.73	2	3	0	15.61	8	0	3	7.50
0	3 $\frac{1}{2}$	0	2.02	2	6	1	1.34	8	3	3	9.23
0	4	0	2.31	2	9	1	3.08	8	6	3	10.97
0	4 $\frac{1}{2}$	0	2.60	3	0	1	4.81	8	9	3	12.70
0	5	0	2.89	3	3	1	6.55	9	0	3	14.44
0	5 $\frac{1}{2}$	0	3.18	3	6	1	8.28	9	3	4	0.17
0	6	0	3.47	3	9	1	10.02	9	6	4	1.91
0	6 $\frac{1}{2}$	0	3.76	4	0	1	11.75	9	9	4	3.64
0	7	0	4.05	4	3	1	13.48	10	0	4	5.37
0	7 $\frac{1}{2}$	0	4.34	4	6	1	15.22	10	3	4	7.11
0	8	0	4.62	4	9	2	0.95	10	6	4	8.84
0	8 $\frac{1}{2}$	0	4.91	5	0	2	2.69	10	9	4	10.58
0	9	0	5.20	5	3	2	4.42	11	0	4	12.31
0	9 $\frac{1}{2}$	0	5.49	5	6	2	6.16	11	3	4	14.05
0	10	0	5.78	5	9	2	7.89	11	6	4	15.78
0	10 $\frac{1}{2}$	0	6.07	6	0	2	9.62	11	9	5	1.52
0	11	0	6.36	6	3	2	11.36	12	0	5	3.25

Weight and Thickness of Glass for Public Lamps.

No. of the Glass or Weight in Ounces per Square Foot.	Thickness in Decimals of an Inch.	No. of the Glass or Weight in Ounces per Square Foot.	Thickness in Decimals of an Inch.
12	. . . 0.059	21	. . . 0.100
13	. . . 0.063	24	. . . 0.111
15	. . . 0.071	26	. . . 0.125
16	. . . 0.077	32	. . . 0.154
17	. . . 0.083	36	. . . 0.167
19	. . . 0.091	42	. . . 0.200

Rule to find the Length of Day and Night.

Day.—The hour of sunset, doubled, is the length of the day.
 Night.—The hour of sunrise, doubled, is the length of the night.

Rule to find the Hours of Sunrise and Sunset.

Deduct the hour of sunset from 12; the difference is the hour of sunrise, and *vice versa*.

The Moon's Rising and Setting.

At 4	days old, the moon sets about	10	o'clock at night.
At 5	"	11	" "
At 6	"	12	" "
At 7	"	1	" in the morning.
At 15	the moon rises	6	" in the evening.
At 16	"	7 $\frac{1}{2}$	" "
At 17	"	8 $\frac{1}{2}$	" "
At 18	"	10	" at night.
At 19	"	11	" "
At 20	"	12	" "

CONSUMERS' GAS METERS.

Gas meters are either "wet" (Figs. 173 and 174) or "dry" (Figs. 175 and 176).

The wet meter has a measuring wheel or drum enclosed in an iron case charged with water up to a certain level, called the "water-line." The drum is divided into compartments similar to the

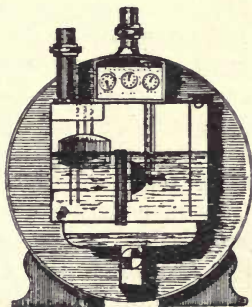


FIG. 173.

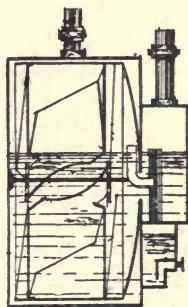


FIG. 174.

station meter, and the measurement and indication, or registration, of the gas passing through it are performed in the same manner.

The dry meter has usually a case of tinned-iron. This is divided into compartments by a central partition and two or more

movable diaphragms with prepared flexible leather sides. The gas enters and leaves these compartments alternately through valves whose passages are made to open and close at the proper moment. The alternate expansion and contraction of the inner

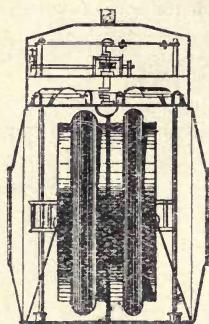


FIG. 175.

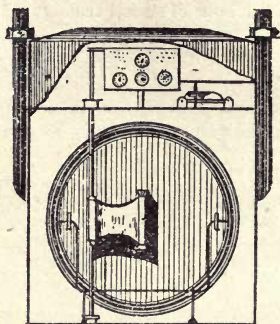


FIG. 176.

and outer spaces (after the manner of the ordinary bellows), by the pressure of the gas exerted on the surfaces of the diaphragms, are communicated by levers and cranks to the wheelwork of the indicators, which are alike in both classes of meter.

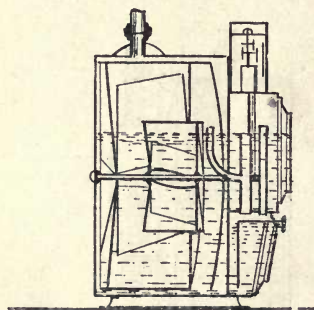


FIG. 177.

Meters as tested under the provisions of the "Sales of Gas Act, 1859," are stamped as correct by the inspector when their registration does not vary from the true standard measure of gas more than 2 per cent. in favour of the seller and 3 per cent. in favour of the consumer. Added together, the range is 5 per cent.

"Compensating" meters were introduced to overcome the difficulty caused by the limitation in the range of the water-level of wet meters.

Most of these have a reservoir of water within the case distinct from the water in which the measuring wheel revolves; and various automatic expedients are adopted for transferring this water as long as it lasts, to the body of the meter, to compensate for the diminution of water therein by evaporation or otherwise.

The action of the Warner & Cowan measuring wheel (Fig. 177) is independent of the water-line; the compensation in this instance being effected by a second and smaller wheel contained within, and revolving with, the larger one, but having its partitions arranged in the opposite direction. When a depression occurs in the water-line of a meter from any cause, a volume of gas in excess of the true quantity is passed; but in this instance the excess in volume of the gas is returned by the small wheel to the meter inlet to be remeasured.

The Sanders & Donovan meter (Fig. 178) is provided with a

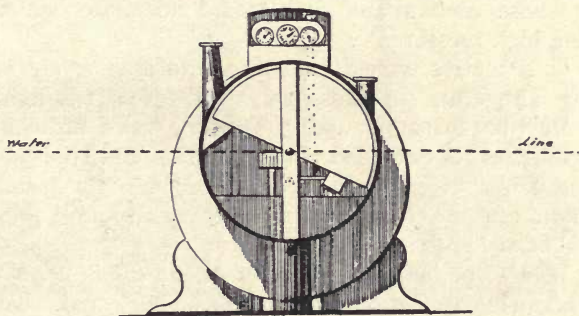


FIG. 178.

compensating hollow float of metal plate, accurately balanced on pivots within the front portion of the case, and independent of the meter's action. As the water is added to or withdrawn, the float rises or sinks in proportion, and thus the correct level is maintained.

When the drum or measuring wheel of a meter is driven at a speed exceeding 120 revolutions per hour (except two and three lights, when it may have a speed of 144), it absorbs an undue amount of the available gas pressure, and its registration is falsified. It is important, therefore, to see that all meters fixed are adequate to the supply of the greatest number of lights in use at one time on the premises of the consumer.

Mr. Urquhart's "Reliance" meter and Mr. Hunt's meter, both of which are on the compensating principle, though different in character, are exceptions to the rule above stated, as they measure correctly even when the measuring wheel is caused to revolve at speeds in excess of the normal rate. This result is obtained by a reverse action, by which the gas enters through

passages in the valve chamber in the body of the meter, and thence into the drum, from which it makes its escape through the bent tube to the outlet. The inlet pressure thus bears upon nearly the whole surface of the contained water, and the measuring chambers are practically unaltered in capacity.

It need scarcely be pointed out, however, that anything like a general resort to the practice of allowing the use of meters too small for the consumption except at extraordinary pressures, is a serious evil in various ways—loss by leakage is increased; the illuminating power of the gas is practically reduced; and consumers whose meters and fittings are adequate, suffer by the prevailing high pressure.

One-light meters, which formerly were extensively employed, are now altogether inadmissible; and even two-light meters should only be sparingly used. The low price at which gas is sold encourages its extended consumption; and the houses are becoming fewer in number every day where this small size is sufficient to afford an adequate supply, at reasonable pressures, to the number of lights in regular use.

The regular periodical inspection of meters is a point of the utmost importance, and ought never to be neglected. The indices of wet meters in dwelling houses, etc., should be noted, and water supplied to the proper level wherever deficient, at least *once every six weeks*. The meters in mills, manufactories, and large establishments of every kind where the consumption of gas is heavy, should be inspected for the like purpose *once every fourteen days*.

The inspector should always be provided with a supply of leather washers for the different screws and plugs, to replace any that are worn out.

Meters in cold and exposed positions should be protected by a suitable covering during frost, to prevent interruption to the supply of gas by the water becoming frozen. Woollen rags or wrappings of any kind will answer the purpose.

Greenall & Heaton's "Positive" meter (Fig. 179) differs in construction from those above described. The meter has two measuring cylinders, each divided into two separate chambers by a hollow cylindrical piston, sealed with glycerine within the annular space between the inner and outer parts of the cylinders. The chambers are connected by the gas-ways to the respective valve ports. The length of the stroke of the pistons is fixed and

definite, so that the displacement of gas at each stroke is the same and does not vary. One piston is set half a stroke in advance of the other, and thus each carries the other over the centre. The glycerine seal is not affected by the initial pressure, but only by the slight differential pressures above and below the pistons; in other words, only the slight pressure which is required to actuate the meter.

The motive power meter is but rarely required, but it is

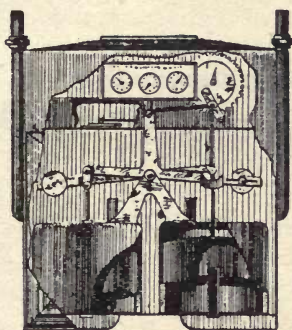


FIG. 179.



FIG. 180.

exceedingly useful in certain positions, where the pressure, from some unavoidable cause, is insufficient to afford an adequate supply of gas. In construction it is like an ordinary meter, but instead of the gas pressure being the motive power, the gas is exhausted from the main by the measuring wheel. This is set in motion by a descending weight, attached to which is a cord wound on a drum revolving in bearings on the top of the meter case, the drum being geared to the shaft of the measuring wheel, which projects through the back of the case. The speed of the meter, and consequently the pressure of gas obtained, are regulated by the weight aforementioned. Parkinson's motive power meter is shown in Fig. 180.

The "prepayment" or "slot" meter, of which there are various forms, is an ingenious device for extending the sale of gas amongst small consumers. By the addition of a simple mechanism contained in a box attached to the ordinary wet or dry meter, and

on dropping a penny through a slot therein, a quantity of gas of the value of the penny is allowed to pass to the burner. When the gas thus paid for is consumed, the supply ceases until another prepayment is made.

By another arrangement, on prepayment of a given sum—say 4*d.* for 100 cub. ft.—an extra dial on the meter is set to pass the quantity of gas; and when this is consumed a valve shuts off the supply, unless, in the meantime, a further payment has been made, and the dial is reset.

For the sizes of meters and their measuring capacity, see under Internal Fittings.

Board of Trade: Standards Department.

Actual Sizes in Inches and Parts of an Inch of Standard Gas Meter Union Gauges, 1901.

Denomination. No. of Lights.	Diameter.	Depth of Thread.	Pitch.
	Inches.	Inch.	
80-100	3'018	0'057	11
60	2'448	0'057	11
50	2'250	0'057	11
30	2'052	0'058	11
20	1'820	0'057	11
10	1'451	0'057	11
5	1'153	0'055	12
3	0'986	0'036	18

The pitch varies $\pm 0\cdot002$ and $0\cdot003$ inch.

Dimensions of Inside of Screw-Plug.

No. of Lights.	Inches.	No. of Lights.	Inches.
80-100	2'31	20	1'41
60	2'01	10	1'06
50	1'76	5	0'82
30	1'56	3	0'67

$\pm 0\cdot001$ inch.

NOTE.—The above sizes are the actual measurements of the minimum diameter of "boss" opening to admit "short shank of lining."

Variations in the dimensions of unions for equal-sized meters are a source of expense in the case of changing from one make to another.

The Board of Trade in 1901 suggested that the unions of gas meters throughout the trade should be made of uniform size, and the preceding table gives the dimensions and other particulars proposed.

Testing Meters.—For the verification of gas meters by a public inspector under the "Sales of Gas Act," a somewhat elaborate set of apparatus is required.

For ordinary use in testing meters in a gas-works, the following may be provided (Fig. 181):—

A standard gasholder of 10 cub. ft. capacity; a proving bench; an overhead water cistern; a float of lights; and thermometers for taking the temperature of the air and water.

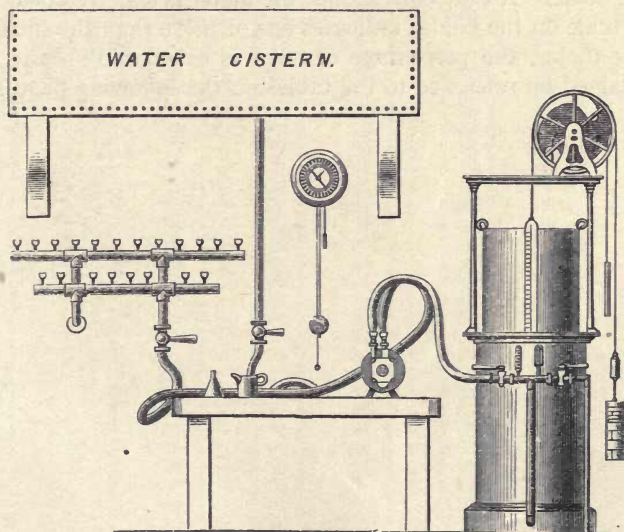


FIG. 181.

In testing, it is important to secure uniformity in the temperature of the air or gas in the test holder, the water in the tank, and the air in the room, viz.—60° Fahr.; otherwise corrections for varying temperatures have to be made.

Place the meter to be tested on the proving bench, charge it with water to the proper water-line (if a wet meter), and connect it with the holder and to the float of lights (if gas is being used).

See that the pointer of the small metal drum above the index in the wet meter, or of the small circle on the index plate of the dry meter, coincides with one of the figures marked thereon. If it does not, pass a small quantity of gas through till the necessary adjustment is effected.

Next, fill up the test holder till the zero line of the scale upon it is exactly opposite its pointer.

This being done, turn the gas or air on to the meter, and allow the meter to work till the small metal drum has made one or more revolutions, taking care to close the stop-cock when the pointer of the drum is exactly over the figure from which the start was made.

The meter registration is then compared with that of the holder scale. If they correspond, the meter is exactly correct; but if the scale on the holder indicates less or more than the small drum on the meter, the percentage of error is calculated; or it can be ascertained on reference to the tables on the following pages.

TABLES.

Showing the Percentage of Error in Meters according as their Registration differs from the Indications of the Test Gasholder.

The sign + is used to indicate fast, and - to indicate slow.
Meters not exceeding 2 per cent. fast, or 3 per cent. slow, are correct within the meaning of the "Sales of Gas Act."

Meter Registering 1 Foot.		Meter Registering 2 Feet.		Meter Registering 3 Feet.		Meter Registering 3 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Foot.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
0.90	+ 11.11	1.80	+ 11.11	2.70	+ 11.11	3.10	- 3.22
.91	+ 9.89	.81	+ 10.50	.71	+ 10.70	.11	- 3.54
.92	+ 8.70	.82	+ 9.89	.72	+ 10.30	.12	- 3.85
.93	+ 7.25	.83	+ 9.29	.73	+ 9.89	.13	- 4.16
.94	+ 6.36	.84	+ 8.70	.74	+ 9.49	.14	- 4.46
.95	+ 5.26	.85	+ 8.11	.75	+ 9.09	.15	- 4.76
.96	+ 4.17	.86	+ 7.53	.76	+ 8.70	.16	- 5.06
.97	+ 3.09	.87	+ 6.95	.77	+ 8.31	.17	- 5.36
.98	+ 2.04	.88	+ 6.38	.78	+ 7.92	.18	- 5.66
.99	+ 1.01	.89	+ 5.82	.79	+ 7.53	.19	- 5.85
1.00	Nil.	1.90	+ 5.26	2.80	+ 7.14	3.20	- 6.25
.01	- 1.00	.91	+ 4.71	.81	+ 6.76	.21	- 6.54
.02	- 1.97	.92	+ 4.17	.82	+ 6.38	.22	- 6.82
.03	- 2.92	.93	+ 3.63	.83	+ 6.01	.23	- 7.12
.04	- 3.85	.94	+ 3.09	.84	+ 5.63	.24	- 7.41
.05	- 4.74	.95	+ 2.56	.85	+ 5.26	.25	- 7.70
.06	- 5.66	.96	+ 2.04	.86	+ 4.89	.26	- 7.98
.07	- 6.54	.97	+ 1.52	.87	+ 4.53	.27	- 8.26
.08	- 7.40	.98	+ 1.01	.88	+ 4.17	.28	- 8.54
.09	- 8.26	.99	+ 0.50	.89	+ 3.81	.29	- 8.82
1.10	- 9.10	2.00	Nil.	2.90	+ 3.45	3.30	- 9.09
.11	- 9.91	.01	- 0.50	.91	+ 3.09	.31	- 9.36
.12	- 10.07	.02	- 0.99	.92	+ 2.74	.32	- 9.64
		.03	- 1.48	.93	+ 2.39	.33	- 9.91
		.04	- 1.96	.94	+ 2.04	.34	- 10.18
		.05	- 2.44	.95	+ 1.69		
		.06	- 2.91	.96	+ 1.35		
		.07	- 3.38	.97	+ 1.01		
		.08	- 3.85	.98	+ 0.67		
		.09	- 4.31	.99	+ 0.33		
		2.10	- 4.76	3.00	Nil.		
		.11	- 5.21	.01	- 0.33		
		.12	- 5.66	.02	- 0.66		
		.13	- 6.10	.03	- 0.99		
		.14	- 6.54	.04	- 1.32		
		.15	- 6.98	.05	- 1.64		
		.16	- 7.41	.06	- 1.96		
		.17	- 7.83	.07	- 2.28		
		.18	- 8.26	.08	- 2.60		
		.19	- 8.68	.09	- 2.91		

Meter Registering 5 Feet.		Meter Registering 5 Feet.		Meter Registering 5 Feet.		Meter Registering 10 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
4·50	+ 11·11	5·02	- 0·40	5·54	- 9·75	9·00	+ 11·11
·51	+ 10·86	·03	- 0·60	·55	- 9·91	·01	+ 10·99
·52	+ 10·62	·04	- 0·79	·56	- 10·07	·02	+ 10·86
·53	+ 10·38	·05	- 0·99	·57	- 10·23	·03	+ 10·74
·54	+ 10·13	·06	- 1·19	·58	- 10·39	·04	+ 10·62
·55	+ 9·89	·07	- 1·38	·59	- 10·55	·05	+ 10·50
·56	+ 9·65	·08	- 1·57	5·60	- 10·71	·06	+ 10·38
·57	+ 9·41	·09	- 1·77	·61	- 10·87	·07	+ 10·25
·58	+ 9·17	5·10	- 1·96	·62	- 11·03	·08	+ 10·13
·59	+ 8·93	·11	- 2·15	·63	- 11·19	·09	+ 10·01
4·60	+ 8·70	·12	- 2·34			9·10	+ 9·89
·61	+ 8·46	·13	- 2·53			·11	+ 9·77
·62	+ 8·23	·14	- 2·72			·12	+ 9·65
·63	+ 7·99	·15	- 2·91			·13	+ 9·53
·64	+ 7·76	·16	- 3·10			·14	+ 9·41
·65	+ 7·53	·17	- 3·29			·15	+ 9·29
·66	+ 7·30	·18	- 3·47			·16	+ 9·17
·67	+ 7·07	·19	- 3·66			·17	+ 9·05
·68	+ 6·84	5·20	- 3·85			·18	+ 8·93
·69	+ 6·61	·21	- 4·03			·19	+ 8·81
4·70	+ 6·38	·22	- 4·21			9·20	+ 8·70
·71	+ 6·16	·23	- 4·40			·21	+ 8·58
·72	+ 5·93	·24	- 4·58			·22	+ 8·46
·73	+ 5·71	·25	- 4·76			·23	+ 8·34
·74	+ 5·49	·26	- 4·94			·24	+ 8·23
·75	+ 5·26	·27	- 5·12			·25	+ 8·11
·76	+ 5·04	·28	- 5·30			·26	+ 7·99
·77	+ 4·82	·29	- 5·48			·27	+ 7·87
·78	+ 4·60	5·30	- 5·66			·28	+ 7·76
·79	+ 4·38	·31	- 5·84			·29	+ 7·64
4·80	+ 4·17	·32	- 6·02			9·30	+ 7·53
·81	+ 3·95	·33	- 6·19			·31	+ 7·41
·82	+ 3·73	·34	- 6·37			·32	+ 7·30
·83	+ 3·52	·35	- 6·54			·33	+ 7·18
·84	+ 3·31	·36	- 6·72			·34	+ 7·07
·85	+ 3·09	·37	- 6·89			·35	+ 6·95
·86	+ 2·88	·38	- 7·06			·36	+ 6·84
·87	+ 2·67	·39	- 7·24			·37	+ 6·72
·88	+ 2·46	5·40	- 7·41			·38	+ 6·61
·89	+ 2·25	·41	- 7·58			·39	+ 6·50
4·90	+ 2·04	·42	- 7·75			9·40	+ 6·38
·91	+ 1·83	·43	- 7·92			·41	+ 6·27
·92	+ 1·63	·44	- 8·09			·42	+ 6·16
·93	+ 1·42	·45	- 8·26			·43	+ 6·04
·94	+ 1·21	·46	- 8·42			·44	+ 5·93
·95	+ 1·01	·47	- 8·59			·45	+ 5·82
·96	+ 0·81	·48	- 8·76			·46	+ 5·71
·97	+ 0·60	·49	- 8·93			·47	+ 5·60
·98	+ 0·40	5·50	- 9·09			·48	+ 5·49
·99	+ 0·20	·51	- 9·26			·49	+ 5·37
5·00	Nil.	·52	- 9·42			9·50	+ 5·26
·01	- 0·20	·53	- 9·59			·51	+ 5·15

CONSUMERS' GAS METERS

Meter Registering 10 Feet.		Meter Registering 10 Feet.		Meter Registering 10 Feet.		Meter Registering 10 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
9·52	+ 5·04	10·04	- 0·40	10·56	- 5·30	11·08	- 9·75
·53	+ 4·93	·05	- 0·50	·57	- 5·39	·09	- 9·83
·54	+ 4·82	·06	- 0·60	·58	- 5·48	11·10	- 9·91
·55	+ 4·71	·07	- 0·70	·59	- 5·57	·11	- 9·99
·56	+ 4·60	·08	- 0·79	10·60	- 5·66	·12	- 10·07
·57	+ 4·49	·09	- 0·89	·61	- 5·75	·13	- 10·15
·58	+ 4·38	10·10	- 0·99	·62	- 5·84	·14	- 10·23
·59	+ 4·28	·11	- 1·09	·63	- 5·93	·15	- 10·31
9·60	+ 4·17	·12	- 1·19	·64	- 6·02	·16	- 10·39
·61	+ 4·06	·13	- 1·28	·65	- 6·10	·17	- 10·47
·62	+ 3·95	·14	- 1·38	·66	- 6·19	·18	- 10·55
·63	+ 3·84	·15	- 1·48	·67	- 6·28	·19	- 10·63
·64	+ 3·73	·16	- 1·57	·68	- 6·37	11·20	- 10·71
·65	+ 3·63	·17	- 1·67	·69	- 6·45	·21	- 10·79
·66	+ 3·52	·18	- 1·77	10·70	- 6·54	·22	- 10·87
·67	+ 3·41	·19	- 1·86	·71	- 6·63	·23	- 10·95
·68	+ 3·31	10·20	- 1·96	·72	- 6·72	·24	- 11·03
·69	+ 3·20	·21	- 2·06	·73	- 6·80	·25	- 11·11
9·70	+ 3·09	·22	- 2·15	·74	- 6·89		
·71	+ 2·99	·23	- 2·25	·75	- 6·98		
·72	+ 2·88	·24	- 2·34	·76	- 7·06		
·73	+ 2·77	·25	- 2·44	·77	- 7·15		
·74	+ 2·67	·26	- 2·53	·78	- 7·24		
·75	+ 2·56	·27	- 2·63	·79	- 7·32		
·76	+ 2·46	·28	- 2·72	10·80	- 7·41		
·77	+ 2·35	·29	- 2·82	·81	- 7·49		
·78	+ 2·25	10·30	- 2·91	·82	- 7·58		
·79	+ 2·15	·31	- 3·01	·83	- 7·66		
9·80	+ 2·04	·32	- 3·10	·84	- 7·75		
·81	+ 1·94	·33	- 3·19	·85	- 7·83		
·82	+ 1·83	·34	- 3·29	·86	- 7·92		
·83	+ 1·73	·35	- 3·38	·87	- 8·00		
·84	+ 1·63	·36	- 3·47	·88	- 8·09		
·85	+ 1·52	·37	- 3·57	·89	- 8·17		
·86	+ 1·42	·38	- 3·66	10·90	- 8·26		
·87	+ 1·32	·39	- 3·75	·91	- 8·34		
·88	+ 1·21	10·40	- 3·85	·92	- 8·42		
·89	+ 1·11	·41	- 3·94	·93	- 8·51		
9·90	+ 1·01	·42	- 4·03	·94	- 8·59		
·91	+ 0·91	·43	- 4·12	·95	- 8·68		
·92	+ 0·81	·44	- 4·21	·96	- 8·76		
·93	+ 0·70	·45	- 4·31	·97	- 8·84		
·94	+ 0·60	·46	- 4·40	·98	- 8·93		
·95	+ 0·50	·47	- 4·49	·99	- 9·01		
·96	+ 0·40	·48	- 4·58	11·00	- 9·09		
·97	+ 0·30	·49	- 4·67	·01	- 9·18		
·98	+ 0·20	10·50	- 4·76	·02	- 9·26		
·99	+ 0·10	·51	- 4·85	·03	- 9·34		
10·00	Nil.	·52	- 4·94	·04	- 9·42		
·01	- 0·10	·53	- 5·03	·05	- 9·51		
·02	- 0·20	·54	- 5·12	·06	- 9·59		
·03	- 0·30	·55	- 5·21	·07	- 9·67		

Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 20 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
18·00	+ 11·11	18·52	+ 7·99	19·04	+ 5·04	19·56	+ 2·25
·01	+ 11·05	·53	+ 7·93	·05	+ 4·98	·57	+ 2·20
·02	+ 10·99	·54	+ 7·87	·06	+ 4·93	·58	+ 2·15
·03	+ 10·92	·55	+ 7·82	·07	+ 4·87	·59	+ 2·09
·04	+ 10·86	·56	+ 7·76	·08	+ 4·82	19·60	+ 2·04
·05	+ 10·80	·57	+ 7·70	·09	+ 4·76	·61	+ 1·99
·06	+ 10·74	·58	+ 7·64	19·10	+ 4·71	·62	+ 1·94
·07	+ 10·68	·59	+ 7·59	·11	+ 4·65	·63	+ 1·88
·08	+ 10·62	18·60	+ 7·53	·12	+ 4·60	·64	+ 1·83
·09	+ 10·56	·61	+ 7·47	·13	+ 4·54	·65	+ 1·78
18·10	+ 10·50	·62	+ 7·41	·14	+ 4·49	·66	+ 1·73
·11	+ 10·44	·63	+ 7·36	·15	+ 4·43	·67	+ 1·68
·12	+ 10·38	·64	+ 7·30	·16	+ 4·38	·68	+ 1·63
·13	+ 10·31	·65	+ 7·24	·17	+ 4·33	·69	+ 1·57
·14	+ 10·25	·66	+ 7·18	·18	+ 4·28	19·70	+ 1·52
·15	+ 10·19	·67	+ 7·13	·19	+ 4·22	·71	+ 1·47
·16	+ 10·13	·68	+ 7·07	19·20	+ 4·17	·72	+ 1·42
·17	+ 10·07	·69	+ 7·01	·21	+ 4·11	·73	+ 1·37
·18	+ 10·01	18·70	+ 6·95	·22	+ 4·06	·74	+ 1·32
·19	+ 9·95	·71	+ 6·90	·23	+ 4·00	·75	+ 1·26
18·20	+ 9·89	·72	+ 6·84	·24	+ 3·95	·76	+ 1·21
·21	+ 9·83	·73	+ 6·78	·25	+ 3·89	·77	+ 1·16
·22	+ 9·77	·74	+ 6·72	·26	+ 3·84	·78	+ 1·11
·23	+ 9·71	·75	+ 6·66	·27	+ 3·78	·79	+ 1·06
·24	+ 9·65	·76	+ 6·61	·28	+ 3·73	19·80	+ 1·01
·25	+ 9·59	·77	+ 6·55	·29	+ 3·68	·81	+ 0·96
·26	+ 9·53	·78	+ 6·50	19·30	+ 3·63	·82	+ 0·91
·27	+ 9·47	·79	+ 6·44	·31	+ 3·57	·83	+ 0·86
·28	+ 9·41	18·80	+ 6·38	·32	+ 3·52	·84	+ 0·81
·29	+ 9·35	·81	+ 6·32	·33	+ 3·46	·85	+ 0·75
18·80	+ 9·29	·82	+ 6·27	·34	+ 3·41	·86	+ 0·70
·31	+ 9·23	·83	+ 6·21	·35	+ 3·36	·87	+ 0·65
·32	+ 9·17	·84	+ 6·16	·36	+ 3·31	·88	+ 0·60
·33	+ 9·11	·85	+ 6·10	·37	+ 3·25	·89	+ 0·55
·34	+ 9·05	·86	+ 6·04	·38	+ 3·20	19·90	+ 0·50
·35	+ 8·99	·87	+ 5·98	·39	+ 3·14	·91	+ 0·45
·36	+ 8·93	·88	+ 5·93	19·40	+ 3·09	·92	+ 0·40
·37	+ 8·87	·89	+ 5·87	·41	+ 3·04	·93	+ 0·35
·38	+ 8·81	18·90	+ 5·82	·42	+ 2·99	·94	+ 0·30
·39	+ 8·76	·91	+ 5·76	·43	+ 2·93	·95	+ 0·25
18·40	+ 8·70	·92	+ 5·71	·44	+ 2·88	·96	+ 0·20
·41	+ 8·64	·93	+ 5·65	·45	+ 2·82	·97	+ 0·15
·42	+ 8·58	·94	+ 5·60	·46	+ 2·77	·98	+ 0·10
·43	+ 8·52	·95	+ 5·54	·47	+ 2·72	·99	+ 0·05
·44	+ 8·46	·96	+ 5·49	·48	+ 2·67	20·00	Nil.
·45	+ 8·40	·97	+ 5·43	·49	+ 2·61	·02	- 0·10
·46	+ 8·34	·98	+ 5·37	19·50	+ 2·56	·04	- 0·20
·47	+ 8·29	·99	+ 5·31	·51	+ 2·51	·06	- 0·30
·48	+ 8·23	19·00	+ 5·26	·52	+ 2·46	·08	- 0·40
·49	+ 8·17	·01	+ 5·20	·53	+ 2·40	20·10	- 0·50
18·60	+ 8·11	·02	+ 5·15	·54	+ 2·35	·12	- 0·60
·51	+ 8·05	·03	+ 5·09	·55	+ 2·30	·14	- 0·70

CONSUMERS' GAS METERS

Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 30 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
20·16	— 0·79	21·20	— 5·66	22·24	— 10·07	27·00	+ 11·11
·18	— 0·89	·22	— 5·75	·26	— 10·15	·02	+ 11·03
20·20	— 0·99	·24	— 5·84	·28	— 10·23	·04	+ 10·95
·22	— 1·09	·26	— 5·93	22·30	— 10·31	·06	+ 10·86
·24	— 1·19	·28	— 6·02	·32	— 10·39	·08	+ 10·78
·26	— 1·28	21·30	— 6·10	·34	— 10·47	27·10	+ 10·70
·28	— 1·38	·32	— 6·19	·36	— 10·55	·12	+ 10·62
20·30	— 1·48	·34	— 6·28	·38	— 10·63	·14	+ 10·54
·32	— 1·57	·36	— 6·37	22·40	— 10·71	·16	+ 10·46
·34	— 1·67	·38	— 6·46	·42	— 10·79	·18	+ 10·38
·36	— 1·77	21·40	— 6·54	·44	— 10·87	27·20	+ 10·30
·38	— 1·86	·42	— 6·63	·46	— 10·95	·22	+ 10·21
20·40	— 1·96	·44	— 6·72	·48	— 11·03	·24	+ 10·13
·42	— 2·06	·46	— 6·80	22·50	— 11·11	·26	+ 10·05
·44	— 2·15	·48	— 6·89			·28	+ 9·97
·46	— 2·25	21·50	— 6·98			27·30	+ 9·89
·48	— 2·34	·52	— 7·06			·32	+ 9·81
20·50	— 2·44	·54	— 7·15			·34	+ 9·73
·52	— 2·53	·56	— 7·24			·36	+ 9·65
·54	— 2·63	·58	— 7·32			·38	+ 9·57
·56	— 2·73	21·60	— 7·41			27·40	+ 9·49
·58	— 2·82	·62	— 7·49			·42	+ 9·41
20·60	— 2·91	·64	— 7·58			·44	+ 9·33
·62	— 3·01	·66	— 7·66			·46	+ 9·25
·64	— 3·10	·68	— 7·75			·48	+ 9·17
·66	— 3·19	21·70	— 7·83			27·50	+ 9·09
·68	— 3·29	·72	— 7·92			·52	+ 9·01
20·70	— 3·38	·74	— 8·00			·54	+ 8·93
·72	— 3·47	·76	— 8·09			·56	+ 8·85
·74	— 3·57	·78	— 8·17			·58	+ 8·78
·76	— 3·66	21·80	— 8·26			27·60	+ 8·70
·78	— 3·75	·82	— 8·34			·62	+ 8·62
20·80	— 3·85	·84	— 8·42			·64	+ 8·54
·82	— 3·94	·86	— 8·51			·66	+ 8·46
·84	— 4·03	·88	— 8·59			·68	+ 8·38
·86	— 4·12	21·90	— 8·68			27·70	+ 8·31
·88	— 4·21	·92	— 8·76			·72	+ 8·23
20·90	— 4·31	·94	— 8·84			·74	+ 8·15
·92	— 4·40	·96	— 8·93			·76	+ 8·07
·94	— 4·49	·98	— 9·01			·78	+ 7·99
·96	— 4·58	22·00	— 9·09			27·80	+ 7·92
·98	— 4·67	·02	— 9·18			·82	+ 7·84
21·00	— 4·76	·04	— 9·26			·84	+ 7·76
·02	— 4·85	·06	— 9·34			·86	+ 7·68
·04	— 4·94	·08	— 9·42			·88	+ 7·61
·06	— 5·03	22·10	— 9·51			27·90	+ 7·53
·08	— 5·12	·12	— 9·59			·92	+ 7·45
21·10	— 5·21	·14	— 9·67			·94	+ 7·38
·12	— 5·30	·16	— 9·75			·96	+ 7·30
·14	— 5·39	·18	— 9·83			·98	+ 7·22
·16	— 5·48	22·20	— 9·91			28·00	+ 7·14
·18	— 5·57	·22	— 9·99			·02	+ 7·07

Meter Registering 20 Feet.		Meter Registering 30 Feet.		Meter Registering 30 Feet.		Meter Registering 30 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
28·04	+ 6·99	29·08	+ 3·16	30·12	- 0·40	31·16	- 3·72
·06	+ 6·92	29·10	+ 3·09	·14	- 0·47	·18	- 3·79
·08	+ 6·84	·12	+ 3·02	·16	- 0·53	31·20	- 3·85
28·10	+ 6·76	·14	+ 2·95	·18	- 0·60	·22	- 3·91
·12	+ 6·69	·16	+ 2·88	30·20	- 0·66	·24	- 3·97
·14	+ 6·61	·18	+ 2·81	·22	- 0·73	·26	- 4·03
·16	+ 6·53	29·20	+ 2·74	·24	- 0·79	·28	- 4·09
·18	+ 6·46	·22	+ 2·67	·26	- 0·86	31·30	- 4·16
28·20	+ 6·38	·24	+ 2·60	·28	- 0·92	·32	- 4·22
·22	+ 6·31	·56	+ 2·53	30·30	- 0·99	·34	- 4·28
·24	+ 6·23	·28	+ 2·46	·32	- 1·06	·36	- 4·34
·26	+ 6·16	29·30	+ 2·39	·34	- 1·12	·38	- 4·40
·28	+ 6·08	·32	+ 2·32	·36	- 1·19	31·40	- 4·46
28·30	+ 6·01	·34	+ 2·25	·38	- 1·26	·42	- 4·52
·32	+ 5·93	·36	+ 2·18	30·40	- 1·32	·44	- 4·58
·34	+ 5·86	·38	+ 2·11	·42	- 1·38	·46	- 4·64
·36	+ 5·78	29·40	+ 2·04	·44	- 1·44	·48	- 4·70
·38	+ 5·71	·42	+ 1·97	·46	- 1·51	31·50	- 4·76
28·40	+ 5·63	·44	+ 1·90	·48	- 1·57	·52	- 4·82
·42	+ 5·56	·46	+ 1·83	30·50	- 1·64	·54	- 4·88
·44	+ 5·49	·48	+ 1·76	·52	- 1·71	·56	- 4·94
·46	+ 5·41	29·50	+ 1·69	·54	- 1·77	·58	- 5·00
·48	+ 5·34	·52	+ 1·63	·56	- 1·83	31·60	- 5·06
28·50	+ 5·26	·54	+ 1·56	·58	- 1·89	·62	- 5·12
·52	+ 5·19	·56	+ 1·49	30·60	- 1·96	·64	- 5·18
·54	+ 5·11	·58	+ 1·42	·62	- 2·02	·66	- 5·24
·56	+ 5·04	29·60	+ 1·35	·64	- 2·09	·68	- 5·30
·58	+ 4·96	·62	+ 1·28	·66	- 2·15	31·70	- 5·36
28·60	+ 4·89	·64	+ 1·21	·68	- 2·22	·72	- 5·42
·62	+ 4·82	·66	+ 1·14	30·70	- 2·28	·74	- 5·48
·64	+ 4·75	·68	+ 1·08	·72	- 2·34	·76	- 5·54
·66	+ 4·67	29·70	+ 1·01	·74	- 2·40	·78	- 5·60
·68	+ 4·60	·72	+ 0·94	·76	- 2·47	31·80	- 5·66
28·70	+ 4·53	·74	+ 0·88	·78	- 2·53	·82	- 5·72
·72	+ 4·45	·76	+ 0·81	30·80	- 2·60	·84	- 5·78
·74	+ 4·38	·78	+ 0·74	·82	- 2·66	·86	- 5·84
·76	+ 4·31	29·80	+ 0·67	·84	- 2·72	·88	- 5·90
·78	+ 4·24	·82	+ 0·60	·86	- 2·78	31·90	- 5·96
28·80	+ 4·17	·84	+ 0·53	·88	- 2·85	·92	- 6·02
·82	+ 4·10	·86	+ 0·47	30·90	- 2·91	·94	- 6·08
·84	+ 4·02	·88	+ 0·40	·92	- 2·97	·96	- 6·13
·86	+ 3·95	29·90	+ 0·33	·94	- 3·04	·98	- 6·19
·88	+ 3·88	·92	+ 0·26	·96	- 3·10	32·00	- 6·25
28·90	+ 3·81	·94	+ 0·20	·98	- 3·16	·02	- 6·31
·92	+ 3·73	·96	+ 0·13	31·00	- 3·22	·04	- 6·37
·94	+ 3·66	·98	+ 0·07	·02	- 3·29	·06	- 6·42
·96	+ 3·59	30·00	Nil.	·04	- 3·35	·08	- 6·48
·98	+ 3·52	·02	- 0·07	·06	- 3·42	32·10	- 6·54
29·00	+ 3·45	·04	- 0·13	·08	- 3·48	·12	- 6·60
·02	+ 3·38	·06	- 0·20	31·10	- 3·54	·14	- 6·66
·04	+ 3·31	·08	- 0·27	·12	- 2·60	·16	- 6·72
·06	+ 3·24	30·10	- 0·33	·14	- 3·66	·18	- 6·77

CONSUMERS' GAS METERS

Meter Registering 30 Feet.		Meter Registering 30 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
32·20	— 6·83	33·24	— 9·75	36·00	+ 11·11	37·04	+ 7·99
·22	— 6·89	·25	— 9·81	·02	+ 11·05	·06	+ 7·98
·24	— 6·95	·28	— 9·86	·04	+ 10·99	·08	+ 7·87
·26	— 7·01	33·30	— 9·91	·06	+ 10·92	37·10	+ 7·82
·28	— 7·07	·32	— 9·96	·08	+ 10·86	·12	+ 7·76
32·30	— 7·12	·34	— 10·01	36·10	+ 10·80	·14	+ 7·70
·32	— 7·18	·36	— 10·07	·12	+ 10·74	·16	+ 7·64
·34	— 7·24	·38	— 10·12	·14	+ 10·68	·18	+ 7·59
·36	— 7·30	33·40	— 10·18	·16	+ 10·62	37·20	+ 7·53
·38	— 7·36	·42	— 10·23	·18	+ 10·56	·22	+ 7·47
32·40	— 7·41	·44	— 10·28	36·20	+ 10·50	·24	+ 7·41
·42	— 7·47	·46	— 10·34	·22	+ 10·44	·26	+ 7·36
·44	— 7·53	·48	— 10·39	·24	+ 10·38	·28	+ 7·30
·46	— 7·59	33·50	— 10·45	·26	+ 10·31	37·30	+ 7·24
·48	— 7·64	·52	— 10·50	·28	+ 10·25	·32	+ 7·18
32·50	— 7·70	·54	— 10·55	36·30	+ 10·19	·34	+ 7·13
·52	— 7·76	·56	— 10·61	·32	+ 10·13	·36	+ 7·07
·54	— 7·82	·58	— 10·66	·34	+ 10·07	·38	+ 7·01
·56	— 7·87	33·60	— 10·71	·36	+ 10·01	37·40	+ 6·95
·58	— 7·93	·62	— 10·76	·38	+ 9·95	·42	+ 6·90
32·60	— 7·98	·64	— 10·82	36·40	+ 9·89	·44	+ 6·84
·62	— 8·04	·66	— 10·87	·42	+ 9·83	·46	+ 6·78
·64	— 8·10	·68	— 10·93	·44	+ 9·77	·48	+ 6·72
·66	— 8·15	33·70	— 10·98	·46	+ 9·71	37·50	+ 6·66
·68	— 8·21	·72	— 11·03	·48	+ 9·65	·52	+ 6·61
32·70	— 8·26	·74	— 11·09	36·50	+ 9·59	·54	+ 6·55
·72	— 8·32	·76	— 11·14	·52	+ 9·53	·56	+ 6·50
·74	— 8·37	·78	— 11·19	·54	+ 9·47	·58	+ 6·44
·76	— 8·43			·56	+ 9·41	37·60	+ 6·38
·78	— 8·49			·58	+ 9·35	·62	+ 6·32
32·80	— 8·54			36·60	+ 9·29	·64	+ 6·27
·82	— 8·60			·62	+ 9·23	·66	+ 6·21
·84	— 8·66			·64	+ 9·17	·68	+ 6·16
·86	— 8·71			·66	+ 9·11	37·70	+ 6·10
·88	— 8·77			·68	+ 9·05	·72	+ 6·04
32·90	— 8·82			36·70	+ 8·99	·74	+ 5·98
·92	— 8·87			·72	+ 8·93	·76	+ 5·93
·94	— 8·93			·74	+ 8·87	·78	+ 5·87
·96	— 8·99			·76	+ 8·81	37·80	+ 5·82
·98	— 9·04			·78	+ 8·76	·82	+ 5·76
33·00	— 9·09			36·80	+ 8·70	·84	+ 5·71
·02	— 9·15			·82	+ 8·64	·86	+ 5·65
·04	— 9·20			·84	+ 8·58	·88	+ 5·60
·06	— 9·26			·86	+ 8·52	37·90	+ 5·54
·08	— 9·31			·88	+ 8·46	·92	+ 5·49
33·10	— 9·36			36·90	+ 8·40	·94	+ 5·43
·12	— 9·42			·92	+ 8·34	·96	+ 5·37
·14	— 9·47			·94	+ 8·29	·98	+ 5·31
·16	— 9·53			·96	+ 8·23	38·00	+ 5·26
·18	— 9·59			·98	+ 8·17	·02	+ 5·20
33·20	— 9·64			37·00	+ 8·11	·04	+ 5·15
·22	— 9·70			·02	+ 8·05	·06	+ 5·09

Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
38·08	+ 5·04	39·12	+ 2·25	40·16	- 0·40	41·20	- 2·91
38·10	+ 4·98	·14	+ 2·20	·18	- 0·45	·22	- 2·96
·12	+ 4·93	·16	+ 2·15	40·20	- 0·50	·24	- 3·01
·14	+ 4·87	·18	+ 2·09	·22	- 0·55	·26	- 3·06
·16	+ 4·82	39·20	+ 2·04	·24	- 0·60	·28	- 3·10
·18	+ 4·76	·22	+ 1·99	·26	- 0·65	41·30	- 3·15
38·20	+ 4·71	·24	+ 1·94	·28	- 0·70	·32	- 3·19
·22	+ 4·65	·26	+ 1·88	40·30	- 0·75	·34	- 3·24
·24	+ 4·60	·28	+ 1·83	·32	- 0·79	·36	- 3·29
·26	+ 4·54	39·30	+ 1·78	·34	- 0·84	·38	- 3·34
·23	+ 4·49	·32	+ 1·73	·36	- 0·89	41·40	- 3·38
38·30	+ 4·44	·34	+ 1·68	·38	- 0·94	·42	- 3·43
·32	+ 4·38	·36	+ 1·63	40·40	- 0·99	·44	- 3·47
·34	+ 4·33	·38	+ 1·57	·42	- 1·04	·46	- 3·52
·36	+ 4·28	39·40	+ 1·52	·44	- 1·09	·48	- 3·57
·38	+ 4·22	·42	+ 1·47	·46	- 1·14	41·50	- 3·61
38·40	+ 4·17	·44	+ 1·42	·48	- 1·19	·52	- 3·66
·42	+ 4·11	·46	+ 1·37	40·50	- 1·24	·54	- 3·71
·44	+ 4·06	·48	+ 1·32	·52	- 1·28	·56	- 3·75
·46	+ 4·00	39·50	+ 1·26	·54	- 1·33	·58	- 3·80
·48	+ 3·95	·52	+ 1·21	·56	- 1·38	41·60	- 3·85
38·50	+ 3·90	·54	+ 1·16	·58	- 1·43	·62	- 3·90
·52	+ 3·84	·56	+ 1·11	40·60	- 1·48	·64	- 3·94
·54	+ 3·78	·58	+ 1·06	·62	- 1·53	·66	- 3·99
·56	+ 3·73	39·60	+ 1·01	·64	- 1·57	·68	- 4·03
·58	+ 3·68	·62	+ 0·96	·66	- 1·62	41·70	- 4·08
38·60	+ 3·63	·64	+ 0·91	·68	- 1·67	·72	- 4·12
·62	+ 3·57	·66	+ 0·86	40·70	- 1·72	·74	- 4·17
·64	+ 3·52	·68	+ 0·81	·72	- 1·77	·76	- 4·21
66	+ 3·46	39·70	+ 0·75	·74	- 1·82	·78	- 4·26
·68	+ 3·41	·72	+ 0·70	·76	- 1·86	41·80	- 4·31
38·70	+ 3·36	·74	+ 0·65	·78	- 1·91	·82	- 4·36
·72	+ 3·31	·76	+ 0·60	40·80	- 1·96	·84	- 4·40
·74	+ 3·25	·78	+ 0·55	·82	- 2·01	·86	- 4·45
76	+ 3·20	39·80	+ 0·50	·84	- 2·06	·88	- 4·49
·78	+ 3·14	·82	+ 0·45	·86	- 2·10	41·90	- 4·54
38·80	+ 3·09	·84	+ 0·40	·88	- 2·15	·92	- 4·58
·82	+ 3·04	·86	+ 0·35	40·90	- 2·20	·94	- 4·63
·84	+ 2·99	·88	+ 0·30	·92	- 2·25	·96	- 4·67
86	+ 2·93	39·90	+ 0·25	·94	- 2·30	·98	- 4·72
·88	+ 2·88	·92	+ 0·20	·96	- 2·34	42·00	- 4·76
38·90	+ 2·82	·94	+ 0·15	·98	- 2·39	·02	- 4·81
·92	+ 2·77	·96	+ 0·10	41·00	- 2·44	·04	- 4·85
·94	+ 2·72	·98	+ 0·05	·02	- 2·49	·06	- 4·90
96	+ 2·67	40·00	Nil.	·04	- 2·53	·08	- 4·94
·98	+ 2·61	·02	- 0·05	·06	- 2·58	42·10	- 4·99
39·00	+ 2·56	·04	- 0·10	·08	- 2·63	·12	- 5·03
·02	+ 2·51	·06	- 0·15	41·10	- 2·68	·14	- 5·08
·04	+ 2·46	·08	- 0·20	·12	- 2·72	·16	- 5·12
96	+ 2·40	40·10	- 0·25	·14	- 2·78	·18	- 5·17
·08	+ 2·35	·12	- 0·30	·16	- 2·82	42·20	- 5·21
39·10	+ 2·30	·14	- 0·35	·18	- 2·87	·22	- 5·26

CONSUMERS' GAS METERS

Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
42·24	- 5·30	43·28	- 7·58	44·32	- 9·75	45·00	+ 11·11
·26	- 5·35	43·30	- 7·62	·34	- 9·79	·02	+ 11·06
·28	- 5·39	·32	- 7·66	·36	- 9·83	·04	+ 11·01
42·30	- 5·44	·34	- 7·71	·38	- 9·87	·06	+ 10·96
·32	- 5·48	·36	- 7·75	44·40	- 9·91	·08	+ 10·91
·34	- 5·53	·38	- 7·79	·42	- 9·95	45·10	+ 10·86
·36	- 5·57	43·40	- 7·83	·44	- 9·99	·12	+ 10·81
·38	- 5·62	·42	- 7·88	·46	- 10·03	·14	+ 10·76
42·40	- 5·66	·44	- 7·92	·48	- 10·07	·16	+ 10·72
·42	- 5·71	·46	- 7·96	44·50	- 10·11	·18	+ 10·67
·44	- 5·75	·48	- 8·00	·52	- 10·15	45·20	+ 10·62
·46	- 5·80	43·50	- 8·05	·54	- 10·19	·22	+ 10·67
·48	- 5·84	·52	- 8·09	·56	- 10·23	·24	+ 10·52
42·50	- 5·88	·54	- 8·13	·58	- 10·27	·26	+ 10·48
·52	- 5·93	·56	- 8·17	44·60	- 10·31	·28	+ 10·43
·54	- 5·98	·58	- 8·22	·62	- 10·35	45·30	+ 10·38
·56	- 6·02	43·60	- 8·26	·64	- 10·39	·32	+ 10·33
·58	- 6·06	·62	- 8·30	·66	- 10·43	·34	+ 10·28
42·60	- 6·10	·64	- 8·34	·68	- 10·47	·36	+ 10·23
·62	- 6·15	·66	- 8·38	44·70	- 10·51	·38	+ 10·18
·64	- 6·19	·68	- 8·42	·72	- 10·55	45·40	+ 10·13
·66	- 6·24	43·70	- 8·47	·74	- 10·59	·42	+ 10·08
·68	- 6·28	·72	- 8·51	·76	- 10·63	·44	+ 10·03
42·70	- 6·33	·74	- 8·55	·78	- 10·67	·46	+ 9·99
·72	- 6·37	·76	- 8·59	44·80	- 10·71	·48	+ 9·94
·74	- 6·41	·78	- 8·64	·82	- 10·75	45·50	+ 9·89
·76	- 6·45	43·80	- 8·68	·84	- 10·79	·52	+ 9·84
·78	- 6·50	·82	- 8·72	·86	- 10·84	·54	+ 9·79
42·80	- 6·54	·84	- 8·76	·88	- 10·87	·56	+ 9·75
·82	- 6·59	·86	- 8·80	44·90	- 10·91	·58	+ 9·70
·84	- 6·63	·88	- 8·84	·92	- 10·95	45·60	+ 9·65
·86	- 6·68	43·90	- 8·89	·94	- 10·99	·62	+ 9·60
·88	- 6·72	·92	- 8·93	·96	- 11·03	·64	+ 9·55
42·90	- 6·76	·94	- 8·97	·98	- 11·07	·66	+ 9·50
·92	- 6·80	·96	- 9·01	45·00	- 11·11	·68	+ 9·46
·94	- 6·85	·98	- 9·05			45·70	+ 9·41
·96	- 6·89	44·00	- 9·09			·72	+ 9·36
·98	- 6·94	·02	- 9·14			·74	+ 9·31
43·00	- 6·98	·04	- 9·18			·76	+ 9·27
·02	- 7·02	·06	- 9·22			·78	+ 9·22
·04	- 7·06	·08	- 9·26			45·80	+ 9·17
·06	- 7·11	44·10	- 9·30			·82	+ 9·12
·08	- 7·15	·12	- 9·34			·84	+ 9·07
43·10	- 7·20	·14	- 9·38			·86	+ 9·03
·12	- 7·24	·16	- 9·42			·88	+ 8·98
·14	- 7·28	·18	- 9·47			45·90	+ 8·93
·16	- 7·32	44·20	- 9·51			·92	+ 8·88
·18	- 7·37	·22	- 9·55			·94	+ 8·84
43·20	- 7·41	·24	- 9·59			·96	+ 8·79
·22	- 7·45	·26	- 9·63			·98	+ 8·75
·24	- 7·49	·28	- 9·67			46·00	+ 8·70
·26	- 7·54	44·30	- 9·71			·02	+ 8·65

Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
46·04	+ 8·60	47·08	+ 6·20	48·12	+ 3·91	49·16	+ 1·71
·06	+ 8·56	47·10	+ 6·16	·14	+ 3·86	·18	+ 1·67
·08	+ 8·51	·12	+ 6·11	·16	+ 3·82	49·20	+ 1·63
46·10	+ 8·46	·14	+ 6·07	·18	+ 3·77	·22	+ 1·59
·12	+ 8·41	·16	+ 6·02	48·20	+ 3·73	·24	+ 1·55
·14	+ 8·37	·18	+ 5·98	·22	+ 3·69	·26	+ 1·50
·16	+ 8·32	47·20	+ 5·93	·24	+ 3·65	·28	+ 1·46
·18	+ 8·28	·22	+ 5·89	·26	+ 3·60	49·30	+ 1·42
46·20	+ 8·23	·24	+ 5·84	·28	+ 3·56	·32	+ 1·38
·22	+ 8·18	·26	+ 5·80	48·30	+ 3·52	·34	+ 1·34
·24	+ 8·13	·28	+ 5·75	·32	+ 3·48	·36	+ 1·29
·26	+ 8·09	47·30	+ 5·71	·34	+ 3·44	·38	+ 1·25
·28	+ 8·04	·32	+ 5·67	·36	+ 3·39	49·40	+ 1·21
46·30	+ 7·99	·34	+ 5·62	·38	+ 3·35	·42	+ 1·17
·32	+ 7·94	·36	+ 5·58	48·40	+ 3·31	·44	+ 1·13
·34	+ 7·90	·38	+ 5·53	·42	+ 3·27	·46	+ 1·09
·36	+ 7·85	47·40	+ 5·49	·44	+ 3·22	·48	+ 1·05
·38	+ 7·81	·42	+ 5·44	·46	+ 3·18	49·50	+ 1·01
46·40	+ 7·76	·44	+ 5·40	·48	+ 3·13	·52	+ 0·97
·42	+ 7·71	·46	+ 5·35	48·50	+ 3·09	·54	+ 0·93
·44	+ 7·67	·48	+ 5·31	·52	+ 3·05	·56	+ 0·89
·46	+ 7·62	47·50	+ 5·26	·54	+ 3·01	·58	+ 0·85
·48	+ 7·58	·52	+ 5·22	·56	+ 2·96	49·60	+ 0·81
46·50	+ 7·53	·54	+ 5·17	·58	+ 2·92	·62	+ 0·77
·52	+ 7·48	·56	+ 5·13	48·60	+ 2·88	·64	+ 0·73
·54	+ 7·44	·58	+ 5·08	·62	+ 2·84	·66	+ 0·68
·56	+ 7·39	47·60	+ 5·04	·64	+ 2·80	·68	+ 0·64
·58	+ 7·35	·62	+ 5·00	·66	+ 2·75	49·70	+ 0·60
46·60	+ 7·30	·64	+ 4·95	·68	+ 2·71	·72	+ 0·56
·62	+ 7·25	·66	+ 4·91	48·70	+ 2·67	·74	+ 0·52
·64	+ 7·21	·68	+ 4·86	·72	+ 2·63	·76	+ 0·48
·66	+ 7·16	47·70	+ 4·82	·74	+ 2·59	·78	+ 0·44
·68	+ 7·12	·72	+ 4·78	·76	+ 2·54	49·80	+ 0·40
46·70	+ 7·07	·74	+ 4·73	·78	+ 2·50	·82	+ 0·36
·72	+ 7·02	·76	+ 4·69	48·80	+ 2·46	·84	+ 0·32
·74	+ 6·98	·78	+ 4·64	·82	+ 2·42	·86	+ 0·28
·76	+ 6·93	47·80	+ 4·60	·84	+ 2·38	·88	+ 0·24
·78	+ 6·89	·82	+ 4·56	·86	+ 2·33	49·90	+ 0·20
46·80	+ 6·84	·84	+ 4·51	·88	+ 2·29	·92	+ 0·16
·82	+ 6·79	·86	+ 4·47	48·90	+ 2·25	·94	+ 0·12
·84	+ 6·75	·88	+ 4·42	·92	+ 2·21	·96	+ 0·08
·86	+ 6·70	47·90	+ 4·38	·94	+ 2·17	·98	+ 0·04
·88	+ 6·66	·92	+ 4·34	·96	+ 2·12	50·00	Nil.
46·90	+ 6·61	·94	+ 4·30	·98	+ 2·08	·02	- 0·04
·92	+ 6·56	·96	+ 4·25	49·00	+ 2·04	·04	- 0·08
·94	+ 6·52	·98	+ 4·21	·02	+ 2·00	·06	- 0·12
·96	+ 6·47	48·00	+ 4·17	·04	+ 1·96	·08	- 0·16
·98	+ 6·43	·02	+ 4·13	·06	+ 1·91	50·10	- 0·20
47·00	+ 6·38	·04	+ 4·08	·08	+ 1·87	·12	- 0·24
·02	+ 6·34	·06	+ 4·04	49·10	+ 1·83	·14	- 0·28
·04	+ 6·29	·08	+ 3·99	·12	+ 1·79	·16	- 0·32
·06	+ 6·25	48·10	+ 3·95	·14	+ 1·75	·18	- 0·36

CONSUMERS' GAS METERS

Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
50·20	— 0·40	51·24	— 2·42	52·70	— 5·12	55·30	— 9·59
·22	— 0·44	·26	— 2·45	·75	— 5·21	·35	— 9·67
·24	— 0·48	·28	— 2·49	·80	— 5·30	·40	— 9·75
·26	— 0·52	51·30	— 2·53	·85	— 5·39	·45	— 9·83
·28	— 0·56	·32	— 2·57	·90	— 5·48	55·50	— 9·91
50·30	— 0·60	·34	— 2·61	·95	— 5·57	·55	— 9·99
·32	— 0·64	·36	— 2·65	53·00	— 5·66	·60	— 10·07
·34	— 0·68	·38	— 2·69	·05	— 5·75	·65	— 10·15
·36	— 0·71	51·40	— 2·72	·10	— 5·84	·70	— 10·23
·38	— 0·75	·42	— 2·76	·15	— 5·93	·75	— 10·31
50·40	— 0·79	·44	— 2·80	·20	— 6·02	·80	— 10·39
·42	— 0·83	·46	— 2·83	·25	— 6·10	·85	— 10·47
·44	— 0·87	·48	— 2·87	·30	— 6·19	·90	— 10·55
·46	— 0·91	51·50	— 2·91	·35	— 6·28	·95	— 10·63
·48	— 0·95	·52	— 2·95	·40	— 6·37	56·00	— 10·71
50·50	— 0·99	·54	— 2·99	·45	— 6·45	·05	— 10·79
·52	— 1·03	·56	— 3·02	53·50	— 6·54	·10	— 10·87
·54	— 1·07	·58	— 3·06	·55	— 6·63	·15	— 10·95
·56	— 1·11	51·60	— 3·10	·60	— 6·72	·20	— 11·03
·58	— 1·15	·62	— 3·14	·65	— 6·80	·25	— 11·11
50·60	— 1·19	·64	— 3·18	·70	— 6·89		
·62	— 1·23	·66	— 3·21	·75	— 6·98		
·64	— 1·27	·68	— 3·25	·80	— 7·06		
·66	— 1·30	51·70	— 3·29	·85	— 7·15		
·68	— 1·34	·72	— 3·33	·90	— 7·24		
50·70	— 1·38	·74	— 3·36	·95	— 7·32		
·72	— 1·42	·76	— 3·40	54·00	— 7·41		
·74	— 1·46	·78	— 3·43	·05	— 7·49		
·76	— 1·49	51·80	— 3·47	·10	— 7·58		
·78	— 1·53	·82	— 3·51	·15	— 7·66		
50·80	— 1·57	·84	— 3·55	·20	— 7·75		
·82	— 1·61	·86	— 3·58	·25	— 7·83		
·84	— 1·65	·88	— 3·62	·30	— 7·92		
·86	— 1·69	51·90	— 3·66	·35	— 8·00		
·88	— 1·73	·92	— 3·70	·40	— 8·09		
50·90	— 1·77	·94	— 3·74	·45	— 8·17		
·92	— 1·81	·96	— 3·77	54·50	— 8·26		
·94	— 1·85	·98	— 3·81	·55	— 8·34		
·96	— 1·88	52·00	— 3·85	·60	— 8·42		
·98	— 1·92	·05	— 3·94	·65	— 8·51		
51·00	— 1·96	·10	— 4·03	·70	— 8·59		
·02	— 2·00	·15	— 4·12	·75	— 8·68		
·04	— 2·04	·20	— 4·21	·80	— 8·76		
·06	— 2·07	·25	— 4·31	·85	— 8·84		
·08	— 2·11	·30	— 4·40	·90	— 8·93		
51·10	— 2·15	·35	— 4·49	·95	— 9·01		
·12	— 2·19	·40	— 4·58	55·00	— 9·09		
·14	— 2·23	·45	— 4·67	·05	— 9·18		
·16	— 2·26	52·50	— 4·76	·10	— 9·26		
·18	— 2·30	·55	— 4·85	·15	— 9·34		
51·20	— 2·34	·60	— 4·94	·20	— 9·42		
·22	— 2·38	·65	— 5·03	·25	— 9·51		

Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
90·00	+ 11·11	92·65	+ 7·93	95·30	+ 4·93	97·95	+ 2·09
·05	+ 11·05	·70	+ 7·87	·35	+ 4·87	98·00	+ 2·04
·10	+ 10·99	·75	+ 7·82	·40	+ 4·82	·05	+ 1·99
·15	+ 10·92	·80	+ 7·76	·45	+ 4·76	·10	+ 1·94
·20	+ 10·86	·85	+ 7·70	95·50	+ 4·71	·15	+ 1·88
·25	+ 10·80	·90	+ 7·64	·55	+ 4·65	·20	+ 1·83
·30	+ 10·74	·95	+ 7·59	·60	+ 4·60	·25	+ 1·78
·35	+ 10·68	93·00	+ 7·53	·65	+ 4·54	·30	+ 1·73
·40	+ 10·62	·05	+ 7·47	·70	+ 4·49	·35	+ 1·68
·45	+ 10·56	·10	+ 7·41	·75	+ 4·43	·40	+ 1·63
90·50	+ 10·50	·15	+ 7·36	·80	+ 4·38	·45	+ 1·57
·55	+ 10·44	·20	+ 7·30	·85	+ 4·33	98·50	+ 1·52
·60	+ 10·38	·25	+ 7·24	·90	+ 4·28	·55	+ 1·47
·65	+ 10·31	·30	+ 7·18	·95	+ 4·22	·60	+ 1·42
·70	+ 10·25	·35	+ 7·13	96·00	+ 4·17	·65	+ 1·37
·75	+ 10·19	·40	+ 7·07	·05	+ 4·11	·70	+ 1·32
·80	+ 10·13	·45	+ 7·01	·10	+ 4·06	·75	+ 1·26
·85	+ 10·07	93·50	+ 6·95	·15	+ 4·00	·80	+ 1·21
·90	+ 10·01	·55	+ 6·90	·20	+ 3·95	·85	+ 1·16
·95	+ 9·95	·60	+ 6·84	·25	+ 3·89	·90	+ 1·11
91·00	+ 9·89	·65	+ 6·78	·30	+ 3·84	·95	+ 1·06
·05	+ 9·83	·70	+ 6·72	·35	+ 3·78	99·00	+ 1·01
·10	+ 9·77	·75	+ 6·66	·40	+ 3·73	·05	+ 0·96
·15	+ 9·71	·80	+ 6·61	·45	+ 3·68	·10	+ 0·91
·20	+ 9·65	·85	+ 6·55	96·50	+ 3·63	·15	+ 0·86
·25	+ 9·59	·90	+ 6·50	·55	+ 3·57	·20	+ 0·81
·30	+ 9·53	·95	+ 6·44	·60	+ 3·52	·25	+ 0·75
·35	+ 9·47	94·00	+ 6·38	·65	+ 3·46	·30	+ 0·70
·40	+ 9·41	·05	+ 6·32	·70	+ 3·41	·35	+ 0·65
·45	+ 9·35	·10	+ 6·27	·75	+ 3·36	·40	+ 0·60
91·50	+ 9·29	·15	+ 6·21	·80	+ 3·31	·45	+ 0·55
·55	+ 9·23	·20	+ 6·16	·85	+ 3·25	99·50	+ 0·50
·60	+ 9·17	·25	+ 6·10	·90	+ 3·20	·55	+ 0·45
·65	+ 9·11	·30	+ 6·04	·95	+ 3·14	·60	+ 0·40
·70	+ 9·05	·35	+ 5·98	97·00	+ 3·09	·65	+ 0·35
·75	+ 8·99	·40	+ 5·93	·05	+ 3·04	·70	+ 0·30
·80	+ 8·93	·45	+ 5·87	·10	+ 2·99	·75	+ 0·25
·85	+ 8·87	94·50	+ 5·82	·15	+ 2·93	·80	+ 0·20
·90	+ 8·81	·55	+ 5·76	·20	+ 2·88	·85	+ 0·15
·95	+ 8·76	·60	+ 5·71	·25	+ 2·82	·90	+ 0·10
92·00	+ 8·70	·65	+ 5·65	·30	+ 2·77	·95	+ 0·05
·05	+ 8·64	·70	+ 5·60	·35	+ 2·72	100·00	Nil.
·10	+ 8·58	·75	+ 5·54	·40	+ 2·67	·05	- 0·05
·15	+ 8·52	·80	+ 5·49	·45	+ 2·61	·10	- 0·10
·20	+ 8·46	·85	+ 5·43	97·50	+ 2·56	·15	- 0·15
·25	+ 8·40	·90	+ 5·37	·55	+ 2·51	·20	- 0·20
·30	+ 8·34	·95	+ 5·31	·60	+ 2·46	·25	- 0·25
·35	+ 8·29	95·00	+ 5·26	·65	+ 2·40	·30	- 0·30
·40	+ 8·23	·05	+ 5·20	·70	+ 2·35	·35	- 0·35
·45	+ 8·17	·10	+ 5·15	·75	+ 2·30	·40	- 0·40
92·50	+ 8·11	·15	+ 5·09	·80	+ 2·25	·45	- 0·45
·55	+ 8·05	·20	+ 5·04	·85	+ 2·20	100·50	- 0·50
·60	+ 7·99	·25	+ 4·98	·90	+ 2·15	·55	- 0·55

CONSUMERS' GAS METERS

Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.	
Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.	Reading of Scale of Gas- holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
100·60	— 0·60	103·25	— 3·15	105·90	— 5·57	108·55	— 7·88
·65	— 0·65	·30	— 3·19	·95	— 5·62	·60	— 7·92
·70	— 0·70	·35	— 3·24	106·00	— 5·66	·65	— 7·96
·75	— 0·75	·40	— 3·29	·05	— 5·71	·70	— 8·00
·80	— 0·79	·45	— 3·34	·10	— 5·75	·75	— 8·05
·85	— 0·84	103·50	— 3·38	·15	— 5·80	·80	— 8·09
·90	— 0·89	·55	— 3·43	·20	— 5·84	·85	— 8·13
·95	— 0·94	·60	— 3·47	·25	— 5·88	·90	— 8·17
101·00	— 0·99	·65	— 3·52	·30	— 5·93	·95	— 8·22
·05	— 1·04	·70	— 3·57	·35	— 5·98	109·00	— 8·26
·10	— 1·09	·75	— 3·61	·40	— 6·02	·05	— 8·30
·15	— 1·14	·80	— 3·66	·45	— 6·06	·10	— 8·34
·20	— 1·19	·85	— 3·71	106·50	— 6·10	·15	— 8·38
·25	— 1·24	·90	— 3·75	·55	— 6·15	·20	— 8·42
·30	— 1·28	·95	— 3·80	·60	— 6·19	·25	— 8·47
·35	— 1·33	104·00	— 3·85	·65	— 6·24	·30	— 8·51
·40	— 1·38	·05	— 3·90	·70	— 6·28	·35	— 8·55
·45	— 1·43	·10	— 3·94	·75	— 6·33	·40	— 8·59
101·50	— 1·48	·15	— 3·99	·80	— 6·37	·45	— 8·64
·55	— 1·53	·20	— 4·03	·85	— 6·41	109·50	— 8·68
·60	— 1·57	·25	— 4·08	·90	— 6·45	·55	— 8·72
·65	— 1·62	·30	— 4·12	·95	— 6·50	·60	— 8·76
·70	— 1·67	·35	— 4·17	107·00	— 6·54	·65	— 8·80
·75	— 1·72	·40	— 4·21	·05	— 6·59	·70	— 8·84
·80	— 1·77	·45	— 4·26	·10	— 6·63	·75	— 8·89
·85	— 1·82	104·50	— 4·31	·15	— 6·68	·80	— 8·93
·90	— 1·87	·55	— 4·36	·20	— 6·72	·85	— 8·97
·95	— 1·91	·60	— 4·40	·25	— 6·76	·90	— 9·01
102·00	— 1·96	·65	— 4·45	·30	— 6·80	·95	— 9·05
·05	— 2·01	·70	— 4·49	·35	— 6·85	110·00	— 9·09
·10	— 2·06	·75	— 4·54	·40	— 6·89	·10	— 9·18
·15	— 2·10	·80	— 4·58	·45	— 6·94	·20	— 9·26
·20	— 2·15	·85	— 4·63	107·50	— 6·98	·30	— 9·34
·25	— 2·20	·90	— 4·67	·55	— 7·02	·40	— 9·42
·30	— 2·25	·95	— 4·72	·60	— 7·06	·50	— 9·51
·35	— 2·30	105·00	— 4·76	·65	— 7·11	·60	— 9·59
·40	— 2·34	·05	— 4·81	·70	— 7·15	·70	— 9·67
·45	— 2·39	·10	— 4·85	·75	— 7·20	·80	— 9·75
102·50	— 2·44	·15	— 4·90	·80	— 7·24	·90	— 9·83
·55	— 2·49	·20	— 4·94	·85	— 7·28	111·00	— 9·91
·60	— 2·53	·25	— 4·99	·90	— 7·32	·10	— 9·99
·65	— 2·58	·30	— 5·03	·95	— 7·37	·20	— 10·07
·70	— 2·63	·35	— 5·08	108·00	— 7·41	·30	— 10·15
·75	— 2·68	·40	— 5·12	·05	— 7·45	·40	— 10·23
·80	— 2·72	·45	— 5·17	·10	— 7·49	·50	— 10·31
·85	— 2·78	105·50	— 5·21	·15	— 7·54	·60	— 10·39
·90	— 2·82	·55	— 5·26	·20	— 7·58	·70	— 10·47
·95	— 2·87	·60	— 5·30	·25	— 7·62	·80	— 10·55
103·00	— 2·91	·65	— 5·35	·30	— 7·66	·90	— 10·63
·05	— 2·96	·70	— 5·39	·35	— 7·71	112·00	— 10·71
·10	— 3·01	·75	— 5·44	·40	— 7·75	·10	— 10·79
·15	— 3·06	·80	— 5·48	·45	— 7·79	·20	— 10·87
·20	— 3·10	·85	— 5·53	108·50	— 7·83	·30	— 10·95

NOTE.—Any other quantity may be calculated by the rule of proportion, thus:—

Meter registering 100'00 feet
 Reading of scale of test gasholder 89'95 „

Difference 10'05 „

89'95 : 100 :: 10'05 : 11'17 fast.

And meter registering 100'00 feet

Reading of scale of test gasholder 112'55 „

Difference 12'55 „

112'55 : 100 :: 12'55 : 11'15 slow.

TABLE

Showing the Dilatation of Gas in Contact with Water and Saturated with Aqueous Vapour, for Given Temperature. (Professor Airey.)

(Used in making Corrections for Temperature in the Testing of Gas Meters.)

Temperature in Fahrenheit's Scale.	Percentage of Dilatation.	Temperature in Fahrenheit's Scale.	Percentage of Dilatation.	Temperature in Fahrenheit's Scale.	Percentage of Dilatation.
31·40	0	54·33	5½	74·30	11
33·54	½	56·24	6	75·94	11½
35·70	1	58·12	6½	77·23	12
37·84	1½	60·02	7	78·81	12½
39·91	2	62·00	7½	80·40	13
42·05	2½	63·77	8	81·94	13½
44·17	3	65·63	8½	83·44	14
46·22	3½	67·43	9	84·88	14½
48·25	4	69·18	9½	86·39	15
50·32	4½	70·90	10	87·83	15½
52·36	5	72·60	10½	89·20	16

NOTE.—The table shows the percentage of increase of the volume of gas above its volume at the temperature of 31·4° Fahr.

INTERNAL FITTINGS.

The advantages of an ample supply of good and pure gas are frequently neutralised by the defective manner in which premises are fitted internally.

Bad gas-fittings are generally the result of cupidity or ignorance. They are a common cause of complaint from consumers who are often ready to attribute the inefficient light which they afford to a want of pressure or purity, or a low illuminating power in the gas.

In the matter of internal fittings, the gas manager, by judgment and tact, can exercise a useful supervision even without the aid of statutory powers; and his advice in regard to the sizes of pipes, and the kind of burners and lamps to be used in different situations, will generally be accepted and acted upon.

The following regulations (with such additions and modifications as may be found necessary) may be adopted with advantage by gas authorities.

Regulations as to Internal Fittings.

1. The Company's (or Local Authority's) servants will in all cases lay on the service pipe, conveying the same through the outer wall of the premises to be supplied with gas.

2. The main-cock must be attached to the end of the service pipe within the building and close to the outer wall.

3. The gas meter must be placed perfectly level, either on the floor or on a substantial support, and within 2 ft. 6 in. of the main-cock.

4. The piping attached to the meter, whether inlet or outlet, must not be smaller in internal diameter than that of the meter unions.

5. The following are the sizes of meters and their measuring capacity, from which the number of lights which they supply can be readily calculated:—

Wet Meters.

Size of Meters.	Size of Inlet and Outlet. Inches.	Measuring Capacity per Revolution. Cub. Ft.	Measuring Capacity per Hour. Cub. Ft.
2-light	$\frac{1}{2}$	$\frac{1}{2}$	12
3 "	$\frac{3}{4}$	$\frac{3}{4}$	18
5 "	1	1	30
10 "	1	2	60
15 "	1	3	90
20 "	1 $\frac{1}{4}$	4	120
30 "	1 $\frac{1}{2}$	6	180
50 "	2	10	300
60 "	2	12	360
80 "	2 $\frac{1}{2}$	16	480
100 "	3	20	600
150 "	3	30	900
200 "	3	40	1200
250 "	4	50	1500
300 "	4	60	1800
400 "	4	80	2400
500 "	5	100	3000
600 "	5	120	3600

Dry Meters.

Size of Meters.	Size of Inlet and Outlet. Inches.	Measuring Capacity per Revolution. Cub. Ft.	Measuring Capacity per Hour. Cub. Ft.
2-light	1	0'083	12
3 "	1	0'125	18
5 "	1	0'200	30
10 "	1	0'333	60
20 "	1	0'500	120
30 "	1	0'833	180
50 "	1	1'428	300
60 "	1	1'666	360
80 "	2	2'500	480
100 "	2	2'857	600
120 "	2	3'333	720
150 "	3	5'000	900
200 "	3	6'666	1200
250 "	4	7'333	1500
300 "	4	8'333	1800
400 "	4	14'250	2400
500 "	5	20'000	3000
600 "	6	22'222	3600
800 "	7	25'000	4800
1000 "	8	33'333	6000

To ascertain the number of lights which any size of meter will supply, divide the measuring capacity per hour by the quantity of gas per hour which each jet is estimated to consume. Example: What number of lights, consuming 4 cub. ft. of gas per hour, will a 20-light meter supply? Then, $\frac{120}{4} = 30$ lights.

6. The following are the sizes and lengths of iron, lead, or composition tubes to be used according to the number of ordinary lights:—

Internal Diameter of Tubing. Inches.	Greatest Length allowed. Feet.	Greatest No. of Burners allowed.
20	20	3
30	30	6
40	40	12
50	50	20
1	70	35
1 $\frac{1}{4}$	100	60
1 $\frac{1}{2}$	150	100
2	200	200
2 $\frac{1}{2}$	300	300
3	450	450

Tubing of $\frac{1}{4}$ -inch bore is not allowed to be used.

7. The tubes or pipes must be laid with proper fall, and in such a manner that they are easily accessible, and protected from liability to damage. Attention is to be given to leaving a space

round them at such places as wall crossings, etc., where fracture or crushing of the pipes might be caused by the subsidence of the building. The joining of the tubes and pipes is to be made in the most solid and substantial manner, and carefully rounded bends (not elbows) are to be used wherever the direction of a pipe is changed.

8. Floor boards covering pipes must be secured with screws, so that they may be easily removed to afford access to the pipes, especially at the points of connection.

9. On the completion of the work of fitting, and before the piping is covered up, notice thereof must be given in writing to the gas manager (the requisite form for that purpose being obtained at the gas office), who will cause an inspection to be made of the work, and if found in accordance with the regulations herein contained, it will be passed by the Company (or Local Authority), and the gas turned on.

10. If the regulations are not conformed to in every respect, the Company (or Local Authority) reserve the right to refuse a supply of gas until the necessary alterations are made.

11. Gas-fitters complying with these regulations have their names registered on the Company's (or Local Authority's) list of approved fitters, and they are at liberty to designate themselves "Authorized Gas-Fitters." Repeated negligence will cause the licence to be withdrawn.

A handy and useful apparatus for testing the soundness of gas-fittings, has been devised by Harrison & Sheard. It consists of a small force pump and a King's pressure gauge, in which mercury is employed instead of water; the two being connected together on one base board, and provided with a coupling for ready attachment to the fittings to be tested.

To use the apparatus, air is forced, by means of the pump, into the fittings, until the pressure therein is equivalent to, say, 12 in. of water, as indicated on the dial of the gauge. The pump is then shut off by means of a stopcock, and it is noted whether the pressure is maintained or falls away. If the pointer remains stationary, the fittings are sound; while if it goes back there is leakage.

To facilitate the discovery of leakages, gas may be forced into

the fittings by connecting an inlet pipe on the pump, by means of india-rubber tubing, with any convenient gas supply, when the gas escaping through the defective fittings at a high pressure enables the locality of the leakages to be readily discovered.

Another device for the same purpose is the "Reliable" leak testing machine of James Milne & Son.

Ordinary dining and sitting-rooms are best lighted by means of a central pendant. When the room is of large dimensions, wall brackets may be added. A bracket at each side of the mantelpiece has a tasteful appearance, and lights are handy in that position.

The burners of the pendants should be not less than 36 in. from the ceiling.

In the case of the old water-slide pendants, many of which are still in use, a teaspoonful of salad oil added on the top of the water in the tube tends, in a great measure, to prevent or retard evaporation of the water.

The system of incandescent gas-lighting is a notable advance in artificial illumination, and is now in all but general use.

The designs of the burners, upright and inverted, and the variety of fittings, plain and ornamental, are innumerable. All the specialists in street lighting cater for private lighting.

The Welsbach lamp consists of a Bunsen burner, on which is suspended a mantle composed of a textile filament coated with thorium and cerium oxides. On lighting the burner, the textile portion is consumed, leaving the refractory portion in position, and this becomes incandescent, giving out a strong steady light. The fragility of the mantle was a hindrance to its early adoption, but this has proved to be less of a drawback than was at first anticipated, as is shown by the fact of the universal application of the system. The saving of gas that is effected by its use, the increase in illuminating effect, and the comparative coolness of the light, with the subsequent improvements in construction, have earned for it a deserved reputation.

Various improvements have been made in the mantle as originally devised by Welsbach.

Ramie fibre is being largely used in substitution of cotton fibre, the former being less friable.

The Welsbach-Plaissetty is a cotton fibre mantle, but before being impregnated with the thorium and cerium oxides, is heated by a special process, which prevents shrinkage.

Copper-cellulose has also been introduced as a base for the mantle, with a view to increasing its durability.

After the burning-off process all mantles are dipped in a collodion or silica solution to facilitate handling and export.

A novelty in domestic lighting is the "Telephos" apparatus for lighting and extinguishing. It consists of a dry cell, controller, spitfire igniter, a length of twin wire, and a push.

The controller is fitted in the supply pipe above the lamp, and from this the gas and electric current pass to form the by-pass. On pressing the push, which may be arranged at a convenient place on the wall, the gas supply is turned on and the by-pass is ignited by the electric spitfire. On relieving the push the by-pass is extinguished. Another pressing of the button turns the light out.

This arrangement is also fitted to lamps with a number of burners, and is specially designed for use in shop windows and other places where a permanent by-pass may be objectionable.

Ventilating Lights.—The question of the efficient ventilation of rooms where gas is being consumed is of importance both to the gas producer and the user.

Ventilating globe and other lights of various designs have been introduced by Sugg, Cowan, Bray, Strode, Wenham (whose lamp is also regenerative), and other makers, with highly satisfactory results. Fig. 182 shows one of Cowan's ventilating lights, and Fig. 183 the ventilating sunlight as made by Strode; either flat-flame or incandescent burners may be adopted.

An interesting and novel arrangement is the "Nonpareil" Ventilating Gas Sun burner of James Milne & Son (Figs. 184 and 184A).

The burner is fitted with by-pass ignition and special lowering and raising facilities; and is exceptionally well suited for places of public assembly.

The burner may be constructed with 9, 16, or 28 inverted lights with an illuminating power ranging from 675 to 2100 candles.

The shaft above the burner is connected with a duct leading to the outside of the building, and is suitable for any type of roof.

Flat flame burners are still in considerable use in bedrooms, cellars and as flare-lights.

The burners of this class made by Sugg and Bray are so well known as to need no recommendation.

Shades, moons, or globes, as they are variously named, have

kept pace with the improvements in burners; being constructed not only of better and purer materials than formerly, but according to scientific principles.

At one time they were invariably made with the bottom openings about 2 in. in diameter; the effect being to direct the current

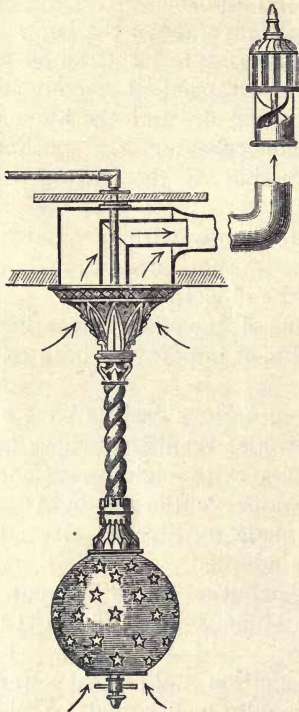


FIG. 182.

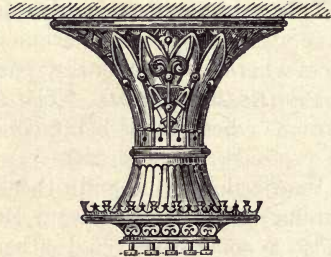


FIG. 183.

of air upon the flame, lowering the temperature, impairing the illuminating effect, and causing an unpleasant flickering.

These have given place to globes with openings at least 4 in. in diameter, whereby the foregoing defects are entirely obviated, whilst the concave sides also act as reflectors of the light in the downward direction, especially below 45° from the horizontal. As Professor Lewes points out: "In order to gain any true idea of illuminating

effect, it is necessary to take the light emitted over all the working angles, and not on the horizontal plane.”

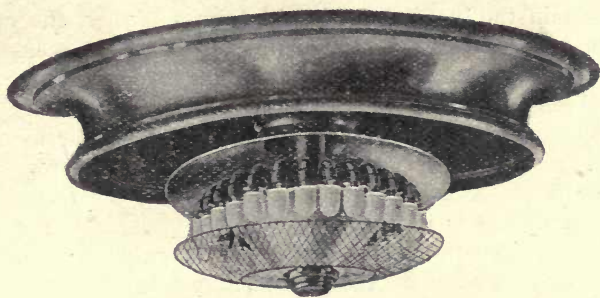


FIG. 184.

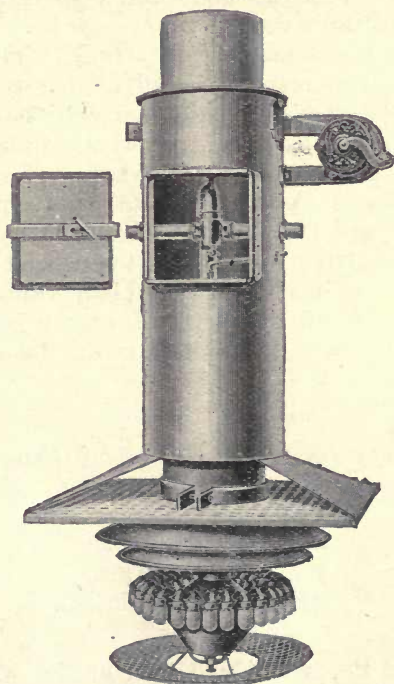


FIG. 184A.

Globes made of good and suitable materials, and untinted,

diffuse the light without seriously obstructing it, even when the test is applied on the horizontal plane. This is particularly noticeable with the "holophane" globe and with the pure white opal globes.

To obtain the maximum of light from a burner, the pressure, when that is in excess in the mains, as it must necessarily be, should be controlled and regulated in the passage of the gas to the point of ignition.

This cannot be accomplished satisfactorily by checking either the taps on the fittings or the stopcock at the meter, because there is a continual variation of pressure according to the consumption that is in progress.

The house governor or regulator was invented to achieve that end. It may be fixed on the pipe leading from the meter outlet, or, what is better, on the principal pipe supplying each floor-level of the premises. Peebles's and Stott's governors are of this class and are extensively used.

The regulator is automatic in its action; and when weighted to afford the required pressure for all the burners in use, it will continue to give a practically uniform supply, however much the pressure in the mains may vary, or whether the whole or only a portion of the burners being supplied through it may be alight at one time. Sugg's regulator gas-burner, Peebles's "Needle" governor burner, and the "Acme" regulating burner of Wright, are examples of regulation applied close to the point of consumption.

Dr. Letheby found that a vulcanized india-rubber tube of about 30 ft. in length reduced the power of a weak gas to the extent of nearly 25 per cent., by absorbing the illuminating hydrocarbons.

Varnish to Prevent the Escape of Gas through India-Rubber Tubing.

1½	parts	treacle.
2	"	gum arabic.
7	"	white wine.
3½	"	strong alcohol.

First dissolve the treacle and gum in the white wine, and afterwards add the alcohol very slowly, constantly stirring the mixture to prevent the gum from being thrown down.

LEAD AND COMPOSITION PIPES FOR GAS.

Weights per Yard, and Lengths usually Manufactured.

LIGHT.			HEAVY.		
Diameter Inside.	Weight per Yard.	Lengths of Bundles usually Manufactured.	Diameter Inside.	Weight per Yard.	Lengths of Bundles usually Manufactured.
1 in.	0 11½	80 yards.	1 in.	0 15	67 yards.
1 ¼	1 2	60 "	1 ¼	1 6½	46 "
1 ½	2 0	32 "	1 ½	2 10	16 "
1 ¾	2 4	25 "	1 ¾	3 0	20 "
2	3 3	23 "	2	3 12	19 "
2 ¼	4 8	26 "	2 ¼	6 0	20 "
2 ½	8 0	16 "	2 ½	10 0	12 "
2 ¾	12 0	10 "	2 ¾	14 0	9 "
3	18 0	5 "	3	21 0	5 "

BRASS TUBE PLAIN—WEIGHT PER FOOT.

Diameter. In.	Weight. Lbs. Oz.	Diameter. In.	Weight. Lbs. Oz.
1 ¼	0'08 or 1'28	1 ¼	0'50 or 8'00
1 ½	0'15 2'40	1 ½	0'59 9'44
1 ¾	0'19 3'04	1 ¾	0'81 12'96
2	0'21 3'36	2	1'00 16'00
2 ¼	0'25 4'00	2 ¼	1'12 17'92
2 ½	0'31 4'96	2 ½	1'25 20'00
2 ¾	0'37 5'92	2 ¾	1'50 24'00
3	0'43 6'88	3	1'87 29'92

The size of brass and copper tubes is measured by the outside diameter.

BRASS TUBE, SPIRAL AND FLUTED—WEIGHT PER FOOT.

Diameter. In.	Spiral Weight. Oz.	Fluted Weight. Oz.	Diameter. In.	Spiral Weight. Oz.	Fluted Weight. Oz.
3 8	3	2 ¾	3 8	6	6
1 7 8	3 ½	3 ¼	1 7 8	7 ½	7
1 6 8	3 ¾	3 ½	1	9	8
1 5 8	4	4 ½	1 ¼	12	11
1 4 8	4 ½	4	1 ½	15	14

SOLDERS.

Fine Solder is an alloy of 2 parts of block tin and 1 of lead (melts at 360° Fahr.). This is used for fine work—such as soldering the drums of meters, for pewter, etc.

Glazing Solder.—Equal parts of block tin and lead. Used for lead.

Plumbing Solder.—1 part block tin, 2 lead. For all kinds of plumbers' joints and for tin and zinc.

Solder for Copper.—Hard : 3 parts brass, 1 zinc. Soft : 8 parts brass, 1 zinc.

Brazing Solder or Spelter.—Hard : 1 part copper, 1 zinc. Soft : 4 parts copper, 3 zinc, 1 block tin. For fine brass work : 1 part silver, 8 copper, 8 zinc.

Solder for Steel.—19 parts silver, 3 copper, 1 zinc.

Pewterers' Soft Solder.—2 parts bismuth, 4 lead, 3 tin. Common : 1 part bismuth, 1 lead, 2 tin.

FLUXES FOR SOLDERING.

Iron and steel	Borax or sal ammoniac.
Tinned-iron	Resin or zinc chloride.
Copper and brass	Sal ammoniac or zinc chloride.
Lead and composition pipes	Resin and sweet oil.
Zinc	Zinc chloride.

FOR TINNING BRASS OR IRON.

$\frac{1}{2}$ oz. muriatic acid.

$\frac{1}{4}$ oz. mercury.

$\frac{1}{2}$ oz. ground block tin.

Mix together, and dilute the whole with a small quantity of cold water. Apply with the finger or a cork.

BRAZING.

The edges of the articles, either iron or brass, to be brazed are scraped thoroughly clean, covered with the brazing solder or spelter in the form of borings or turnings sprinkled over with powdered borax, and exposed to the heat of a clear fire till the solder flows. A smokeless coke or gas fire is best for the purpose. In brazing iron, a covering of loam is sometimes placed over the solder, to exclude the air, till it melts.

BRONZE.

- 1 quart common vinegar.
- 2 oz. sal ammoniac.
- 1 oz. blue stone (copper sulphate).

The sal ammoniac and blue stone are well pounded, and then allowed to dissolve in the vinegar. The solution, when ready, is laid on with a common brush, black-leaded whilst damp, and then polished. Lacquer is then applied as described hereafter.

Green Bronze.

To imitate the antique.

- 1 quart of common vinegar.
- 2 oz. verdigris.
- 1 oz. sal ammoniac.

Boil for a quarter of an hour, filter through paper, and dilute with water. Immerse the article to be bronzed until it acquires the green tinge desired; then wash carefully, and dry in sawdust.

Bronze Powders.

These can be purchased from any dealer in artists' material. They are prepared as follows:—

Copper Bronze Powder.

Strips of copper are dissolved in nitric acid in a glass vessel, and then strips of iron are added, when the dissolved copper is precipitated in the form of a very fine powder. This powder is washed with water and dried, and is then ready for use.

Gold Bronze Powder, or Aurum Mosaicum,

Is the basis of many bronze powders. Any desired colour can be produced by mixing it with the common dry pigments. Thus a red bronze powder is obtained by grinding red lead with it; and a green by the use of verdigris. It is prepared in the following manner:—

One pound of tin is melted in a crucible, and then poured cautiously into an iron dish containing half a pound of mercury. When cold it is reduced to powder, mixed with seven ounces of flowers of sulphur, and eight ounces of

sal ammoniac, and triturated in a mortar. The mixture is then calcined in a flask, which expels the sulphur, mercury, and ammonia, and leaves a residuum in the form and colour of a bright flaky gold powder.

Size for Bronze Powders.

The size is made by boiling four ounces of gum animi to every pound of pure linseed oil in a flask, until the mixture is of the consistency of cream, after which it is diluted with turpentine as required.

The article to be bronzed is coated, by means of a soft brush, with this size; and when nearly dry, a piece of soft leather is wrapped round the finger, dipped into the powder, and rubbed gently over it. Or it may be laid on with a camel's-hair pencil, and then left to dry thoroughly, after which all the loose powder is brushed off.

The bronze may also be mixed with a strong solution of isinglass, and applied in the moist state, like varnish, with a brush. This latter mode, however, is not suitable for articles exposed to the weather.

For Silvering Metals.

Silver nitrate,	10 parts.
Common salt,	10 "
Cream of tartar,	30 "

Moisten with water when ready to apply, and lay the mixture on with a soft brush.

LACQUER AND VARNISH.

The solution of spirits of wine and shellac, known as "simple pale" lacquer, is the basis of most other lacquers. The two ingredients in their proper proportions, as stated overleaf, are put into a jar or bottle, and allowed to remain for forty-eight hours, being briskly shaken three or four times during the interval. At the expiration of the time named, most of the shellac will be dissolved. The mixture is then carefully strained through filtering paper, to free it from grit and other foreign substances, and to remove any particles of undissolved shellac that may remain.

Different tints or shades, producing red, green, yellow, etc., are obtained by mixing with the pale lacquer various colouring ingredients, such as dragon's blood, arnotto, gamboge, turmeric, saffron, etc. The proper way of adding these is to stir them in a cup with a small quantity of the pale lacquer, afterwards straining the whole through a piece of thin cloth or gauze, and filtering if necessary.

The article to be lacquered is heated slightly by means of a steam kettle or stove; or it may be held over a hot iron plate till just as hot as to allow of its being touched by the finger without burning. The heat must not be greater than this. The lacquer is then applied with a soft camel's-hair brush.

Simple Pale Lacquer.

1 pint of spirits of wine.
4 oz. of shellac.

Fine Pale Lacquer.

1 pint of spirits of wine.
1 oz. of pure white shellac.
1 dr. of gamboge.
2 drs. of Cape alces.

*Fine Pale Lacquer, for Silvered
or Tinned Work.*

1 pint of spirits of wine.
1 oz. of pure white shellac.

Gold Lacquer.

1 pint of spirits of wine.
3 oz. of shellac.
 $\frac{1}{2}$ oz. of turmeric.
2 drs. of arnotto.
2 drs. of saffron.

Deep Gold Lacquer.

1 pint of spirits of wine.
3 oz. of shellac.
 $\frac{1}{2}$ oz. of turmeric.
4 drs. of dragon's blood.

Red Lacquer.

1 pint of spirits of wine.
4 oz. of shellac.
4 drs. of dragon's blood.
1 dr. of gamboge.

Yellow Lacquer.

1 pint of spirits of wine.
2 oz. of shellac.
2 drs. of gamboge.
4 drs. of Cape aloes.

Green Lacquer for Bronze.

1 pint of spirits of wine.
4 oz. of shellac.
4 drs. of turmeric.
 $\frac{1}{2}$ dr. of gamboge.

Iron Lacquer.

1 quart of turpentine.
 $\frac{3}{4}$ lb. of pitch.
2 oz. of shellac.

To Clean Old Brass Work for Lacquering.

Boil a strong lye of wood ashes, and strengthen with soap lees; put in the brass work, and the old lacquer will come off. Next dip it in a solution of nitric acid and water strong enough to remove the dirt; wash it immediately in clean water; dry well, and lacquer.

Varnish for Iron Work.

Boil a quantity of gas tar for four or five hours, till it runs as thin as water; add one quart of turpentine to a gallon of the tar, and boil another half-hour. Apply the varnish whilst hot.

Golden Varnish.

Pulverize 1 drachm of saffron and $\frac{1}{2}$ a drachm of dragon's blood, and put them into one pint of spirits of wine. Add 2 ounces of gum shellac and 2 drachms of Soccotrine aloes. Dissolve the whole by gentle heat. Yellow painted work, varnished with this mixture, will appear almost equal to gold.

Glue Cement to Resist Moisture.

1 part glue.
1 part black resin.
 $\frac{1}{4}$ part red ochre.

Mix with a very small quantity of water.

COAL GAS TESTING APPLIANCES AND METHODS.

A gas may have a high illuminating power, and yet contain impurities that ought to be removed. Purity is not always in the ratio of illuminating power.

TESTS FOR IMPURITIES.

The tests for the detection of impurities in coal gas, after it has undergone the different processes of purification, are the following:—

Test for Ammonia.—Expose yellow turmeric paper slightly moistened with water, or litmus paper first reddened by any weak

acid, to a jet of unlighted gas for about a minute. If the yellow colour of the turmeric be turned to brown, or if the blue of the litmus be restored, ammonia is present.

Turmeric and litmus papers may be purchased at the chemist's, or they can be prepared as follows:—

Turmeric Paper.—Six parts by weight of spirits of wine are added to one of turmeric powder in a stoppered bottle, and well shaken up occasionally for three days. A portion of the clear fluid is then poured on a plate, and pieces of unsized white filtering paper well soaked therein. These are then dried in air, cut into strips $\frac{1}{2}$ in. wide and 2 in. long, and kept for use in a bottle away from the light.

Litmus Paper.—Six parts by weight of water to one of powdered litmus, shaken well together, allowed to stand for several days, and then filtered. Pieces of white filtering paper are then thoroughly soaked in the solution, dried, and cut into strips, which should be kept in a close stoppered bottle, excluded as much as possible from the air and light. Should it be desired to redden the solution, add (after filtration) a small quantity of very dilute sulphuric acid, gradually, drop by drop, until the pink or neutral tinge is obtained.

Test for Carbon Dioxide.—Make a solution of pure barytes, and pass the gas through it. If carbon dioxide is present, barium carbonate will be precipitated; or pass the gas through clear lime water, and calcium carbonate will be precipitated.

It may also be detected by adding to water impregnated with the gas a few drops of sulphuric acid, when minute bubbles of carbon dioxide will be rapidly disengaged.

Lime Water is prepared by agitating slaked lime with distilled water in a bottle or other vessel. It is then allowed to stand until the excess of lime has been deposited, when the clear liquid is poured off, and filtered through filtering paper.

Test for Sulphuretted Hydrogen.—Moisten a piece of writing-paper with a solution of lead acetate in distilled water, and expose it for not less than a minute to a jet of unlighted gas. If sulphuretted hydrogen be present, the paper will be browned or blackened.

A solution of silver nitrate is a more delicate test than the above. This requires to be kept in a bottle coated outside with

tinfoil, and placed in a drawer or other dark place to protect it from the influence of the light.

Lead paper may be made of white filtering paper soaked in the lead acetate solution, then dried, cut into slips, and kept in a well-corked bottle for use. But the solution applied to the paper at the time of making the test is preferable.

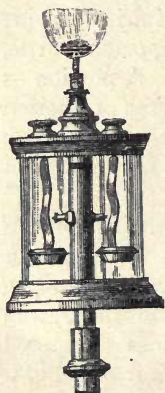


FIG. 185.

The Gas-Works Clauses Act, 1871, Schedule A, contains the following regulations in respect of the apparatus and mode of testing for this impurity :—

Apparatus.—“ A glass vessel (Fig. 185) containing a strip of bibulous paper moistened with a solution of lead acetate, containing 60 grs. of crystallized lead acetate dissolved in one fluid ounce of water.

Mode of Testing.—“ The gas shall be passed through the glass vessel containing the strip of bibulous paper moistened with the solution of the lead acetate for a period of three minutes, or such longer period as may be prescribed ; and if any discoloration of the test paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas.”

Test for Sulphur.—The sulphur present in gas, due to compounds other than sulphuretted hydrogen, notably carbon bisulphide, is estimated by burning a jet of the gas at the rate of 1 cub. ft., or $\frac{1}{2}$ cub. ft. per hour, for twenty-four hours, from a Leslie or other burner arranged within the wide end of a trumpet tube whose upper and smaller end is inserted in a condenser, from the opposite end of which a tube carries off the uncondensed vapour, and creates a current through the apparatus. (See Fig. 186.) Through the lower and wide end, where the burner is fixed, a supply of air, to support combustion, enters, carrying with it the vapour of ammonia from liquid ammonia or pieces of the carbonate contained in a suitable receptacle surrounding the burner. The ammonia combining with the sulphurous acid from the gas flame is deposited within the condenser as sulphite and sulphate of ammonia, from which the quantity of sulphur per 100 cub. ft. of gas is calculated.

Mr. J. T. Sheard's method of estimating carbon dioxide in coal

gas consists in passing a definite volume of gas through a solution of barium hydrate of known strength, which absorbs the carbon dioxide out of the gas; the amount of free hydrate remaining after the operation being determined by titration with deci-normal hydrochloric acid. Either the volume or the weight of impurity that has been absorbed can thence be calculated.

The gas absorption tube is of the form shown in Fig. 187; the straight part above the bulbs being filled with glass beads.

To make a test, two absorption tubes are charged with 20 or 30 c.c. each, of a barium hydrate solution, the strength of which has been accurately determined by titration with deci-normal acid, and which should be approximately of equal strength with the acid. The apparatus being connected up as shown (Fig. 187A), 500 c.c. of gas are drawn by means of the aspirator slowly through the liquid, and followed immediately, without stopping the current, by an equal quantity of air, which is done by slipping off the india-rubber tube at the inlet of the apparatus, as the water running from the aspirator passes the mark of a 500 c.c. flask, and then running out a further quantity of 500 c.c. into another flask held in readiness. The bulbs are then washed down with water free from carbon dioxide, a few drops of phenol-phthalein (sufficient to impart a distinct purple red colour to the liquid) added, and the whole titrated with deci-normal hydrochloric acid—the acid being added a few drops at a time, with frequent agitation of the liquid until the colour is destroyed. The amount of barium hydrate that has been neutralized is equivalent to the amount of carbon dioxide absorbed from 500 c.c. of gas; from which the percentage of the impurity present, or its weight per cubic foot of gas, can be determined.

EXAMPLE.—Two gas absorption tubes charged, respectively, with 30 c.c. and 20 c.c. of barium hydrate solution. One cubic centimetre of the barium hydrate having previously been found by experiment as equivalent to $1.09 \frac{N}{10}$ acid.

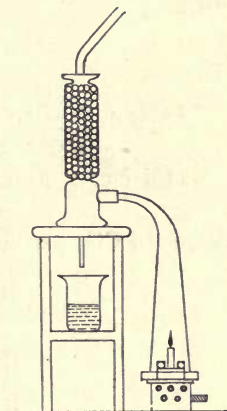


FIG. 186.

	1st Tube.	2nd Tube.
Equivalent of barium hydrate employed . . .	32.7 c.c.	21.8 c.c.
$\frac{N}{10}$ acid required to neutralize resultant liquid	21.6 c.c.	21.4 c.c.
	11.1 c.c.	0.4 c.c.

Then—

$$\frac{11.5 \text{ c.c.} \times 0.0022 \text{ gm.} \times 100}{0.914 \text{ gm.}} = 2.77 \text{ per cent. by volume of CO}_2$$

$$\frac{11.5 \text{ c.c.} \times 0.0022 \text{ gm.} \times 15.432 \text{ grs.} \times 28,315 \text{ c.c.}}{500 \text{ c.c.}} = 22.1$$

grains of CO₂ per cubic foot of gas.¹

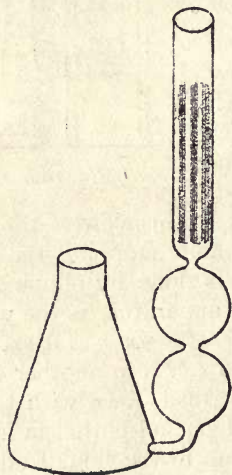


FIG. 187.

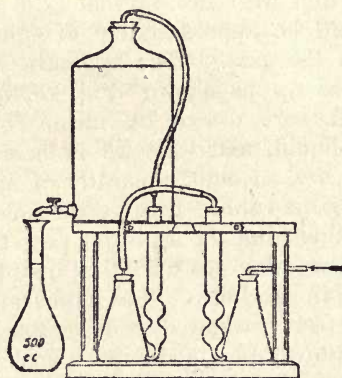


FIG. 187A.

These calculations may be shortened by employing the factor 0.241 for percentage by volume, and 1.92 for grains per cubic foot. Thus—

$$11.5 \times 0.241 = 2.77 \text{ per cent. by volume of CO}_2$$

$$11.5 \times 1.92 = 22.1 \text{ grs. of CO}_2 \text{ per cubic foot of gas.}$$

¹ It may be explained that—

0.0022 gm. is the weight of CO₂ to which 1 c.c. of $\frac{N}{10}$ acid is equivalent.

0.914 gm. is the weight of 500 c.c. of CO₂ saturated with moisture.

15.432 grs. is the value of 1 gm.

28,315 c.c. is the value of 1 cubic foot.

A complete test can be made in fifteen minutes, and perfectly accurate results obtained.

The apparatus is equally applicable to the estimation of ammonia and sulphuretted hydrogen in the gas, the former being absorbed by sulphuric acid of deci-normal strength, and the latter by a 10 per cent. solution of copper sulphate. When sulphuretted hydrogen is passed into an aqueous solution of cupric sulphate, a precipitate of cupric sulphide is deposited, and free sulphuric acid is formed in the solution, previously neutral. After filtering out the precipitate, the acidity of the solution can be determined by titration with deci-normal ammonia, using methyl orange as indicator. Each cubic centimetre of $\frac{N}{10}$ ammonia required to neutralize the solution represents 1.48 grs. of sulphuretted hydrogen per cubic foot of gas. Likewise each cubic centimetre of $\frac{N}{10}$ acid neutralized by the ammonia in the gas represents 1.48 grs. of ammonia per cubic foot of gas.

The manipulation of the apparatus is the same as above described for carbon dioxide, and all three impurities may be determined in the same sample of gas. For this purpose one absorption tube is charged with acid for absorbing ammonia, followed by one containing cupric sulphate for sulphuretted hydrogen, and this by the tubes containing barium hydrate for carbon dioxide. Then 500 c.c. of gas are drawn through the whole series, followed by 1000 c.c. of air to clear the apparatus. The subsequent treatment will be understood from what has gone before.

Harcourt's Colour Tests.—This is one of the most useful apparatus in the gas manager's laboratory for determining with ease and celerity the amount of carbon bisulphide, sulphuretted hydrogen, and carbon dioxide in coal gas. The following is a description of the test, and directions for its use:—

Testing for Carbon Bisulphide.—The arrangement of the colour test is shown in Fig. 188; the fire-clay cylinder being represented by dotted lines. The bulb, which is filled with platinized pumice, is to be so adjusted that it may be about an inch above the burner, and in the middle of the cylinder.

To use the apparatus, turn on first the upper stopcock, sending gas through the bulb at the rate of about half a cubic foot an hour, as may be judged by lighting the gas for a moment at the

end of the horizontal arm, when a flame about an inch in length should be produced. Raise the cylinder, which will be supported by the pressure of the wires, light the burner, and turn down the flame till it forms a blue non-luminous ring. Lower the cylinder, and place the small clay pieces upon it round the neck of the bulb.

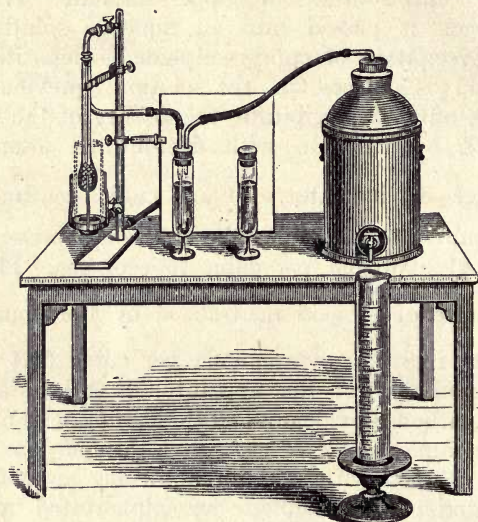


FIG. 188.

A testing may be made five minutes after the burner is lighted, except when the apparatus is first used, when the gas should be allowed to flow through the bulb for a quarter of an hour, or a little longer, and any number of testings, one after another, as long as the heat is continued.

The mode of testing is as follows: Lay a piece of white paper on the table by the side of the burner, and fix a piece of cardboard upright in the brass clip; the cardboard serves as a background against which to observe the colour of the contents of the glasses, and should receive a side light, and be as clear as possible from shadows. Fill one glass (once for all) up to the mark with standard coloured liquid, and cork it tightly. Dilute some of the lead syrup with twenty times its volume of distilled water, and fill the other glass up to the mark with a portion of the liquid thus

prepared. Insert the caoutchouc plug with capillary tube and elbow tube, and connect, as shown in the figure, with the bulb and aspirator, placing the two glasses side by side.

The aspirator should be full of water at starting, and the measuring cylinder empty. Turn the tap of the aspirator gradually ; a stream of bubbles will arise through the solution of lead. Turn off the tap for a minute, and observe the liquid at the bottom of the capillary tube. If it gradually rises, the india-rubber connections are not air-tight, and must be made so before proceeding. Avoid pressing the plugs into the glass or the aspirator while they are connected, which would drive up the lead solution into the inlet tube. When the connections are air-tight, let the water run into the measuring cylinder in a slender stream until the lead solution has become as dark as the standard. As the ascending bubbles interfere somewhat with the observation of the tint, it is best to turn off the tap when the colour seems almost deep enough ; compare the two ; turn on the tap, if necessary, for a few moments, then compare again ; and so on, till the colour of the two liquids is the same.

The volume of water which the measuring cylinder now contains is equal to the volume of gas which has passed through the lead solution.

This volume of gas contained a quantity of sulphur as carbon bisulphide which, as lead sulphide, has coloured the liquid in the test glass up to the standard tint. The standard has been made such that, to impart this tint to the volume of liquid, 0.0187 gr. of lead sulphide must be present, containing 0.0025 gr. of sulphur. Hence, supposing the measuring cylinder, each division of which corresponds to $\frac{1}{2000}$ cub. ft., to have been filled to the 30th division, $\frac{30}{2000}$ cub. ft. of gas contained 0.0025 gr. of sulphur. From this ratio the number of grains of sulphur existing as bisulphide in 100 cub. ft. of the sample of gas tested can easily be calculated.

The following table gives the relation between (V) the divisions of the measuring cylinder filled with water and (S) the grains of sulphur existing as bisulphide in 100 cub. ft. of gas. Since gas contains, besides carbon bisulphide, some other sulphur compounds which are not transformed into sulphuretted hydrogen by the action of heat, and which contain sulphur amounting ordinarily to 7 or 8 grs. in 100 cub. ft., this quantity must be added

to that found by the test, if it is wished to know approximately the total amount of sulphur.

TABLE I.

$$S = \frac{500}{V}$$

V	S	V	S	V	S	V	S
10	50'0	33	15'1	56	8'9	79	6'3
11	45'4	34	14'7	57	8'8	80	6'2
12	41'7	35	14'3	58	8'6	81	6'2
13	38'5	36	13'9	59	8'5	82	6'1
14	35'7	37	13'5	60	8'3	83	6'0
15	33'3	38	13'2	61	8'2	84	6'0
16	31'3	39	12'8	62	8'1	85	5'9
17	29'4	40	12'5	63	7'9	86	5'8
18	27'8	41	12'2	64	7'8	87	5'7
19	26'3	42	11'9	65	7'7	88	5'7
20	25'0	43	11'6	66	7'6	89	5'6
21	23'8	44	11'4	67	7'5	90	5'6
22	22'7	45	11'1	68	7'4	91	5'5
23	21'7	46	10'9	69	7'2	92	5'4
24	20'8	47	10'6	70	7'1	93	5'4
25	20'0	48	10'4	71	7'0	94	5'3
26	19'2	49	10'2	72	6'9	95	5'3
27	18'5	50	10'0	73	6'9	96	5'2
28	17'9	51	9'8	74	6'8	97	5'2
29	17'2	52	9'6	75	6'7	98	5'1
30	16'7	53	9'4	76	6'6	99	5'1
31	16'1	54	9'2	77	6'5	100	5'0
32	15'6	55	9'1	78	6'4	150	3'3

For the next testing the test glass is to be disconnected and recharged. The water in the measuring cylinders is poured back into the aspirator.

The colour of the standard is unaffected by exposure to light, but deepens if the liquid is warmed, returning to its original shade as the liquid cools. If, therefore, the glass containing the standard has been in a warm place, it must be let cool before testing.

The liquid which has been used becomes colourless after being exposed to the light for a few hours, and may thus be used over and over again for twenty times or more, if it is not allowed to absorb carbon dioxide from the air. The best mode of working is to have two well-corked flasks, into one of which the coloured liquid is emptied while the glass is recharged from the other.

Testing for Sulphuretted Hydrogen and Carbon Dioxide.
—The apparatus may also be used without the bulb tube and stand to test the amount of sulphuretted hydrogen or carbon dioxide in gas at any stage in its purification.

The gas is led in this case directly into the test glass, which is charged with lead solution for sulphuretted hydrogen, and with a saturated solution of barium hydrate (baryta water) for carbon dioxide.

When the gas contains more than 50 grs. of sulphur as sulphuretted hydrogen in 100 cub. ft. a smaller cylinder, containing $\frac{1}{200}$ cub. ft., is used to measure the volume of liquid run from the aspirator. The divisions on the smaller cylinder are tenths of the corresponding divisions on the larger cylinder; therefore when it is used the numbers under S in Table I. must be read as whole numbers by omitting the decimal points.

TABLE II.

V	C	V	C	V	C	V	C
10	0'72	33	0'22	56	0'13	79	0'09
11	0'65	34	0'21	57	0'13	80	0'09
12	0'60	35	0'21	58	0'12	81	0'09
13	0'55	36	0'20	59	0'12	82	0'09
14	0'51	37	0'20	60	0'12	83	0'09
15	0'48	38	0'19	61	0'12	84	0'09
16	0'45	39	0'18	62	0'11	85	0'08
17	0'42	40	0'18	63	0'11	86	0'08
18	0'40	41	0'17	64	0'11	87	0'08
19	0'38	42	0'17	65	0'11	88	0'08
20	0'36	43	0'17	66	0'11	89	0'08
21	0'34	44	0'16	67	0'11	90	0'08
22	0'33	45	0'16	68	0'11	91	0'08
23	0'31	46	0'16	69	0'10	92	0'08
24	0'30	47	0'15	70	0'10	93	0'08
25	0'29	48	0'15	71	0'10	94	0'08
26	0'28	49	0'15	72	0'10	95	0'08
27	0'27	50	0'14	73	0'10	96	0'07
28	0'26	51	0'14	74	0'10	97	0'07
29	0'25	52	0'14	75	0'10	98	0'07
30	0'24	53	0'14	76	0'09	99	0'07
31	0'23	54	0'13	77	0'09	100	0'07
32	0'22	55	0'13	78	0'09	150	0'05

To estimate carbon dioxide a standard liquid containing a definite amount of suspended barium carbonate is used for comparison. The glasses are placed side by side on a blackened board or piece of paper and with a black background behind them. The passage of the gas should be interrupted, and the test glass slightly shaken once or twice to wash down any particles of carbonate which may cling to the sides of the glass above the surface of the liquid. The standard should also be shaken before the comparison is made, in order that the precipitates may be in a similar condition. When the two liquids are judged to be equally white and opaque, the volume of water in the measuring cylinder gives the volume

of gas which has precipitated a known weight of barium carbonate. Table II gives the relation between (V) the divisions of the large measuring cylinder filled with water, and (C) the volume of carbon dioxide in 100 volumes of gas. When the gas contains more than 0.72 per cent. of carbon dioxide, the smaller measuring cylinder should be used, and the values of C multiplied by moving the decimal point one place to the right.

After each testing the glass and capillary tube should be cleared with a little dilute hydrochloric acid and well rinsed with distilled water. The turbid liquid is poured into a flask, which should be kept well corked, containing an excess of crystallized barium hydrate. After the suspended precipitate has subsided, the clear liquid is poured off, or, if necessary, filtered, into another flask, also kept well corked, from which it may be poured into the test glass when required. Care should be taken not to expose the solution to the air longer than necessary.

Notification of the London Gas Referees.—These instructions as to the times and mode of testing for illuminating power and purity are applicable, primarily to the Metropolis; but secondarily, they will be found useful by every gas manager; the description of the *modus operandi* of testings, as well as of the appliances, being full and precise. They are here summarized as follows:—

SERVICE PIPES TO THE TESTING PLACES.

If obstruction of the service pipe is found, or if there is reason to think that the quality of the gas is suffering from any change occurring within the service pipe, the service pipe may be washed out in the presence of and by arrangement with the gas examiner, either with hot water alone or with any usual solvent such as benzol, naphtha, or petroleum, but the use of such solvents is to be followed by a washing with hot water. In every case where the service pipe is washed out, the gas company shall send a letter to the gas referees explaining why the washing was considered necessary. The gas companies may, if they think fit, provide a tap and funnel in any testing place for the purpose of such washing out.

No testing for illuminating power or calorific power is to be made until after the lapse of an hour since the last washing out.

STANDARD LAMP TO BE USED FOR TESTING ILLUMINATING POWER.

The standard to be used in testing the illuminating power of gas shall be a Pentane 10-candle Lamp which has been examined and certified by the gas referees. The residue of pentane in the saturator shall, at least once in each calendar month, be removed, and shall not be used again in any testings.

The pentane to be used in this lamp shall be prepared as described, and shall show when tested the properties specified.

Harcourt's 10-Candle Pentane Lamp (Fig. 189) is one in which air is saturated with pentane vapour, the air-gas so formed descending by its gravity to a steatite ring burner. The flame is drawn into a definite form, and the top of it is hidden from view, by a long brass chimney above the steatite burner. The chimney is surrounded by a larger brass tube, in which the air is warmed by the chimney, and so tends to rise. This makes a current which, descending through another tube, supplies air to the centre of the steatite ring. No glass chimney is required, and no exterior means have to be employed to drive the pentane vapour through the burner.

Figure 189 shows the general appearance of the lamp. The saturator is at starting about two-thirds filled with pentane.¹ It should be replenished from time to time so that the height of liquid as seen against the windows may not be less than one-eighth of an inch, and is connected with the burner by means of a piece of wide india-rubber tube. The rate of flow of the gas can be regulated by the stop-cock or by checking the ingress of air. For this latter purpose a metal cone, acting as a damper, is suspended by its apex from one end of a lever, to the other end of which is attached a thread for moving the cone up or down. The lever is supported by an upright arm clamped to the upper end of the stop-cock immediately beneath the cone. From the top of the lamp the thread descends to a small pulley on the table, and thence passes horizontally to the end of a screw moving in a small block, by turning which the gas examiner can regulate the lamp without leaving his seat. It is best so to turn the stop-cock as to allow the flame to be definitely too high, but not to turn it full on, before letting down the regulating cone to its working position. Both stop-cocks should be turned off when the lamp is not alight.

The chimney tube should be turned so that no light passing through the mica window near its base can fall upon the photoped. The lower end of this tube should, when the lamp is cold, be set 47 millimetres above the steatite ring burner. A cylindrical boxwood gauge, 47 millimetres in length and 32 in diameter, is provided with the lamp to facilitate this adjustment. The exterior tube communicates with the interior of the ring-burner by means of the connecting box above the tube and the bracket on which the burner is

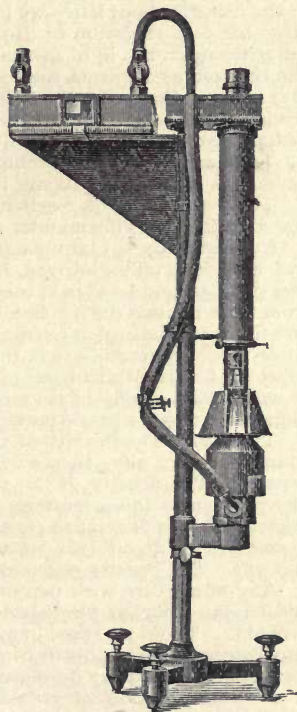


FIG. 189.—HARCOURT'S 10-CANDLE PENTANE LAMP.

¹ CAUTION.—Pentane is extremely inflammable; it gives off at ordinary temperatures a heavy vapour which is liable to ignite at a flame at a lower level than the liquid. The saturator must never have pentane poured into it when in position, if the lamp or the gas of the photometer is alight.

supported. A conical shade is provided. This should be placed so that the whole surface of the flame beneath the tube may be seen at the photoped through the opening.

The lamp should be adjusted by its levelling screws so that the tube, as tested with a plumb-line, is vertical, and so that the upper surface of the steatite burner is 353 millimetres from the table. A gauge is provided to facilitate this latter measurement. The tube is brought centrally over the burner by means of the three adjusting screws at the base of the tube. These three screws should not be quite screwed up, but only sufficiently so to keep the chimney tube central. The adjustment is facilitated by means of the boxwood gauge.

When the lamp is in use the stop-cocks are to be regulated so that the tip of the flame is about half-way between the bottom of the mica window and the cross-bar. A variation of a quarter of an inch either way has no material influence upon the light of the flame. The saturator should be placed upon the bracket as far from the central column as the stop at the end will allow. If it is found that, after the lamp has been lighted for a quarter of an hour, the tendency of the flame is to become lower, the saturator may be placed a little nearer the central column.

To prevent a gradual accumulation of dust in either the burner or the air-passage, a small cover should be kept upon the lamp when not in use.

The pentane to be used in the 10-candle lamp should be prepared and tested in the following manner:—

PREPARATION.—Light American petroleum, such as is known as gasoline and used for making air-gas, is to be further rectified by three distillations, at 55° C., 50°, and 45° in succession. The distillate at 45° is to be shaken up from time to time during two periods of not less than three hours each with one-tenth its bulk of (1) strong sulphuric acid, (2) solution of caustic soda. After these treatments it is to be again distilled, and that portion is to be collected for use which comes over between the temperatures of 25° and 40°. It will consist chiefly of pentane, together with small quantities of lower and higher homologues whose presence does not affect the light of the lamp.

TESTING.—The density of the liquid pentane at 15° C. should not be less than 0·6235 nor more than 0·626 as compared with that of water of maximum density. The density of the pentane when gaseous, as compared with that of hydrogen at the same temperature and under the same pressure, may be taken. This is done most readily and exactly by Gay Lussac's method, under a pressure of about half an atmosphere and at temperatures between 25° and 35°. The density of gaseous pentane should lie between 36 and 38.

Any admixture with pentane of hydrocarbons belonging to other groups and having a higher photogenic value, such as benzene or amylene, must be avoided. Their presence may be detected by the following test. Bring into a stoppered 4-oz. bottle of white glass 10 c.c. of nitric acid, specific gravity 1·32 (made by diluting pure nitric acid with half its bulk of water); add 1 c.c. of a dilute solution of potassium permanganate, containing 0·1 gram of permanganate in 200 c.c. Pour into the bottle 50 c.c. of the sample of pentane, and shake strongly during five successive periods of 20 seconds. If no hydrocarbons other than paraffins are present, the pink colour, though somewhat paler, will still be distinct; if there is an admixture of as much as $\frac{1}{2}$ per cent. of amylene or benzene, the colour will have disappeared.

TIMES AND MODE OF TESTING FOR ILLUMINATING POWER.

I.—Testings with the Metropolitan Argand Burner, No. 2.

The testings for illuminating power made with the Standard Argand shall be three in number daily. "The tests for illuminating power shall be taken at intervals of not less than one hour." "The average of all the testings at any testing place on each day of the illuminating power of the gas supplied by the company at such testing place shall be deemed to represent the illuminating power of such gas on that day at such testing place." (Gaslight and Coke and other Gas Companies Acts Amendment Act, 1880, sections 7 and 8.)

But "If on any one day the gas supplied by the company at any testing place is of less illuminating power to an extent not exceeding one candle than it ought to be, the average of all the testings made at such testing place on that day and on the preceding day and on the following day shall be deemed to represent the illuminating power of the gas on such one day at such testing place." (London Gas Act, 1905, section 4 (3).)

The gas supplied by the gas companies is required to have an illuminating power of 14 candles. (London Gas Act, 1905, section 4. The Gaslight and Coke Company's Act, 1909, section 38.)

The photometer to be used in the testing places shall be the Table Photometer.

The several parts of the apparatus stand upon a well-made and firm table, 5 ft. 6 in. by 3 ft. 6 in., and 2 ft. 5 in. high. The upper surface of this table is smooth, level, and dead black. Upon this are placed or clamped in the positions shown—

(1) The gas meter; (2) the gas governor; (3) the regulating tap; (4) the Metropolitan Argand Burner, No. 2, and sliding base; (5) the flat flame burner and sliding base; (6) the slide, connecting rod, and photometric scale and index; (7) the connecting pipes; (8) the pentane 10-candle lamp; (9) the photoped; (10) the aerorthometer; (11) the stop clock; (12) dark screens; mirrors; measuring rod; small block, and pulley.

[All these several parts are described in great detail in the Notification.]

The air-gas in the lamp is to be kept burning so that the flame is near its proper height for at least ten minutes before any testing is made. At the completion of every testing the air-gas is to be turned off; but if the interval between two testings does not much exceed one hour and the gas examiner is present during the interval, he may, instead of turning it off completely, turn it down low.

The Argand Burner (Fig. 190) attached to each photometer shall be a standard burner called the Metropolitan Argand Burner, No. 2.

A clean chimney is to be placed on the burner before each testing, and care should be taken that the glass does not become dimmed by the smoking of the flame.

The gas under examination is to be kept burning, at about the usual rate, for at least fifteen minutes before any testing is made; the damper shall not be in action during this interval. No gas shall pass through the meter attached to the photometer except that which is consumed in testing or during the intervals between the testings made on any day, and that which is used in proving the meter.

The paper used in the photoped of the photometer shall be white in colour, unglazed, of fine grain and free from water marks. It shall be as translucent as is possible consistently with its being sufficiently opaque to prevent any change in the apparent relative brightness of the two portions of the

illuminated surface when the head is moved to either side. This paper should, when not in use, be covered to protect it from dust; and if it has been in any way marked or soiled a fresh piece is to be substituted.

Each testing shall be made as follows:—

The index of the regulating tap shall be so adjusted that the meter hand makes one complete revolution in not less than 59 or more than 61 seconds.

The damper for regulating the air supply to the burner shall be screwed upwards until the flame is on the point of tailing above the chimney and then immediately be turned down only so far as to ensure that the flame burns without any smoking. The connecting rod shall now be pushed to and fro by the gas examiner until the illumination of the photoped by the two sources of light is judged to be equal. A balance is best attained by making small alternations of decreasing amplitude rather than by a very slow movement in one direction only. The reading on the photometric scale shall be noted. This observation is to be made four times in all, and the mean of the results taken to the second decimal place. The time that the meter hand takes to make exactly two revolutions shall then be

observed by the aid of a stopclock or stopwatch. The mean of the four readings of the photometric scale shall be multiplied by the number of seconds in the time recorded and by the aerorthometer (Fig. 197) reading and divided by 120. The quotient is the illuminating power which should be stated to the nearest hundredth of a candle.

If the gas is so rich that it cannot be made to burn at the prescribed rate without tailing above the chimney or smoking, or if the burner cannot be pushed far enough away to produce equality of illumination on the photoped, the rate must be reduced until the flame burns properly within the chimney or a balance is produced when the burner is at the far end of the slide. In all other respects the testing and calculation shall be made as described.

If, in very exceptional circumstances, the aerorthometer scale or the table does not include the conditions that are met with, the gas examiner shall in calculating the illuminating power use the formula printed below the table.

Each testing place must be provided with a standard clock that will go for a week without rewinding.

The gas examiner shall, at least once a week, compare the stopclock in the testing place with the standard clock or with his watch.

The gas examiner shall enter in his book the particulars of every testing of illuminating power made by him at the testing places, during or immediately after such testing; and in the case of any testing which he rejects he shall also state the cause of rejection. No testing is to be rejected on the ground that the result seems improbable.

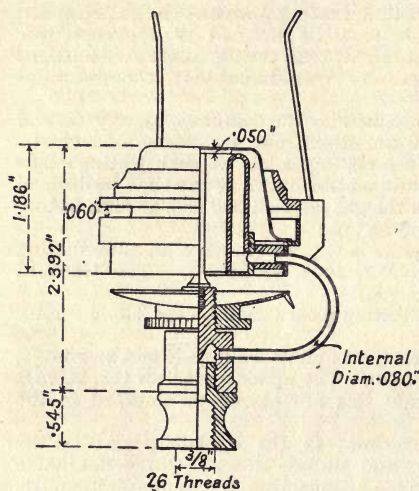


FIG. 190.

II.—*Testings with the Standard Flat Flame Burner.*

The testings for illuminating power made with the flat-flame burner shall be made at such times as the controlling authority shall direct. (London Gas Act, 1905, section 5.) The burner shall be that described. The testings made with it shall be conducted in the same way as those with the Argand; but when a testing with the Argand has been made immediately before, the testing with the flat-flame burner may be made when the gas has been burning through it at the usual rate for five minutes. A new burner shall be used every week.

If the gas is so poor that the burner cannot be brought near enough to produce equality of illumination on the photoped, the rate of consumption must be increased, until a balance is produced when the burner is at the near end of the slide. In all other respects the testing shall be carried out as described.

TIMES AND MODE OF TESTING FOR SULPHURETTED HYDROGEN.

“The gas supplied by the company shall not exhibit any trace of sulphuretted hydrogen when tested in a mode to be from time to time prescribed and certified by the gas referees for testing and recording the presence “of sulphuretted hydrogen, which mode shall not be more stringent than the mode prescribed in Schedule A of the Gas Works Clauses Act, 1871.” (London Gas Act, section 6.)

The apparatus (Fig. 191) is to be used in testing gas for sulphuretted hydrogen. The gas as it leaves the service pipe shall be passed through the glass vessel in which are suspended six slips of bibulous paper which have been recently moistened by dipping them in a solution consisting of 6.5 grams (100 grains) of crystallized acetate of lead dissolved in 100 cubic centimetres of water.

One testing shall be made daily.

The apparatus (Fig. 191) consists of a plate with a circular channel half filled with mercury in which rests a bell-glass, held down in position by an arm and cap not shown in the figure. A central tube connected below with the gas-inlet rises nearly to the top of the bell-glass, and carries mid-way six wires pointed and curved at the end, from each of which a slip of lead-paper hangs.

A second pipe passing through the plate and terminating above in a short elbow provides an outlet for the gas, which is burnt as it issues from a governor-burner passing gas at about the rate of five cubic feet per hour.

In making the testing, gas shall be turned on to the apparatus, and lit at the burner as soon as the air has been swept out. When the gas has burnt for three minutes it is to be turned off, and one of the slips of paper is to be compared with another similar slip which has not been exposed to the gas. The gas is to be taken as exhibiting a trace of sulphuretted hydrogen if the slip of paper which has been exposed to it is unmistakably the darker of the two.

In this event two of the test-slips which have been exposed to the gas

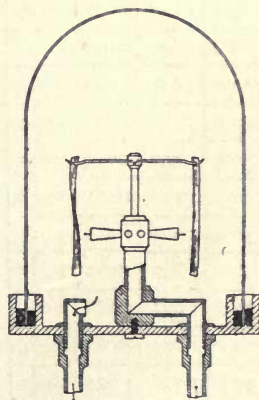


FIG. 191.

**Tabular Numbers : being a Table to facilitate the Correction
tures and under different**

BAR.	THERMOMETER—			FAHRENHEIT.							
	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	60°
28·0	0·979	0·974	0·970	0·965	0·960	0·956	0·951	0·946	0·942	0·937	0·932
28·1	0·983	0·978	0·973	0·969	0·964	0·959	0·955	0·951	0·945	0·941	0·936
28·2	0·986	0·981	0·977	0·972	0·967	0·963	0·958	0·953	0·949	0·944	0·939
28·3	0·990	0·985	0·980	0·976	0·971	0·966	0·961	0·957	0·952	0·947	0·942
28·4	0·993	0·988	0·984	0·979	0·974	0·970	0·965	0·960	0·955	0·951	0·946
28·5	0·997	0·992	0·987	0·983	0·978	0·973	0·968	0·964	0·959	0·954	0·949
28·6	1·001	0·995	0·991	0·986	0·981	0·977	0·972	0·967	0·962	0·958	0·953
28·7	1·004	0·999	0·994	0·990	0·985	0·980	0·975	0·970	0·966	0·961	0·956
28·8	1·007	1·003	0·998	0·993	0·988	0·984	0·979	0·974	0·969	0·964	0·959
28·9	1·011	1·006	1·001	0·997	0·992	0·987	0·982	0·977	0·973	0·968	0·963
29·0	1·014	1·010	1·005	1·000	0·995	0·990	0·986	0·981	0·976	0·971	0·966
29·1	1·018	1·013	1·008	1·004	0·999	0·994	0·989	0·984	0·979	0·975	0·969
29·2	1·021	1·017	1·012	1·007	1·002	0·997	0·992	0·988	0·982	0·978	0·973
29·3	1·025	1·020	1·015	1·011	1·006	1·001	0·996	0·991	0·986	0·981	0·976
29·4	1·028	1·024	1·019	1·014	1·009	1·004	0·999	0·995	0·990	0·985	0·980
29·5	1·032	1·027	1·022	1·018	1·013	1·008	1·003	0·998	0·993	0·988	0·983
29·6	1·036	1·031	1·026	1·021	1·016	1·011	1·006	1·001	0·996	0·992	0·986
29·7	1·039	1·034	1·029	1·025	1·019	1·015	1·010	1·005	1·000	0·995	0·990
29·8	1·043	1·038	1·033	1·028	1·023	1·018	1·013	1·008	1·003	0·998	0·993
29·9	1·046	1·041	1·036	1·031	1·026	1·022	1·017	1·012	1·007	1·002	0·997
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 calculated from the formula on the Fahrenheit scale, and a the tension of aqueous vapour at t° . If v is any pressure, $V = v n$.

*of the Volume of Gas Measured over Water at different Tempera-
Atmospheric Pressures.*

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

$n = \frac{1764(h - a)}{460 + t}$, where h is the height of the barometer in inches, t the temperature volume at t° and h inches pressure and V the corresponding volume at 60° and 30 inches

shall be placed in a stoppered bottle and kept in the dark at the testing place ; one of the remaining slips shall be forwarded with each daily report, and the comparison slip shall be retained by the gas examiner for the use of the chief gas examiner.

MODE OF TESTING FOR SULPHUR COMPOUNDS OTHER THAN SULPHURETTED HYDROGEN.

This testing shall be made on such days as the controlling authority shall direct. (London Gas Act, 1905, section 5.) The apparatus (Fig. 192) is to be set up in a room or closet where no other gas is burning. The gas shall pass through a meter by reference to which the rate of flow can be adjusted, and which is provided with a self-acting movement for shutting off the gas when 10 cubic feet have passed.

Pieces of sesqui-carbonate of ammonia, from the surface of which any efflorescence has been removed, are to be placed round the stem of the burner. The index of the meter is to be then turned forward to the point at which the catch falls and will again support the lever-forward in the horizontal position. The lever is made to rest against the catch so as to turn on the gas. The index is turned back to a little short of zero, and the burner lighted. When the index is close to zero the trumpet tube is placed in position on the stand and its narrow end connected with the tubulure of the condenser. At the same time the long chimney-tube is attached to the top of the condenser.

As soon as the testing has been started, a first reading of the Aerorthometer is to be made and recorded, and a second reading as near as may be to the time at which the gas is shut off. The rate of burning, which with practice can be judged very nearly by the height of the flame, is to be so adjusted that the meter hand shall make half a revolution in not less than four minutes.

After each testing the flask or beaker, which has received the liquid products of the combustion of the 10 cubic feet of gas, is to be emptied into a measuring cylinder and then replaced to receive the washings of the condenser. Next the trumpet tube is to be removed and well washed out with distilled water into the measuring cylinder. The condenser is then to be flushed twice or thrice by pouring quickly into the mouth of it 40 or 50 cubic centimetres of distilled water. These washings are brought into the

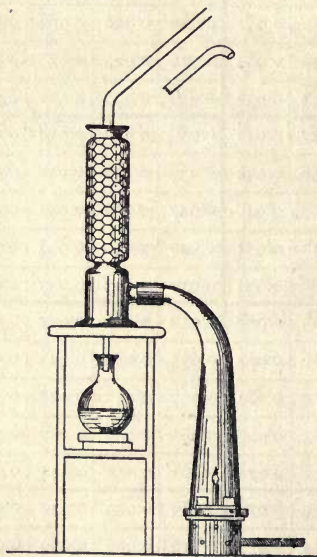


FIG. 192.

measuring cylinder, whose contents are to be well mixed and divided into two equal parts.

One-half of the liquid so obtained is to be set aside, in case it should be desirable to repeat the determination of the amount of sulphur which the liquid contains.

The other half¹ of the liquid is to be brought into a flask, or beaker covered with a large watch-glass, treated with hydrochloric acid sufficient in quantity to leave an excess of acid in the solution, and then raised to the boiling point. An excess of a solution of barium chloride is now to be added and the boiling continued for five minutes. The vessel and its contents are to be allowed to stand till the barium sulphate has settled at the bottom of the vessel, after which the clear liquid is to be as far as possible poured off through a paper filter. The remaining liquid and barium sulphate are then to be brought on to the filter, and the latter is to be well washed with hot distilled water. (In order to ascertain whether every trace of barium chloride and ammonium chloride has been removed, a small quantity of the washings from the filter should be placed in a test-tube, and a drop of a solution of silver nitrate added; should the liquid, instead of remaining perfectly clear, become cloudy, the washing must be continued until on repeating the test no cloudiness is produced). Dry the filter with its contents, and transfer it into a weighed platinum crucible. Heat the crucible over a lamp, increasing the temperature gradually, from the point at which the paper begins to char, up to bright redness.² When no black particles remain, allow the crucible to cool; place it when nearly cold in a desiccator over strong sulphuric acid, and again weigh it. The difference between the first and second weighings of the crucible will give the number of grains of barium sulphate. Multiply this number by 11 and divide by 4; the result is the number of grains of sulphur in 100 cubic feet of the gas.³

This number is to be corrected for the variations of temperature and atmospheric pressure in the manner indicated under the head of Illuminating Power, with this difference, that the mean of the first and second aerorthometer readings shall be taken as the reading.

The correction by means of the aerorthometer reading may be made most simply and with sufficient accuracy in the following manner:—

When the aerorthometer reading is between 0.955–0.965, 0.965–0.975, 0.975–0.985, 0.985–0.995 diminish the number of grains of sulphur by 4, 3, 2, and 1 per cent.

When the aerorthometer reading is between 0.995–1.005, no correction need be made.

When the aerorthometer reading is between 1.005–1.015, 1.015–1.025, 1.025–1.035 increase the number of grains of sulphur by 1, 2, and 3 per cent.

¹ If preferred, a smaller proportion (say, $\frac{1}{n}$ th part of the liquid) may be taken for the determination, in which case the number of grains of barium sulphate obtained must be multiplied by $\frac{11}{8}n$ instead of being multiplied by 11 and divided by 4.

² An equally good and more expeditious method is to drop the filter with its contents, drained but not dried, into the red-hot crucible.

³ 233 grains of barium sulphate are formed from 32 grains of sulphur; w grains of barium sulphate have been obtained from 5 cubic feet of gas.

Hence in 100 cubic feet of gas there are $\frac{32}{233} \times \frac{100}{5} = \frac{11}{4} w$ grains of sulphur.

Example:—

Grains of barium sulphate from 5 cub. ft. of gas	10·4	
Multiply by 11 and divide by 4	11	Aerorthometer reading 1·018
	4)114·4	
Grains of sulphur in 100 cub. ft. of gas	(uncorrected) 28·60	
Add $28·6 \times \frac{2}{100} =$	0·57	
Grains of sulphur in 100 cub. ft. of gas (corrected)	29·17	Result: 29·2 grains.

The aerorthometer reading is the reciprocal of the tabular number. The gas examiner shall, not less often than once a month, compare the aerorthometer reading with the reciprocal of the tabular number deduced from observations of the barometer and thermometer, and if there is a difference of more than one-half per cent. the aerorthometer is to be readjusted.

The gas is burnt in a small bunsen burner with a steatite top, which is mounted on a short cylindrical stand, perforated with holes for the admission of air, and having on its upper surface, which is also perforated, a deep circular channel to receive the wide end of a glass trumpet-tube. There are both in the side and in the top of this stand fourteen holes of five millimetres in diameter, or an equivalent air-way. On the top of the stand, between the narrow stem of the burner and the surrounding glass trumpet-tube, are to be placed pieces of commercial sesqui-carbonate of ammonia weighing in all about 2 ounces (Fig. 192).

The products both of the combustion of the gas and of the gradual volatilization of the ammonia salt go upwards through the trumpet-tube into a vertical glass cylinder with a tubulure near the bottom, and drawn in at a point above this to about half its diameter. From the contracted part to the top the cylinder is packed with balls of glass about fifteen millimetres in diameter, to break up the current and promote condensation. From the top of this condenser there proceeds a long glass pipe or chimney tube slightly bent over at the upper end, serving to effect some further condensation, as well as to regulate the draught and afford an exit for the uncondensable gases. The chimney-tube is suspended by a tape, tied round the middle of it and attached above to a bracket projecting from the wall, in such a manner that its lower end may be connected with or disconnected from the condenser with little change of position, or it may rest upon the bracket, being also attached to it by a girdle. In the bottom of the condenser is fixed a small glass tube, through which the liquid formed during the testing drops into a flask placed beneath.

The following cautions are to be observed in selecting and setting up the apparatus:—

See that the inlet-pipe fits gas-tight into the burner, and that the holes in the circular stand are clear. If the burner gives a luminous flame, remove the top piece, and having hammered down gently the nozzle of soft metal, perforate it afresh, making as small a hole as will give passage to two-thirds of a cubic foot of gas per hour at a convenient pressure.

See that the tubulure of the condenser has an internal diameter of not less than 18 millimetres, and that its outside is smooth and of the same size as the small end of the trumpet-tube; also that the internal diameter of the contracted part is not less than 30 millimetres.

See that the short piece of india-rubber pipe fits tightly both to the trumpet-tube and to the tubulure of the condenser.

The small tube at the bottom of the condenser should have its lower end contracted, so that when in use it may be closed by a drop of water.

The end of the chimney-tube carries an india-rubber adapter or perforated plug, which, respectively, should fit over or into, and not simply rest upon, the top of the condenser.

A central hole, about 50 millimetres in diameter, may with advantage be made in the shelf of the stand. If a beaker is kept on the table below, the liquid will still be preserved if by any accident the flask is not in its place.

MODE OF TESTING THE CALORIFIC POWER OF THE GAS.

In the testing-places for the Gaslight and Coke Company, "One testing only for calorific power shall be made at each testing-place daily, but in the event of the calorific power being on any testing ascertained to be below one hundred and twelve and one-half calories, the gas examiner shall forthwith give notice thereof to the Gaslight Company, and a second testing shall be made at an interval of not less than one hour from the time of making the first testing at that testing-place, and the average of the two testings shall be deemed to be the calorific power of the gas at such testing-place on that day." (The Gaslight and Coke Company's Act, 1909, section 39.)

In the testing-places for the South Metropolitan Gas Company, and for the Commercial Gas Company, the testing of the calorific power of the gas shall be made on such days as the controlling authority shall direct. (London Gas Act, 1905, section 5.)

The calorimeter (Fig. 193) to be used in testing the calorific power of the gas shall be one which has been examined and certified by the gas referees.

A unit of heat, termed a calorie, is the amount of heat which will raise the temperature of a litre of water one degree centigrade.

The heating or calorific power of any sample of gas is represented by the number of calories produced by the combustion of one cubic foot of such gas measured at 60 deg. Fahr. and under a pressure of 30 inches of mercury.

When the products of combustion are cooled before they escape, the heat imparted includes that which is due to the condensation into water of some of the steam formed by combustion, and that which is due to the cooling of the water thus formed from its boiling point to a lower temperature.

The maximum calorific power which gas can thus exert is determined directly by the calorimeter. This is a true measure of the total heating power, and is termed *the gross calorific power of the gas*. But in many cases in which gas is used as a heating agent the steam which is formed escapes into the air uncondensed and thus the heat due to the condensation of the steam and the cooling of the water so formed is not utilized. The amount of heat thus lost can be estimated, and if it is subtracted from the total heat yielded by the combustion of gas in the calorimeter another value is obtained which is termed *the net calorific power of the gas*. Since, however, when steam escapes uncondensed the uncondensable products of combustion also pass away at a high temperature, and since the loss of heat thus arising is commonly the greater of the two, the customary partial correction from gross to net has not much significance.

In order to test the gas for calorific power, the gas shall first pass through a meter, and an efficient governor. This may be a balance governor, or a diaphragm governor of a pattern approved by the gas referees, and in the latter case the governor may conveniently be placed in the base of the

calorimeter. When so placed, a non-conducting sleeve should be introduced into the burner-tube to prevent the governor from being unduly warmed by conduction. The gas shall be turned on and lighted, and the form of the two flames observed. If either is out of shape, this must be rectified either by clearing the burner or by substituting another burner. The tap of the calorimeter shall then be so adjusted as to allow the meter hand to make one turn in from 60 to 75 seconds. The water shall be turned on so that when the regular flow through the calorimeter has been established a little may pass the overflow of the funnel and trickle over into the sink. Water must be poured in through one of the holes in the lid until it begins to run out at the condensation outlet. The calorimeter may then be placed upon its base. The measuring vessel carrying the change-over funnel should then be placed in position in the sink so that the outlet water is led into the sink. The hot water outlet tube of the calorimeter should be above but should not touch the change-over funnel. After an interval of not less than 30 minutes the gas examiner, after bringing the reading glasses into position on the thermometers used for measuring the temperature of the inlet and outlet water, shall then make the following observations. When the meter hand is at 75 he shall read the inlet temperature; when it reaches 100 he shall move the funnel so as to direct the outflow into the measuring vessel and at the same time he shall start the stop-clock or a stop-watch. When the meter hand reaches 25 he shall make the first reading of the outlet temperature. He shall continue to read the outlet temperature at every quarter turn until fifteen readings have been taken. The meter hand will then be at 75. He shall also at every turn of the meter except the last make a reading of the inlet temperature when the meter hand is between 75 and 100. When the meter hand reaches 100 after the last outlet temperature has been read, the gas examiner shall shift the funnel so as to direct the outlet water into the sink again and at the same time stop the clock or watch. The barometer and the thermometers showing that temperatures of the effluent gas, of the air near the calorimeter and of the gas in the meter, shall then be read. The time shown by the stop-clock shall be recorded. The mean of the four readings of the inlet temperature is to be subtracted from the mean of the fifteen readings of the outlet temperature and the difference is to be multiplied by 3 and by the number of litres of water collected and the product is to be divided by the tabular number. The difference in degrees centigrade of the temperature of the effluent gas and of the surrounding air shall be taken, and one-sixth of this difference shall be added to the result previously found if the effluent gas is the warmer of the two, or subtracted if the effluent gas is the cooler of the two. The result is the gross calorific power of the gas in calories per cubic foot.

In addition to the observations described, the amount of condensed water resulting from the combustion of the gas shall be measured. For this purpose the condensation water shall be led into a flask not less than twenty minutes after the calorimeter has been placed in position. The amount collected in not less than thirty minutes shall be measured, the time of collection having been accurately noted.

The number of cubic centimetres collected shall be multiplied by the number of seconds in the time indicated by the stop-clock and by the number 1·86. The number of seconds in the time during which the condensed water was being collected shall be multiplied by the tabular number. The first product shall be divided by the second. The quotient is to be subtracted from the gross calorific power. The difference is the net calorific power in calories per cubic foot. The gross and net calorific power in British thermal units can be obtained by multiplying the corresponding numbers

of calories by 3.968. The British thermal unit (B.Th.U.) is the amount of heat which will raise the temperature of one pound of water one degree Fahrenheit.

A form on which the gas examiner may conveniently set down his observations and the whole of the figures needed for the calculation is given on page 376. The figures in italic type are specimen figures, and represent such as might be written by the gas examiner.

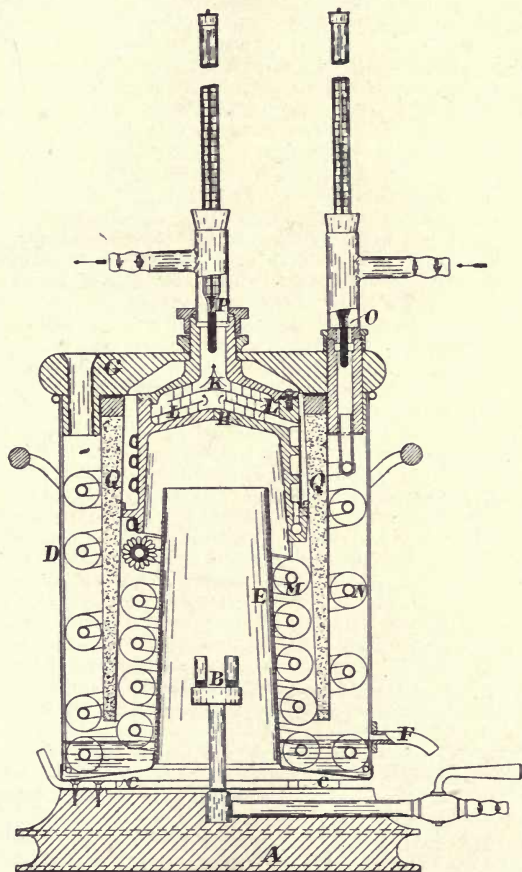


FIG. 193.

The gas calorimeter, which has been designed by Mr. Boys, is shown in vertical section in Fig. 193. It consists of three parts, which may be separated or which, if in position, may be turned relatively to one another about their common axis. The parts are (1) the base, A, carrying a pair of burners, B,

and a regulating tap. The upper surface of the base is covered with a bright metal plate held in place by three centering and lifting blocks, C. The blocks are so placed as to carry (2) the vessel D, which must rest upon the horizontal portion of the blocks and not upon their upturned ends. This vessel is provided with a central copper chimney E and a condensed water outlet F. The diameter of the chimney, E, at the base is $3\frac{1}{2}$ inches and at the top $2\frac{1}{2}$ inches and its thickness $\frac{3}{20}$ inch. The base of the outer vessel shown in the drawing as a separate piece is preferably spun in one piece with the chimney, F, by the accidental contact of the flow of condensed water from the outlet, F, by the accidental contact of the thin brass protecting wall of the pipe system a small dimple is punched in the outer casing on either side of the outlet, F, so as to project inwardly about $\frac{1}{16}$ inch. Resting upon the rim of the vessel, D, are (3) the water circulating system of the calorimeter attached to the lid, G. Beginning at the centre where the outflow is situated there is a brass box which acts as a temperature equalizing chamber for the outlet water. Two dished plates of thin brass, KK, are held in place by three scrolls of thin brass, LLL. These are simply strips bent round like unwound clock springs, so as to guide the water in a spiral direction inwards, then outwards and then inwards again to the outlet. The lower or pendant portion of this box is kept cool by circulating water, the channel for which may be made in the solid metal, as shown, on the right side, or by sweating on a tube as shown on the left. Connected to the water channel at the lowest point by a union are five or six turns of copper pipe such as is used in a motor-car radiator of the kind known as Clarkson's. In this a helix of copper wire threaded with copper wire is wound round the tube, and the whole is sweated together by immersion in a bath of melted solder. A second coil of pipe of similar construction surrounding the first is fastened to it at the lower end by a union. This terminates at the upper end in a block, to which the inlet water box and thermometer holder are secured by a union as shown at O. An outlet water box, P, and thermometer holder are similarly secured above the equalizing chamber, H. The lowest turns of the two coils, MN, are immersed in the water which in the first instance is put into the vessel D.

Between the outer and inner coils, MN, is placed a brattice, Q, made of thin sheet brass, containing cork dust to act as a heat insulator. The upper annular space in the brattice is closed by a wooden ring and that end is immersed in melted rosin and beeswax cement to protect it from any moisture which might condense upon it. The brattice is carried by an internal flange which rests upon the lower edge of the casting, H. A cylindrical wall of thin sheet brass, a very little smaller than the vessel D, is secured to the lid so that when the instrument is lifted out of the vessel and placed upon the table, the coils are protected from injury. The narrow air space between this and the vessel, D, also serves to prevent interchange of heat between the calorimeter and the air of the room.

The two thermometers for reading the water temperatures and a third for reading the temperature of the outlet air are all near together and at the same level. The lid may be turned round into any position relatively to the gas inlet and condensed water drip that may be convenient for observation, and the inlet and outlet water boxes may themselves be turned so that their branch tubes point in any direction.

A regular supply of water is maintained by connecting one of the two outer pipes of the overflow funnel to a small tap over the sink. The overflow funnel is fastened to the wall about one metre above the sink and the other outer pipe is connected to a tube in which there is a diaphragm with a hole about 2.3 mm. in diameter. This tube is connected to the inlet pipe of the calorimeter. A piece of stiff rubber pipe long enough to carry the outflow

water clear of the calorimeter is slipped on to the outflow branch and the water is turned on so that a little escapes by the middle pipe of the overflow funnel, and is led by a third piece of tube into the sink. The amount of water that passes through the calorimeter in four minutes should be sufficient to fill the graduated vessel shown in Fig. 194 to some point above the lowest division, but insufficient in five minutes to come above the highest division. If this is not found to be the case, a moderate lowering of the overflow funnel or reaming out of the hole in the diaphragm will make it so. The overflow funnel should be provided with a lid to keep out dust.

The thermometers for reading the temperature of the inlet and outlet water should be divided on the Centigrade scale into tenths of a degree, and they should be provided with reading lenses and pointers that will slide upon them. The thermometers are held in place by corks (not india-rubber), making an air-tight fit within the inlet and outlet water boxes. Care must be taken that the bulbs are fully immersed. The positions of these thermometers should be interchanged every month. The thermometers for reading the temperature of the air near the instrument and of the effluent gas should be divided on the centigrade scale into degrees.

The flow of air to the burners is determined by the degree to which the passage is restricted at the inlet and at the outlet. The blocks, C, which determine the restriction at the inlet are made of metal $\frac{3}{16}$ inch or about 5 millimetres thick, while the holes round the lid which determine the restriction at the outlet are five in number and are $\frac{3}{8}$ ths inch or 16 millimetres in diameter. The thermometer used for finding the temperature of the effluent gas is held by a cork carrying a helix of wire which rests on the lid so that the bulb is within one of the five holes and is thereby exposed to the effluent gas.

The calorimeter should stand on a table by the side of a sink so that the condensed water and hot water outlets overhang and deliver into the sink. A suitable change-over funnel is shown. A piece of india-rubber tube reaching nearly to the base should be attached to the waste-water pipe so as to avoid splashing, and another piece may conveniently be slipped on to the condensed-water outlet so as to lead the condensed water into a flask, but care should be taken that the small side hole is not covered by the tube. A glass vessel must be provided of the size of the vessel, D, containing water in which is dissolved sufficient carbonate of soda to make it definitely alkaline. The calorimeter after use is to be lifted out of its vessel, D, and placed in the alkaline solution and there left until it is again required for use. The liquid should not, when the calorimeter is placed in it, come within two inches of the top of the vessel. The liquid must be replenished from time to time, and its alkalinity must be maintained.

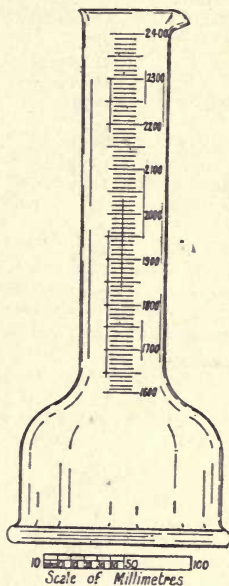


FIG. 194.

CALORIFIC POWER OF GAS.

Form with example of Calculation.

Water.		Air.		Time by Stop Clock.
Inlet.	Outlet.	Inlet.	Outlet.	
8.45° C.	33.22° C.	15° C.	12° C.	4 minutes 2 seconds = 242 seconds. One-sixth difference = 0.5.
	0.23			
	0.23			
8.46	0.23			Barometer, 29.9 inches } Meter thermo., 60° F. } Tabular Number = 0.997.
	0.21			
	0.22			
	0.23			
8.46	0.23			Water collected, 2.080 litres. Condensed water in 30 minutes = 1800 seconds, 60.4 c.c.
	0.22			
	0.21			
	0.23			
8.47	0.24	Log. 24.77	= 1.3939	(rise of temperature)
8.46	0.24	Log. 3	= 0.4771	(1/3 cubic foot)
	0.24	Log. 2.080	= 0.3181	(volume of water collected)
	5) 3.41		2.1891	
	3) 0.682	Log. 0.997	= 7.9987	(tabular number)
	33.23	Log. 155.0	= 2.1904	
	8.46			
	24.77	Subtract 0.5		(one-sixth difference)
	154.5	154.5	=	Gross Calorific Power.
(condensed water) Log. 60.4	= 1.781	Log. 1800 = 3.255	(time in seconds)	
(time in seconds) Log. 242	= 2.384	Log. 0.997 = 7.999	(tabular number)	
(a constant) Log. 1.86	= 0.270	3.254		
Gross Calorific Power 154.5	4.435	3.254		
(heat due to steam) Log. 15.2	= 1.181			
	139.3	= Net Calorific Power.		

MODE OF TESTING THE PRESSURE AT WHICH GAS IS SUPPLIED.

Testings of pressure shall be made at such times and in such places as the controlling authority may from time to time appoint (Gaslight and Coke and other Gas Companies Acts Amendment Act, 1880 Section 6). In order

to make this testing, the gas examiner who makes it shall unscrew the governor and burner of one of the ordinary public lamps, and shall attach in their stead a portable pressure-gauge. In places where incandescent burners are used for street lighting, one street lamp in each street or group of streets may be provided under the lantern with a branch closed by a screw stopper. The gas examiner shall in such cases connect the pressure-gauge by screwing to it an L-shaped pipe fitted with a union, by means of which it may be connected to the service pipe in the place of the screw stopper. The L-shaped pipe is to be of such dimensions as to enable the pressure-gauge to be fixed outside the lantern but at about the same level as the incandescent burner. It should be provided with a tap.

The gauge to be used for this purpose consists of an ordinary pressure-gauge enclosed in a lantern, which also holds a candle for throwing light upon the tubes and scale. The difference of level of the water in the two limbs of the gauge is read by means of a sliding scale, the zero of which is made to coincide with the top of the lower column of liquid.

The gas examiner having fixed the gauge gas-tight, and as nearly as possible vertical on the pipe of the lamp, and having opened the cocks of the lamp and gauge, shall read and at once record the pressure shown. From the observed pressure one-tenth of an inch is to be deducted to correct for the difference between the pressure of gas at the top of the lamp column and that at which it is supplied to the basement of neighbouring houses.

The pressure prescribed in the Acts of the three Metropolitan Gas Companies is to be such as to balance from midnight to sunset a column of water not less than six-tenths of an inch in height, and to balance from sunset to midnight a column of water not less than one inch in height.

METERS.

The meters used for measuring the gas consumed in making the various testings shall be wet meters constructed with measuring drums which allow one-twelfth of a cubic foot of gas to pass for every revolution. A hand is fastened directly to the axle of the drum and passes over a dial divided into one hundred equal divisions. The dial and hand are protected by a glass. In the meter employed in testing the purity of gas the pattern of dial for showing the number of revolutions and the automatic cut-off hitherto in use shall be retained, but in the meters employed for testing illuminating power and calorific power, only the dial above described is needed. The meters should be provided with Fahrenheit thermometers. At least once in every year, each meter thermometer is to be compared with a calorimeter thermometer, and if the discrepancy is more than half a degree Fahrenheit the meter thermometer is to be replaced by a new one. The stop-clock may be either attached to the meter or separate.

The meters used for measuring the gas consumed in making the various testings shall have been certified by the referees, and shall, at least once in seven days, be proved by the gas examiners by means of the referees' one-twelfth of a cubic foot measure. A description of this instrument, with directions how to use it, is given on next page.

The Gas Referees' Street Lamp Pressure Gauge.

This instrument (Fig. 195) is for the purpose of testing in any street at any hour the pressure at which gas is supplied. Its construction and mode of use are as follows:—

Within a lantern provided with a handle for carrying and feet for resting on the ground, is placed a candle-lamp, to give light for reading the gauge.

In front of the candle-lamp is a sheet of opal glass, and in front of this a glass U-tube, partly filled with coloured water, and communicating at one end with the air, at the other with a metal pipe, which passes through the bottom of the lantern. In order to read easily and accurately the difference of level of the liquid in the two limbs, a scale divided into tenths of an inch is made to slide between them with sufficient friction to retain it in any position. The zero of the scale having been brought level with the surface of the liquid which is exposed to the gas, the height above this of the surface which is exposed to the air can be read directly. The lantern is closed in front by a glass door, at each side of which is a reflector for throwing light upon the scale of the gauge. Above each limb of the U-tube is a tap which can be closed when the instrument is not in use, to prevent the liquid being accidentally spilt.

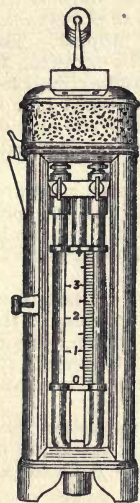


FIG. 195.

To make a testing of pressure the governor and burner of a street lamp are to be removed, and the pressure-gauge is to be screwed on to the gas-pipe, by which it is supported. In places where incandescent burners are used, the L-shaped pipe described on page 377 is to be used for the attachment of the pressure-gauge. The cock is then turned on, and a reading made. If on turning off the cock the level of the liquid is unchanged, or changes slowly, the reading is correct; but if the level changes quickly, the junction between the lamp and the gauge must be made more perfect, and the testing repeated. A small leakage is immaterial, provided the cock is turned fully on.

The pressure at the top of a lamp column is greater by about 0·1 inch than that at the main, which is the pressure required. Accordingly a deduction of 0·1 inch from the observed pressure is to be made.

The Gas Referees' One-Twelfth of a Cubic Foot Measure.

This instrument, which was designed by Mr. Harcourt, is represented in Fig. 196; it consists of a vessel of blown glass of a cylindrical form with rounded ends terminating in short tubes about 40 millimetres in diameter outside, which tubes are reduced at their outer ends to about 20 millimetres in diameter outside. Lines are etched round each tubular neck in such positions that the capacity of that portion of the vessel included between these marks is exactly one-twelfth of a cubic foot when the glass is at the ordinary temperature. No correction is needed for the cubical expansion of the glass. The two tubular necks of the instrument pass through two boards placed below and parallel to the top of a small four-legged table. For convenience the upper one of these two boards is made in two parts and hinged to the legs.

Into each end of the instrument a glass tube about 8 millimetres in diameter outside is fitted gas- and water-tight by means of india-rubber corks, in such positions that the inner end of the upper tube lies exactly in the plane of the mark at its end of the instrument, while that of the lower is about 1 mm. below the mark.

The upper tube terminates in a tee, each branch of which is provided with a stopcock.

A separate stand carries two shelves, the upper one about 40 millimetres below the level of the upper mark and the lower one below the level of the lower mark. The lower shelf is adjustable, and must be so placed that the action about to be described shall take place.

A water vessel is provided having a capacity of about one-tenth of a cubic foot. It should be made of brass or copper, tinned on the inside. It has a tubulure near the bottom, to which is fitted a metal tap. The end of the tap is to be turned slightly downwards, and is to have a diameter outside of about 8 millimetres. The size of the way through the tap and of the connections is such that when a meter is being proved in the manner to be described, the water fills the instrument from one mark to the other in about one minute. The water vessel has a tubulure above for filling it, closed by a cork through which passes a narrow glass tube, so that air may enter or escape. The end of the tube is bent round upon itself in the form of a crook, so as to exclude dust and dirt. An india-rubber tube connects the tube at the base of the measure with the stopcock of the water vessel. An ordinary chemical thermometer is provided for taking the temperature of the water.

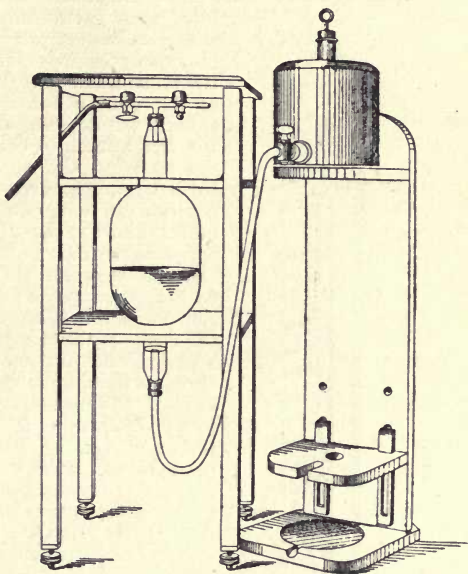


FIG. 196.

The pipe supplying gas to each meter is provided near the meter with a three-way stopcock carrying a short branch pipe, so formed that it either connects the gas supply only with the branch pipe, the meter only with the branch pipe, or the gas supply with the meter, in which latter case the branch pipe is cut off from both. The index of the tap shows which communication is open. The branch pipe is so shaped as to be convenient for the attachment of an india-rubber tube.

In order to put the instrument in adjustment the water vessel is placed upon the upper shelf, and water is poured into it until the water has risen about one-quarter of an inch in the upper narrow tube of the glass measure. One branch of the glass tee is then connected by an india-rubber pipe with the branch of the three-way stopcock. This is now turned so as to connect the branch pipe with the gas supply. The stopcock in the branch of the glass tee to which the rubber tube is attached is turned on, and the water vessel is placed on the lower shelf. The water will run back into the vessel. The flow should cease when the water has just begun to descend in the lower tube; if not, the height of the lower shelf must be adjusted until this is the case.

The space above the upper mark is always filled with gas, and that below the lower mark with water, so that the capacity of these portions of the instrument has no effect upon the measurements. The narrow tubes are so small that a variation of even an inch of the level at which the water stands in them has no appreciable effect upon the meter reading.

The apparatus shall only be used in proving a meter when the temperature

of the meter and of the water in the water vessel have been found not to differ by more than two degrees Fahrenheit.

In order to prove the meters used in the various testings, the position of the index is taken when the instrument has been put in adjustment and filled with gas as described. The tap of the water vessel is turned off; the three-way tap is turned half-way towards the position which will connect the instrument with the gas-meter, and the pressure of the gas in the instrument is reduced to atmospheric pressure by momentarily opening the tap in the free branch of the glass tee. The water vessel is placed upon the upper shelf, the regulating tap is turned on, the three-way tap is turned into such a position as will connect the instrument with the meter, and the tap of the water vessel is turned on. One-twelfth of a cubic foot of gas will then be discharged through the meter. The three-way stop-cock is then turned so as to fill the instrument with gas, the water vessel is placed upon the lower shelf, the gas is reduced to atmospheric pressure as before, and a second, and again a third quantity is discharged through the meter. Should the hand attached to the axle of the measuring drum have travelled in the three revolutions as much as one division beyond the point from which it started, some water must be removed from the meter; if the travel of the meter hand is as much as one division short of this point, some water must be poured in. The operation is then to be repeated until the error is found to fall within the specified limits.

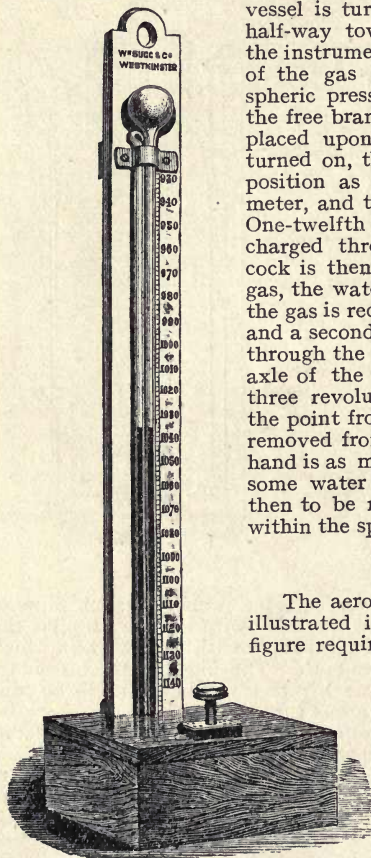


FIG. 197.

The Aerorthometer.

The aerorthometer, devised by Mr. Harcourt, is illustrated in Fig. 197. A reading furnishes the figure required for correcting the volume of a gas measured over water at any ordinary temperature and pressure to that which the gas would have if measured over water under a pressure of 30 inches of mercury and at a temperature of 60° Fahr. Thus its reading corresponds with a figure derivable from a reading of the barometer and the thermometer and a reference to a table giving the tension of aqueous vapour at different temperatures.

The instrument consists of a bulb and vertical stem in which sufficient water is present to ensure that the air is saturated. The measuring tube, which terminates in a closed bulb, and a companion tube of the same calibre which is open to the air, dip into a reservoir of mercury in the base, the capacity of which can be adjusted by a regulating screw pressing on a level cover. The relative volume of the bulb and tube down to any division is represented by the number belonging to that division. The capillary tube above the bulb is closed by a very small

amount of sealing-wax. In order to adjust the instrument the sealing-wax is softened by heat and a small hole made through it. When the bulb has acquired the temperature of the air the regulating screw is to be turned until the two columns of mercury stand level at the calculated aerorthometer reading. Then the sealing-wax stopping is again melted where it was perforated, by being touched from above with a heated wire while the base of the tube and the bulb are protected from heat by a wrapping of cotton-wool.

In using the aerorthometer, turn the screw up until the level of the mercury in the open tube is some distance below that of the mercury in the bulb tube; then turn the screw slowly down until the mercury stands at the same level in both tubes. The division at which the mercury now stands is the aerorthometer reading.

A second form of aerorthometer which has the advantage of being attached to the meter and of having its bulb inside the meter case, is proposed as a substitute for that now in use. For the present the gas referees, while thinking the new form more suitable for use with a meter, are prepared to sanction the use of either form. The gas examiner shall, not less often than once a month, compare the aerorthometer reading with the reciprocal of the tabular number deduced from observations of the barometer and thermometer, and if there is a difference of more than one-half per cent. the aerorthometer is to be readjusted. If at any time the aerorthometer is out of order the reciprocal of the tabular number is to be used.

The second form of aerorthometer gives a more exact correction-figure whenever the water in the meter and the air around differ in temperature.

The bulb of the instrument is filled about three-quarters with hydrogen, and one-quarter with a dark liquid. Water blackened with ink has been found suitable for the purpose. The stem, which descends to the bottom of the bulb, is graduated above, over the range through which the liquid will rise with a low barometer in summer, and will fall with a high barometer in cold weather. For safe transport and to check evaporation the stem ends in a stopcock which is opened for two or three seconds only before each reading. Since, whenever the conditions have changed, air will enter or leave the stem on opening the stopcock, and the air passing out will generally be more nearly saturated with moisture than that which enters if the tube opens directly into the air, a gradual evaporation will take place. This evaporation being chiefly from the sides of the tube left wet by the fall of the liquid would in course of time leave a stain upon the glass as well as diminishing the volume of liquid. The small bulb holding water at the top of the stem is for the purpose of saturating the air which enters.

So much for the notification of the London gas referees.

ILLUMINATING POWER.

For testing the illuminating power of gas in accordance with the general statutory provisions, the Bunsen photometer is used; and the Letheby-Bunsen (Fig. 198) or the Evans enclosed form of the apparatus is that generally adopted.

The standard candle is a sperm candle, six of which weigh 1 lb., and each burns 120 grs. of sperm per hour.

The gas is supplied through an experimental meter, and burns at one end of a graduated bar, and the candle at the other; a movable disc of prepared paper being placed between the two.

This disc, which is contained within a sliding box or carriage, fitted with two reflectors, is moved between the two lights until its opposite sides are equally illuminated, whereupon the illuminating power of the gas is read off by the operator on inspection of the figures on the graduated bar.

The bar is graduated in accordance with the law that lights which equally illuminate an object are to each other as the square of their distance from such object. Thus, assuming that the distance from the disc to the gas flame is 80 in., and to the candle flame 20 in., $80^2 = 6400$, and $20^2 = 400$, or as 16 to 1, the illuminating value of the gas as compared with the candle.

The following apparatus are also required, viz. : A governor to regulate the gas pressure ; a clock striking every minute ; a King's pressure gauge ; a candle balance and weights ; a thermometer and a barometer.

The apparatus is arranged and fixed on a substantially made table, placed in the photometer room. This room may be conveniently made about 10 or 12 ft. square, and should be ventilated ; but currents of air which would affect the steadiness of the gas

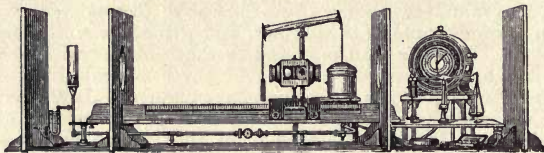


FIG. 198.

and candle flame must be guarded against. Provision is made to exclude the daylight ; and the walls are coloured a dull black.

Statutory Regulations for Testing the Illuminating Power of Gas.

The provisions in Schedule A of the Gas-Works Clauses Act, 1871, in regard to the apparatus for and the mode of testing the illuminating power of gas, are as follows :—

Regulations in respect of Testing Apparatus.

“ The apparatus for testing the illuminating power of the gas shall consist of the improved form of Bunsen's photometer, known as Letheby's open 60-inch photometer, or Evans's enclosed 100-inch photometer, together with a proper meter, minute clock, governor, pressure gauge, and balance.

“The burner to be used for testing the gas shall be such as shall be prescribed.

“The candles used for testing the gas shall be sperm candles of six to the pound, and two candles shall be used together.”

Mode of Testing for Illuminating Power.

“The gas in the photometer is to be lighted at least fifteen minutes before the testings begin, and it is to be kept continuously burning from the beginning to the end of the tests.

“Each testing shall include ten observations of the photometer, made at intervals of a minute.

“The consumption of the gas is to be carefully adjusted to 5 cub. ft. per hour.

“The candles are to be lighted at least ten minutes before beginning each testing, so as to arrive at their normal rate of burning, which is shown when the wick is slightly bent and the tip glowing. The standard rate of consumption for the candles shall be 120 grs. each per hour. Before and after making each set of ten observations of the photometer, the gas examiner weighs the candles; and if the combustion shall have been more or less per candle than 120 grs. per hour, he shall make and record the calculations requisite to neutralize the effects of the difference.

“The average of each set of ten observations is to be taken as representing the illuminating power of that testing.”

The disc used in the photometer is either the Leeson or the Bunsen disc. The chimneys should be cleaned daily.

The rate of burning of the gas in each burner should be 5 cub. ft. per hour—a rate of consumption which is shown by the long hand of the meter making exactly one revolution per minute for several minutes consecutively.

Instead of weighing the candles, the examiner may observe the time in which 40 grs. are burnt. This should not exceed 10.5 or fall short of 9.5 minutes.

At the time of each testing the examiner observes and records the pressure and temperature of the gas as shown by the barometers attached to the meters, and also the height of the thermometer. The volumes of the gas operated upon during the testings may be corrected from these data (the standard of comparison being, for the barometer 30 in., and for the thermometer 60 deg.) by means of

the Table (*ante*, pp. 366-7). Suppose, for example, the thermometer stands at 54 deg., and the barometer at 30.3 in. : multiply the quantity of gas consumed by the corresponding *tabular number*—the product will be the corrected volume of the gas—*i.e.*, the volume the gas would have occupied when measured over water at the standard temperature and pressure. Thus :—

Volume of gas consumed 5 cub. ft.

Tabular number for barometer and thermometer 1.025.

Then $1.025 \times 5 = 5.125$, the corrected volume.

Instead of thus correcting the volume of gas consumed, the same object may be attained by dividing the observed illuminating power by the tabular number.

The calculations for working out the corrections, etc., for the illuminating power of the gas proceed in the following manner : Add the observations together, and divide the sum by 10 to get the average ; then as two candles are used, multiply by 2, to get the illuminating power of the gas if tried against one candle. Then, as the standard rate of the consumption of the candles (*viz.*, 120 grs.) is to the average number of grains consumed by each per hour, so is the above-obtained number to the actual illuminating power. Finally, the correction for temperature and pressure is made by dividing the illuminating power by the tabular number. For example (taking the tabular number as 1.025)—

Observations—1st minute—	7.8	Consumption of the 2 candles in
2nd „	7.8	10 minutes,
3rd „	8.1	= 41 grains.
4th „	8.2	3
5th „	8.3	—
6th „	8.5	123 = consumption of 1 candle
7th „	8.6	per hour.
8th „	8.4	
9th „	8.3	
10th „	8.6	
	10)82.6	
Average, by 2 candles =	8.26	
	2	
Average, by 1 candle =	16.52	
Consumption by 1 candle	} 123 grains.]	
per hour		
	4956	
	3304	
	1652	
Standard con-		
sumption . . .	120)203196	
Correction for	1025)16933	(16.5 = corrected illum. power in
temp. & pres. .	1025	candles.
	6683	
	6150	
	5330	

The foregoing calculation can be shortened as follows :—

Average, by 2 candles = 8.26
Consumption by 2 candles in ten minutes 41 grains

$$\begin{array}{r} 826 \\ 3304 \\ \hline 2)33866 \end{array}$$

Tabular number 1025)16933(16.5 = corrected illum. power in candles.

$$\begin{array}{r} 1025 \\ 6683 \\ 6150 \\ \hline 5330 \end{array}$$

Rule for Photometer Table on next Page.—Multiply the number standing beneath the number of grains consumed by the candle, and opposite the number of feet consumed by the gas-burner, by the illuminating power as read off from the scale of the photometer; the product is the correct value of the gas reduced to the standard of 120 grs. per hour and 5 cub. ft. per hour.

FOREIGN AND OTHER (PROPOSED) HOME STANDARDS OF LIGHT.

The sperm candle has long been considered an unsatisfactory standard, owing chiefly to the shade of colour emitted by it differing somewhat from that of the gas, and the inequality of its rate of consumption.

Various standards of light have been advocated from time to time to supersede the candle.

The Carcel lamp is the standard in France; the light, equal to 9.6 standard sperm candles, being produced by purified colza (rape) oil, burning at the rate of 648 grs. per hour. The upper portion of this lamp is shown in section in Fig. 199, and the dimensions of its various parts are as follows :—

External diameter of burner	0.9055 inch
Internal diameter of air tube	0.6692 "
External diameter of air tube	1.7912 inches
Total length of chimney	11.4170 "
Length from base to neck of chimney	2.4015 "
External diameter of chimney at level of neck	1.8503 inches.
External diameter of chimney at top	1.3385 "
Mean thickness of the glass	0.0787 inch.

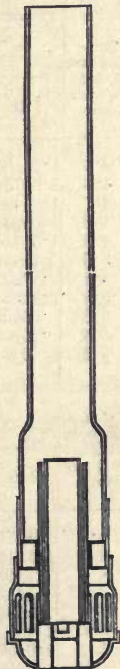


FIG. 199.

PHOTOMETER TABLE.

Calculated for One Candle. (Sugg.)*

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	110	111	112	113	114	115	116	117	118
4.5	1.01851	1.02777	1.03703	1.04629	1.05555	1.06481	1.07407	1.08333	1.09259
4.6	.99637	1.00543	1.01449	1.02355	1.03260	1.04166	1.05072	1.05978	1.06884
4.7	.97517	.98404	.99290	1.00177	1.01063	1.01950	1.02836	1.03723	1.04609
4.8	.95486	.96354	.97222	.98090	.98958	.99826	1.00694	1.01562	1.02430
4.9	.93537	.94387	.95238	.96088	.96938	.97789	.98639	.99489	1.00340
5.0	.91666	.92500	.93333	.94166	.95000	.95833	.96666	.97499	.98333
5.1	.89869	.90686	.91503	.92320	.93137	.93954	.94771	.95588	.96405
5.2	.88141	.88942	.89743	.90544	.91346	.92147	.92948	.93750	.94551
5.3	.86477	.87264	.88050	.88836	.89622	.90408	.91194	.91981	.92767
5.4	.84876	.85648	.86419	.87191	.87962	.88734	.89506	.90277	.91049
5.5	.83333	.84090	.84848	.85606	.86363	.87121	.87878	.88636	.89393

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	119	120	121	122	123	124	125	126	127
4.5	1.10185	1.11111	1.12037	1.12962	1.13888	1.14814	1.15740	1.16666	1.17592
4.6	1.07789	1.08695	1.09601	1.10507	1.11413	1.12318	1.13224	1.14130	1.15036
4.7	1.05496	1.06383	1.07269	1.08156	1.09042	1.09929	1.10815	1.11702	1.12588
4.8	1.03298	1.04166	1.05034	1.05902	1.06770	1.07638	1.08506	1.09375	1.10243
4.9	1.01190	1.02040	1.02891	1.03741	1.04591	1.05442	1.06292	1.07142	1.07993
5.0	.99166	1.00000	1.00833	1.01666	1.02499	1.03333	1.04166	1.04999	1.05832
5.1	.97222	.98039	.98856	.99673	1.00490	1.01307	1.02124	1.02941	1.03758
5.2	.95352	.96153	.96955	.97756	.98557	.99358	1.00160	1.00961	1.01762
5.3	.93553	.94339	.95125	.95911	.96698	.97484	.98270	.99056	.99842
5.4	.91820	.92592	.93364	.94135	.94907	.95679	.96450	.97222	.97993
5.5	.90151	.90909	.91666	.92424	.93181	.93939	.94696	.95454	.96212

Con- sumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	128	129	130	131	132	133	134	135	..
4.5	1.18518	1.19444	1.20370	1.21296	1.22222	1.23148	1.24074	1.25000	..
4.6	1.15942	1.16847	1.17753	1.18659	1.19565	1.20471	1.21376	1.22282	..
4.7	1.13475	1.14361	1.15248	1.16134	1.17021	1.17907	1.18794	1.19680	..
4.8	1.11111	1.11979	1.12847	1.13715	1.14583	1.15451	1.16319	1.17187	..
4.9	1.08843	1.09693	1.10544	1.11394	1.12244	1.13095	1.13945	1.14795	..
5.0	1.06666	1.07500	1.08333	1.09166	1.10000	1.10833	1.11666	1.12500	..
5.1	1.04575	1.05392	1.06209	1.07026	1.07843	1.08660	1.09477	1.10294	..
5.2	1.02564	1.03365	1.04166	1.04967	1.05769	1.06570	1.07371	1.08173	..
5.3	1.00628	1.01415	1.02201	1.02987	1.03773	1.04559	1.05345	1.06132	..
5.4	.98765	.99537	1.00308	1.01080	1.01851	1.02623	1.03395	1.04168	..
5.5	.96969	.97727	.98484	.99242	1.00000	1.00757	1.01515	1.02272	..

* Mr. Sugg also published, in book form, a series of useful photometrical tables from 9.5 to 20 candles.

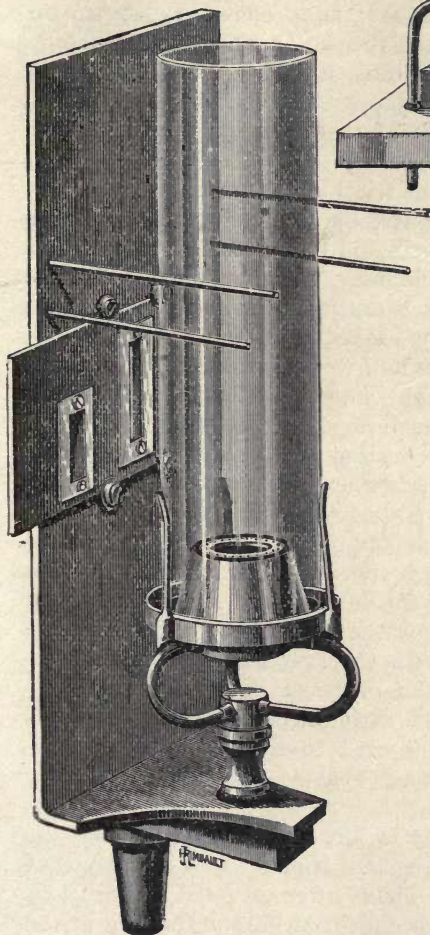


FIG. 200.

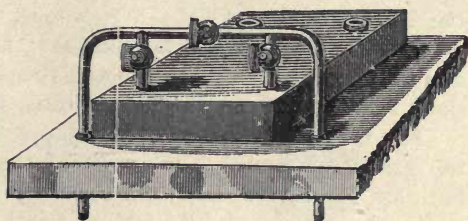


FIG. 201.

The wick used is that known as "lighthouse wick," and the plait is composed of 75 strands; a piece 4 in. long weighing 55.5 grs. When the consumption of oil is less than 586 grs., or exceeds 710 grs. per hour, the trial is cancelled.

The German normal paraffin candle is equal to 1.05 standard sperm candles. It has a diameter of 20 mm., and is made of the purest possible paraffin, with an addition of 2 per cent. of stearine. Its wick is of 24 cotton threads plaited as uniformly as possible.

The Hefner-Alteneck unit equals 0.88 standard sperm candle, being the illuminating power of a freely burning flame, in still, pure air, supplied by a section of solid wick and fed with amylo-

tate; the wick tube being circular and of German silver, measuring 8 mm. internal and 8.3 mm. external diameter, and 25 mm. high; the flame being 40 mm. high, measured

from the edge of the wick tube, at least ten minutes after lighting the lamp.

Mr. Keates invented a moderator lamp consuming sperm oil and yielding a light equal to 10 and 16 sperm candles, with different slots, which he advocated as a suitable standard.

The most ingenious standard proposed is that of a portion of the gas flame itself. The credit of the conception is shared by both Mr. Fiddes and Mr. John Methven.

In the course of his photometrical observations, Mr. Fiddes found that if a circular hole about $\frac{3}{8}$ in. diameter were made at a given height in an opaque chimney, and this placed over an argand flame in lieu of the usual glass chimney, the amount of light passing through the hole was a constant quantity, notwithstanding variations in the illuminating power of the gas.

Mr. Methven's researches led him to a similar conclusion; his later experiments showing that the amount of light (equal to two standard candles) passing through a slot 1 in. long and $\frac{1}{4}$ in. wide, in an opaque screen, is constant with gases ranging from 15 to 20 candles power; and that, when either common or cannel gas is carburetted with gasoline (light petroleum spirit, boiling point below 120° Fahr.), the amount of light yielded by a flame $2\frac{1}{2}$ in. long is constant whatever the illuminating power of the gas employed. As the result of this latter discovery, Mr. Methven uses a shorter and wider slot for the carburetted gas. Fig. 200 shows the Methven standard with the long and short slots combined on the same slide for the ordinary and carburetted gas respectively. Fig. 201 shows the carburettor fitted with by-pass arrangement, so that when connected to the gas supplying the Methven standard, either ordinary gas or carburetted gas may be used.

In the first pentane standard of Mr. A. Vernon Harcourt, the gas employed for producing the light is a mixture of air with that portion of American petroleum which, after repeated rectification, distils at a temperature not exceeding 122° Fahr. Burning at the rate of $\frac{1}{2}$ a cubic foot per hour, this gas gives a flame which yields a light equal to that of the standard candle.

Mr. Harcourt devised a new pentane standard lamp on a different principle to that above referred to, in which, instead of a mixture of pentane and air, pentane only is burned. The lamp, shown in Fig. 202, resembles an ordinary spirit lamp, with the

chimney added to keep the flame steady and raise the temperature of combustion. A wick is employed, not, as in the ordinary lamp at the point of ignition, but several inches from it; its use being to convey the liquid pentane by capillary action to the part of the tube where volatilization of the pentane takes place by the warmth conducted downwards from the flame. The wick is enclosed in a tube jacketed by another tube to produce a steady temperature, and this again is covered by the larger tube with the contracted upper end, as shown. The chimney is movable for adjustment at any required height.

To put the lamp in action, first remove the lower tube, and having warmed the inner tubes, light the pentane vapour, as it rises in the smaller one. Put on the large tube with the chimney attached, and the top of the flame, on raising the wick slightly, will pass into the chimney.

Two narrow slots are cut in the chimney on opposite sides, so that the tip of the flame is visible through either of them. When the chimney is set at a definite height above the lower tube, and the flame is adjusted so that its tip is between the upper and lower limits of the slots, the centre portion of the flame appearing between the lower tube and the chimney gives a definite quantity of light.

The 10-candle pentane Argand was the result of the combined efforts of Mr. A. Vernon Harcourt and Mr. Dibdin, and was recommended to Parliament in 1895 by the Standards of Light Committee, as a trustworthy standard for official use in testing the illuminating power of the gas supplied by the London Gas Companies.

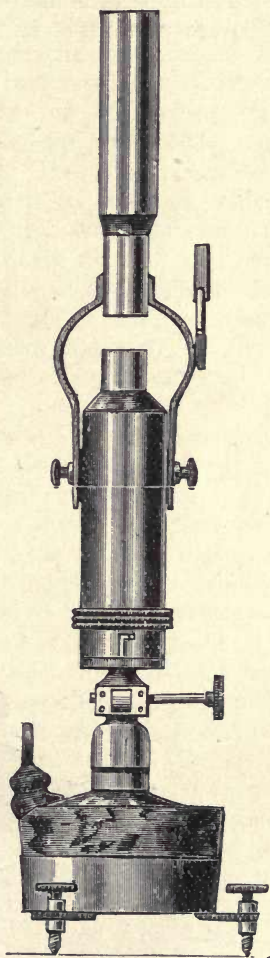


FIG. 202.

A description of Mr. Dibdin's apparatus, Fig. 203, is given in Section IX. of the appendix of the Committee's Report as follows:—

The apparatus used in producing this standard consists of two separate portions—viz., the burner and the carburettor.

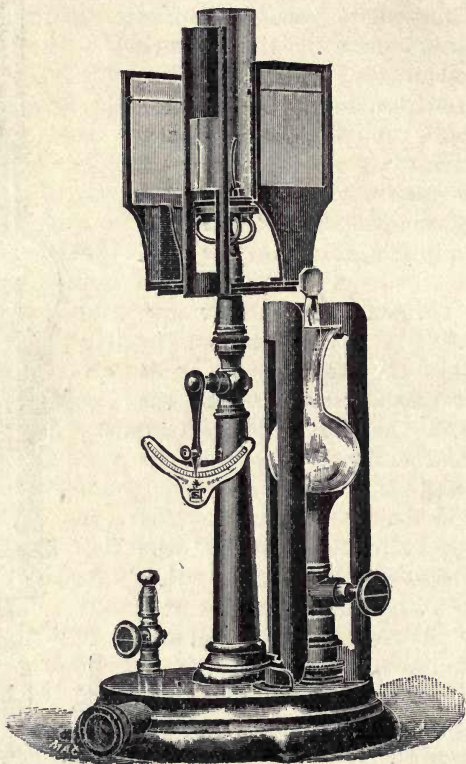


FIG 203.—DIBDIN'S 10-CANDLE PENTANE ARGAND.

Measurements of Burner.

Number of holes	42	
Diameter of holes	0'71 mm.	= 0'028 in.
Inside diameter of seatite	9'90 "	= 0'390 "
Outside diameter of seatite	19'05 "	= 0'750 "
Diameter of inside of metal cone at top	23'62 "	= 0'930 "
Chimney, length	152'40 "	= 6'000 "
" inside diameter	38'10 "	= 1'500 "
Height of cut-off	54'61 "	= 2'150 "

The burner is a specially constructed tricurrent Argand burner, the annular steatite ring being perforated with 42 holes, each hole being 0.71 mm. in diameter. The three air currents are: (1) The central current rising inside the steatite to the inner portion of the flame; (2) a current rising outside the steatite, and caused to impinge upon the flame by an inner metal perforated and incurved cone, the top of which is level with the top of the steatite. (3) An outer current rising on the outside of the above cone, and between that cone and the glass chimney. The inner perforated cone is punctured with ten apertures, 0.25 in. in diameter, which are provided for the purpose of equalizing the two outer currents of air as may be required to suit the height of the flame.

The glass chimney is carried in the groove provided on the outer cone, which answers the purpose of a gallery, the dimensions of the chimney being 6 in. high and 1½ in. inside diameter.

The centre of the flame to be immediately over the terminal of the photometer bar.

The top of the flame should be maintained as nearly as possible at 3 in. above the steatite, this point being indicated by the wires crossing the blue glass screens carried on each side of the burner on the metal supports. The flame is steadied by the small air-directing cone situated centrally beneath the steatite, the apex being 0.03 in. below the metal support carrying the steatite.

On the side of the burner to be presented to the photometer disc, a metal screen 8½ in. in height is placed and screwed securely to the base-plate. The middle portion of this screen is cut away so as to leave above the top of the steatite burner an opening 2.15 in. in height and 1.4 in. in width, the lower portion of this opening being exactly level with the top of the steatite. The light emitted horizontally through this opening by the flame produced by the combustion of the gaseous mixture of atmospheric air and pentane, formed in the carburettor described below, is used as the standard of light. It is equal to the light emitted by 10 parliamentary sperm candles.

The lower portion of the screen has an opening 1 in. wide by 2.3 in. in height, to allow free access of air to the under portion of the burner.

The position of the burner in relation to the photometer disc is to be fixed by the burner fitting gas-tight into a faced joint attached to the photometer at the required point; and the burner is to be

set at such a height that the centre of the illuminated disc and the bottom edge of the cut-off shall be in the same horizontal plane. The length of the connection between the burner and carburettor may be varied, but should not be more than 5 ft. The centre of the flame is to be immediately over the terminal point of the photometer bar.

The carburettor for the 10-candle pentane Argand consists of a circular vessel constructed of tinned plate, 203·2 mm. (8 in.) in diameter and 50·8 mm. (2 in.) in depth, having a spiral division 25·4 mm. (1 in.) in width. This division is made by soldering a strip of metal, 4 ft. 6 in. in length and 2 in. wide, gas-tight, to the under side of the top of the carburettor; so that when the top is fixed on, the bottom of the strip comes close to the bottom of the vessel, and is sealed by the pentane; thus the air has to pass over pentane for a distance of about 4 ft. 6 in. and becomes thoroughly saturated. At the end of the spiral division, near the side of the carburettor, a bird fountain is fixed for charging the carburettor, and keeping it charged at a constant level with liquid pentane. The lower end of the liquid fountain tube is closed, and rests upon the bottom of the tank. Through the side of the tube, which is 0·4 in. (10·1 mm.) in diameter, 16 holes, 1 mm. in diameter, are bored close to the bottom, and through these the pentane enters the carburettor. At the inside of the inlet tube, 1 in. from the lower end, a small tube, 3 mm. in diameter and 20 mm. in length, is connected thereto and turned upwards. The fountain inlet tube is carried up through the top of the carburettor, and continued in the form of a bulb having a capacity of about 200 c.c. Stopcocks are provided at the top and bottom of the bulb, for convenience in filling with pentane; and the portion above the upper stopcock is opened out in a funnel shape for the same purpose. When the carburettor is being charged, the gas must be extinguished to avoid the risk of the vapour firing and causing an explosion.

The inlet for gas or air is at the side of the carburettor and at the terminal of the spiral division, the outlet being placed in the centre of the vessel so that the air or gas may travel over the liquid pentane throughout the whole length of the spiral division, and thus become fully charged with the volatile vapour of the pentane.

When using this standard the pentane must be visible in the fountain bulb.

JET PHOTOMETERS.

The three following instruments, which are each employed to determine the illuminating value of gas, though only approximately correct in their indications, are yet sufficiently trustworthy to render them useful auxiliaries to the more absolute methods of testing already described.

Their action depends on the relation which the specific gravity of the coal gas bears to its illuminating power. The flame being kept at a given height, the pressure required, and therefore the rate of consumption, will vary according to the density of the gas and its consequent illuminating value.

These instruments are not of use when there is a mixture of water gas—blue or carburetted.

The Jet Photometer.

Lowe's jet photometer, as improved by Sugg & Kirkham (Fig. 204), affords a ready means of ascertaining, by a momentary inspection, whether the gas being produced is uniform in quality. The apparatus consists of a King's gauge of delicate construction, with its semi-circular scale indicating the pressure. A steatite jet having a fine orifice is fixed at the top of this, and the gas issuing therefrom, and being lighted, gives a flame which should be constantly maintained at 7 in.

The scale shown in Fig. 205 is for gas of 14 to 19 candles illuminating power. The same scale is used for 20, 25, or 30 candle gas, but with a different jet and a lesser consumption per hour, the gauge pointing to the place where the figure 16 stands, but with the number changed to 20, 25, or 30, conforming to the standard

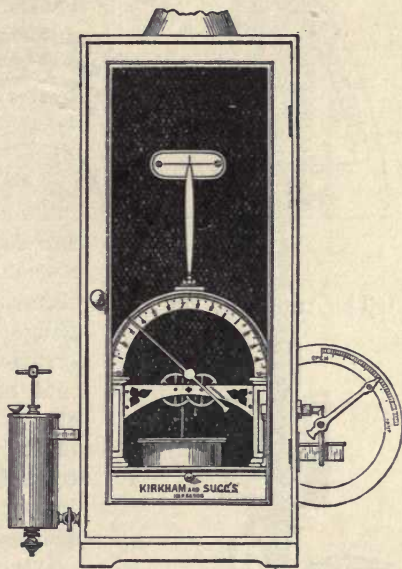


FIG. 204.

quality of the gas that has to be supplied according to the Special Act of Parliament.

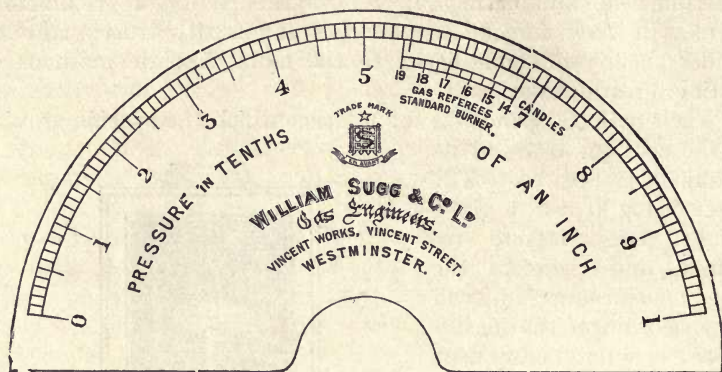


FIG. 205.

The range of the jet is necessarily short. It is correct at the gauge point, but with a slightly increasing error on the numbers above and below—the error being against the gas in going up, and in favour of it in going down. This is due to variations in the pressure—increasing or diminishing—at the point of ignition. Within the degrees marked on the scale, however, this error is not important.

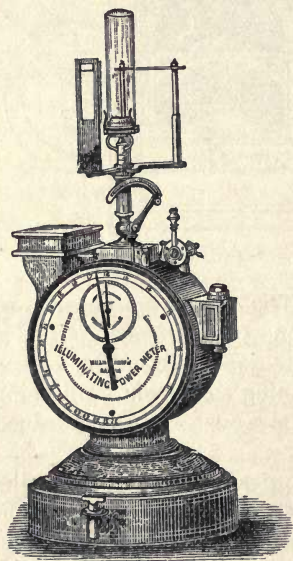
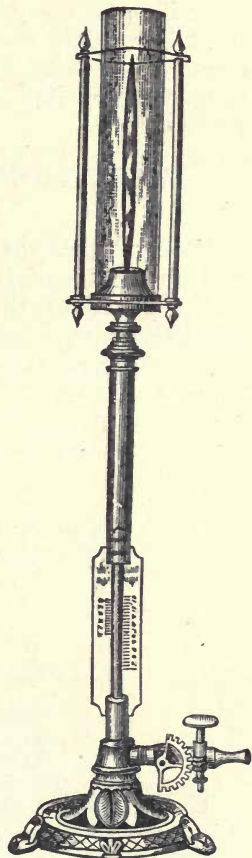


FIG. 206.

The gas tap is shown on the right side of the instrument. The small cylinder on the left side is in communication with the water cistern in the body of the gauge, and contains a compensator, which, on being screwed up or down as required, adjusts the water-line, so that the pointer of the gauge stands at zero when the gas tap is closed.

Sugg's Illuminating Power Meter.

This instrument is shown in Fig. 206, and, as the name indicates, is used for ascertaining the illuminating power of gas. The mode of putting it in operation is as follows: Having filled it up to the water-line scratched on the glass in the small box on the right side, connect it to the gas supply with a piece of metal tube. The inlet is a ground union joint, fixed in the centre of the back of the instrument. Turn the lever so as to make the gas pass through the measuring drum, and let it get rid of all the air, or other kind of gas in it. Light the burner and adjust the flame to 3 in. in height. Then, when the large hand arrives at 16, change the position of the lever, so as to make the gas pass to the burner without going through the measuring drum. The large hand will then stop at 16. Wind up the clock by means of the *remontoir* on the top of the meter just in the rear of the dial ring. Start the clock by moving the slide which is on the left of the meter, close to the governor. Then, when the hand of the clock is passing any one of the divisions of the minute, change the position of the lever of the by-pass, so as to make the gas pass through the meter. When the hand has made one complete revolution, stop the meter by means of the lever, in the manner before described, and read off the illuminating power. The minute clock should not be stopped either before or after the observation, unless it is desired to put the clock entirely at rest.



[FIG. 207.

Thorp and Tasker's Jet Photometer.

This is an ingenious and handy instrument (Fig. 207) for enabling the illuminating value of the gas to be ascertained from inspection

at any time and place. It is well understood that the quantity of gas passed in a given time will bear a proportion to the size of the orifice; and further, that the gas flame being maintained at a given height, the quantity of gas consumed, and the pressure, will vary as the illuminating power. A movable or floating disc inside the glass tube regulates the size of the orifice, and its position in the tube, corresponding to the graduations of the scale at the side, indicates the illuminating value.

VARIATIONS IN THE ILLUMINATING POWER OF GAS.

Most gas managers, in the course of their experience, must have observed variations, sometimes considerable, in the illuminating power of their gas, for which they have been unable satisfactorily to account. These variations are unquestionably due, to a great extent, to changes of atmospheric pressure. When the pressure is augmented, the luminosity is increased, and *vice versa*. To determine this point, Dr. Frankland instituted a series of important experiments, of which the following are the results:—

Pressure of Air in Inches of Mercury.	Observed Illuminating Power.
30·2	100·0
28·2	91·4
26·2	80·6
24·2	73·0
22·2	61·4
20·2	47·8
18·2	37·4
16·2	29·4
14·2	19·8
12·2	12·5
10·2	3·6

The diminution of luminosity follows a fixed and definite law, which may be thus expressed: the decrease in illuminating power is directly proportional to the decrease of atmospheric pressure. Of 100 units of light emitted by a gas flame burning in air, 5·1 units are extinguished by each reduction of 1 mercurial inch of atmospheric pressure. On the other hand, if a lightless flame be made to burn under augmented pressure, it becomes luminous. The chief cause of the difference is the increase in the volume, and therefore decrease of the density, of those heavy hydrocarbons

to which the luminosity of a gas flame is attributed when the atmospheric pressure is reduced, and *vice versa*.

TABLE

Showing the Percentage of Loss of Light by Mixing Air with Coal Gas.

Per Cent. Air.	Loss of Light. Per Cent.	Per Cent. Air.	Loss of Light. Per Cent.
1	6	8	58
2	11	9	64
3	18	10	67
4	26	15	80
5	33	20	93
6	44	30	98
7	53	40	100

TABLE

Comparing (approximately) the Specific Gravity of Gas (Air being 1·000) with the Illuminating Power in Standard Sperm Candles.

No. of Candles.	Spec. Grav.	No. of Candles.	Spec. Grav.	No. of Candles.	Spec. Grav.
10 equal to about	0·380	20 equal to about	0·508	30 equal to about	0·678
11	0·392	21	0·522	31	0·694
12	0·405	22	0·537	32	0·708
13	0·416	23	0·550	33	0·722
14	0·430	24	0·565	34	0·738
15	0·443	25	0·585	35	0·755
16	0·455	26	0·605	36	0·775
17	0·468	27	0·625	37	0·790
18	0·482	28	0·645		
19	0·495	29	0·662		

THE SPECIFIC GRAVITY OF GAS.

Specific Gravity a Test of Quality.

If coal gas is free from carbon dioxide, sulphuretted hydrogen, and air, specific gravity is a proper test of quality; the denser it is, the greater will be its illuminating power—increase in weight and light-giving property being due to the presence of a larger proportion of olefiant gas (ethylene) and the other richer and heavier hydrocarbons.

Ordinary Method of Determining the Specific Gravity.

The apparatus required in determining the specific gravity of gas are a thin glass globe of about 100 cub. in. capacity, with two

stopcocks on opposite sides, a good air-pump, and a very delicate balance. The experimental room should also be furnished with a barometer, showing the atmospheric pressure, and thermometers indicating the temperature both of the air and gas. The method of manipulation is as follows:—

First.—Open the two stopcocks; the globe will then be full of air at the atmospheric pressure and temperature. Carefully weigh the globe while in this state, and make a note of the weight.

Second.—Attach the globe by one of the stopcocks to the air-pump, close the other stopcock, and exhaust it as perfectly as possible. Having closed the stopcock, remove the globe and weigh it in its exhausted state. Suppose that it now weighs 31·5 grains less than before, then these 31·5 grains represent the weight of the air abstracted.

Third.—Now attach the globe either to an experimental gas-holder or to a gas-pillar connected by a pipe to the main, and fill the globe with the gas. When full, remove it and weigh it a third time. Suppose that the weight is now 14·2 grains more than when in its exhausted state, then these 14·2 grains represent the weight of the contained gas. Then, as 31·5 (the weight of the air) is to 14·2 (the weight of the gas), so is 1·000 (the specific gravity of the air) to the specific gravity of the gas. Or divide the weight of the gas by the weight of the air, and the quotient is the specific gravity of the gas; thus:—

$$\frac{14\cdot2}{31\cdot5} = 0\cdot450, \text{ specific gravity of the gas compared with air as unity, or } 1\cdot000.$$

Dr. Letheby's Method of Determining the Specific Gravity.

With Dr. Letheby's apparatus (Fig. 208) the use of the air-pump is dispensed with. It consists of a similar glass globe about 6 in. in diam., furnished with two stopcocks, to one of which is attached a glass tube $\frac{1}{2}$ an inch in diam. and 7 in. long, fitted with a jet for burning the gas, and having a thermometer inside of the tube to indicate the temperature. The other stopcock can be attached by a suitable nozzle to a gas-pillar, and in practice the gas is kept flowing through the apparatus, being consumed from the jet at the upper end. The exact weight of the globe when full of air at mean temperature and pressure is engraved upon it; and a counter-

poise weight is provided, exactly equal to the weight of the globe when exhausted.

When it is required to determine the specific gravity of the gas, the lower or supply-cock is first closed, and the upper one immediately afterwards. This order is necessary to be observed in the shutting of the cocks, because if the upper one were first closed, the gas within the globe would be at the pressure of the gas within the main, instead of that of the atmosphere. The globe is then placed in the balance and a sufficient number of grains and fractional parts added to the pan containing the counterpoise weight to equalize the beam. Suppose that it takes 15 grs., then these represent the weight of the gas, and say that the globe full of air weighs 35 grs., then—

$$\frac{15}{35} = 0.429, \text{ the specific gravity of the gas.}$$

But it is necessary in making such observations to correct the volume of gas to mean temperature and pressure, and to allow for the moisture present in all aëriiform bodies in contact with water. To these points the observations which follow apply.



FIG. 208.

CORRECTIONS FOR TEMPERATURE, BAROMETRIC PRESSURE, AND MOISTURE.

Owing to the contraction and expansion which takes place in the bulk of all aëriiform bodies, due to the variations in atmospheric temperature and pressure, it is necessary, when estimating and comparing their volume, to adopt one common temperature and barometric pressure as the standard. The mean temperature and pressure of 60° Fahr. and 30 in. of mercury have been adopted as the most convenient, and to this standard their volume is accordingly reduced. For example:—

Correction for Temperature.—All aëriiform bodies expand 1.4914 part of their volume at 32° Fahr. for every degree of increase of temperature (1.273 of the volume of the gas at 0° Centigrade for each degree of the same scale). Now suppose it is required to ascertain what volume 1000 cub. ft. of gas at 68° will

occupy at 60° the mean temperature. We know by the above-mentioned law that a quantity of gas which at 32° is 491·4 parts, will at 60° become 519·4 (60-32 = 28 + 491·4 = 519·4) and at 68°, 527·4 (68-32 = 36 + 491·4 = 527·4), then—

$$\frac{1000 \times 519\cdot4}{527\cdot4} = 984\cdot83 \text{ cub. ft.}$$

Or again, if it is required to know the volume which 1000 cub. ft. of gas at 56° will occupy at 60°, then—

$$\frac{1000 \times 519\cdot4}{515\cdot4} = 1007\cdot76 \text{ cub. ft.}$$

Correction for Pressure.—The amount of decrease or increase in volume is inversely as the pressure. To ascertain what volume 1000 cub. ft. of gas at 28·5 in. will occupy when the mercury stands at 30 in., the mean barometric pressure, then—

$$\frac{1000 \times 28\cdot5}{30} = 950 \text{ cub. ft.}$$

Or again, if it is desired to ascertain the volume which 1000 cub. ft. of gas at 30·6 in. will occupy at 30 in., then—

$$\frac{1000 \times 30\cdot6}{30} = 1020 \text{ cub. ft.}$$

Or,

Correcting at Once for Temperature and Pressure.—Suppose it is required to ascertain what volume 1000 cub. ft. of gas at 72° temperature and 29·8 in. pressure will occupy at standard temperature and pressure, then—

$$1000 \times \frac{519\cdot4}{531\cdot4} \times \frac{29\cdot8}{30} = 970\cdot90 \text{ cub. ft.}$$

Correction for Moisture.—It has been proved by experiment that 1 cub. in. of permanent aqueous vapour at the mean temperature of 60° and the mean pressure of 30 in. weighs 0·1929 grs.; and the following Table, founded on the researches of Dalton & Ure, and given by Faraday in his "Chemical Manipulation," shows the proportion by volume of aqueous vapour existing in any gas standing over or in contact with water, at the different temperatures indicated, and at a mean barometric pressure of 30 in.

Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.	Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.	Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.
40	0'00933	54	0'01533	68	0'02406
41	0'00973	55	0'01586	69	0'02483
42	0'01013	56	0'01640	70	0'02566
43	0'01053	57	0'01693	71	0'02653
44	0'01093	58	0'01753	72	0'02740
45	0'01133	59	0'01810	73	0'02830
46	0'01173	60	0'01866	74	0'02923
47	0'01213	61	0'01923	75	0'03020
48	0'01253	62	0'01980	76	0'03120
49	0'01293	63	0'02060	77	0'03220
50	0'01333	64	0'02120	78	0'03323
51	0'01380	65	0'02190	79	0'03423
52	0'01426	66	0'02260	80	0'03533
53	0'01480	67	0'02330		

To determine by means of this Table the quantity of aqueous vapour present, it is necessary to multiply the volume of the gas by the tabular number corresponding to the temperature, thus: Suppose 100 cub. in. of gas weigh 16 grs. at the temperature of 72°, and at mean barometric pressure, then, according to the Table, the volume of aqueous vapour present is—

$$100 \times 0'02740 = 2'74 \text{ cub. in.}$$

This corrected to mean temperature will be—

$$2'74 \times \frac{49'4 + 28}{49'4 + 40} = 2'678 \text{ cub. in.}$$

Now, with respect to the volume of the gas, 100 cub. in. at 72° are equal to—

$$100 \times \frac{49'4 + 28}{49'4 + 40} = 97'7 \text{ cub. in. at a temperature of } 60'.$$

Hence 97'7—2'678 = 95'022 cub. in., the volume of dry gas at mean temperature and pressure.

To arrive at the weight of the volume of dry gas, the volume of aqueous vapour must be multiplied by 0'1929 grs., the weight of a cubic inch of permanent aqueous vapour, as before stated, and the product deducted from the total weight of 16 grs. ; thus:—

$$16 - (2'678 \times 0'1929) = 15'483 \text{ grs.}$$

Then for the weight for 100 cub. in. of dry gas we have—

$$\frac{15'483 \times 100}{95'022} = 16'293 \text{ grs.}$$

And as 100 cub. in. of air at mean temperature and pressure weigh 31 grs., we have—

$$\frac{16.293}{31} = 0.525, \text{ as the specific gravity of the gas.}$$

If, instead of making the correction for moisture, it is preferred to dry the gas as it passes into the globe, this may be done by causing it to flow through a glass tube, $\frac{1}{2}$ an inch in diameter and about 18 to 20 in. long, containing pieces of dry calcium chloride; that substance having a strong affinity for moisture. Before using, the calcium chloride should be fused in an earthenware crucible at a low temperature, then poured on a clean stone surface, and, as soon as cold, broken in pieces and put in the tube. The gas in passing through the tube to fill the globe should be made to travel slowly, about 15 minutes being the usual time allowed.

Wright's Method of Determining the Specific Gravity.

For ascertaining the specific gravity of gas, Mr. Wright used a light balloon (Fig. 209), capable of containing 1 cub. ft. or 1728 cub. in.

His directions for performing the experiment are as follows:—

Expel the air from the balloon by folding it in the form in which it is first received, ascertain the weight of the balloon and car, fill the balloon with gas, insert the stopper, and put as many grains¹ in the car as will balance it in the air; add the number of grains which it carries to the weight of the balloon, and deduct the amount from the tabular number corresponding to the degree of temperature indicated by the thermometer, and the pressure indicated by the barometer (pp. 366, 367); divide the result by the tabular number due to the temperature and pressure of the gas (to ascertain which allow the gas to blow upon the bulb of the thermometer until the mercury is stationary), and the first three figures are the specific gravity.



FIG. 209.

¹ The weights used are not troy grains, 100 of them being equal to 53.56 troy grains; they are each equal to 1.728 cub. in. of air, when the barometer is at 30 in. and the thermometer at 60°.

EXAMPLE I.

Temperature of the air 70° }
 Barometer 28.5 in. } Tabular number, 924.
 Temperature of the gas 56° }
 Barometer (always the same as air) 28.5 in. } Tabular number, 959.

Weight of the balloon and grains in car, 560.

Then— $\frac{924 - 560}{959} = 0.379$, the specific gravity.

EXAMPLE II.

Temperature of the air 40° }
 Barometer 30.5 in. } Tabular number, 1067.
 Temperature of the gas 62° }
 Barometer (always the same as air) 30.5 in. } Tabular number, 1012.

Weight of balloon and grains in car, 560.

Then— $\frac{1067 - 560}{1012} = 0.501$, the specific gravity.

Lux's Specific Gravity Apparatus.

The gas balance, shown in Fig. 210, for determining the specific gravity of illuminating gas, is the invention of Mr. Frederick Lux.

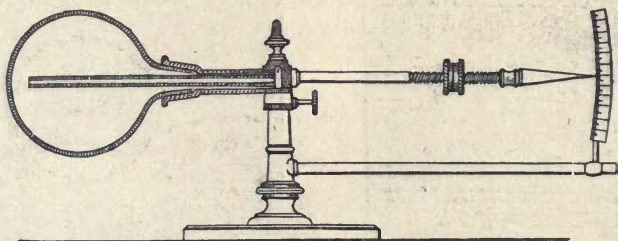


FIG. 210.

It is constructed on the principle of the common lever balance, with a curved scale attached by means of a coupling rod to the standard. The scale is graduated from 0 to 1, and the tongue or pointer moving in close proximity thereto enables the operator to take a direct reading of the specific gravity of the gas under examination.

Instead of consuming the gas through the vertical tube, a pipe can be arranged to convey the gas to the photometer for the purpose of testing its illuminating power.

THE GRAVITOMETER.

But the latest method of determining the specific gravity is by means of the Gravimeter of Simmance and Abady.

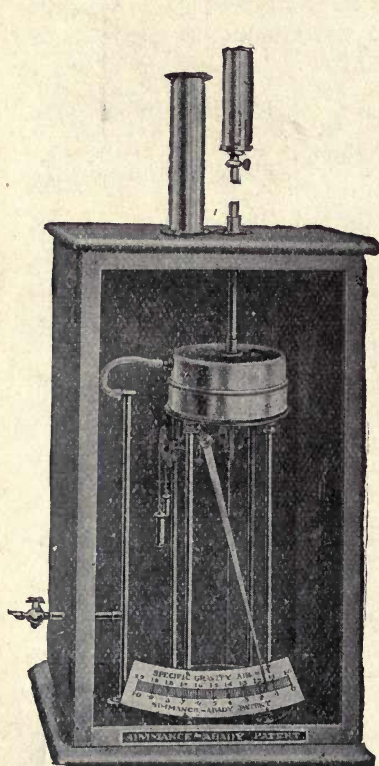


FIG. 211.

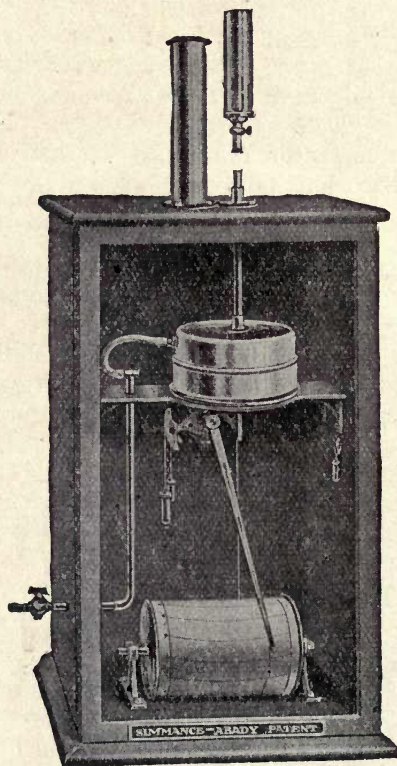


FIG. 212.

This instrument is made in two forms (Figs. 211 and 212). In the former the specific gravity is continuously indicated on a dial, and in the latter it is continuously recorded on a chart.

The principle of the instruments consists in passing the gas continuously over the crown of a suspended bell and thence up a vertical tube. If air is passed, the weight of the ascending stream above the crown of the bell is equal to the weight of air beneath it, and the pointer remains at zero. Gas being lighter than air, the weight of the ascending stream above the crown of the bell is lighter than the weight of air beneath it, and the bell rises in exact proportion to the gravity while the pointer moves over the scale and stops when equilibrium is reached, indicating the specific gravity of the gas.

To find the Weight in Pounds of any Quantity of Gas at 60° Fahr. and 30 in. Bar., the Specific Gravity being known.

RULE.—Multiply the quantity in feet by the specific gravity and the product by 0·07497 (weight of a cubic foot of air), and the answer will be the weight of gas in lbs. avoirdupois.

EXAMPLE.—What is the weight of 9400 cub. ft. of gas, its specific gravity being 0·480?

$$9400 \times 0\cdot480 \times 0\cdot07497 = 338\cdot26 \text{ lbs. of gas.}$$

TABLE.

WEIGHT OF 1000 CUBIC FEET OF COAL GAS OF DIFFERENT SPECIFIC GRAVITIES AT 60° FAHR. AND 30 INCHES BAR., SATURATED WITH MOISTURE.

Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.	Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.	Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.
·380	28·489	·470	35·235	·560	41·983
·385	28·863	·475	35·610	·565	42·358
·390	29·238	·480	35·985	·570	42·732
·395	29·613	·485	36·360	·575	43·107
·400	29·988	·490	36·735	·580	43·482
·405	30·363	·495	37·110	·585	43·857
·410	30·738	·500	37·485	·590	44·232
·415	31·113	·505	37·860	·595	44·607
·420	31·487	·510	38·235	·600	44·982
·425	31·862	·515	38·610	·605	45·357
·430	32·237	·520	38·984	·610	45·732
·435	32·612	·525	39·359	·615	46·107
·440	32·987	·530	39·734	·620	46·481
·445	33·362	·535	40·109	·625	46·856
·450	33·737	·540	40·484	·630	47·231
·455	34·111	·545	40·859	·635	47·606
·460	34·486	·550	41·234	·640	47·981
·465	34·861	·555	41·608	·645	48·356

CALORIMETRY.

The calorific or heating value of coal gas is destined to be a controlling factor in the manufacture of gas.

At the present time gas is employed for purposes in which calorific value is of greater importance than illuminating power, and although the one has a relation to the other within a certain range, the calorific value of coal gas is dependent on its composition.

TABLE OF VARIOUS GASES.

THEIR DENSITY, SPECIFIC GRAVITY, AND WEIGHT,
DRY AND SATURATED WITH MOISTURE,
AT THE STANDARD BAROMETRIC PRESSURE OF 30 INCHES.

Name.	Symbol.	Density.	Specific Gravity, Air equal 1·000.	Weight of 1 Cubic Foot in Grains.		Cubic Feet equal to lb. av'rdupois.	
				At 32° F. Dry.	At 60° F. Saturated.	At 32° F. Dry.	At 60° F. Satrd.
Hydrogen	H	1·000	·0693	39·15	36·39	173·80	192·86
Light Carburetted Hydrogen	CH ₄	7·985	·554	312·61	290·57	22·39	24·09
Ammonia	NH ₃	8·510	·590	333·17	309·68	21·01	22·60
Acetylene	C ₂ H ₂	12·970	·899	507·58	471·99	13·79	14·83
Carbon Monoxide	CO	13·965	·968	546·73	508·19	12·80	13·77
Olefiant Gas	C ₂ H ₄	13·970	·969	546·93	508·37	12·80	13·77
Nitrogen	N	14·020	·9721	548·88	510·19	12·75	13·72
Air		14·422	1·000	564·62	524·82	12·40	13·84
Nitric Oxide	NO	14·990	1·039	586·86	545·49	11·93	12·83
Oxygen	O	15·960	1·1066	624·83	580·78	11·20	12·05
Sulphuretted Hydrogen	H ₂ S	16·990	1·178	665·16	618·27	10·52	11·32
Carbon Dioxide	CO ₂	21·945	1·522	859·15	798·58	8·15	8·76
Nitrous Oxide	N ₂ O	22·000	1·525	861·30	800·58	8·13	8·74
Sulphur Dioxide	SO ₂	31·950	2·257	1,250·84	1,162·66	5·59	6·02
Chlorine	Cl	35·370	2·452	1,384·74	1,287·11	5·06	5·44
Carbon Bisulphide	CS ₂	37·965	2·632	1,486·33	1,381·55	4·71	5·07

There are many types of calorimeters suitable for the purpose of ascertaining the heating value of gas, amongst which are the Junkers, Simmance-Abady, and Boys (described in the Notification of the Gas Referees, page 373).

In all the types of calorimeters (with the exception of the "recording") the gross value of the gas is first determined—that is to say, the total quantity of heat which the gas is capable of generating per cubic foot, including the heat derived from the conversion of the steam produced in the calorimeter into water.

To determine the net value, a deduction of 0·6 of a calorie is made for every cubic centimetre of water condensed.

The difference, therefore, between the gross and net values is the latent heat of the steam.

In an ordinary gas fire, gas engine, and other heating and power apparatus, it is not practically possible to condense the products of combustion, hence they pass away hot, and the net value only of the gas is developed.

The test for calorific value is obviously useful not only to gas authorities but also to consumers of gas for power purposes.

The following is a method of making a test with the Junkers calorimeter.

After making all the water connections and lighting the burner, allow the water to pass until there is a difference of about 20° between the inlet and outlet temperatures.

Any convenient fraction of a cub. ft. of gas may be taken, or any specific quantity of water may be passed.

In the former case, we will assume one-twelfth of a cubic foot.

When ready to make the test, note the meter and turn the water passing from the outlet of the calorimeter into a graduated measuring chamber, at the same time noting the inlet and outlet temperatures as indicated by the thermometers.

Take ten readings of the outlet temperature, and as soon as the one-twelfth cubic foot of gas has been consumed, turn the water supply off from the measuring chamber.

The average of the ten readings of the outlet temperature is taken, and from this is deducted the inlet temperature, the difference multiplied by the volume of water in litres equals the gross calorific value per one-twelfth cubic foot, and this multiplied by twelve equals the gross value per cubic foot.

A typical example of the calculation is as follows :—

Assuming the inlet temperature to be 14° Cent., the average of the ten outlet readings 35·5 Cent. and the volume of water 631 c.c., all at N.T.P. then :—

$$35\cdot5 - 14 = 21\cdot5$$

$$21\cdot5 \times 631 \times 12 \div 1000 = 162\cdot79 \text{ calories per cubic foot.}$$

The condensed products are now collected during the consumption of one cubic foot of gas.

Assuming these to be 27 c.c., multiplied by 0·6 = 16·2 calories,

this must be deducted from the gross value of 162·79, leaving 146·59 as the net value of the gas.

To convert calories to B.Th.U.'s multiply by 3·97.

The recording calorimeter (Beasley's patent) was the first designed to give a continuous record of the heating value of a gaseous fuel.

The gas is first automatically controlled by a governing apparatus, and is then burned within a well-radiated chimney, which constitutes the body of the calorimeter.

The working of the calorimeter depends upon the fact that the average rise in temperature of this chimney is directly proportional to the heat developed by the flame. The chimney contains an annular chamber, which forms one limb of a U-tube, the other being a simple tube maintained at atmospheric pressure, and both terminating in tanks. The U-tube is filled with oil having a large coefficient of expansion, and by the aid of floats and pulleys the differences in level of the two limbs, caused by the expansion of the oil, operates a lever carrying a marker which records the net value of the gas upon a moving band of paper.

The calorimeter is also made with recording mechanism, the value being indicated by means of a pointer and scale.

A simple and compact apparatus is the Simmance & Abady Calorgraph.

The Calorgraph (or recording calorimeter) has practically no moving parts, and consists simply of a pressure governor, a burner, and a differential recording thermometer, which latter actuates a four-bar mechanism carrying a pen which inscribes the net values per cubic foot on a disc chart.

The instrument is made with two charts covering two ranges of net B.Th.U.'s. One from 0 to 300, and the other from 300 to 600 B.Th.U.'s.

THE ENRICHMENT OF COAL GAS.

When a higher illuminating power than that yielded by the gas produced from ordinary bituminous coal is desired, some method of enrichment is resorted to, although in these days of incandescent lighting there is less need of enrichment than formerly.

There is just this to be considered ; whether it is not economical

to have large makes of gas of low quality per ton of coal and to bring up the illuminating value by enrichment.

It may be said that the enriching medium is apt to be deposited soon after leaving the works. That is so with semi-saturated gases, but low quality gas has a greater retaining power.

Cannel was formerly the only medium employed for this purpose, and it is the best and simplest, inasmuch as the gas from it is a more regular and durable enricher than any other, and does not require any special and separate apparatus for its production; but of recent years other methods of enrichment by means of oil of different kinds have been introduced, owing to their being less costly.

It does not follow, however, that cannel is or will be entirely abandoned for enrichment purposes; all depends upon the price.

Gas enrichment is of less pressing concern to-day than it was at one time, because the principles of economical lighting are now better understood and more widely applied, resulting in the introduction of improved burners and the better regulation of the pressure at or near to the point of consumption.

The incandescent gaslight, also, has shown how a vastly increased illuminating power may be obtained without resorting to enrichment, with, at the same time, a striking economy in gas consumption.

The chief advantage derived from enrichment is the assistance it lends towards preventing the deposition of naphthalene, the richer gas tending to keep this hydrocarbon suspended within it in the gaseous form.

The following is a résumé of the various enriching methods employed:—

The Peebles Process consists in cracking or decomposing oil in iron retorts at a temperature of 1750° Fahr., and washing the resultant gas by the fresh oil, which is afterwards decomposed in a similar manner. Blue oil, having a specific gravity of 0.85, is generally used. Its illuminating value as an enriching agent is about 90 candles per 5 cub. ft. of the gas. The yield of coke is 5½ cwt. to the ton.

The Maxim Patent Carburettor.—This carburettor, which is largely in use, consists of an evaporator in the form of a multitubular boiler, an injector, and a steam pump. The steam pump is used for pumping the enriching material from an

underground storage tank into the evaporator, where it is vaporized under sufficient pressure (say, from 25 to 30 lbs.) to ensure a proper blend with the coal gas in the injector.

The injector draws a portion of the coal gas from the main and mixes it with the enriched gas from the evaporator, and then returns it to the main again. It will be seen that by this means it is only necessary to take from the main the small proportion of gas that is required.

The enriching material used may be either 90 per cent. benzol, or a light petroleum spirit having a total evaporating point not exceeding 260° Fahr.

One gallon of good 90 per cent. benzol will enrich 20,000 cubic feet of gas one candle, and one gallon of petroleum spirit will enrich 8000 cubic feet of gas one candle.

The Whessoe-Munich Method of enrichment is by means of benzol. This is volatilized in a vessel heated by steam, and fitted with ribbed trays covered with cloth, on to which the benzol drops. It is claimed as one of the advantages of this system (like the foregoing), that it is only necessary to pass a portion of the coal gas through the carburettor, and that such portion, being enriched, acts as an enricher for the rest. The quantity of benzol required to enrich 1000 cub. ft. of gas one candle is 3 oz.

The Dvorkovitz System enriches by means of solar distillate oil, specific gravity 0.886. This is cracked or decomposed in iron retorts heated to a bright red, and the gas so produced, mixing in the proportion of 3 per cent. with ordinary coal gas of 15 to 16 candles value, raises the illuminating power about $1\frac{1}{2}$ to 2 candles. The inventor claims a high value for the residual tar and oil.

PUBLIC ILLUMINATIONS.

In provincial towns the gas manager is usually called upon to arrange and superintend the illuminations that are given to celebrate any great national or local event. On such occasions the following particulars will be found useful:—

Mode of Supply and Price of Gas.—Illumination devices are generally supplied with gas direct from the main, without the interposition of a meter to register the consumption. Where the illuminations are anything like universal, the fixing of meters is altogether impracticable.

Taking the consumption of each jet¹ to be at the rate of one cubic foot of gas per hour, which is a fair average, including loss by leakage and trial lighting, the following will be the rate of charge according to the price per 1000 cubic ft. :—

At per 1000.				At per 1000.			
s.	d.			s.	d.		
6	6	0'078	of rd. per jet ¹ per hour.	4	2	0'050	of rd. per jet ¹ per hour.
6	5	0'077	" " "	4	1	0'049	" " "
6	4	0'076	" " "	4	0	0'048	" " "
6	3	0'075	" " "	3	11	0'047	" " "
6	2	0'074	" " "	3	10	0'046	" " "
6	1	0'073	" " "	3	9	0'045	" " "
6	0	0'072	" " "	3	8	0'044	" " "
5	11	0'071	" " "	3	7	0'043	" " "
5	10	0'070	" " "	3	6	0'042	" " "
5	9	0'069	" " "	3	5	0'041	" " "
5	8	0'068	" " "	3	4	0'040	" " "
5	7	0'067	" " "	3	3	0'039	" " "
5	6	0'066	" " "	3	2	0'038	" " "
5	5	0'065	" " "	3	1	0'037	" " "
5	4	0'064	" " "	3	0	0'036	" " "
5	3	0'063	" " "	2	11	0'035	" " "
5	2	0'062	" " "	2	10	0'034	" " "
5	1	0'061	" " "	2	9	0'033	" " "
5	0	0'060	" " "	2	8	0'032	" " "
4	11	0'059	" " "	2	7	0'031	" " "
4	10	0'058	" " "	2	6	0'030	" " "
4	9	0'057	" " "	2	5	0'029	" " "
4	8	0'056	" " "	2	4	0'028	" " "
4	7	0'055	" " "	2	3	0'027	" " "
4	6	0'054	" " "	2	2	0'026	" " "
4	5	0'053	" " "	2	1	0'025	" " "
4	4	0'052	" " "	2	0	0'024	" " "
4	3	0'051	" " "	1	10	0'022	" " "

When the ordinary No. 1, 2, and 3 fish-tail burners are employed, the consumption may be reckoned at the rate of 3, 4, and 5 cub ft. per hour each respectively, and charged accordingly.

It is proper to stipulate that no illumination should amount to less than 50s.

Service or Supply Pipes.—It is the usual rule for the gas authorities to convey at their own cost a service pipe from the main, and from 8 to 12 ft. up the front of the building to be illuminated, provided the whole length of pipe required does not exceed 36 ft. A charge is made for any additional length.

¹ By the term "jet," as here used, is meant the small gas flame at each hole drilled or punched in the pipes forming the different devices.

The expense of fixing the devices in their position is also charged. To the end of the pipe in front of the building a stopcock is attached for shutting off or regulating the supply of gas.

Care should be taken to have the pipes of ample capacity, otherwise the illumination will be poor and ineffective.

When the building to be illuminated is large, it is advisable to run up a service pipe at each end, and one in the centre, connecting them together in the front; each pipe, of course, having a distinct connection with the main in the street.

The service pipe should be laid with a slight fall to the main; and the use of all abrupt angles—such as square elbows—should be avoided, bends being employed instead.

The service pipes are temporary only, being lent by the gas authorities, and are removed by them when the illuminations are over.

Devices.—The devices are paid for by the private inhabitants or the local authorities, or by both, as the case may be.

They may consist of—

Initial and other letters, single-lined—thus, **A**—and

double-lined—thus, **A**

Mottoes—straight, curved, or circular.

Lanterns with coloured devices.

Laurel scrolls.

Garlands.

Festoons.

True lovers' knots.

Stars of various kinds.

Mitres.

Crescents.

Crosses.

Plumes, as Prince of Wales' feathers.

Aureoles.

Crowns.

Shields.

Anchors.

Masonic emblems.

Heraldic crests.

Corporation arms.

Other devices suitable to the particular occasion.

The devices are made by the manufacturers of gas-fittings, wrought-iron tubing, and others, and are supplied to gas authorities and the trade at about the prices as follows:—

Single-lined Letters, in Iron or Copper, fitted with Strong Union Couplings.

Length of Letter.	Size of Inlet.	Price.	
		s.	d.
18 inches	1 1/2 inch bore	11	6 each.
24 "	"	12	6 "
30 "	"	13	6 "
36 "	"	15	0 "
42 "	"	18	0 "
48 "	"	21	0 "
54 "	"	25	0 "
60 "	"	30	0 "

Double-lined Letters, in Iron or Copper, fitted with Strong Union Couplings.

Length of Letter.	Size of Inlet.	Price.	
		s.	d.
18 inches	1 1/2 inch bore	12	6 each.
24 "	"	15	0 "
30 "	"	17	6 "
36 "	"	20	0 "
42 "	"	24	0 "
48 "	"	28	0 "
54 "	"	33	0 "
60 "	"	40	0 "

Brunswick Stars and Stars with Eight Points, made of Wrought-Iron Welded Pipe, and fitted with Strong Union Couplings.

Diameter.	Size of Inlet.	Price with Star Centre.		Price with Shield Centre.		Price with Plume Centre.	
		£	s. d.	£	s. d.	£	s. d.
3 feet	1 inch bore	2	0 0	2	2 0	2	17 0
4 "	1 1/4 "	2	12 0	2	15 0	3	10 0
5 "	1 1/2 "	3	6 6	3	10 0	4	5 0
6 "	1 3/4 "	4	15 0	5	0 0	5	15 0
7 "	1 7/8 "	6	3 6	6	10 0	7	5 0
8 "	2 "	7	7 0	7	15 0	8	10 0

Crowns and plumes cost about one-third more than stars.

Scrolls, garlands, heraldic crests, and other devices, at prices varying according to the elaboration of the design.

Wrought-iron pipes, drilled, and with star jets inserted, are supplied at about the ordinary list-price.

The devices may be "home-made," and if so will be less expensive; but unless constructed by skilled and tasteful workmen, they will present a scraggy, irregular appearance when lighted up.

Illuminated Borders.—A very pretty effect, easily managed, and one that gives a rich fulness to the central illumination of a

building, is obtained by running wrought-iron tubing along the principal angles, with holes drilled in the tube at distances about 6 in. apart, and having small jets or star burners inserted. The burners may be placed wider apart, and globes made use of. These prevent the lights from being extinguished by the wind, and also heighten the general effect. In this case a short piece of brass tube, with elbow socket and gallery, must be inserted. Globes ground all over, or white opal globes, or white and coloured globes arranged alternately, show to the best advantage.

Coloured Fires.—A display of coloured fires, at intervals, from prominent points of elevation, adds greatly to the effect of an illumination.

The following are some excellent recipes for their production :—

Lilac Fire.

		oz.	drms.
Chlorate of potash	49 parts, or	7	13
Sulphur	25 "	4	0
Chalk	20 "	3	3
Black oxide of copper	6 "	1	0

Weight 1 lb.; cost, 2s. 3d.

Purple Fire.

		oz.	drms.
Chlorate of potash	43 parts, or	6	14
Nitrate of potash (saltpetre)	22½ "	3	10
Sulphur	22½ "	3	10
Black oxide of copper	10 "	1	9
Black sulphide of mercury (Ethiop's mineral)	2 "	0	5

Weight, 1 lb.; cost, 2s. 3d.

Yellow Fire.

		oz.	drms.
Nitrate of soda	75 parts, or	12	0
Sulphur	19 "	3	1
Charcoal or lamp-black	6 "	0	15

Weight, 1 lb.; cost, 1s. 6d.

Blue or Bengal Fire.

		oz.	drms.
Dry nitrate of potash	6 parts, or	10	10½
Sulphur	2 "	3	9½
Tersulphide of antimony	1 "	1	12

Weight, 1 lb.; cost, 1s.

Or

		oz.	drms.
Ammonic sulphate of copper	8 parts, or	8	8
Chlorate of potash	6 "	6	7
Shellac	1 "	1	1

Weight, 1 lb.; cost, 2s. 3d.

Green Fire.

		oz.	drms.
Nitrate of baryta	77 parts, or	12	5
Sulphur	13 "	2	1
Chlorate of potash	5 "	0	13
Charcoal or lamp-black	3 "	0	8
Metallic arsenic	2 "	0	5

Weight, 1 lb.; cost, 1s. 6d.

Or

		oz.	drms.
Nitrate of baryta	9 parts, or	10	10
Shellac	3 "	3	9
Chlorate of potash	1½ "	1	13

Weight, 1 lb.; cost, 1s. 6d.

Crimson Fire.

		oz.	drms.
Nitrate of strontia	80 parts, or	10	0
Sulphur	22½ "	2	14
Chlorate of potash	20 "	2	8
Charcoal or lamp-black	5 "	0	10

Weight, 1 lb.; cost, 1s. 6d.

Red Fire.

		oz.	drms.
Nitrate of strontia	40 parts, or	10	0
Sulphur	13 "	3	2
Chlorate of potash	5 "	1	3
Charcoal or lamp-black	3 "	0	11
Sulphide of antimony	4 "	1	0

Weight, 1 lb.; cost, 1s. 6d.

Or

		oz.	drms.
Nitrate of strontia	9 parts, or	10	10
Shellac	3 "	3	9
Chlorate of potash	1½ "	1	13

Weight, 1 lb.; cost, 1s. 6d.

White Indian Fire.

		oz.	drms.
Nitrate of potash	24 parts, or	11	10
Sulphur	7 "	3	6
Sulphide of arsenic (realgar)	2 "	1	0

Weight, 1 lb.; cost, 1s.

In no case should the chlorate of potash be ground along with the sulphur, as ignition, caused by the friction, would ensue.

The ingredients should be reduced to the finest powder (excepting the shellac, which should only be beaten into small fragments) by bruising them in a mortar made of hard wood, the chlorate of potash being ground separately. They should then be intimately mixed together, by passing them three or four times through a

hair sieve. When mixed, keep the material in a close-stoppered bottle to prevent spontaneous combustion. *All the ingredients must be perfectly dry to ensure success.*

The mixtures are best fired in hemispherical dishes, or ladles made of beaten iron, about 5 in. diameter and $2\frac{1}{2}$ in. deep in the centre. The fumes arising from the different fires should be avoided.

A pound in weight of any of the mixtures is sufficient for a fire (though any quantity may be used), and the cost varies from 1s. to 2s. 3d. each. The ingredients can be obtained from almost any chemist and druggist.

THE USE OF GAS FOR PURPOSES OTHER THAN LIGHTING.

The use of gas for cooking, heating, and motive power has made rapid strides of recent years, and the steady increase that is taking place in the consumption of gas for purposes other than illumination is a matter of interest. Thirty to thirty-five years ago this consumption was only beginning to make itself felt, yet within the brief period which has elapsed, large industries, giving employment to much capital and many workpeople, have been called into existence to produce the machinery and appliances required, to describe which would need a treatise in itself. These, which are of the most numerous and varied kind, are of great excellence, whilst improvements are constantly being effected therein.

For domestic and greenhouse use there are numberless heating stoves of superior design and workmanship, and in cooking stoves and ovens there is equal variety; so also in geysers for water heating.

The uses to which gas may be advantageously put in every branch of trade where heat is required are only limited by the number of such trades. For example, in the gassing of yarn, in coffee-roasting, in the manufacture of confectionery, the baking of bread, the finishing of shoes, in dentistry, in the production of jewellery, in wire-welding, tempering steel, enamelling, and many others.

The gas engine successfully competes with the steam motor for all purposes where the power required to be exerted is intermittent and within moderate limits.

For handiness in application, and cleanliness and safety in use, gas, as a fuel, is unsurpassed. The use of gas in these ways means

a saving of time and labour, and is an important step towards the solution of the smoke difficulty in towns.

Taking its advantages in these respects into account, there is economy in its employment even when, as in scattered districts, its price per 1000 cub. ft. may be considered high. In towns where the price of gas is comparatively low, there is a positive economy in its adoption, beyond the special recommendations named.

The manufacture of gas engines was at first confined to the smaller sizes, from 1-horse power to 10-horse power, but larger sizes, equal to as high as 1500-horse power, are now made.

In adopting this motor, neither boiler nor chimney is required, and hence it can be employed in buildings and in out-of-the-way corners in establishments where a steam engine is altogether inadmissible. It is always available for work on the opening of a tap, and it goes on working continuously day and night with the least possible attention. Moreover, the percentage efficiency of the gas engine is greatly in excess of that evolved by the steam motor.

As a ventilating agent the gas flame is of the greatest use, and in rooms where the means of ventilation are provided, it promotes their efficiency, though it has not been employed in this direction as extensively as its merits deserve. In spacious assembly rooms in which crowded meetings are held, the gas "sunlight," or the "regenerative" light, or the "Nonpareil" sun burner (Fig. 184), with their ventilating tubes, may be recommended as superior to any other method of artificial lighting.

One of the best methods—perhaps the very best method—of reducing the proportion which capital expenditure in gas-works bears to revenue, is to cultivate a day consumption of gas, by affording facilities for, and encouraging in every legitimate way, the use of gas for cooking, heating, ventilating, and motive power. It is interesting to ascertain approximately, and to keep a permanent record of, the proportion of gas consumed in the daytime as compared with the night. To do this it is necessary to take the stock of gas in the holders at 8 a.m., 3 p.m., and 12 midnight.

This policy, if pursued to a successful issue, is virtually to reduce the percentage of capital in the proportion of such consumption, because the plant is brought to bear in earning profit during the daylight as well as in the lighting hours.

If local governing authorities (or some of them) in possession

of gas-works had the real, permanent good of their respective communities at heart—or were less narrow and short-sighted in their views—instead of appropriating large gas profits in aid of rates (a policy which, besides being unjust, always tends to waste and extravagance), would aim at reducing the selling price of the gas, they would, by so doing, give encouragement to the establishment and growth of what may be termed THE MINOR INDUSTRIES, whose success, and even existence, are so largely dependent upon a cheap, cleanly, and handy fuel for heating and motive power purposes.

This wise policy of selling gas at cost price (including, of course, interest on capital) has a threefold advantage, inasmuch as it promotes the day consumption, it goes a long way towards abolishing the smoke nuisance, and it broadens the base of the general prosperity by the encouragement it gives to the growth of a variety of trade interests.

THE RESIDUAL PRODUCTS.

One, and not the least important, of the duties of the gas manager is to do what in his power lies to promote the interests of the undertaking under his charge by utilizing the residual products of gas manufacture to the utmost extent.

It is a remarkable fact that there are no waste products in a properly conducted gas-works. The coke, breeze, tar, ammoniacal liquor, sulphur, spent lime and oxide, retort carbon, and even the clinker and ash from the furnaces, all are marketable, and therefore of more or less value. The flue gases from the retort stack are even utilized for the generation of steam and for heating the air supply to the combustion chamber where the regenerative system is applied.

Coke and Breeze.—Coke, as ordinarily produced, is not well adapted for domestic use for kitcheners, and for use in other ways, and, in consequence, its sale is often restricted. To render it suitable for these purposes, it requires to be broken into pieces of smaller and more uniform size.

Wherever means have been adopted for this purpose, the article has been found to command a ready sale; and instead of mountains of coke in every available corner of the works, the material is, as a rule, cleared out almost as quickly as it is produced.

The labour, inconvenience, and waste attendant on stacking

are thus avoided, the premises can be kept in better order, and the revenue is augmented.

For breaking the coke by hand, a hammer of the form shown in Fig. 213, with a chisel edge at one end and four prongs at the other, may be recommended.

Various coke-cutting machines have been devised for this purpose.

The machines of R. Cort & Sons are made for either hand or power driving, and in several sizes, the largest of which will break twenty to twenty-five tons of coke per hour.

The cutters of the machines can be adjusted to enable the sizes of the coke broken to be altered to suit requirements.

The chief desideratum in any machine is the minimum quantity of breeze it will make, although no hard-and-fast rule can be laid down on account of the different classes of coke to be dealt with.

It is usual to cut the coke and screen same for ordinary domestic purposes; but if required for smiths' fires, producer plants, and similar purposes, it should also be sized. The sizes most generally used are $\frac{3}{8}$ in. to $\frac{1}{2}$ in., $\frac{1}{4}$ in. to 1 in., 1 in. to $1\frac{1}{2}$ in., and $1\frac{1}{2}$ in. to 2 in.; the after treatment of the sized coke will depend on the market there is for it.

The screens for sizing are either of the "rotary" or of the "jigging" type, such as the "Zimmer," "Marcus," and "Bentley."

Elevators may be used for lifting the broken coke from the breaker to the screens, which may be placed on the top of storage hoppers, from which the coke can be discharged direct into carts.

The cost of a plant will vary according to its design and completeness, but a plant for say ten tons per hour with coke breaker, elevator, screens, hoppers, engines for driving, etc., will range from £1500 to £2000.

Such a plant would require to work it, presuming that the coke is brought straight from the retort house to the hopper of the coke breaker, one man to feed the breaker and another man to attend to the engines, elevator, screens, loading of the coke, and general supervision of the plant.

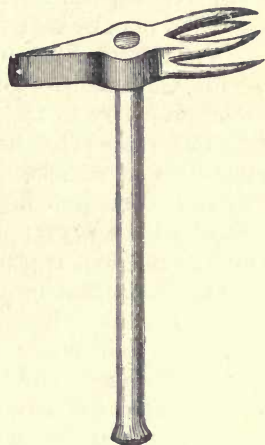


FIG. 213.

The coke thus manipulated finds a ready and constant market as quickly as it is produced, the result being an average net gain of 1s. 6d. to 2s. per ton.

Coke, immediately on being slaked with water, weighs about 15 per cent. more than when unslaked; the bulk of the moisture, however, evaporates; about 3 per cent. only being retained.

A ton of coke is about a chaldron and a half.

A chaldron of coke varies in weight from 12½ to 15 cwt.

For the quantity of coke produced by different coals, see the tables on pp. 12 to 17.

Coal Tar.—The yield of tar from coal per ton in gas-works ranges up to 12 gals., and from cannel up to about 17 gals. The average production in gas-works throughout the country will not exceed 10 gals. per ton. The total production of coal tar in the United Kingdom is probably about 900,000 tons.

The utilization of the tar for its products is not pursued at many gas-works, though it is done at a few, and, if well managed, it is a source of profit.

Considerably more skill and care are required in the distillation of tar than in the manufacture of sulphate of ammonia; nevertheless, it is safe to predict that before many years have elapsed, this branch of practical chemistry will be widely practised on those gas-works where there is space and convenience.

The manufacture on gas-works may be wisely restricted to the distillation of the tar for the light and heavy oils and the production of anthracene and pitch.

The principal dangers to be apprehended in the process are the leaking or boiling over of the stills and the firing of vapours, causing conflagration; and the stoppage of the pipe passages with accretions of solid matter, chiefly naphthalene, resulting in explosion; but these dangers can be minimized or altogether averted under proper supervision and by the use of efficient apparatus.

TABLE

Showing about the Average Proportion of the several Products obtained from the Distillation of 10,000 Gallons of Coal Tar. (Dr. Letheby.)

Ammoniacal liquor	240°0 gals.	Solvent naphtha	41°8 gals.
40 per cent. benzol	34°4 "	Last runnings	12°0 "
90 " "	53°1 "	Dead oil	3018°7 "
Pitch . . . . .	.	.	.
		36 tons.	

TABLE

Showing the Average Percentage of the Products obtained from 100 Tons of Coal Tar. (Roscoe.)

	1	2
Naphtha	3'0	2'0 per cent.
Light oils and carbolic acid	1'5	0'8 "
Heavy oils, naphthalene, anthracene	35'0	25'0 "
Pitch	50'0	60'0 "
Water and loss	10'5	12'2 "
	100'0	100'0

Mr. C. Greville Williams remarks (*King's Treatise*, vol. iii., p. 281) that "the working results to be obtained from a charge of 1200 gals. vary so greatly, according to the nature of the tar and the care with which the distillation has been made, that it is exceedingly difficult to give any average which will be satisfactory to distillers in different parts of the country. The following figures are placed side by side as extreme cases."

	Lancashire : (Watson Smith).	London : (<i>Chemistry as applied to the Arts and Manufactures</i>).
Ammoniacal liquor gallons	30	50
First light oils "	33	20
Second light oils "	157	20
Creosote oils "	104	250
Anthracene oils "	229	50
Pitch tons	3'25	4

The following yield of by-products from each ton of tar distilled is given by Mr. Colson from his own working :—

Crude naphtha, 30 per cent., at 120° C.	6'79 gals.
Carbolic acid, crude 60° C.	3'50 "
Heavy naphtha, 20 per cent., at 160° C.	3'55 "
Creosote	58'04 "
Ammoniacal liquor, 10 oz.	5'00 "
Naphthalene	33'91 lbs.
Anthracene, 33 per cent.	13'60 "
Pitch	12'67 cwt.

The coals used were best Derbyshire, 73 per cent. ; South Yorkshire, 18 per cent. ; Nottinghamshire cannel, 9 per cent. ; and, carbonized at fairly high heats, the mixture yielded 10,436 cub. ft. of 17-candle gas, 12'1 gals. tar, and 32'8 gals. ammoniacal liquor of 10 oz. strength per ton. The sulphate made per ton of coal was 29'82 lbs.

Tar Pavement.—This is made of the breeze, ashes, and clinker of gas-works and mill furnaces, along with shingle or coarsely ground granite, mixed with coal tar.

A coke fire is first made on the ground, and the solid ingredients cessed in a heap round and over it; layer after layer being gradually added as the heat penetrates through the mass, until sufficient bulk of the material is ready.

If preferred, or if a large quantity of material has to be dried and heated, a raised sheet-iron floor may be made, supported on bricks, with the coke fire underneath; or a permanent fire-brick floor may be constructed, ramified with flues underneath leading to a chimney, and having a fire-grate at one end.

In the meantime, whilst the solid ingredients are being dried and heated, the tar is being boiled, and when ready, the two are taken and mixed together in small heaps (say, about three ordinary barrow loads) in the proportion by measure of 1 part tar to 7 parts solid.

The whole is then turned over immediately whilst hot, and thoroughly mixed, until every particle of the solid ingredients has received a coating of tar.

The mixed material is then sorted into three separate heaps of graduated fineness, by passing it through two sieves, with $\frac{3}{4}$ in. and $\frac{3}{8}$ in. meshes respectively. It is now ready for use, and may be laid down at once or kept in stock for a short time until required.

It is preferred by some to sort the solid ingredients before mixing with the tar, as the latter is liable to clog the sieves. In this case an ordinary screen, $\frac{3}{4}$ in. between the bars, and supported at an angle, is employed; and all that passes through it is afterwards riddled through a $\frac{3}{8}$ in. sieve.

The three different grades of material are then dried and made hot as described, and thoroughly mixed with hot tar in these 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 " 1 " |
| 3. Fine material | { 1 part tar
6 parts solid } | or 36 " 1 " |

The footpath being properly kerbed, the upper edge of the

stones standing 3 in. above the solid bottom of the path, the rough prepared material, No. 1, is put down 2 in. thick, then No. 2 about $\frac{5}{8}$ in. thick, and finally No. 3 about $\frac{3}{8}$ in. thick. Each layer as it is put down is rolled with a 10 cwt. roller until thoroughly consolidated. Corners which cannot be reached by the roller must be consolidated by punning. Derbyshire spar or fine granite sprinkled over the surface improves the appearance of the pavement.

Three tons of the rough (No. 1) and $1\frac{1}{2}$ tons of the fine prepared material (Nos. 2 and 3) will cover 60 sq. yds., or a footpath 2 yds. wide and 30 yds. long.

The Application of Tar to Country Roads, with a view to minimizing the cost of maintenance, and abating the dust nuisance, is being largely adopted, and with excellent results.

Tar for this purpose must be water freed, and various dehydrating plants have been designed to this end.

Wilson's dehydrating plant, manufactured by the Chemical Engineering Company, is a simple and efficient plant for freeing tar of its water, ammoniacal liquor, and phenoloid bodies.

The principle underlying the process is the heating of the tar in a confined space and then releasing it, with the result that the water and light oils evaporate (and are collected) leaving a dehydrated and acid-free tar, ready for the use of the road surveyor or contractor.

Ammoniacal Liquor.—The quantity of liquor obtained up to the outlet of the scrubbers per ton of coal carbonized varies from 15 to 45 gals. of 10 oz. strength, depending on the class of coal used and the efficiency of the apparatus for arresting the ammonia.

The product of ammoniacal water or liquor, when treated with sulphuric acid, is sulphate of ammonia; when treated with muriatic or hydrochloric acid, it is muriate of ammonia or sal ammoniac.

The manufacture of sulphate of ammonia from the ammoniacal liquor is becoming general in gas-works, and properly so, as the process is both simple and profitable. That it must be more profitable to use the liquor at the place of production than at a distance away is evident, taking into account the saving of the cost of transport of a bulky material. The estimated annual make of sulphate of ammonia in the United Kingdom is 250,000 tons.

The apparatus required in its manufacture is neither complicated nor costly; the process is free from danger (though fatal

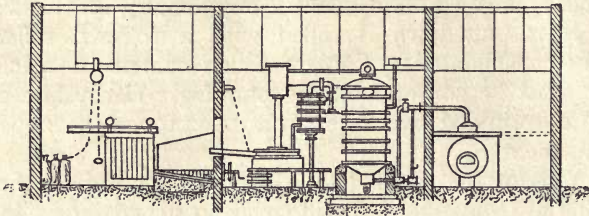


FIG. 214.

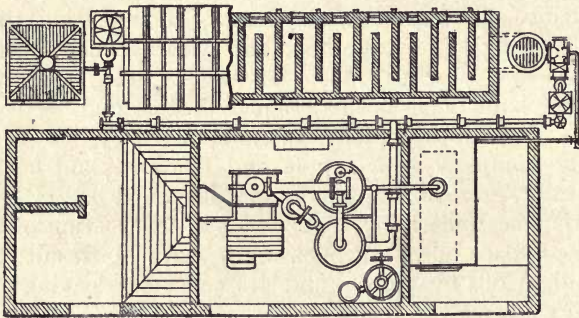


FIG. 215.

accidents have occurred through carelessness, or the use of imperfect appliances), and an intelligent labourer can learn it in a week's time.

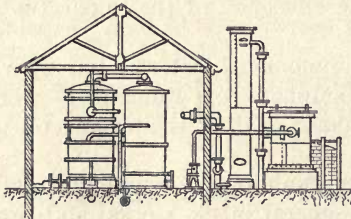


FIG. 216.

Sulphate of ammonia is manufactured either by the continuous or the intermittent system, and there is much to be said in favour of each.

In the continuous system (see Figs. 214, 215, and 216), the crude ammoniacal liquor is first pumped up into an overhead supply tank, and thence flows in a regulated stream into a tubular heater, the liquor traversing the tubes, which are surrounded by the hot waste gases from the saturator. In this way, raised to boiling point, it goes forward into the column still, which is supplied with steam at a regulated pressure.

The upper portion of the still consists of a series of trays having each a cast-iron hood, through the serrated edges of which the heated liquor travels and parts with its free ammonia. Descending into the liming chamber of the still, the liquor mixes with the cream of lime supplied thereto by means of a force pump. The limed liquor then flows into the lower portion of the still, or into another smaller still adjoining, and passing over and through a second series of trays and hoods with serrated edges, the fixed ammonia is liberated.

The term "free ammonia" is not strictly accurate, but it is well understood as referring to the ammonia in combination with the feeble acids sulphuretted hydrogen and carbon dioxide, as ammonium sulphide and carbonate, and which is liberated by boiling. The "fixed ammonia," on the other hand, is that which exists in combination with hydrochloric, sulphuric, and other strong acids, as ammonia chloride, thiocyanate, sulphate, thiosulphate, and ferrocyanide. This is not expelled by boiling, but is liberated from these salts by decomposition in the presence of cream of lime. The proportion of free ammonia in the liquor is about 70 per cent., and of fixed ammonia about 30 per cent. of the whole.

The ammonia and other gases escape by the pipe rising from the cover of the still, and passing first through a baffle box, to have the moisture removed, they go forward into the saturator. This is made either of solid virgin lead or is a wood vessel lead-lined, and contains weak sulphuric acid, which, on being sufficiently saturated with the incoming ammonia gas, precipitates sulphate of ammonia in the vessel. The sulphate is then fished out with a scoop, or is discharged by mechanical means, on to a lead draining table.

The spent liquor flowing from the still should not contain more than 0.003 per cent. of ammonia. It is run into a cooling and depositing tank, and thence overflows into the drain.

When the quantity of spent liquor, however, is large, some method of purification must be employed, if conflict with the sanitary authorities is to be avoided.

A simple and inexpensive plant has been designed by Mr. J. Radcliffe of East Barnet for this purpose, and is practically continuous and automatic.

After purification the liquor may be turned into the drain.

The waste gases, after traversing the heater, are conveyed away by a pipe to the condenser, and forward, either through an open purifier containing oxide of iron, or through a Claus plant for the recovery of the sulphur.

In actual practice the intermittent system is a simpler process, the heat being applied directly to a boiler containing ammoniacal liquor. The firing is continued until the ammonia is driven off, when the residuary water is run out of the boiler and the vessel recharged with ammoniacal liquor. Steam is generated at the same time that the ammonia is driven off, and the two together conducted to the saturator, from which point the processes are similar.

1 ton of average gas coal yields	28 lbs. of sulphate of ammonia.
100 tons	yield 1 $\frac{1}{4}$ tons
12 ,, (2622 gals.) ammoniacal liquor, 5° Twaddel,	yield 1 ton

The strength, and consequent value, of ammoniacal liquor is commonly ascertained by Twaddel's hydrometer, and also by the quantity of sulphuric acid of the specific gravity 1845 (water 1000) required to neutralize the ammonia contained in 1 gal.

Each degree of Twaddel is equal, as nearly as possible, to 2 oz. of acid per gallon of the liquor; hence arises the description of its value—

Liquor of 5 degrees Twaddel is called	10 oz. liquor.
,, 6	12 ,,
,, 7	14 ,,

And so on, at the rate of 2 oz. for each degree, so that 10 oz., 12 oz., or 14 oz. liquor means ammoniacal liquor of such a strength that 10 oz., 12 oz., or 14 oz. of sulphuric acid, of the specific gravity of 1845, are required to neutralize the ammonia contained in a

gallon of it. Each ounce strength is equal to 0.347 oz. ammonia per gallon of liquor.

To convert degrees of Twaddel's hydrometer into specific gravity, multiply the number of degrees by 5 and add 1000 to the product.

EXAMPLE.—Twaddel $6 \times 5 + 1000 = 1030$ specific gravity.

To convert specific gravity into degrees of Twaddel, deduct 1000 from the specific gravity, and divide the remainder by 5.

EXAMPLE.—Specific gravity $1030 - 1000 \div 5 = 6$ degrees of Twaddel.

To determine the weight of a gallon of ammoniacal liquor of any strength, find the specific gravity by the above rule. This will represent the number of ounces avoirdupois in weight per cubic foot. Divide by 16 to ascertain the number of pounds per cubic foot, and by 6.25 (gallons per cubic foot) for the weight of a gallon of the liquor.

EXAMPLE.—Required the weight per gallon of 10 oz. liquor (5° Twaddel)—

$(5 \times 5) + 1000 = 1025$, specific gravity and weight per cubic foot
in ounces avoirdupois.

$$\frac{1025}{16} = 64.063 \text{ lbs. per cubic foot.}$$

$$\frac{64.063}{6.25} = 10.25 \text{ lbs. weight per gal. of 10 oz. liquor.}$$

Or the weight may be found more expeditiously by the rule given on the next page.

It is well known that the greater the proportion of ammoniacal gas contained in a pure solution, the less the density or specific gravity of such solution. How, then, it may be asked, is the apparent contradiction to be explained that the larger the quantity of ammonia contained in gas liquor, the greater the density?

The explanation is to be found in the circumstance that gas liquor is not a solution of ammonia pure and simple, but contains other gases in solution, and in combination with the ammonia in the form of salts, which increase its specific gravity; and the more ammonia liquor contains, the greater is its power of arresting and absorbing such other gases.

It is by reason of this latter-mentioned fact that Twaddel's hydrometer is tolerated as a gauge of the strength and value of the ammoniacal liquor of gas-works. At the best, however, its employment for this purpose is very unsatisfactory.

The method of testing by saturating the liquor with sulphuric acid is an improvement on the hydrometer; but even that is imperfect, as has been pointed out by Mr. Greville, who ascertained by experiments on nine different samples of liquor that an average of 22.5 per cent. of the ammonia present in combination was not indicated by the acid.

The mode of testing by Mr. Thomas Wills meets the difficulty. His plan is to mix with the liquor a caustic alkali for which the acids of the salts contained in the liquor have a stronger affinity than for the ammonia with which they are combined. On the mixture being strongly heated, the salts are decomposed in presence of the caustic alkali, and the ammonia being driven off in the gaseous state and conveyed into a solution of sulphuric acid, is secured as sulphate of ammonia. This and the other methods of testing are fully detailed by Mr. Hartley in his brochure on *Ammonia Liquor Tests*.

It will be seen by the following table that the weight of the liquor in pounds avoirdupois per gallon is obtained by simply placing the decimal point after the first two figures of the number representing the specific gravity. Thus, liquor of 1025 specific gravity is 10.25 lbs.; and of 1037.5 specific gravity is 10.375 lbs. weight per gallon.

Each degree of Twaddel represents 350 grs. above the weight of distilled water. Consequently, 5 degrees represent 1750 grs., or $\frac{1}{4}$ lb.; 20 degrees, 7000 grs., or 1 lb.

In Beaumé's hydrometer, which was the first instrument of the kind, the divisions are equidistant; and it has two modes of graduation according as it is intended for liquids heavier or lighter than water. This instrument is the one principally in use on the Continent.

Sulphur Recovery.—Claus's plant, made by C. & W. Walker, for the recovery of sulphur in a marketable form from the sulphuretted hydrogen passing from the saturator in the manufacture of sulphate of ammonia, is not only efficient for the purpose, but it possesses the further merit of simplicity.

The hot gases from the saturator are passed through the heater

of the sulphate plant, where they are partially cooled in heating the liquor flowing towards the still, and thence through the condenser, where they are cooled to the temperature of the air. They then pass into the air inlet box, into which air is pumped in the proportion of $2\frac{1}{2}$ parts air to 1 part sulphuretted hydrogen. The

TABLE

Showing the Specific Gravity, Weight per Cubic Foot, Weight per Gallon, and Ounce Strength of Ammoniacal or Gas Liquor of different degrees Twaddel.

Degrees Twaddel Liquor.	Specific Gravity Water = 1000 and Weight per Cubic Foot in Ounces Avoirdupois.	Weight per Gallon. lbs.	Ounce Strength.	Degrees Twaddel Liquor.	Specific Gravity Water = 1000 and Weight per Cubic Foot in Ounces Avoirdupois.	Weight per Gallon. lbs.	Ounce Strength.
0	1000	10'0	0	12½	1062'5	10'625	25
½	1002'5	10'025	1	13	1065	10'65	26
1	1005	10'05	2	13½	1067'5	10'675	27
1½	1007'5	10'075	3	14	1070	10'7	28
2	1010	10'1	4	14½	1072'5	10'725	29
2½	1012'5	10'125	5	15	1075	10'75	30
3	1015	10'15	6	15½	1077'5	10'775	31
3½	1017'5	10'175	7	16	1080	10'8	32
4	1020	10'2	8	16½	1082'5	10'825	33
4½	1022'5	10'225	9	17	1085	10'85	34
5	1025	10'25	10	17½	1087'5	10'875	35
5½	1027'5	10'275	11	18	1090	10'9	36
6	1030	10'3	12	18½	1092'5	10'925	37
6½	1032'5	10'325	13	19	1095	10'95	38
7	1035	10'35	14	19½	1097'5	10'975	39
7½	1037'5	10'375	15	20	1100	11'0	40
8	1040	10'4	16	20½	1102'5	11'025	41
8½	1042'5	10'425	17	21	1105	11'05	42
9	1045	10'45	18	21½	1107'5	11'075	43
9½	1047'5	10'475	19	22	1110	11'1	44
10	1050	10'5	20	22½	1112'5	11'125	45
10½	1052'5	10'525	21	23	1115	11'15	46
11	1055	10'55	22	23½	1117'5	11'175	47
11½	1057'5	10'575	23	24	1120	11'2	48
12	1060	10'6	24	25	1125	11'25	50

mixture of gas and air then enters the kiln, which is of wrought-iron lined with fire-bricks, and having a fire-brick grate on which rests a layer of loose broken fire-bricks covered with a layer of hydrated oxide of iron about 3 ft. deep. Passing down through

the oxide of iron, the oxygen of the air combines with the hydrogen of the H_2S , forming water, leaving the sulphur to unite with the iron, forming sulphide of iron, which is immediately reoxydized by the air. The reaction takes place with such rapidity that the mass of oxide becomes incandescent, the heat so caused volatilizing

*Beaumé's Hydrometer Compared with Specific Gravity.
For Liquids Heavier than Water.*

Degrees Beaumé.	Specific Gravity. Water = 1'000.	Degrees Beaumé.	Specific Gravity. Water = 1'000.	Degrees Beaumé.	Specific Gravity. Water = 1'000.
0	1'000	26	1'206	52	1'520
1	1'007	27	1'216	53	1'535
2	1'013	28	1'225	54	1'551
3	1'020	29	1'235	55	1'567
4	1'027	30	1'245	56	1'583
5	1'034	31	1'256	57	1'600
6	1'041	32	1'267	58	1'617
7	1'048	33	1'277	59	1'634
8	1'056	34	1'288	60	1'652
9	1'063	35	1'299	61	1'670
10	1'070	36	1'310	62	1'689
11	1'078	37	1'321	63	1'708
12	1'085	38	1'333	64	1'727
13	1'094	39	1'345	65	1'747
14	1'101	40	1'357	66	1'767
15	1'109	41	1'369	67	1'788
16	1'118	42	1'381	68	1'809
17	1'126	43	1'395	69	1'831
18	1'134	44	1'407	70	1'854
19	1'143	45	1'420	71	1'877
20	1'152	46	1'434	72	1'900
21	1'160	47	1'448	73	1'924
22	1'169	48	1'462	74	1'949
23	1'178	49	1'476	75	1'974
24	1'188	50	1'490	76	2'000
25	1'197	51	1'495		

the sulphur, which goes forward with the other gases through the fire-brick grating at the bottom of the kiln into the depositing chamber. This chamber is built of ordinary brickwork, excepting the portion nearest the kiln, which has a lining of fire-brick. A number of transverse baffle walls in the chamber retard the flow of the gas and finely divided sulphur, cooling the latter and causing its deposition.

The chamber is covered with slate slabs, and in the side walls are doorways for clearing out the sulphur at intervals.

The waste gas remaining passes through a cast-iron scrubber filled with limestone, down which a small stream of water is constantly flowing, and in this any sulphur dioxide which may be present is arrested. Finally, an open purifier filled with oxide of iron receives the spent gas, and arrests any H_2S that may have escaped decomposition, whilst the remaining innocuous gas escapes into the air.

*Beaumé's Hydrometer Compared with Specific Gravity.
For Liquids Lighter than Water.*

Degrees Beaumé.	Specific Gravity. Water = 1·000.	Degrees Beaumé.	Specific Gravity. Water = 1·000.	Degrees Beaumé.	Specific Gravity. Water = 1·000.
10	—	27	0·896	44	0·811
11	0·993	28	0·890	45	0·807
12	0·986	29	0·885	46	0·802
13	0·980	30	0·880	47	0·798
14	0·973	31	0·874	48	0·794
15	0·967	32	0·869	49	0·789
16	0·760	33	0·864	50	0·785
17	0·954	34	0·859	51	0·781
18	0·948	35	0·854	52	0·777
19	0·942	36	0·849	53	0·773
20	0·936	37	0·844	54	0·768
21	0·930	38	0·839	55	0·764
22	0·924	39	0·834	56	0·760
23	0·918	40	0·830	57	0·757
24	0·913	41	0·825	58	0·753
25	0·907	42	0·820	59	0·749
26	0·901	43	0·816	60	0·745

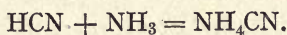
Should there be an excess or insufficiency of air delivered into the kiln with the foul gases, the outlet gas of the chamber will contain traces of sulphurous acid or sulphuretted hydrogen, which are taken up respectively by the limestone scrubber and the oxide purifier.

Under proper conditions of working, the yield of marketable sulphur reaches 90 per cent. of the sulphur passing into the kiln, and is of very pure quality. In Figs. 214, 215, and 216 are shown C. & W. Walker's sulphate of ammonia plant, and the Claus sulphur recovery plant alongside.

Cyanogen.—The presence of cyanogen in coal gas has long been known, but it is only in recent years that its recovery has been made commercially profitable.

The production of cyanides is generally attributed to high temperature distillation, in which ammonia is decomposed by the incandescent coke and carbon monoxide, with the formation of hydrocyanic acid and hydrogen.

Hydrocyanic acid has no affinity for ammonia whilst in a heated state, but on cooling is capable of combining to form the cyanide of the alkali radical thus—



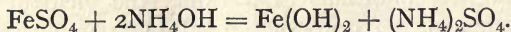
Ammonium cyanide (NH_4CN) is practically the only cyanide present in the cooled gas, all other compounds being formed during purification.

The cyanogen compounds found in the ammoniacal liquor are: Ammonium cyanide, ammonium ferrocyanide, and ammonium thiocyanate; and in the purifiers: Ferrous cyanide, ammonium ferrocyanide, ammonium ferrous-ferrocyanide, ammonium carbonyl ferrocyanide, and Prussian blue.

With regard to the yield of cyanogen per ton of coal, this varies with the percentage of nitrogen contained in the coal and the temperature of distillation. A temperature of over 1750° Fahr. must be attained, and its formation reaches its maximum at the end of the distillation; hence the longer the hours' charges, the greater the production. The average yield is from 3 to 4 lbs. of prussiate per ton of coal distilled.

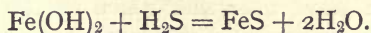
There are several processes at present in use for obtaining this residual product in a marketable form, amongst which are the Rowland & Bueb, Knublauch & Foulis, and the Davis Neill. These all depend upon the reaction that hydrocyanic acid is absorbed by a mixture of an alkali and iron salt, with the formation of the prussiate of the alkali used.

In the Davis Neill process a strong solution of copperas is precipitated by concentrated ammonia in suitable tanks, thus—

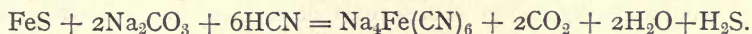


The ferrous hydrate is allowed to settle and drain, and is then passed through a filter press. The filtrate may be conveyed to the sulphate plant.

The ferrous hydrate in the filter press is thoroughly washed with water, and a calculated amount of sodium carbonate and water added. The mixture is agitated and run into a rotary washer-scrubber. The sulphuretted hydrogen in the crude gas interacts with the ferrous hydrate, producing ferrous sulphide, thus—

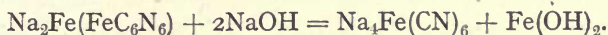


The mixture now consists of ferrous sulphide and sodium carbonate, and is capable of extracting the hydrocyanic acid from the gas to form sodium ferrocyanide, thus—



The liquor from the rotary washer is run off usually once per day, and consists of prussiate of soda, with a proportion of ammonium thiocyanate and ammonium ferrous-ferricyanide as impurities, together with an excess of sodium carbonate, ferrous sulphide, ammonium carbonate, and sulphuretted hydrogen.

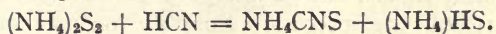
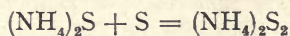
This liquor is passed through an ammonia still in which the whole of the gases are driven off and recovered. Midway down the still the liquor comes in contact with a small quantity of concentrated sodium hydrate which decomposes the insoluble sodium ferrous-ferricyanide, forming the soluble prussiate, thus—



The prussiate liquor on leaving the still is cooled and filtered to separate the ferrous sulphide mud, and consists of approximately a 10 per cent. solution of sodium ferrocyanide and 1 per cent. of impurities. This is evaporated and the distillate crystallized. The crystals obtained are washed with mother liquor to remove impurities, and then dissolved in pure water and recrystallized.

Another process—namely, Chance & Hunt's (British Cyanide Company)—depends upon the fact that ammonium sulphide will dissolve free sulphur, forming ammonium polysulphide, this latter having an affinity for the hydrocyanic acid in the gas, converting it into ammonium thiocyanate.

Small pieces of granular sulphur are put into a rotary washer-scrubber, the ammoniacal liquor in which is between 5° and 6° Twaddell at the inlet. The following reactions take place :—



Where no special process is adopted for the recovery of cyanogen, and oxide purification is used, the cyanogen is retained in the purifiers and transformed into a compound—a varying mixture of cyanogen, iron, and ammonia—a crude form of Prussian blue.

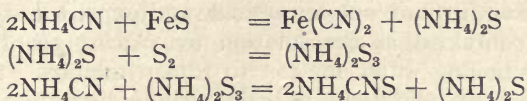
In recovering the cyanogen by oxide, the following points must be kept in view, otherwise much of the material may be caught elsewhere, destroyed, or turned into less valuable products. It is very essential that the gas be not overwashed with strong ammoniacal liquor, as the ammonium sulphide has a great tendency to form ammonium sulphocyanide with the cyanogen.

Air for revivification *in situ* must on no account be introduced before the washers, as the oxygen liberates free sulphur, which combines again with the ammonium sulphide to form polysulphide—a very energetic absorber of the cyanogen. Entrance of air, due to faulty plant, may also account for a large loss. The following analysis by A. O. Nauss, Karlsruhe Gas-Works, shows the loss that may take place from this cause:—

At the outlet of	Pounds of cyanogen calculated as potassium ferrocyanide per 10,000 cub. ft. of gas.	
Tar extractor	2·68 lbs.	100 per cent.
Scrubber	1·86	69
Purifiers	0·17	6

So that over 30 per cent. is lost in the ammoniacal liquor. In order to get a good yield of cyanogen in the oxide, the ammoniacal liquor should not contain more than about 0·15 per cent. ammonium sulphocyanide, which is the average of several gas-works where material rich in cyanogen is obtained. In works where the gas is overwashed and air introduced before the washers, as much as 1 per cent. of ammonium sulphocyanide is easily reached, which corresponds to about 2·5 lbs. of potassium ferrocyanide per ton of coal distilled—representing a loss of over half the cyanogen present. It has been found that if the ammonia washers are worked specially for cyanogen recovery in the oxide, the amount absorbed in this process may be reduced to 1 per cent. of the total cyanogen present. The more efficient an ammonia washer is, and therefore the shorter the time the gas is in contact with the ammoniacal liquor, the smaller will be the loss of cyanogen in this part of the process. Rotary washers are therefore

better than the tower scrubber. In working the purifiers for cyanogen, Dr. Leybold, in his *Cyanogen in Gas Manufacture*, 1893, recommends the slow passage of the gas through the purifiers, and that the gas must be nearly free from ammonia before entering these. Oxides which contain large amounts of ammonia nearly always contain a very large proportion of the cyanogen as sulphocyanide, which is formed by the following equation:—



the sulphur being obtained from the ferric hydrate turning into $\text{FeS} + \text{S}$, the sulphur therefore is *in statu nascendi* and very active.

On emptying the purifiers, care must be taken that the material does not get too hot, otherwise the Prussian blue compound may be decomposed. It is best to spread immediately and keep the mass well moistened.

That oxide of iron is a very efficient absorbing material can be seen from the following table; and if the various possible causes of loss are guarded against, the process leaves little to be desired as an economical and simple method of recovery.

		Pounds potassium ferrocyanide per 10,000 ft. of gas.	
At outlet of washers	.	4.64 lbs.	100 per cent.
„ purifier 1	.	3.71 „	80 „
„ „ 2	.	2.46 „	53 „
„ „ 3	.	0.46 „	10 „

The oxide in use contained—

Moisture	.	.	.	12.5 per cent.
Sulphur	.	.	.	39.7 „
NH_3	.	.	.	0.24 „
Blue— $\text{Fe}_7(\text{CN})_{18}$	.	.	.	8.7 „

The source of the fresh hydrated oxide of iron, whether natural or artificial, exerts no influence on the cyanogen recovered, nor the addition of up to 2 per cent. of air in revivification *in situ*, provided the air be added after the washers.

Estimation of Cyanogen in Coal Gas.—Take several absorption bottles, each of a capacity of 250 cubic centimetres, and place in each 100 c.c. of ammonium polysulphide solution.

Pass 10 to 12 cub. ft. of the gas to be tested through the solution at a rate of 1 cub. ft. per hour.

Add the solution from each absorption bottle together and make up to one litre with distilled water, and take 100 c.c. in a beaker for analysis.

Acidify with dilute sulphuric acid, and expel the sulphuretted hydrogen contained in the solution by placing the beaker and contents in boiling water for ten to fifteen minutes. Should the solution be too acid, add a little sodium hydrate to make it almost neutral. A few small pinches of lead carbonate are then added to combine with traces of sulphuretted hydrogen not previously expelled. Heat in boiling water, as before, filter, and wash the precipitate.

To the filtrate and washings add in excess sulphurous acid and copper sulphate, and allow the precipitate to settle. Filter and wash well. The precipitate (cuprous thiocyanate) is then placed in a beaker and 50 c.c. of boiling water and 25 to 30 c.c. normal sodium hydrate added, and the whole boiled over a Bunsen burner. Filter and wash the precipitate until the washings are free from thiocyanate. Add to filtrate, when cool, dilute nitric acid in excess, and a few drops of a 10 per cent. solution of iron alum as an indicator. Titrate with deci-normal silver nitrate.

Each cubic centimetre of deci-normal silver nitrate = 0.0076 gramme of ammonium thiocyanate.

The following is an example of the calculation, assuming that 10 cub. ft. has passed the meter at normal temperature and pressure and 28 c.c. of deci-normal silver required.

$$\begin{aligned}
 \text{Then } 28 \times 0.0076 &= 0.2128 \text{ grm. ammon. thiocyanate} \\
 &= 2.128 \text{ ,, ,, ,, in 10 c. ft.} \\
 &= 2.128 \text{ kg. ,, ,, in 10,000 c. ft.} \\
 1 \text{ kg.} &= 2.2046 \text{ lbs. ,, ,,} \\
 2.128 \text{ kg.} &= 4.69 \text{ lbs. ,, ,,}
 \end{aligned}$$

Corresponding to 2.71 lbs. ammonium cyanide.

Spent Oxide of Iron.—The oxide of iron used in gas purification may be considered as "spent" when the quantity of free

sulphur contained in it ranges between 45 and 55 per cent. by weight (dry basis) of the whole bulk of the material.

Although by continuing to use it the proportion of sulphur can be increased, it is not economical to do this beyond a certain point, as the purifiers would have to be changed more frequently, and the labour required for that purpose would be out of proportion to the benefit derived. If, however (see *ante*, pp. 156-7), a small proportion of air or oxygen is sent through the purifiers along with the gas, and the reverse action of purification adopted, the oxide can be charged up to 75 per cent. of free sulphur.

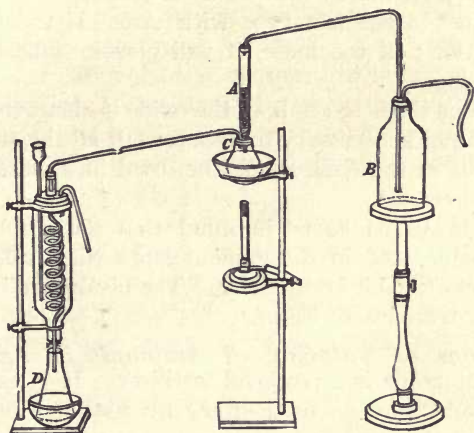


FIG. 217.

In addition to the sulphur, the spent oxide usually contains a small percentage of ammonium salts, and some insoluble cyanides of iron, which are of value.

The spent oxide is generally sold at per unit of contained sulphur.

Mr. Andrew Stephenson devised a handy apparatus (Fig. 217) for estimating the amount of sulphur in the oxide, and gives the following instructions for using the same.

Weigh 100 grs. of spent oxide, dry at 212° Fahr., and weigh to ascertain moisture; put the dried material in the test tube, A, which is provided at the bottom with a filter of cotton-wool.

Carbon bisulphide is then blown from the holder, B, into

the test tube, A, on top of the spent oxide. It percolates the mass gradually, and dissolves out the sulphur, the solution finding its way by gravitation into the flask, C, which is placed in a water-bath.

The Bunsen burner is then lighted, and the application of heat soon vaporizes the carbon bisulphide from the flask C. The vapour finds its way through the connecting tube into the condenser and is recovered in the receiver, D, under water, ready for further use.

The sulphur is left in the flask (the weight of which has been previously noted), and when all the carbon bisulphide is driven off, the quantity of sulphur may be ascertained.

Fit the filter in the test tube with care. If too tight, it will prevent filtration; if too loose, it will permit some of the oxide to pass through.

Three or four times the bulk of the oxide is about the proportion of carbon bisulphide necessary to dissolve out all the sulphur.

The sulphur in the flask should be dried in a water-oven until the weight is constant.

It must always be borne in mind that carbon bisulphide is very inflammable, and in the gaseous state when mixed with air in certain proportions it is explosive. The bisulphide in the holder, B, should be covered with water.

Applications of Sulphate of Ammonia in Agriculture.—Sulphate of ammonia is a powerful fertilizer. It is especially rich in nitrogen; and may be used either by itself or in conjunction with farmyard manure.

It contains more than 20 per cent. of nitrogen, hence its excellent effect upon all corn crops, which is chiefly expended in increasing the yield of grain, but not the straw.

Manure rich in nitrogen increases the proportion of gluten in cereals; and this increase is stated by Boussingault to be as much as 10 per cent. With an increase, therefore, of 10 per cent. in quality and a larger yield, sulphate of ammonia ought to be more freely used.

Mr. W. Arnold states that the most suitable dressing is one of from 2 to 3 cwt. per acre, mixed with an equal weight of fine dry earth or sand, and applied early in the spring (say, March or April) in moist or showery weather. It should be thoroughly mixed in a barn or dry shed, and, if at all lumpy, beaten with a shovel, and passed through a 45-mesh riddle. It should be carefully sown by hand, or, if in large quantities, with a manure drill. If wheat

is to be grown entirely with sulphate of ammonia, it is better to put it on in two dressings—one half in autumn and the other half in spring.

Gas or Spent Lime : Its Composition, and Use in Agriculture.

—In a valuable paper on gas lime, published in the *Journal of Gas Lighting*,¹ Professor Voelcker states that a copious supply of air is necessary to transform the injurious sulphur compounds contained in the material into fertilizing agents.

When exposed to the air (and the longer it is kept exposed the better), gas lime is in some respects superior to quicklime as a manure.

The oxygen of the atmosphere destroys the offensive smell, and changes the sulphuret of calcium in it—first into sulphite, and finally into sulphate of lime or gypsum, well known as a valuable fertilizing substance.

In addition to its chemical virtues, gas lime exercises a beneficial *mechanical* effect upon land, by rendering stiff, heavy, clayey land more porous and friable, and by consolidating light sandy soils.

As a general rule, two tons per acre is the quantity of gas lime which ought to be put on land.

The proper time for its application is in the autumn or winter.

During the period of storage, the heap should be turned over once or twice to ensure its complete exposure to the air.

The following is an analysis by Professor Voelcker of a sample of gas lime, *kept long enough to be used with safety as a manure.*

Composition of Gas or Spent Lime (Dried at 212° Fahr.).

Water of combination and a little organic matter	7.24	per cent.
Oxides of iron and alumina, with traces of phosphoric acid	2.49	„
Sulphate of lime (gypsum)	4.64	„
Sulphite of lime	15.19	„
Carbonate of lime	49.40	„
Caustic lime	18.23	„
Magnesia and alkalies	2.53	„
Insoluble siliceous matter	0.28	„
	<hr/>	
	100.00	

In fresh gas lime, the proportion of water varies usually from 30 to 40 per cent.

¹ See vol. xiv., p. 210.

COAL PRODUCTS.

Table of Substances Obtained in the Manufacture of Coal Gas, and in the Utilization of the Residual Products arising therefrom.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Acenaphthene . . .	$C_{12}H_{10}$	95°	277.5°	A solid hydrocarbon of the C_nH_{2n-14} series, found in coal tar.
Acenaphthene hydride	$C_{12}H_{12}$	—	260°	A solid hydrocarbon of the C_nH_{2n-14} series, found in coal tar.
Acetic acid . . .	$C_2H_4O_2$	16°	119°	A constituent of wood tar, and slightly present in coal tar. Sp. gr. at 15° C. 1.0497.
Acetone	C_3H_6O	—	56°	A highly inflammable liquid oxygenated hydrocarbon. Sp. gr. at 18° C. 0.7921. Present in coal tar.
Acetylene	C_2H_2	—	—	Starting - point of the acetylene series of hydrocarbons. General formula, C_nH_{2n-2} . A constituent of coal gas and of the light oils of coal tar, but in small proportions. Only slightly soluble in tar and water. This hydrocarbon in combination with copper produces a compound of a highly explosive nature, giving rise to obstructions in copper pipes, and in the attempt to remove which, dangerous accidents have occurred. Sp. gr. at 0° C. 0.898.
Acridine	$C_{13}H_9N$	111°	Above 360°	A basic alkaloid found in crude anthracene. A solution causes acute stinging on the skin, and the dust violent sneezing.
Alizarin	$C_{14}H_6O_2(OH)_2$	290°	—	Chief constituent of madder root, and derived from anthracene.
Alum (ammonia alum).	$Al_2(SO_4)_3, (NH_4)_2SO_4, 24H_2O$	—	—	Obtained by adding a solution of sulphate of ammonium to one of sulphate of alumina.
Amido benzene, <i>see</i> Aniline.				
Ammonia	NH_3	—	—	A colourless gas, having a powerfully pungent smell and a caustic taste. Turns red litmus blue and yellow turmeric brown. It is found in crude coal gas both in a free and combined state, and is the most important constituent of gas liquor. Attacks brass and copper fittings, and burns to nitric acid. Water at 16° C. absorbs 764 times its own vol. of ammonia.
Ammoniacal liquor . .	—	—	—	The aqueous portion of the condensed coal products, being a solution chiefly of carbonate, sulphide, and sulphocyanide of ammonium. Average yield of coal, 25 gallons per ton of 8-oz. liquor.
Ammonium acetate . .	$NH_4C_2H_3O_2$	—	—	A constituent of ammoniacal liquor.
Ammonium bicarbonate	NH_4HCO_3	—	—	A constituent of ammoniacal liquor, and sometimes found in gas purifiers.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Ammonium carbonate	$(\text{NH}_4)_2\text{CO}_3$	—	—	A constituent of ammoniacal liquor. When heated to 60° C. the salt breaks up into carbon dioxide, ammonia, and water. Commercial carbonate of ammonia is a mixture of ammonium bicarbonate and ammonium carbamate.
Ammonium chloride, or (when sublimated) sal ammoniac.	NH_4Cl	—	—	The important salt which is produced from ammoniacal liquor when the latter is saturated with muriatic or hydrochloric acid. Nearly all the medicinal preparations of ammonia are obtained from this salt. Used also in fixing the colours in woollen.
Ammonium cyanide	NH_4CN	—	—	A constituent of ammoniacal liquor. A colourless salt, soluble in water. Very volatile and unstable.
Ammonium ferrocyanide.	$(\text{NH}_4)_4\text{Fe}(\text{CN})_6$	—	—	A constituent of spent oxide of iron and of ammoniacal liquor.
Ammonium hydrate	NH_4OH	—	—	A solution of ammonia in water, and a constituent of ammoniacal liquor.
Ammonium sulphate	$(\text{NH}_4)_2\text{SO}_4$	—	—	The valuable salt produced by the neutralization of the ammonia from ammoniacal liquor with sulphuric acid. Largely used as a manure, and, by the addition of a solution of sulphate of alumina, in the manufacture of ammonia alum.
Ammonium sulphhydrate.	NH_4SH	—	—	A constituent of ammoniacal liquor.
Ammonium sulphide	$(\text{NH}_4)_2\text{S}$	—	—	A constituent of ammoniacal liquor, formed by the combination of sulphuretted hydrogen and ammonia in excess.
Ammonium sulphite	$(\text{NH}_4)_2\text{SO}_3$	—	—	A constituent of ammoniacal liquor.
Ammonium sulphocyanate.	$(\text{NH}_4)\text{CNS}$	—	—	Present in ammoniacal liquor, coal tar, and spent oxide of iron.
Ammonium thiosulphate.	$(\text{NH}_4)_2\text{S}_2\text{O}_3$	—	—	A constituent of ammoniacal liquor.
Ammonium thiocyanate, see Ammonium sulphocyanate.				
Amylene	C_5H_{10}	—	39°	Valerene, pentylene, a limpid, mobile liquid of the ethylene series of hydrocarbons. Found in coal gas and in coal tar; and more abundantly in boghead tar, petroleum, etc. Sp. gr. at 10° C. 0.6549.
Amylic hydride, see Pentane.				
Aniline	$\text{C}_6\text{H}_7\text{N}$	-8°	182°	Phenylamine, amido benzene, a constituent of coal tar, and the base of all the dyes bearing this name. Sp. gr. at 16° C. 1.020.
Anthracene	$\text{C}_{14}\text{H}_{10}$	213°	360°	Contained in the least volatile portion of the coal oils. The colouring principle of madder, alizarin, is derived from this substance.
Anthracene dihydride.	$\text{C}_{14}\text{H}_{12}$	106°	305°	Found in coal tar.
Anthracene hexahydride.	$\text{C}_{14}\text{H}_{16}$	63°	290°	Do. do.
Anthracene perhydride	$\text{C}_{14}\text{H}_{24}$	88°	250°	Probably a constituent of coal tar.
Anthraquinon	$\text{C}_{14}\text{H}_8\text{O}_2$	273°	382°	Derived from anthracene.
Anthrol	$\text{C}_{14}\text{H}_{10}\text{O}$	—	—	Anthrol and phenanthrol have been found accompanying anthracene.
Antipyrène	—	—	—	A coal tar product. Said to be the most powerful agent known for reducing temperature in fevers.
Aqueous vapour	H_2O	—	—	A constituent of crude gas, and removed, though not entirely, by condensation.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Benzene	C_6H_6	$4.5^{\circ}-7^{\circ}$	80.4°	Phenyl hydride, hydrocarbon of the general formula, C_nH_{2n-6} , of which series it is the first, and from which all aromatic compounds are derived. It is a constituent of coal tar, and is a colourless, mobile liquid, slightly soluble in water. It dissolves iodine, sulphur, fats, resin, gutta-percha, and is the chief constituent of naphtha. Sp. gr. at $0^{\circ} C.$ 0.90023.
Benzol	—	—	—	Formerly a synonym for benzene, but now mostly used for the commercial mixture of benzene, toluene, etc., in varying proportions.
Benzerythrene . .	$C_{21}H_{18}$	$307^{\circ}-8^{\circ}$	—	A constituent of coal tar.
Benzoic acid . .	$C_7H_6O_2$	121°	249°	A constituent of the residue from the manufacture of phenol.
Benzonitrile . .	C_6H_5CN	—	191°	A constituent of coal tar. A colourless oil, smelling of almonds, and produced by passing dimethylaniline through a red-hot tube. Sp. gr. at $0^{\circ} C.$ 1.023.
Biophen	$C_4H_4S_2$	—	$165^{\circ}-70^{\circ}$	A probable constituent of coal tar.
Bisulphide of carbon, <i>see</i> Carbon disulphide.	—	—	—	Certain hydrocarbons present in coal tar pitch.
Bisulphuret of carbon, <i>see</i> Carbon disulphide.	—	—	—	Contained in coal tar.
Bitumens	—	—	—	Diethyl, butyric-hydride. A hydrocarbon existing in coal gas, and belonging to the marsh gas series of hydrocarbons. It is insoluble in water. Burns with a strongly luminous flame. Sp. gr. 2.0r.
Brunolic acid . .	—	—	1°	Tetrylene, ditetryl, oil gas. A hydrocarbon of the ethylene series, found both in coal gas and coal tar. Sp. gr. 1.94.
Butane (normal) .	C_4H_{10}	—	—	
Butylene (normal) .	C_4H_8	—	-5°	
Butyric hydride, <i>see</i> Butane.	—	—	—	
Calcium hydro-sulphide	$Ca(SH)_2$	—	—	A compound of lime and sulphuretted hydrogen found in gas purifiers.
Calcium hydroxy hydro-sulphide.	$CaOHSH$	—	—	A hydrated sulphide of lime found in gas purifiers. $Ca(SH)_2 + H_2O = CaOHSH + H_2S$.
Calcium sulphide .	CaS	—	—	Spent lime, formed by the absorption of sulphuretted hydrogen by lime. The fouled lime of the purifiers. Efficacious in absorbing from the gas the carbon disulphide impurity. Used as a manure or top-dressing for land.
Caproylene, <i>see</i> Hexylene.	—	—	—	
Caproylic hydride, <i>see</i> Hexane.	—	—	—	
Caprylic hydride, <i>see</i> Octane.	—	—	—	
Carbazol	$C_{12}H_9N$	238°	355°	A constituent of coal tar.
Carbinol, <i>see</i> Methyl alcohol.	—	—	—	
Carbolic acid, <i>see</i> Phenol.	—	—	—	
Carbon	C	—	—	This element is the basis of the illuminating qualities of coal gas, and of all hydrocarbons. The solid deposit upon the interior surface of gas-retorts is almost pure carbon.

Name.	Formula or Symbol.	Melting Point, Degrees Centigrade.	Boiling Point, Degrees Centigrade.	Remarks.
Carbon dioxide, called also "black-damp."	CO ₂	—	—	The final combustion product of carbon. The presence of this impurity in coal gas to the extent of only 1 per cent. will reduce the illuminating power about 5 per cent. Soluble in its own vol. of water. Entirely removed from gas by the use of lime. Sp. gr. 1.52.
Carbon disulphide	CS ₂	—	46°	One of the impurities in coal gas, and one of the most difficult to eliminate. Removable by sulphide of calcium. A colourless, mobile, highly refractive liquid. It burns with a blue flame, forming sulphur dioxide. Sp. gr. at 0° C. 1.292.
Carbon monoxide, called also "choke-damp."	CO	—	—	The first oxidation product of carbon, and a constituent, in small proportion, of coal gas. Test, an ammoniacal solution of cuprous chloride. Sp. gr. 0.967 (air = 1).
Carbon oxysulphide	COS	—	—	A constituent of coal tar and ammoniacal liquor.
Carbonic acid	H ₂ CO ₃	—	—	A solution of carbon dioxide in water. A constituent of ammoniacal liquor.
Cespite	C ₅ H ₁₃ N	—	—	A constituent of coal tar.
Chinaldin	C ₁₀ H ₉ N	—	243°	Do. do.
Chinoline, <i>see</i> Quinoline.				
Chrysene	C ₁₈ H ₁₂	250°	436°	Obtained by distilling coal tar pitch as far as coke, and found mixed with pyrene. It remains as a residue on extracting the pyrene with carbon bisulphide.
Chrysene hydride	C ₁₈ H ₂₈	—	360°	A probable constituent of coal tar.
Chrysene perhydride	C ₁₈ H ₂₀	115°	353°	Do. do.
Chrysogene	?	—	—	A constituent of coal tar. Of an intense orange colour.
Cimramene, <i>see</i> Styrolene.				
Clinker	—	—	—	The vitrified residue from the consumed coke. Used in road-making, etc. Inserted here to show that there is no waste in gas manufacture.
Coke	—	—	—	The valuable product obtained in the manufacture of coal gas. Consists mainly of carbon.
Collidine	C ₈ H ₁₁ N	—	171°-2°	A constituent of coal tar. Found in the light oils. Sp. gr. at 0° C. 0.921.
Condensable hydrocarbons.	—	—	—	Includes all the hydrocarbons existing in coal tar. But, indeed, the whole of the more volatile hydrocarbons existing in coal gas are liable to be condensed at low temperatures. Hence the importance of preventing the gas from being subjected to a temperature below 50° F.
Coridine	C ₁₀ H ₁₅ N	—	211°	A constituent of coal tar.
Creosote	—	—	—	A mixture of substances of phenolic character. Obtained in large quantities in the distillation of coal tar. Used in the preservation of timber. It is also useful as a fuel, and in combination with caustic soda and tallow, as a dip for washing sheep.
Cresol, <i>see</i> Cresylic acid.				

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Cresylic acid, <i>see also</i> Ortho- Para- Meta-Cresol.	C_7H_8O	—	About 200°	Cresol, oxytoluene, commercial cresylic acid, is a mixture of the isomers ortho-para- and meta-cresol. It is a constituent of coal tar, and is a colourless refractive liquid.
Crotonylene . . .	C_4H_6	—	18°	A colourless liquid hydrocarbon of the acetylene series and a constituent of coal tar.
Crude naphtha . . .	—	—	—	The first naphtha obtained in the distillation of coal tar, coming over at 82° to 150° C.
Cryptidine . . .	$C_{11}H_{11}N$	—	274°	One of the coal tar alkaloids.
Cumarone . . .	C_8H_6O	—	168·5°-191°	A constituent of the light coal tar oils.
Cumene, <i>see</i> Pseudocumene.				
Cumidine, <i>see</i> Parvoline.				
Cumole, <i>see</i> Pseudocumene.				
Cyanogen	CN	—	—	Produced during the destructive distillation of coal, but, with the exception of a very small proportion which passes into the gas, is condensed and carried into the well along with the ammoniacal liquor. Absorbed by alkalis and alkaline sulphides. Combined with iron it forms Prussian blue, and is the cause of the bluish green colour in spent lime. It is used in the cyanide process of gold extraction. In union with ammonium sulphide, it forms ammonium sulpho-cyanide, a substance used by photographers, and in the preparation of the constituent of the toys known as "Pharaoh's Serpents." It is a highly poisonous gas. Sp. gr. 1·8 (air = 1). See article on page 431.
Cyclopentadiene . . .	C_5H_6	—	42·5°	Propenylene, of the C_nH_{2n-4} series of hydrocarbons. A constituent of the first runnings of coal tar benzene.
Cymidene	$C_{10}H_{15}N$	—	250°	A constituent of coal tar.
Dead oil, <i>see</i> Creosote.				
Decane I.	$C_{10}H_{22}$	—	158°-161°	Diamyl. A constituent of all tars. Of the marsh gas series of hydrocarbons. Sp. gr. at 18° C. 0·736.
Decane II.	$C_{10}H_{22}$	—	170°-71°	A constituent of coal tar.
Decylene	$C_{10}H_{20}$	—	156°	A constituent of coal tar. Sp. gr. 0·7789.
Diamyl, <i>see</i> Decane.				
Dibutyl, <i>see</i> Octane.				
Dicaproyl, <i>see</i> Duodecane.				
Diethyl, <i>see</i> Butane.				
Dihexyl, <i>see</i> Duodecane.				
Dihydrobenzene . . .	C_6H_8	—	81·5°	A hydrocarbon of the aromatic series (terpenes), found in coal tar.
Dihydrocymene . . .	$C_{10}H_{16}$	—	174°	A probable constituent of coal tar.
Dihydrotoluene . . .	C_9H_{10}	—	105°-8°	Do. do.
Dihydroxylene . . .	C_8H_{12}	—	132°-4°	Do. do.
Dimethyl, <i>see</i> Ethane.				
Dimethylacridine . .	$C_{15}H_{13}N$	71°	—	Do. do.
Dimethylamine . . .	$NH(CH_3)_2$	—	8°-9°	A probable constituent of ammoniacal liquor.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Dimethylanthracene .	$C_{16}H_{14}$	224°-5°	—	A hydrocarbon of the anthracene series, found in coal tar in small quantities.
Dimethylcumarones .	$C_{10}H_{10}$	—	221°-2°	A probable constituent of coal tar.
Dimethylnaphthalene	$C_{12}H_{12}$	—	262°-4°	A hydrocarbon of the naphthalene series, found in coal tar.
Diphenyl	$C_{12}H_{10}$	70·5°	254°	A hydrocarbon with a close relationship to phenanthrene, found in the fraction of coal tar boiling between 220°-270° C.
Diteryl, <i>see</i> Butylene.				
αDithienyl	$C_8H_6S_2$	33°	—	A probable constituent of coal tar.
βDithienyl	$C_8H_6S_2$	132·4°	—	Do. do.
Duodecane	$C_{12}H_{26}$	—	200°-2°	Dicaproyl, ditrexyll, laurylic hydride. Found in boghead tar. A member of the marsh gas series, and an oily, colourless liquid with a turpentine-like smell. Sp. gr. at 18° C. 0·7568.
Durene	$C_{10}H_{14}$	80°-1°	196°	A hydrocarbon found in the fraction of coal tar boiling between 180° and 200° C.
Elayl, <i>see</i> Ethylene .				
Ethane	C_2H_6	—	—	Dimethyl, ethylic hydride. A colourless gas, burning with a non-luminous, bluish flame. A constituent of coal gas, and a member of the C_nH_{2n+2} series of hydrocarbons. Sp. gr. 1·075.
Ethylamine	$NH_2C_2H_5$	—	18·7°	A basic nitrogenized compound present in ammoniacal liquor and coal tar.
Ethylbenzene	C_8H_{10}	—	137°	An isomer of the xylenes, discovered in coal tar xylene.
Ethylene	C_2H_4	—	-110°	Elayl, olefiant gas. First member of the C_nH_{2n} (olefines) series of hydrocarbons. Exists in coal gas in proportions varying from 3 per cent. upwards, and contributes greatly to the illuminating power. Liquefies at 0° C. under 42½ atmospheres. Very slightly soluble in water and is absorbed by fuming sulphuric acid, with formation of ethionic acid. Sp. gr. 0·968 (air = 1).
Ethyl-isomyl	C_7H_{16}	—	90·3°	An isomer of heptane, found in coal tar. Sp. gr. at 0° C. 0·6969.
Ethyl mercaptan . . .	C_2H_5SH	—	36°	A probable constituent of coal tar. Sp. gr. 0·831.
Ethyl alcohol	C_2H_6O	—	78·5°	Spirit of wine. Traces found in benzene and crude benzol. Sp. gr. at 0° C. 0·806.
Ethyl hydride, <i>see</i> Ethane.				
Ethyl sulphide	$(C_2H_5)_2S$	—	91°	One of the mercaptans and a probable constituent of coal tar. Sp. gr. 0·852.
Eupion	—	—	—	Obtained from coal tar and proposed as a substitute for chloroform.
Fire damp, <i>see</i> Light carburetted hydrogen and Methane.				
Fluoranthene	$C_{15}H_{10}$	109°	—	Found in coal tar, accompanying pyrene in the highest boiling fractions. With nitric acid it yields a trinitro product.
Fluorene	$C_{13}H_{10}$	113°	295°	Diphenylene methane. Of the C_nH_{2n-16} series of hydrocarbons, and found in the fraction of coal tar boiling between 295°-310° C.
Green oil	—	—	—	This follows the dead oil in the distillation of coal tar, and, mixed with resin and oil, is used for making railway grease. Lampblack, from which printers' ink is prepared, is also made from it.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Hemellithol . . .	C_9H_{12}	—	175°	A constituent of coal tar oils and of commercial pseudocimidine.
Heptane (normal) . . .	C_7H_{16}	—	98°	Enanthyl hydride. A mobile liquid hydrocarbon of the marsh gas series. A constituent of coal tar. Sp. gr. at 0° C. 0·7006.
Heptylene . . .	C_7H_{14}	—	96°-99°	Enthylene. A liquid hydrocarbon of the ethylene series. Found in coal tar. Its chemical behaviour is like that of anylene and hexylene. Sp. gr. at 18° C. 0·718.
Hexahydrobenzene . . .	C_6H_{12}	—	69°	An aromatic addition product of the general formula, C_nH_{2n} (naphthenes), found in coal tar. Sp. gr. at 0° C. 0·76.
Hexahydroisoxylene . . .	C_8H_{16}	—	118°	An aromatic addition product of the general formula, C_nH_{2n} (naphthenes), found in coal tar. Sp. gr. at 0° C. 0·777.
Hexahydrotoluene . . .	C_7H_{14}	—	97°	An aromatic addition product of the general formula, C_nH_{2n} (naphthenes), found in coal tar. Sp. gr. at 0° C. 0·772.
Hexane (normal) . . .	C_6H_{14}	—	69°-71°	Caproylic hydride. A colourless, mobile hydrocarbon liquid of the marsh gas series. Found in petroleum, cannel and coal tar, and the principal constituent of gasoline. Burns with a bright luminous flame. Sp. gr. at 17° C. 0·663.
Hexoylene . . .	C_6H_{10}	—	80°	Diallyl. A colourless liquid with a penetrating alliaceous smell. A constituent of coal tar. Sp. gr. at 13° C. 0·71.
Hexylene . . .	C_6H_{12}	—	68°-70°	Caproylene. A member of the ethylene series of hydrocarbons, and a constituent of coal tar; contained in the light oil. Sp. gr. at 0° C. 0·6996.
Hydrindene . . .	C_9H_{10}	—	—	A constituent of coal tar, accompanying indene.
Hydrocarbons . . .	—	—	—	The different compounds of carbon and hydrogen, contained in illuminating gas and in coal tar, constituting the light-giving material of the former and the rich and valuable products of the latter.
Hydrocyanic acid . . .	HCN	—	—	A constituent of ammoniacal liquor.
Hydrogen . . .	H	—	—	The lightest known substance in nature (unless helium can now claim that distinction). One of the chief constituents of coal gas, in which it exists to the extent of 12 to 50 per cent. Pure hydrogen burns with a non-luminous flame of high temperature. 100 vols. H_2O absorb 1·93 vols. H. Sp. gr. 0·0691 (air = 1).
Hydrogen sulphide . . .	H_2S	—	—	Sulphuretted hydrogen. The chief impurity in raw or crude coal gas. It is entirely removed by lime and oxide of iron. It is an inflammable gas, and generates sulphurous acid in burning. 1 vol. H_2O at 15° C. absorbs 3·23 vols. H_2S . Test, acetate of lead.
Hydrosulphocyanic acid	$S(CN)H$	—	—	Obtained from coal tar.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Indene	C_9H_8	—	177°-8°	A hydrocarbon of C_nH_{2n-10} series. Found in coal tar, in the fraction of crude benzene boiling at 176°-182° C. A colourless liquid. Indene is also found in the product condensed from coal gas at -10° C. Sp. gr. at 15° C. 1.040.
Iridoline	$C_{10}H_9N$	—	252°-7°	An isomer with quinaldine, and present in coal tar.
Isobutylene	C_4H_8	—	-8°	An isomer of butylene, found both in coal gas and coal tar.
Isopentane	C_5H_{12}	—	30°	Amylic hydride. A colourless, very mobile liquid found in coal tar. One of the isomers of pentane. It burns with a brilliant white flame. Sp. gr. at 18° C. 0.628.
Isoquinoline Klumine, <i>see</i> Acetylene. Laurylic hydride, <i>see</i> Duodecane. Lepidine, <i>see</i> Iridoline. Leticoline, <i>see</i> Quinoline. Light carburetted hydrogen, <i>see</i> Marsh gas and Methane. Light oil	C_9H_7N	18°-23°	236°-7°	A constituent of coal tar along with quinoline.
Lutidine	C_7H_9N	—	142°	The oil that follows the crude naphtha, and precedes the creosote or dead oil, in the destructive distillation of coal tar. It is usually redistilled with the crude naphtha for obtaining benzol. A constituent of coal tar found in the light oil. It is probably γ ethyl pyridine.
Marsh gas, <i>see</i> Methane.	—	—	—	
Mercaptans	—	—	—	Sulphuretted hydrocarbons probably present in coal tar.
Mesitylene	C_9H_{12}	—	163°	A constituent of coal tar.
Metacresol	C_7H_8O	3°-4°	201°	Oxytoluene, cresylic acid. A constituent of coal tar.
Metaxylenols I. . . .	$C_8H_{10}O$	73°	216°	} Isomers of xylenols, and constituents of coal tar.
Metaxylenols II. . . .	$C_8H_{10}O$	26°	211.5°	
Methane	CH_4	—	—	Marsh gas, fire-damp, light carburetted hydrogen. A colourless gas, slightly soluble in water, burning with a pale yellow flame, and present in coal gas to the extent of 30 to 60 per cent. The first of a series of hydrocarbons of the general formula C_nH_{2n+2} . Sp. gr. 0.5566 (air = 1).
2Methylacridine	$C_{14}H_{11}N$	134°	—	} Probable constituents of coal tar.
4Methylacridine	—	88°	—	
Methylamine	$NH_2 \cdot CH_3$	—	—	Substituted ammonia of the fatty series. A constituent of ammoniacal liquor. 1 vol. water at 12° C. absorbs 1040 vols.
Methylbenzene, <i>see</i> Toluene.	—	—	—	
Methylmercaptan	CH_3SH	—	20°	A sulphuretted hydrocarbon present in coal tar.
α Methylnaphthalene	$C_{11}H_{10}$	—	240°-43°	A hydrocarbon of the naphthalene series, and a constituent of coal tar. A colourless oil of an aromatic smell. Sp. gr. 1.0287.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
β Methylnaphthalene .	$C_{11}H_{10}$	32.5°	242°	A hydrocarbon of the naphthalene series present in coal tar and in the distillate between 220° and 270° C.
Methyl alcohol . .	CH_4O	—	66°	Wood spirit, wood naphtha. Occurs in wood tar and probably in coal tar. Sp. gr. at 0° C. 0.812.
Methyl cyanide . .	CH_3CN	—	77°	Acetonitrile. A constituent of light coal tar oils. Sp. gr. 0.835.
Methyl isocyanide .	C_2H_3N	—	59.6°	A constituent of coal tar.
Methyl sulphide .	$(CH_2)_2S$	—	41°	A constituent of coal tar. Sp. gr. 0.845.
Mirbane, <i>see</i> Nitrobenzol.				
Monomethylantracene	C_9H_{12}	$208^{\circ}-12^{\circ}$	—	A constituent of coal tar, present in small quantities.
Muriate of ammonia, <i>see</i> Ammonium chloride.				
Naphtha, <i>see</i> Crude naphtha.				
Naphthalene . . .	$C_{10}H_8$	79°	218°	A hydrocarbon of the $C_{10}H_{2n-12}$ series. Formed in organic substances by the action of heat at a high temperature. A constituent of coal tar to the extent of 5 to 10 per cent. A white, crystalline mass of rhomboidal scales. Not soluble in water, but in alcohol and the phenols, consequently in naphtha and coal tar. Deposited by sudden changes in temperature and by roughnesses and abrupt elbows in mains and pipes. Sp. gr. at 15° C. 1.1517.
Naphthalene dihydride	$C_{10}H_{10}$	—	$200^{\circ}-10^{\circ}$	A viscid fluid product of naphthalene occurring in coal tar.
Naphthalene tetrahydride.	$C_{10}H_{12}$	—	190°	A viscid fluid product of naphthalene occurring in coal tar.
α Naphthol . . .	$C_{10}H_8O$	90°	279°	Constituents of the "green oil" obtained in the manufacture of anthracene.
β Naphthol . . .	$C_{10}H_8O$	122°	294°	
Naphthylamine . .	$C_{10}H_9N$	—	—	A compound produced from naphthalene. The presence of nitrogen in coal gas is sometimes due to irregularity in the working of the exhauster, by which a vacuum is created, and air drawn in through the fissures of the retorts. The nitrogen contained in the coal, and which is eliminated by distillation, is evolved in combination with hydrogen as ammonia. Its effect is to injure the illuminating power. 100 vols. water absorb 1.48 vol.
Nitrogen . . .	N	—	—	
Nitric acid . . .	HNO_3	—	—	A small proportion of this acid is formed when nitrogen is burned with coal gas. Sp. gr. 1.53.
Nitro-benzene . .	$C_6H_5NO_2$	—	213°	A substance produced by the action of fuming nitric acid on benzol naphtha, and which is used for the manufacture of aniline colours. It is also used as an odour resembling oil of bitter almonds to perfume soaps and flavour confectionery.
Nonane	C_9H_{20}	—	130°	A hydrocarbon of the marsh gas series, and a constituent of coal tar. Sp. gr. at 6° C. 0.7242.
Nonone	C_9H_{18}	—	174°	A hydrocarbon of the $C_{11}H_{2n-4}$ series, and a probable constituent of coal tar.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Octane I.	C_8H_{18}	—	119°-20°	Caprylic hydride, dibutyl, valyl. A limp liquid of the marsh gas series, found in petroleum, boghead, and coal tar. Sp. gr. at 17° C. 0.719.
Octane II.	C_8H_{18}	—	124°	An isomer of octane, found in petroleum, cannel, and coal tar. Sp. gr. at 0° C. 0.6969.
Octylene	C_8H_{16}	—	—	A constituent of coal gas.
Odorine, <i>see</i> Picoline.				
Öanthylene, <i>see</i> Heptylene.				
Önanthylic hydride, <i>see</i> Heptane.				
Oil gas, <i>see</i> Butylene.				
Olefiant gas, <i>see</i> Ethylene.				
Ortho-cresol	C_7H_8O	32°	188°	Oxytoluene, cresylic acid. A constituent of coal tar.
Ortho-methylpyridine, <i>see</i> α Picoline.				
Orthoxylenol	$C_8H_{10}O$	62°	225°	One of the oxyleneols and a constituent of coal tar.
Oxygen	O	—	—	A constituent of coal gas and of certain of the tar products. It probably exists in the gas chiefly owing to the drawing in of air through the retorts and apparatus by too rapid working of the exhauster, and also to the opening of the retorts and purifiers for charging and discharging. 2 per cent. of air injures the illuminating power of the gas to the extent of 10 per cent.; 7 per cent. of air diminishes the light one-half, whilst about 25 per cent. of air practically destroys it. Sp. gr. 1.105 (air = 1).
Oxytoluene, <i>see</i> Ortho-Para-Metal-cresol, and Cresylic acid.				
Paracresol	C_7H_8O	36°	199°	Oxytoluene, cresylic acid. A constituent of coal tar.
Paraffin	$C_{17}H_{36}$ to $C_{27}H_{56}$	—	—	A colourless, solid, crystalline, fatty substance, chiefly obtained from the tar from boghead cannel. It is manufactured into candles, giving a brilliant white light; and oil of high lubricating properties is made from it.
Paranaphthalene, <i>see</i> Anthracene.				
Paraxylenol	$C_8H_{10}O$	74.5°	211°-13°	An isomer of the xylenols, and a constituent of coal tar.
Parvoline	$C_9H_{13}N$	—	179°	Cumidine. A constituent of coal tar.
Pentahiroline	$C_{13}H_{15}N$	—	—	A constituent of coal tar, obtained from the heavy oil.
Pentane (normal)	C_5H_{12}	—	37°-39°	Amylichydride. A colourless, very mobile liquid found as a vapour in coal tar. Of the marsh gas series of hydrocarbons, and burning with a brilliant white flame. Sp. gr. at 18° C. 0.6263.
Pentylene, <i>see</i> Amylene.				
Phenanthrene	$C_{14}H_{10}$	99°-100°	340°	An isomer of anthracene, found in the last fraction of coal tar oils.
Phenanthrene octohydride.	$C_{14}H_{18}$	—	—	A probable constituent of coal tar.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Phenanthrene perhy- dride	$C_{14}H_{24}$	-3°	274°	A probable constituent of coal tar.
Phenanthrene tetrahy- dride	$C_{14}H_{14}$	—	300°-400°	Do. do.
Phenic acid, <i>see</i> Phenol.				
Phenol	C_6H_6O	42°	184°	Carbolic acid, phenic acid, phenylic acid, phenylic alcohol. A constituent of coal tar, with valuable antiseptic and disinfecting properties. Sp. gr. at 15° C. 1.065.
Phenyl α naphthyl-car- bazol	$C_{16}H_{11}N$	225°	Above 440°	} Constituents of coal tar.
Phenyl β naphthyl-car- bazol	$C_{16}H_{11}N$	230°	—	
Phenylamine, <i>see</i> Ani- line.				
Phenylethylene, <i>see</i> Styrolene.				
Phenylic acid, <i>see</i> Phenol.				
Phenyl alcohol, <i>see</i> Phenol.				
Phenyl hydride, <i>see</i> Benzene.				
Phloral, <i>see</i> Paraxy- lenol.				
Picene	$C_{22}H_{14}$	364°	518°-20°	A hydrocarbon similar to chrysene, present in the heavy tar oils. It has the highest boiling point of any known hydrocarbon.
Picene eikosehydride .	$C_{22}H_{34}$	—	360°	A probable constituent of coal tar.
Picene perhydride . .	$C_{22}H_{36}$	175°	360°	Do. do.
α Picoline	C_6H_7N	—	135°	Odorine. A colourless liquid present in coal tar. Sp. gr. at 0° C 0.9613.
Pit gas, <i>see</i> Marsh gas.				
Pitch	—	—	—	The residue remaining of the distillation of coal tar, of which it constitutes about 66 per cent. by weight. It is extensively used for asphaltting.
Pittacal	—	—	—	Found in the heaviest portion of coal tar oil.
Propane	C_3H_8	—	-20°	Propyl hydride. A constituent of coal gas, of the marsh gas series of hydrocarbons (C_2H_{2n+2}).
Propylene	C_3H_6	—	-110°	Tritylene. A hydrocarbon of the ethylene series. A constituent both of coal gas and coal tar. Slightly soluble in water, absolute alcohol and glacial acetic acid. Sp. gr. 1.455.
Propyl hydride, <i>see</i> Propane.				
Pseudo-butylene . .	C_4H_8	—	+1°	An isomer of butylene, found both in coal gas and coal tar.
Pseudo-cumene . . .	C_9H_{12}	—	169.5°	A constituent of coal tar.
Pyrene	$C_{16}H_{10}$	148°	—	A constituent of the highest boiling fractions of coal tar.
Pyridene	C_5H_5N	—	116.7°	A colourless, mobile liquid, and a constituent of coal tar. The natural alkaloids are derivatives of pyridene. Sp. gr. 0.9858.
α Pyrocresol	$C_{15}H_{14}O$	196°	350°	} Constituents of coal tar.
β Pyrocresol	$C_{15}H_{14}O$	124°	—	
γ Pyrocresol	$C_{15}H_{14}O$	105°	—	

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade	Remarks.
Pyrrrol	C_4H_5N	—	133°	A colourless liquid with a smell resembling chloroform. A constituent of coal tar, contained in the light oils.
Quatuordecane . .	$C_{14}H_{30}$	—	236°-40°	A hydrocarbon of the methane series, found in coal tar. Sp. gr. 0.796.
Quinaldine . . .	$C_{10}H_9N$	—	243°	A homologue of quinoline and found along with same in coal tar.
Quindecane . . .	$C_{15}H_{32}$	—	258°-62°	A hydrocarbon of the methane series. found in coal tar. Sp. gr. 0.809.
Quinoline	C_9H_7N	—	239°-40°	Leucoline. A constituent of coal tar. Sp. gr. 1.081.
Retene	$C_{18}H_{18}$	98°	350°	Occurs in coal tar. At a red heat it yields anthracene.
Retene dodecahydride	$C_{18}H_{30}$	—	336°	A liquid hydrocarbon occurring in coal tar. Produced by passing acetylene through a red-hot tube.
Rosolic acid . . .	$C_{19}H_{11}O_5$	—	—	A constituent of coal tar.
Rubidine	$C_{11}H_{17}N$	—	230°	Do. do.
Sal ammoniac, <i>see</i> Ammonium chloride.				
Sedecane	$C_{16}H_{34}$	—	280°	A hydrocarbon of the methane series, found in coal tar.
Solid paraffin . . .	$C_{17}H_{36}$ to $C_{27}H_{56}$	40°-60°	—	Hydrocarbons of the methane series, found in coal tar. True paraffin is a colourless, solid, crystalline, fatty substance, chiefly obtained from boghead cannel or shale. It is manufactured into candles. Oil of high lubricating properties is also made from it.
Spent lime, <i>see</i> Calcium sulphide.				
Spent oxide of iron .	—	—	—	The hydrated peroxide of iron, employed in abstracting the sulphuretted hydrogen from the gas, having become charged with free sulphur to the extent of 40 to 75 per cent. by a succession of foulings and revivifications, is used by the manufacturing chemists for making sulphuric acid.
Spirit of wine, <i>see</i> Ethyl alcohol.				
Styrolene	C_8H_8	—	145°	Cimramene, phenylethylene. A hydrocarbon of C_nH_{2n-8} series. Found in small quantities in coal tar. It may be produced synthetically by passing a mixture of benzene and ethylene through a red-hot tube. A colourless mobile oil. Sp. gr. at 16° C. 0.876.
Sulphate of ammonia, <i>see</i> Ammonium sulphate.				
Sulphide of calcium, <i>see</i> Calcium sulphide.				
Sulphocyanogen . .	SCN	—	—	A constituent of crude coal gas.
Sulphohydrocarbons .	—	—	—	Sulphur impurities in coal gas.
Sulphur	S	114.5°	448°	In the best gas-producing coals the amount of sulphur present rarely exceeds 1½ per cent., generally it is much less. In the process of distillation about one-half the contained sulphur remains in the residual coke, whilst the other half is volatilized, and, combining with H and C, constitutes impurities in coal gas. Sulphur has been found in coal tar on distillation.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Sulphur dioxide .	SO ₂	—	—	Sulphurous anhydride. Produced by the combustion of sulphur and its compounds. It is therefore a constituent of the products of combustion of coal gas, which, when purified, yet contains traces of sulphur compounds. The quantity given out, however, even with the most impure gas (say, with 40 grains sulphur in the 100 feet), is so inappreciable as to be perfectly innocuous in its effects, especially where the smallest attention is paid to ventilation. It is a colourless gas, having a suffocating smell, and neither burns nor supports combustion. Sp. gr. 2.211 (air = 1).
Sulphuretted hydrogen, <i>see</i> Hydrogen sulphide.				
Sulphuric acid . . .	H ₂ SO ₄	—	338°	This, the most important and useful of all acids, is largely manufactured from the sulphur obtained from the spent oxide of iron from gas purifiers.
Sulphurous acid .	H ₂ SO ₃	—	—	An unstable acid formed by the combination of sulphur dioxide and water. It rapidly oxidizes to sulphuric acid.
Sulphurous anhydride, <i>see</i> Sulphur dioxide.				
Tar (coal)	—	—	—	The well-known complex, viscid liquid, produced in the destructive distillation of coal, and from which a great variety of valuable products is obtained. It consists almost entirely of hydrocarbon compounds, with a varying proportion of solid carbon. Tar, on distillation, yields on an average— 2.4 per cent. ammoniacal liquor. 1.6 " crude naphtha. 1.2 " light oil. 28.8 " creosote or dead oil. 66.0 " pitch. 100.0 Ordinary coal tar. Sp.gr. 1.120 to 1.150 Cannel coal tar, 0.980 to 1.060. Addition products of the benzene series C _{9H-9} (naphthylenes). Probably a constituent of coal tar.
Tetrahydrobenzene .	C ₆ H ₁₀	—	82°	
Tetrahydrotoluene .	C ₇ H ₁₂	—	103°-5°	Addition products of the benzene series C _{9H-9} (naphthylenes). Probably a constituent of coal tar.
Tetrahydroxylene	C ₈ H ₁₄	—	129°-132	Addition products of the benzene series C _{9H-9} (naphthylenes). Probably a constituent of coal tar.
Tetramethylpyridine .	C ₁₉ H ₁₃ N	—	—	One of the isomers of parvoline, and a constituent of coal tar.
Tetramethylthiophene	C ₈ H ₁₂ S	—	182°-4°	A probable constituent of coal tar.
Tetralene, <i>see</i> Butylene.				
Thiocyanogen, <i>see</i> Sulphocyanogen.				
Thionaphthene . . .	C ₈ H ₅ S	30°-31°	220°	Do. do.

Name.	Formula or Symbol.	Melting Point. Degrees Centigrade.	Boiling Point. Degrees Centigrade.	Remarks.
Thiophen . . .	C_4H_4S	—	48°	Occurs in coal tar benzene. A colourless, mobile liquid. Sp. gr. at 18° C. 1.062.
Thiophene . . .	$C_6H_4S_2$	—	224°-6°	A probable constituent of coal tar.
α Thiitolene . . .	C_5H_4S	—	48°	} Constituents of coal tar, found in commercial toluol.
β Thiitolene . . .	C_5H_6S	—	113°	
Thioxenes . . .	C_6H_6S	—	135°-7°	A sulphuretted hydrocarbon isolated from commercial xylool. Found in coal tar.
Toluene . . .	C_7H_8	—	111°	Methylbenzene. A hydrocarbon of the benzene series, found in coal tar and coal gas. It is a colourless, mobile, strongly refractive liquid. It is insoluble in water. When ignited it burns with a bright and strongly smoking flame. Sp. gr. at 0° C. 0.8824.
Toluidine . . .	C_7H_9N	—	197°	A constituent of coal tar.
Tredecane . . .	$C_{13}H_{28}$	—	218°-20°	A hydrocarbon of the methane series, found in coal tar. Sp. gr. 0.778.
Trimethylthiophene .	$C_7H_{10}S$	—	163°	A probable constituent of coal tar.
Trithienyl . . .	$C_{12}H_8S_3$	147°	357°	. Do. do.
Tritylene, <i>see</i> Propylene.				
Undecane . . .	$C_{11}H_{24}$	—	180°-2°	A hydrocarbon of the marsh gas series found in coal tar. Sp. gr. at 16° C 0.765.
Valerene, <i>see</i> Amylene.				
Validine . . .	$C_{16}H_{21}N$	—	—	A constituent of coal tar, obtained from the heavy oil.
Valyl, <i>see</i> Octane.				
Viridine . . .	$C_{12}H_{19}N$	—	251°	A constituent of coal tar.
Water . . .	H_2O	—	100°	Produced as aqueous vapour, in more or less proportion, during the distillation of coal. It is also one of the products of the combustion of coal gas, from the union of the hydrogen of the gas with the oxygen of the air.
Wood naphtha, <i>see</i> Methyl alcohol.				
Wood spirit, <i>see</i> Methyl alcohol.				
Xylene, orthoxylene .	C_8H_{10}	—	141°-2°	} Hydrocarbons of the benzene series, found in coal tar and coal gas.
Xylene, metaxylene .	C_8H_{10}	—	139°	
Xylene, paraxylene .	C_8H_{10}	15°	137.5°-138°	
Xylenols . . .	C_8H_9O	—	—	Three of the xylenols—viz., ortho-, meta- and para-xylenols—are constituents of coal tar.

TABLE OF ELEMENTARY SUBSTANCES.

Names of Elements.	Symbols.	Atomic Weights.	Names of Elements.	Symbols.	Atomic Weights.
Aluminium	Al	27'1	Neodymium	Nd	143'6
Antimony (Stibium)	Sb	120'0	Neon	Ne	19'92
Argon	A	39'92	Nickel	Ni	58'7
Arsenic	As	75'0	Niobium	Nb	94
Barium	Ba	137'4	Nitrogen	N	14'04
Beryllium	Be	9'1	Osmium	Os	191
Bismuth	Bi	208'5	Oxygen	O	16
Boron	B	11'0	Palladium	Pd	106
Bromine	Br	79'96	Phosphorus	P	31
Cadmium	Cd	112'4	Platinum	Pt	194'8
Cæsium	Cs	133	Potassium (Kalium)	K	39'15
Calcium	Ca	40'1	Praseodymium	Pr	140'5
Carbon	C	12	Radium	Rd	225
Cerium	Ce	140	Rhodium	Rh	103
Chlorine	Cl	35'45	Rubidium	Rb	85'4
Chromium	Cr	52'1	Ruthenium	Ru	101'7
Cobalt	Co	59	Samarium	Sm	150
Copper (Cuprum)	Cu	63'6	Scandium	Sc	44'1
Didymium	Di	143	Selenium	Se	79'1
Erbium	E	166	Silicon	Si	28'4
Fluorine	F	19	Silver (Argentum)	Ag	107'93
Gadolinium	G	155'57	Sodium (Natrium)	Na	23'05
Gallium	Ga	70	Strontium	Sr	87'6
Germanium	Ge	72	Sulphur	S	32'06
Gold (Aurum)	Au	197'2	Tantalum	Ta	183
Helium	He	3'96	Tellurium	Te	127'6
Hydrogen	H	1'01	Terbium	T	158'8
Indium	In	114	Thallium	Tl	204'1
Iodine	I	126'85	Thorium	Th	232'5
Iridium	Ir	193	Thulium	Tu	169'4
Iron (Ferrum)	Fe	55'9	Tin (Stannum)	Sn	118'5
Krypton	Kr	81'56	Titanium	Ti	48'1
Lanthanum	La	138	Tungsten (Wolfram)	W	184
Lead (Plumbum)	Pb	206'9	Uranium	U	239'5
Lithium	Li	7'03	Vanadium	V	51'2
Magnesium	Mg	24'36	Xenon	X	128
Manganese (Manganium)	Mn	55	Ytterbium	Yb	173
Mercury (Hydrargyrum)	Hg	200'3	Yttrium	Y	89
Molybdenum	Mo	96'0	Zinc	Zn	65'4
			Zirconium	Zr	90'7

CHEMICAL AND OTHER MEMORANDA.

The compounds of the non-metallic elements with the metals and with each other have names ending in "ide" or "uret"; as FeS, sulphide or sulphuret of iron.

When two or more atoms or equivalents of the non-metallic elements enter into combination, the number of atoms or equivalents is expressed by prefixes.

- Mon . . . means 1 atom, as CO, carbon monoxide.
- Di, or bi . . . means 2 atoms, as CS₂, bi-sulphide or di-sulphide of carbon.
- Tri . . . means 3 atoms, as SO₃, sulphur tri-oxide; PCl₃, phosphorus tri-chloride.
- Tetr . . . means 4 atoms, as N₂O₄, nitrogen tetr-oxide.
- Pent or penta means 5 atoms, as N₂O₅, nitrogen pent-oxide; PCl₅, phosphorus penta-chloride.
- Sesqui . . . means 1½ atoms (= 2 to 3), as Fe₂O₃, sesqui-oxide of iron.
- Proto or prot means first, as FeO, prot-oxide of iron.
- Sub . . . means under, as Cu₂O, sub-oxide of copper.
- Per . . . means the highest, as HClO₄, per-chloric acid.

The terminations "ic" and "ous" are used for acids, the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo," *under*, and "hyper," *above*, are used.

The smaller number, as H₂, placed to the right of, and slightly below, a symbol, is called the exponent, and indicates the number of times that the combining weight of the substance has to be taken. When the symbol is without a number, thus, H, the number *one* is understood. The small numbers modify only the symbol immediately preceding, but larger numbers *prefixed* to the symbol modify all that follow as far as the next comma or + sign: thus 2H₂SO₄ signifies that four of hydrogen, two of sulphur, and eight of oxygen, or, more correctly, that two of sulphuric acid (H₂SO₄ being the formula for sulphuric acid) are to be taken.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

Alkalies neutralize acids, forming salts.

Alkalies turn vegetable reds to blue, and yellows to brown.

Acids turn vegetable blues to red, and browns to yellow.

A *simple* or *elementary* substance is a body that cannot be resolved or separated into any simpler substances—as oxygen, carbon, iron.

A *compound* substance is one consisting of two or more constituents—as water, carbon-dioxide, olefiant gas.

The equivalent number or atomic or combining weight expresses the relation that subsists between the different proportions by weight in which substances unite chemically with each other.

The equivalent or combining weight of a compound is the sum of the combining weights of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies. Gases are usually compared with air as 1.000, liquids and solids with water as 1.000.

So far as chemists have been able to discover, there are about 80 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three, or four elements.

LIST OF SUBSTANCES,

Simple and Compound, frequently mentioned in connection with the Manufacture and Purification of Coal Gas and the Residual Products resulting therefrom.

Name of Substance.	Formula.
Acetylene	C_2H_2
Ammonia	NH_3
Ammonium carbonate	$(NH_4)_2CO_3$
Ammonium chloride	NH_4Cl
Ammonium sulphate	$(NH_4)_2SO_4$
Aqueous vapour	H_2O
Benzene (benzol)	C_6H_6
Butylene	C_4H_8
Calcium carbonate	$CaCO_3$
Calcium dioxide	CaO_2
Calcium hydroxide	CaO_2H_2
Calcium monosulphide	CaS
Calcium monoxide (caustic lime)	CaO
Carbolic acid	C_6H_6O
Carbon	C
Carbon dioxide (carbonic acid)	CO_2
Carbon disulphide	CS_2
Carbon monoxide (carbonic oxide)	CO
Caustic potash	KOH
Caustic soda	$NaOH$

LIST OF SUBSTANCES—*continued.*

Name of Substance.	Formula.
Cyanogen	C_2N_2
Ethylene (olefiant gas)	C_2H_4
Ferric oxide	Fe_2O_3
Ferric sulphide	Fe_2S_3
Ferrous oxide	FeO
Ferrous sulphide	FeS
Hydrochloric (or muriatic) acid	HCl
Hydrogen	H
Iron disulphide (iron pyrites)	FeS_2
Manganous chloride	$MnCl_2$
Methane (light carburetted hydrogen)	CH_4
Naphthalene	$C_{10}H_8$
Nitric acid	HNO_3
Nitrogen	N
Oxygen	O
Potassium oxide	K_2O
Propylene	C_3H_6
Sodium oxide	Na_2O
Sulphur	S
Sulphur dioxide	SO_2
Sulphuretted hydrogen	H_2S
Sulphuric acid	H_2SO_4
Water	H_2O
Weldon mud	CaO_2MnO_2

To ascertain the proportion, by *weight*, of the different substances in a compound, multiply the atomic weight of each substance by the exponent.

For example: Take olefiant gas (ethylene), C_2H_4 , which, as its formula indicates, consists, by weight, of two atoms of carbon combined with four atoms of hydrogen—

Atomic Weight.	Exponent.	Proportion by Weight.
C 12 × 2 = 24		or 85·715 per cent.
H 1 × 4 = 4		or 14·285 „

So that 24 grs., or 24 oz., or 24 lbs. of carbon combine with 4 grs. or 4 oz., or 4 lbs. of hydrogen to form 28 grs., or 28 oz., or 28 lbs., and so on, of olefiant gas.

COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

Aqua fortis	Nitric acid.
Aqua regia	A mixture of nitric and hydrochloric acids, so called from its property of dissolving gold.
Black-damp	Carbon dioxide.
Bluestone, or blue vitriol	Copper sulphate.
Bog ore	Oxide of iron.
Calomel	Mercurous chloride.
Chloroform	Formyle chloride.
Choke-damp	Carbon monoxide.
Common salt	Sodium chloride.
Copperas, or green vitriol	Sulphate of iron.
Corrosive sublimate	Mercuric chloride.
Dry alum	Sulphate of alumina and potash.
Epsom salts	Magnesium sulphate.
Ethiops mineral	Black sulphate of mercury.
Fire-damp	Light carburetted hydrogen.
Galena	Lead sulphide.
Glauber's salts	Sodium sulphate.
Gouldard water	Basic acetate of lead.
Iron pyrites	Bisulphide of iron.
Jeweller's putty	Oxide of tin.
King's yellow	Sulphide of arsenic.
Laughing gas	Nitrous oxide.
Lime	Calcium oxide.
Lunar caustic	Silver nitrate.
Mosaic gold	Stannic sulphide.
Muriate of lime	Calcium chloride.
Nitre, or saltpetre	Potassium nitrate.
Oil of vitriol	Sulphuric acid.
Potash	Potassium carbonate.
Realgar	Sulphide of arsenic.
Red lead	Lead oxide.
Rust of iron	Oxide of iron.
Sal ammoniac	Ammonium chloride.
Soda	Sodium carbonate.
Spirits of hartshorn	Ammonia.

CHEMICAL SUBSTANCES—*continued.*

Spirit of salt	Hydrochloric or muriatic acid.
Stucco, or plaster of Paris	Calcium sulphate.
Sugar of lead	Lead acetate.
Tincal	Crude borax.
Verdigris	Basic acetate of copper.
Vermilion	Mercuric sulphide.
Volatile alkali	Ammonia.
Wad	Black oxide of manganese.
Water	Oxide of hydrogen.
White vitriol	Zinc sulphate.

TABLE OF VARIOUS GASES.

Their Specific Gravity, Weight, and Solubility in Water.

60° Fahr. 30 in. Barometer.

Name.	Specific Gravity. Air equal 1'000.	Weight of a Cubic Foot in Pounds Avoirdupois.	Weight of a Cubic Foot in Grains.	Number of Cubic Ft. equal to 1 lb.	Solubility. 100 Vols. of Water absorb
Hydrogen	0'0691	0'00529997	37'09	188'68	1'93 Vols.
Light carburetted hydrogen	0'559	0'0428753	300'12	23'32	3'91 "
Ammonia	0'590	0'045253	316'77	22'09	76,400 "
Carbon monoxide	0'967	0'0741689	519'18	13'48	2'43 "
Olefiant gas	0'968	0'0742456	519'71	13'46	16'15 "
Nitrogen	0'9713	0'07449871	521'49	13'42	1'48 "
Air	1'000	0'0767	536'90	13'03	1'70 "
Nitric oxide	1'039	0'0796913	557'83	12'54	{ Not soluble in water.
Oxygen [gen	1'1056	0'08479952	593'59	11'79	2'99 Vols.
Sulphuretted hydro-	1'1747	0'09009949	630'69	11'09	323'26 "
Nitrous oxide	1'527	0'1171209	819'84	8'53	77'78 "
Carbon dioxide	1'529	0'1172743	820'92	8'52	100'20 "
Sulphurous acid	2'247	0'1723449	1206'41	5'80	4276'60 "
Chlorine	2'470	0'189449	1326'14	5'27	236'80 "
Carbon bisulphide	2'640	0'202488	1417'41	4'93	{ Not soluble in water.

To reduce a volume of gas of any specific gravity to pounds avoirdupois, multiply the volume by the sp. gr. and by 0'0767.

EXAMPLE.—Required the weight of 1500 cub. ft. of gas whose specific gravity is 0.520.

$$1500 \times 0.520 \times 0.0767 = 59.826 \text{ lbs.}$$

To find the weight in pounds avoirdupois of a cubic foot of air at different temperatures, and under different pressures.

$$W = \frac{1.3253 \times B}{459 + T}$$

EXAMPLE.—Required the weight of a cubic foot of air, the barometer being at 29.5 in. and the temperature 84° Fahr.

$$\frac{1.3253 \times 29.5}{459 + 84} = 0.072 \text{ lb.}$$

Luting for Experiments in Chemistry.—For temporarily securing the joints of chemical vessels, glass stoppers, etc., use equal parts by weight of linseed meal and whiting made into a stiff paste with water. The two substances should be well triturated in a mortar, and the water added till of the proper consistency.

Pieces of vulcanized india-rubber tubing are very suitable for joining the ends of glass and earthenware tubes. The india-rubber is slipped over the ends, and secured with pack thread.

India-rubber capsules for bottle necks, having a hole through them for the insertion of glass tubes, are handier, and more likely to be gas-tight, than the ordinary corks.

AVERAGE COMPOSITION OF LONDON GAS BY VOLUME.

(*Dr. Letheby, 1866.*)

Constituents.	Common Gas. Per Cent.	Cannel Gas. Per Cent.
Hydrogen	46.0	27.7
Light carburetted hydrogen	39.5	50.0
Olefiant gas	3.8	13.0
Carbonic oxide	7.5	6.8
Carbonic acid	0.7	0.1
Aqueous vapour	2.0	2.0
Nitrogen	0.5	0.4
	100.0	100.0

(Professor Vivian B. Lewes, 1894.)

Constituents.	Gaslight and Coke Company. Per Cent.	South Metropolitan Company. Per Cent.	Commercial Company. Per Cent.
Hydrogen	53'36	52'22	52'96
Unsaturated hydrocarbons	3'58	3'47	3'24
Saturated hydrocarbons	32'69	34'76	34'20
Carbon monoxide	7'05	4'23	4'75
Carbon dioxide	0'61	0'60	0'75
Nitrogen	2'50	4'23	4'10
Oxygen	0'21	0'49	0'00
	<hr/> 100'00	<hr/> 100'00	<hr/> 100'00

TABLE

Indicating the Comparative Salubrity of the Several Illuminating Materials.

The flame of coal gas, and the flames of several combustible bodies that gave an amount of light equal to it, were burned separately in given quantities of atmospheric air, and the times were noted at which the flames were extinguished by the contamination of the air. The following were the results:—

Colza oil	was extinguished in 71 minutes.
Olive oil	" " 72 "
Russian tallow	" " 75 "
Sperm oil	" " 76 "
Stearic acid	" " 77 "
Wax candles	" " 79 "
Spermaceti candles	" " 83 "
Coal gas	" " 98 "
Cannel gas (28 candles)	" " 152 "

From which it appears that the atmosphere of a confined room lighted by a cannel gas will support life twice as long as the atmosphere of the same room lighted equally by tallow candles.

TABLE.
RELATIVE VALUES OF ILLUMINATING AGENTS

*In respect of their Heating and Vitiating Effects on the Atmosphere,
when Burning so as to give the Light of 12 Standard Sperm
Candles. (Dr. Letheby.)*

	Pounds of Water Heated 1° Fahr.	Oxygen Consumed (cub. ft.).	Carbonic Acid Produced (cub. ft.).	Air Vitiated (cub. ft.).
Cannel gas	1950	3'30	2'01	50'2
Common gas	2786	5'45	3'21	80'2
Sperm oil.	2335	4'75	3'33	83'3
Benzol	2326	4'46	3'54	88'5
Paraffin	3619	6'81	4'50	112'5
Camphene	3251	6'65	4'77	119'2
Sperm candles	3517	7'57	5'27	131'7
Wax candles	3831	8'41	5'90	149'5
Stearic candles	3747	8'82	6'25	156'2
Tallow candles	5054	12'06	8'73	218'3

TABLE.

Calorific Power of Various Photogenic Compounds. (F. J. Evans.)

Name of Gas, etc.	Cubic Feet to One Pound.	Pounds of Water raised 1° by the Consumption of 1 Foot of Gas.	Pounds of Water raised 1° by the Consumption of 1 pound of Gas.
Hydrogen	180'0	300	54,000
Newcastle coal gas, sp. gr. 0'410	32'4	650	21,060
Cannel gas, sp. gr. 0'500	26'5	760	20,140
Oil gas, sp. gr. 0'825	16'69	1200	20,028
			1 lb. of candles.
Sperm candles, 6 to the lb.			17,567
			1 lb. of oil.
Sperm oil, burnt in a lamp.			16,490

TABLE.
Combustion Temperature, Explosive Power, and Mechanical Power of Gases. (Lethby.)

Name.	Per lb. Substance.			Pounds Water Heated 1° Fahr.			Temperature of Combustion.				Explosive Power.		Mechanical Power per lb.
	Ox. Used.	CO ₂ Pro- duced.	Air Viti- ated.	Per lb. Sub- stance.	Cubic Foot Substance.	Per lb. Ox. Used.	Open Flame.		Closed Vessel.		With Ox.	With Air.	Tons Raised 1 Foot High.
							With Ox.	With Air.	With Ox.	With Air.			
Hydrogen	Cubic Feet. 98.4	Cubic Feet. 0.0	Cubic Feet. 667	Lbs. 62,080	Lbs. 829	Lbs. 7,754	Deg. 14,510	Deg. 5,744	Deg. 19,035	Deg. 7,852	Atmo- spheres. 25.6	Atmo- spheres. 12.5	Tons. 21,890
Marsh gas	47.2	23.6	826	23,513	996	5,878	14,130	4,762	18,351	6,680	37.0	14.0	8,108
Olefiant gas	40.5	27.0	878	21,344	1,585	6,225	16,535	5,217	21,344	7,200	42.9	15.1	7,860
Propylene	40.5	27.0	878	21,327	2,376	6,220	16,522	5,239	21,327	7,177	67.3	23.5	7,860
Butylene.	40.5	27.0	878	21,327	3,168	6,220	16,522	5,232	21,327	7,177	85.8	30.2	7,860
Acetylene	36.3	29.1	909	18,197	1,251	5,914	17,146	5,142	22,006	7,009	37.9	17.6	6,275
Benzole	36.3	29.1	909	18,197	3,860	5,915	17,146	5,142	22,006	7,009	113.7	52.8	6,275
Carbonic oxide.	6.7	18.5	871	4,325	820	7,569	12,719	5,358	16,178	7,225	21.8	11.7	1,490
Bisulphide carbon	14.9	6.0	689	6,120	1,239	4,845	16,280	4,814	20,031	5,917	30.2	11.6	2,110
Sulph. hydrogen	16.7	0.0	630	7,444	671	5,271	13,688	4,888	17,542	6,026	28.3	12.7	2,567
Cyanogen	14.5	14.5	435	6,712	925	5,142	13,468	5,098	17,645	6,167	35.6	17.8	2,314
Common coal gas	37.5	17.6	618	21,060	650	6,816	14,326	5,228	18,101	7,001	29.2	14.6	7,262
Cannel gas	31.0	22.0	698	20,140	760	6,503	14,435	4,641	19,046	7,186	38.8	18.0	6,945
Wood spirit.	25.3	11.8	432	9,547	819	8,863	11,435	4,641	14,902	6,347	40.3	15.3	3,230
Alcohol	30.9	16.4	533	12,929	1,597	6,195	13,305	4,831	17,223	6,629	46.4	16.1	4,455
Ether	38.9	20.4	664	16,249	3,217	6,158	14,374	5,150	19,225	6,953	58.6	19.0	5,608
Camphine	37.0	25.2	880	19,573	7,134	5,942	16,271	5,026	20,953	6,922	47.6	16.0	6,750
Spermaceti	37.7	25.6	815	17,589	..	6,088	14,599	4,418	..	..	..	..	6,065
Wax.	34.6	24.0	829	15,809	..	4,995	12,921	4,122	..	..	..	..	5,451
Stearic acid.	34.4	24.0	783	17,050	..	6,061	15,885	4,818	..	..	..	..	5,880
Stearin	34.4	24.2	527	18,001	..	6,143	15,815	5,035	..	..	..	..	6,207
Paraffin	40.5	27.0	878	21,327	..	6,220	16,522	5,239	..	..	..	..	7,354
Paraffin oil	40.5	27.0	878	21,327	..	6,220	16,522	5,239	..	..	..	..	7,354
Rape oil	38.7	24.3	801	17,752	..	6,123	15,830	5,087	..	..	..	..	6,121
Sperm oil	38.7	24.3	801	17,250	..	6,088	15,363	4,937	..	..	..	..	5,941
Carbon	31.0	31.5	943	14,544	..	5,447	18,329	3,026	..	..	..	..	5,015

TABLE.
Heats of Combustion with Oxygen.

Substance.	British Thermal Units of Heat.	Pounds of Water at 212° Fahr. Evaporated per Pound of Substance.
Hydrogen	61,500	63·66
Alcohol	12,963	13·42
Benzene	18,600	19·25
Carbon bisulphide	6,152	6·87
Carbon burning to carbon dioxide	12,906	13·36
Carbon burning to carbon monoxide	2,495	2·58
Carbon monoxide burning to carbon dioxide	4,478	4·63
Charcoal, wood	12,455	12·90
Coal, anthracite	15,600	16·14
Coal, best bituminous	15,504	16·05
Coke, produced from ditto	14,375	14·88
Coal, average quality	13,600	14·08
Coke, produced from ditto	12,800	13·25
Ethylene	21,500	22·25
Graphite	14,067	14·56
Light carburetted hydrogen, or marsh gas	24,020	24·86
Lignite	11,710	12·12
Olefiant gas	21,375	22·12
Olive oil	17,784	18·41
Peat, dry	9,983	10·33
Petroleum	20,272	20·98
Propylene	21,200	21·94
Sulphur	4,082	4·17
Sulphuric ether	16,282	16·85
Turpentine	19,566	20·25
Wood, dry	7,824	8·10
	Cubic Feet per lb.	
Coal gas, 17 candles	32·227	22·46
Water gas	22·862	6·88
Producer gas	14·369	1·96
Producer water gas	13·478	1·02

The British standard unit of heat (thermal unit) is the amount of heat required to raise the temperature of 1 lb. avoirdupois of water 1° Fahrenheit.

The French standard unit of heat (calorie) is the amount of heat required to raise the temperature of 1 kilogramme of water 1° Centigrade.

The number of British units of heat required to evaporate 1 lb. of water at boiling point, 212° Fahr., is 966; and at 62° Fahr., 1116.

The number of French units of heat required to evaporate 1 kilo. of water at boiling point, 100° Cent., is 536·7; and at 16·6° Cent., 620·1.

One British unit of heat = 0.251996 French units.

One French unit of heat = 3.96832 British units.

The total heating power of any fuel, expressed in British units, $\div 966 =$ lbs. of water at 212° Fahr. evaporated per lb. of fuel.

EXAMPLE.—1 lb. of hydrogen yields in combustion 61,500 units of heat.

Then $\frac{61,500}{966} = 63.66$ lbs. of water at 212° Fahr. evaporated per lb. of hydrogen.

DISTILLED WATER.

(At 62° Fahr.)

1 pint = 34.65 cub. in., or 1.25 lbs.

1 gal. = 277.274 cub. in., or 10 lbs.

11.2 gals., or 1.792 cub. ft. = 1 cwt.

224 " " 35.34 " = 1 ton.

1 cub. in. = 252.45 grs. or 0.036075 lb.

12 " " = 0.434 lb.

1 " ft. = 6.25 gals., or 1000 oz., or 62.5 lbs.

1.8 " " = 1 cwt.

35.84 " " = 1 ton.

1 cylindrical in. = 0.02842 lb.

12 " " = 0.341 "

1 " ft. = 5 gals., or 50 lbs.

2.282 " " = 1 cwt.

45.64 " " = 1 ton.

Centre of pressure $\frac{2}{3}$ depth from surface.

Water is at its maximum density at 39.2° Fahr. (4° Cent.), and expands $\frac{1}{10}$ part of its bulk on freezing.

SPECIFIC HEAT OF SUBSTANCES.

The meaning implied in the term "specific heat," or more correctly "calorific capacity," is the quantity of heat required to raise the temperature of a substance 1° (independently of the unit of mass and scale of temperature); water being taken as the standard of comparison.

For example : the specific heat of mercury is 0.03332, by which is to be understood that thirty times as much heat is required to raise water to a given temperature as an equal weight of mercury. In other words, the quantity of heat which would raise the temperature of any given weight of mercury through 1°, would only raise the temperature of a like weight of water through 0.03332°.

SPECIFIC HEAT OF SOLIDS AND LIQUIDS.

(Water as 1.)

Acetic acid	0.6589	Lead	0.0314
Alcohol (sp. gr. 0.793)	0.622	Lime, burned	0.217
Aluminium	0.2143	Lithium	0.9408
Antimony, cast	0.05077	Magnesium	0.2499
Arsenic	0.0814	Manganese	0.1217
Bees'-wax	0.45	Marble, white	0.21585
Benzene	0.3952	Mercury	0.03332
Birch	0.48	Nickel	0.10863
Bismuth	0.03084	Oil, olive	0.3096
Brass	0.09391	Oil, sweet	0.31
Brick, common	0.2	Oil of turpentine	0.472
Brick, fire	0.22	Palladium	0.05928
Cadmium	0.05669	Phosphorus	0.18949
Chalk, white	0.21485	Pine	0.65
Charcoal, animal, calcined	0.26085	Platinum	0.03243
Charcoal, wood	0.24111	Potassium	0.1696
Clay, white, burned	0.185	Selenium	0.07616
Coal	0.2777	Silicon, crystallized	0.1774
Cobalt	0.10696	Silicon, fused	0.175
Copper	0.09215	Silver	0.05701
Diamond	0.14687	Sodium	0.2934
Ether	0.5207	Spermaceti	0.32
Glass	0.19768	Steel	0.1175
Gold	0.03244	Sulphur	0.20259
Graphite	0.20187	Sulphuric acid	0.333
Ice	0.504	Tellurium	0.04737
Iodine	0.05412	Thallium	0.03365
Iron, cast	0.12983	Tin	0.05695
Iron, wrought	0.11379	Zinc	0.09555

SPECIFIC HEAT OF GASES AND VAPOURS.

	Specific Heat of Equal Weights.	Specific Heat of Equal Volumes.	Specific Heat of Constant Volumes.
Simple gases.	(Air	0.2374	0.1687
	{Oxygen	0.2175	0.1559
	{Nitrogen	0.2438	0.1740
	{Hydrogen	3.4090	2.4096
	{Chlorine	0.1210	—
Vapour.	{Bromine	0.0555	—
		0.3040	—

		Specific Heat of Equal Weights.	Specific Heat of Equal Volumes.	Specific Heat of Constant Volumes.
Compound gases.	Nitrogen peroxide	0'2315	0'2406	—
	Carbon monoxide	0'2450	0'2370	0'1768
	Carbon dioxide	0'2163	0'3307	0'1714
	Sulphuretted hydrogen	0'2432	0'2857	—
	Sulphur dioxide	0'1553	0'3414	0'1246
	Hydrochloric acid	0'1845	0'2333	—
	Nitrous oxide	0'2262	0'3447	—
	Nitric oxide	0'2317	0'2406	—
	Ammonia	0'5083	0'2966	—
	Marsh gas	0'5929	0'3277	0'4683
	Olefiant gas (ethylene)	0'4040	0'4106	—
	Water (steam)	0'4805	0'2984	0'3337
	Ether	0'4810	1'2296	0'3411
	Chloroform	0'1567	0'6461	—
Vapours.	Alcohol	0'4534	0'7171	0'3200
	Turpentine	0'5061	2'3776	—
	Carbon bisulphide	0'1570	0'4140	—
	Benzole	0'3754	1'0114	—
	Acetone	0'4125	0'8244	—

TABLE

Showing the Expansion of Liquids in Volume from 32° to 212° Fahr.

1000 parts of water	become	1046
" oil.	"	1080
" mercury	"	1018
" spirits of wine	"	1110
" air	"	1373 to 1375

TABLE

Showing the Lineal Expansion of Metals produced by Raising their Temperature from 32° to 212° Fahr.

Zinc	1 part in 322	Gold	1 part in 682
Lead	351	Bismuth	719
Tin (pure)	403	Iron	812
Tin (impure)	500	Antimony	923
Silver	524	Palladium	1000
Copper	581	Platinum	1100
Brass	584	Flint glass	1248

TABLE

Showing the Relative Power of Metals for Conducting Heat.

Gold	1000	Iron	374'3
Silver	973	Zinc	363
Copper	898'2	Tin	303'9
Platinum	381	Lead	179'6

TABLE

Showing the Relative Power of Metals for Reflecting Heat.

Intensity of Direct Radiation, 1'00.

Silver plate	0'97	Steel	0'83
Gold	0'95	Zinc	0'81
Brass	0'93	Polished platinum	0'80
Speculum metal	0'86	Iron	0'77
Tin	0'85		

TABLE.

Melting Points.

	Degrees Fahr.		Degrees Fahr.
Aluminium	1247	Platinum	3227
Antimony	797	Potassium	136'4
Bismuth	504'94	Silver	1832
Bronze	1652	Sodium	203 to 204'08
Copper	2102	Spermaceti	120
Gold	2192	Stearine	131
" coined	2156	Steel	2372 to 2552
Ice	32	Sulphur	230
Iodine	237'5	Tin	549
Iron, cast	1922 to 2382	Wax, white	154
" wrought	2732 to 2912	Wax, yellow	144
Lead	617	Zinc	786'2
Phosphorus	111		

THE GAS INDUSTRY.

Initiation, Development, and Progress.—The manufacture and distribution of coal gas may be justly described as one of the important industries of the world. Like railways and the electric telegraph, it is a product of the Nineteenth Century; for, though coal gas was actually used for illuminating purposes by William Murdoch, the inventor of gas lighting, as early as 1792, at Redruth in Cornwall, and in 1797 at his house at Old Cumnock, Ayrshire, it was not until well into the first decade of the past century that gas began to be generally applied in the lighting of streets, factories, and dwelling-houses.

The illumination of the Soho Works, Birmingham, to celebrate the Peace of Amiens, took place in 1802. These works belonged to Boulton & Watt, and Murdoch was employed as Manager to the firm. The first application of gas to the interior lighting of

large premises was made by Murdoch in Salford in 1805, at the cotton manufactory of Phillips & Lee; and the first street lighted with gas was Pall Mall, London, in 1807. The first Gas Company incorporated by Act of Parliament was the "Chartered" (now the Gaslight and Coke), London, in 1812.

Although in its earliest use coal gas was restricted to the purpose of affording artificial light, no long time elapsed before its value as a heating medium began to be realized. Winsor, one of the pioneers of gas lighting, claimed as an important advantage of the new invention or discovery that gas, besides its light-giving qualities, could be used both for cooking food and warming dwellings, and as early as 1825 attempts were made to apply it for those purposes. It was not, however, till later on in the century that anything like a practical application of gas was made to the cooking of food. Mr. J. Sharp, of Southampton, about the year 1840 began to construct ovens heated by gas for cooking and baking, and these he used for many years, giving public lectures, in the course of which he practically demonstrated their usefulness and value.

Gas, however, in those days was higher in price than now, and although it was evident that it served most efficiently for culinary operations, its cost militated against its extensive adoption in that direction. The prejudice against it was strong, also, on account of the supposed liability of any food cooked by its means to be tainted with the flavour of the gas itself. This operated against its use; and though the prejudice was founded on ignorance of the facts, it is not a matter of wonder that such an idea was entertained, seeing that, even at the present day, in spite of the strongest evidence to the contrary, the same belief is still widely accepted, and still operates with many as a bar to its adoption.

Gas has won for itself an important place as an agent for obtaining motive power. It was from the very first a matter of observation, and not unfrequently of dire and unsought experience, that when gas and atmospheric air were mixed in certain proportions, and the mixture fired, an explosion was the result. Attempts were soon made to utilize the force thus exerted by confining the explosive compound in a suitable cylinder, and exploding it to obtain prime movement.

After many more or less successful attempts by different

inventors, and expenditure of much ingenuity, the "Lenoir" gas-engine, so named after its inventor, was produced (1860), and thus was solved the problem of how to utilize an explosive mixture of gas and air as a prime motor. From that time down to the present the patent records contain the description of many inventions of this character, and gas-engines of great power and efficiency are now produced.

It is occasionally a subject of remark by uninformed or hostile critics that no important improvements have been effected in gas manufacture since the earlier days of its introduction. If this were so, it would either speak well for the inventors of this art, or badly for their successors in the industry. The statement, however, is altogether wide of the truth. True, the method of producing the gas, as in the earlier days, is by distillation of the coal in closed retorts, and the purification, storage, and distribution of gas are effected in apparatus and plant which, in their main features, do not greatly differ from the earlier forms. But it is obvious that a similar invidious comparison might be made in regard to all the most notable inventions. The chief characteristics of an industry are retained, whilst the processes undergo improvement and modification. As a matter of fact, great improvements have been effected in the plant and apparatus for the manufacture of illuminating gas—for example: the vertical retort system has been perfected, whilst the mechanical and chemical principles involved in the production and use of gas are now carefully investigated by gas engineers, and are yearly becoming better understood.

Illuminating Power.—In England, Wales, and Ireland, the gas actually supplied to consumers varies in illuminating power from 14 to 22 standard candles, according to the quality of the coal used; the higher figure above 16 candles being obtained by an admixture of cannel or shale with the ordinary bituminous coal, or the use of oil as an enricher. In Scotland, the range of illuminating value is from 12 to 32 candles.

Cost Price.—The average cost of producing and distributing illuminating gas in England is about two-thirds of the selling price. Taking a selling price of, say, 2s. 6d. per 1000 cub. ft., the cost of producing and distributing the gas, including the net expenditure on coal (after deducting the income from residuals) and working expenses, will be 1s. 8d. per 1000 cub. ft. Analysing

this figure, the expenditure on coal will be 1s. 4d., and deducting the value of the residuals, at present prices, which is equal to about 9d., there is left 7d. as the net cost of the coal. The balance of 1s. 1d. is made up by the working expenses, which include wages, salaries, purifying materials, repairs and renewals, rates and taxes, printing and stationery, and incidental expenses. The difference of 10d. between the prime cost of the gas, 1s. 8d., and its selling price of 2s. 6d., is absorbed in the payment of the interest and dividend on the invested capital in the case of a company; and in the instance of the undertaking belonging to a local authority, in the discharge of the interest on the annuities and borrowed capital (if any), and the provision of a sinking fund.

Selling Price.—The selling price of gas per 1000 cub. ft. ranges throughout England, Wales, and Ireland from 11d. to 6s., and in Scotland from 1s. 7d. to 7s. 6d., with a few of the smallest concerns charging as much as 12s. 6d. per 1000 cub. ft. Taking into consideration, however, that in Scotland gas of a higher illuminating power is supplied than in the other portions of the kingdom, that a smaller consumption per consumer is the consequence, and calculating the price at per theoretical unit of light, the actual difference in price is not so great as appears at first sight. The practical advantages, however, of the higher illuminating powers are not proportionate to the cost of producing the richer gas, and in these days of incandescent lighting they are not required.

Capital Employed.—The capital of a gas undertaking represents or includes (1) the amount of money that has been expended on obtaining an Act of Incorporation, if it be a statutory company; (2) the cost of the land for the site of the works, and the engineering expenses incurred; (3) the cost of the general manufacturing, purifying, and storing plant; and (4) the cost of the distributing pipes and accessories; with (5) an added sum as a floating or working capital to meet current outlay before the revenue begins to accrue.

The amount of the various items making up the aggregate necessarily varies under different conditions. For example, take the first—the money expended on obtaining an Act of Incorporation. When a company have had to contend with and overcome persistent and strong opposition, the cost of their Act will exceed

the cost of one obtained under more favourable conditions, to the extent of 100, 200, or even 300 per cent. Again, the cost of land is a varying factor, and the expense of the erection of works is often increased by the character of the site and its subsoil. It is true that in the case of a large company these several items, even when greatly in excess of a normal amount, do not increase the total capital outlay by any material percentage; but on small and moderate-sized undertakings they are often peculiarly burdensome.

But there are other circumstances, more distinctly marked than these, which contribute to the variations in the relative amount of capital expended by different companies. The character of the district of supply is one of them. The district of some companies is thickly populated with a high class of consumers throughout. Others, again, have a scanty population, and of a poorer class; and although the plant and mains of this latter may be less extensive, yet the proportion of its capital to the production and rental will usually be in excess of the other, whilst there is this paradoxical result in the instances referred to, that those who are least able to afford it have often necessarily to pay a higher price for the gas.

In many instances, companies have wide expanses of country to canalize with miles of mains, on some of which, except at the terminus, there is scarcely a consumer. Again, the district may be a manufacturing one, with mills and workshops consuming gas only during four or five months in the year. The proportion of capital in such case has frequently to be large to provide plant to meet the principal gas demands within a limited period of time. It is no unusual thing, under such circumstances, to find that during nearly one half of the year $\frac{1}{10}$ of the whole plant is standing unproductive.

In contrast to these, there are towns whose gas consumption is comparatively steady all the year round. Take, as an example, the inland watering-places and fashionable seaside towns. Into these there is during the summer and autumn seasons an influx of visitors who consume a large quantity of gas. Such is proved by the fact that the heaviest daily make in these places is generally in the months of August, September, and October. This tends to equalize the consumption in the different seasons, because the resident inhabitants consume their proportion of gas during the

winter and early spring months when the visitors are absent. It is fair to conclude that, owing to this regular and steady consumption, the plant is almost continuously employed, and therefore a smaller capital in proportion to the yearly production is required than in those places where the heavy consumption is spasmodic and brief.

But although this spasmodic consumption appears, at first sight, a serious drawback, in practice it does not always necessitate a higher price for the gas and a much larger capital outlay than is required by those concerns whose consumption or sale of gas is steadier; for in some of the large manufacturing towns the mill consumption is so enormous that, by straining the plant for limited periods, the disadvantage is counterbalanced.

There can be no question that expensive engineering tends to an undue inflation of the capital account. A want of engineering skill in the construction of works has precisely the same effect; for here, as in other matters, extremes meet.

Considerable thought will always be given by a capable and conscientious engineer to the proper arrangement of works. He will so perfect his designs that the works shall not be squandered or sprawling over the site, occupying unnecessary space, but compact and harmonious, so that the different processes in gas making may be conveniently carried on, and economical in the working.

Whilst it is not necessary or desirable that the buildings of a gas-works should be as strong as a castle, it is equally objectionable to set up unstable and flimsy structures that entail an annual heavy expenditure for repairs, constituting a perpetual tax, enhancing the cost of working.

Excessive and unnecessary ornamentation is to be eschewed in all works of this kind. All ornamentation, however, is not useless. Blank thick walls, for example, are not necessarily stronger than others well proportioned—thinner and lighter in parts, but strengthened by suitable projections that add to the beauty of a building by breaking the dull uniformity. The same argument holds good as respects design in apparatus. Taste should not be neglected; and there is ample scope for the exercise of good taste in most departments of a gas-works.

On a closer examination of the question, it will be apparent that there occur times in the history of most gas undertakings when the capital expenditure is either below or in excess of the

average—viz., when the margin of its producing, storing, and distributing resources is closely worked up, and enlargement is required, then the capital compared with the production is low. But extensions have to be carried out. These must necessarily be of such extent as to provide a margin for future increased consumption, and, being larger than the immediate requirements of the district, the capital is swelled out of proportion. This is especially true of times when trade is brisk and labour and materials are dear. Then extensions are costly, and, singular to say, it is at such times that they are most frequently made. Under such circumstances, unless resort can be had to a reserve fund to maintain the dividends, a sacrifice of a portion of the statutory interest has to be submitted to or the price of the gas increased.

But this condition of things is by no means inevitable. One of the evidences of good administrative skill in the conduct of a gas-works is the ensuring that extensions are carried out systematically and with foresight, and in as gradual a manner as may be, not postponing them to the very last extremity: in other words, starving the concern—wearing it threadbare—which is the worst policy possible for the undertaking and all associated with it, including both shareholders and consumers.

The capital of gas-works in the hands of corporations and other local authorities is, in some instances, in excess of that of companies; but this arises from causes well understood. Many towns' authorities have within comparatively recent years become possessed of gas undertakings by purchase from the companies who previously owned them; and, as in most cases they have had to pay the full commercial value for the concern, amounting to from twenty to twenty-eight years' purchase of the annual profits, and even more in some instances, the result is that the capital outlay is large—with this compensatory advantage, however, that the percentage of interest to be paid on such capital is not more, but usually less, than that paid by the company on the smaller capital. As time goes on, and extensions of the corporation works are made, these are carried out with an expenditure, though not necessarily less than that of a company, yet bearing a lower rate of interest, and consequently pressing less heavily on the resources of the undertaking.

But this remark needs qualification. In the case of local

authorities becoming possessed of such works, a sinking fund has to be provided out of the profits to redeem the capital within a given period. Fifty years was formerly a usual term to allow; but there is a tendency (especially on the part of the Local Government Board) to restrict the term to thirty and even twenty years. The result is that the annual charge for interest and sinking fund is in excess of the rate at which a company under the auction clauses can raise its additional capital. True, the sinking fund eventually wipes out the capital liability, and the present generation of overburdened consumers have to be consoled by the knowledge that posterity will reap the benefit of their self-sacrifice.

The immediate effect of an excessively large capital outlay by a gas company is, as has been already remarked, either a sacrifice by the shareholders of a proportion of the statutory dividends, or an augmentation in the selling price of the gas; and not unfrequently, when the capital is greatly in excess, both these undesirable results are experienced.

One of the best, perhaps the very best method of reducing the proportion which capital expenditure bears to revenue, is to cultivate a day consumption of gas, by affording facilities for, and encouraging in every legitimate way, the use of gas for cooking, heating, and motive power. This policy, if pursued to a successful issue, is virtually to reduce the percentage of capital in the proportion of such consumption, because the plant is brought to bear in earning profit during the daylight as well as in the lighting hours.

It is unreasonable to expect that the capital of gas companies and the selling price of gas can ever be uniform throughout the country. It would be just as reasonable to expect that the general rates of different districts can be equalized. All the causes above pointed out, and others not touched upon, militate against such a result.

The "Auction Clauses."—These clauses, which are now, and for many years past have been, introduced into the Bill of every gas company making application to Parliament for money powers, are, without doubt, an ingenious and fairly satisfactory device for securing the economization of capital.

They provide that the additional stock or share capital required shall be raised by public auction or tender, instead of, as formerly, by the allotment of the stock or shares to the existing shareholders *pro rata* at par.

The immediate result of this is that there is no inducement to the company to issue and expend more capital than is, from time to time, absolutely necessary.

A limited amount of ordinary stock is put up to competition, and this bearing, say, a 7 per cent. standard dividend, commands (in a well-managed company) a premium in the market of at least 50 per cent. In other words, £100 par value of stock or shares sells for, say, £150; being thus sold and brought to yield about 4 to 4 $\frac{2}{3}$ per cent. interest.

The 50 per cent., or whatever premium is realized, forms part of the capital for extensions of works, but is not entitled to dividend. In this way, the importation of non-dividend-bearing capital into the concern is advantageous to the general body of consumers, whilst at the same time it tends to give stability to the undertaking.

The "Sliding Scale."—This is not inserted compulsorily in Gas Bills, as are the auction clauses, but at the option of the company applying to Parliament. A standard selling price for the gas and a standard rate of dividend being given, it is provided that for every penny of a reduction in the price of the gas below the standard, the company are empowered to pay a $\frac{1}{4}$ per cent. above the standard dividend, or 1 per cent. for a reduction of fourpence, and *vice versa* if the selling price of the gas is raised.

Where conversion of stock has taken place, and there have been a number such of recent years, with a rate of 4 or 5 per cent. standard dividend on the face capital, the aforementioned increments and diminutions are proportionately reduced.

It is assumed, though it is by no means always the case, that the margin of profit earned after making the reduction is sufficient to allow of the increased dividend to which the shareholders are entitled; otherwise, of course, it cannot be paid, unless there is a balance in hand of revenue that can be drawn upon.

The effect of the sliding scale is to confer a greater benefit on the consumers than on the shareholders; because a reduction of a penny per 1000 cub. ft. on the total quantity of gas sold often amounts to a sum four times larger than that represented by the additional $\frac{1}{4}$ per cent. dividend to which the shareholders are entitled by reason of the reduction. In point of fact, the sliding scale creates a virtual partnership between the gas consumer and the gas proprietor, to the advantage of the former.

The combined effect of the auction clauses and the sliding scale has been to induce the exercise of economy, both in the expenditure of capital and in the general working of the undertaking, and so to secure a gradual reduction in the selling price of the gas.

No doubt the companies who were enabled to adopt the sliding scale of price and dividend in the early days of its inception are to be congratulated on the results they have achieved in the way of enhanced dividends by its application and working ; but there is less room for congratulation to any who adopt it now, with the closer limitations which prevail in fixing the initial or standard price.

It is clear, also, that companies seeking powers at a time when coal and materials generally are low in price, are placed at a disadvantage as compared with other companies applying to Parliament in a time of inflated prices. Notwithstanding all experience, one of the ruling characteristics of average human nature is to conclude that that which actually exists will scarcely ever again be modified to any large extent. Injustice may, therefore, unintentionally, be meted out to one company, and more than justice to another ; and so, when the reaction comes, the circumstances of the first suffer impairment, whilst the other is glutted with a run of good fortune. This want of equal justice in the incidence of the sliding scale, whilst inevitable, is sufficient to convince any disinterested observer that its indiscriminate advocacy is a mistake. It is, moreover, a curious and interesting commentary on the action of the sliding scale that, in spite of the inducement which it offers for a low selling price, there are both gas companies and local authorities who, without it, can produce and sell gas at a price as low as, or even lower than, those who boast its possession.

Sundry Useful Notes.—In choosing the site for a gas-works, consideration should be had to its position, which, if possible, should be at the lowest, or nearly the lowest, part of the district, to obtain the advantage of the natural increase in the pressure of the gas in travelling to the higher levels.

It should, if possible, be alongside a railway, navigable river, or canal, for convenience in the delivery of coal and other materials, and the disposal of such of the residuals as are despatched to a distance.

The buildings and plant should be so set out on the land as to admit of future extensions being made with ease and economy.

The design of a structure should be in keeping with the purpose for which the structure is intended.

Capital is best spent on substantial tanks and apparatus. Mere ornament should be a secondary consideration.

The capital of most gas-works per million cubic feet of gas produced per annum is from £500 to £700, or at the rate of about 10s. to 14s. per 1000 cub. ft. Reckoned on the *maximum* production of gas in 24 hours, the capital will amount to about 2s. 3d. to 2s. 8d. per cubic foot, or, say, £112 to £133 per 1000 cub. ft.

The term "structural value" has reference to the amount of capital expended upon works in their construction.

"Commercial value" is the value of the net annual profits which a firm or company can make by the use of their works.

TABLE

Showing the Time in which the Yearly Consumption of Gas will be Doubled, at Different Annual Rates of Increase.

Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.	Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.	Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.
2	35 years, 1 day.	5½	12 years, 345 days.	9	8 years, 16 days.
2½	28 years, 26 days.	6	11 years, 327 days.	9½	7 years, 253 days.
3	23 years, 164 days.	6½	11 years, 2 days.	10	7 years, 100 days.
3½	20 years, 54 days.	7	10 years, 89 days.	10½	6 years, 344 days.
4	17 years, 246 days.	7½	9 years, 213 days.	11	6 years, 234 days.
4½	15 years, 278 days.	8	9 years, 2 days.	11½	6 years, 134 days.
5	14 years, 75 days.	8½	8 years, 181 days.	12	6 years, 42 days.

Handy Rule for Converting Capital per Million Cubic Feet into Capital per Thousand Cubic Feet.

Point off all the figures after the hundreds as decimals, and multiply by two.

EXAMPLE.—The capital of a gas undertaking is £625 per 1,000,000 cub. ft. of gas sold (or produced) per annum, What is the capital per 1000 cub. ft. ?

Then, $6'25 \times 2 = 12'50$ —say, 12s. 6d. per 1000 cub. ft.

GOLDEN RULES FOR GAS MANAGERS.

Keep up the heats of the retorts.

Keep up the efficiency of the meters.

Keep down the leakage or unaccounted-for.

Keep down the arrears in the gas ledger.

A strict adherence to the advice which they give will ensure the success of any gas undertaking, just as a disregard of them will result in loss and disaster.

COEFFICIENTS

OF THE

Number, Dimensions, and Cost of the various Buildings, Apparatus, Machinery, and Plant of a Gas-Works.

It is an almost impossible task to give a series of coefficients of the number, dimensions, and cost of buildings, apparatus, machinery, and plant applicable to the individual case of every gas-works in the United Kingdom. That such is the fact will be clear when the variations in size, character of subsoil, design (whether substantial or otherwise), and situation of such works are taken into consideration.

Again, although the cost based on the prices of labour and materials ruling at the present time may be applicable, it is evident that the figures will necessarily vary with the fluctuations in the market prices and the effect of competition.

And neither is it possible to fix with perfect accuracy a standard of prices as a basis that will apply even under existing circumstances, as such prices vary, less or more, in different parts of the country.

At the best, it is only an approximation that can be given, and an attempt in this direction is made as follows :—

Prices on which the Coefficients of Cost are based.

Labour.	Average.
Skilled labour	10d. per hour.
Unskilled labour	4d. to 6d. per hour.
Bricksetting, labour only	1s. 3d. per square yard 9 in. thick.
Retort setting, labour only	2s. per mouthpiece.

Labour and Materials combined.	Average.
Steel or wrought-iron in forgings, small . . .	£18 per ton.
" fixing only . . .	£1 "
" in sheets and plates cold- straightened and punched	£18 "
" rivets and fixing . . .	£2 10s. 10d. per ton.
" in rolled steel girders . . .	£8 to £8 10s. "
" fixing only . . .	15s.
" riveted girders . . .	£11 to £12 "
" fixing only . . .	10s. to 15s. "
Sheet lead flashing and linings, and labour placing	18s. 6d. per cwt.

It is on these average prices that the coefficients of cost to be now given are based.

Capacity of the Works.

A gas-works capable of producing a maximum of 630,000 cub. ft. of gas per day of twenty-four hours is taken as a basis, and this size of works is adopted as being, though comparatively small, about a fair average, and to give a wider applicability to the figures than they would have, had a very large works been assumed.

Using 190 as the multiplier, this is equivalent to an annual production of 120 million cubic feet. Reasonable allowance is also made for future growth in the consumption.

The site of such a works will comprise two to three statute acres of land. It is assumed that the site is fairly level and such as to admit of its being fully utilized.

This extent of land is capable of containing without inconvenient crowding, provided the works are laid out with judgment, the whole of the manufacturing, purifying, and storage buildings and apparatus required for the above make of gas per day, and also the buildings and plant for the manufacture of sulphate of ammonia, the recovery of sulphur, and the distillation of tar.

The cost of the apparatus in each case includes erection.

The buildings are assumed to be neat and substantial.

Estimating the production from each mouthpiece or retort (oval or \square -shaped 21 in. by 15 in. by 10 ft. long) at 6000 ft. of gas per day of twenty-four hours on the average—

The number of mouthpieces required is . . . 105

Add by way of surplus to meet contingencies . . . 21

Total mouthpieces required . . . 126

The retorts are assumed to be in settings of sixes or sevens.

Cost.	Description.	Cost reckoned on the Max. daily (24 hours') Gas Pro- duction per 1000 Cubic Feet.			Cost per Mouthpiece.		
		£	s.	d.	£	s.	d.
10,080	<i>Stage Floor Retort House</i> with retort stack 20 ft. wide, 20 ft. space on each side. Retort settings, two dwarf chimneys, regenerator furnaces, all ironwork (including foul main round the inside of the house), tools, and implements; also covered coal stores to contain six weeks' stock of coal calculated on the maximum day's consumption, with railway communication. (Stoking machinery and conveyors are not included here, as it is all but impossible to fix a rate for these.)	16	0	0	80	0	0
6,255	<i>Stage Floor Retort House</i> and coal stores only, as above	9	18	9	49	13	0
3,825	<i>Retort Stack and two Dwarf Chimneys</i> built up from basement, with regenerator furnaces, retort settings, and ironwork, complete.	6	1	3	30	7	0
2,520	<i>Brickwork of Retort Stack</i> and two dwarf chimneys, regenerator furnaces, retorts, and settings, but no ironwork	4	0	0	20	0	0
1,300	<i>Ironwork</i> only of stack complete, including hydraulic and foul mains	2	1	3	10	7	0
630	<i>Retorts</i> , including labour in setting and all fire-clay materials (no ironwork)	1	0	0	5	0	0
630	<i>Regenerator Furnaces</i> and ironwork of same	1	0	0	5	0	0
7,000	<i>Ground Floor Retort House</i> with retort stack 20 ft. wide, 20 ft. space on each side, retort settings, two dwarf chimneys, all ironwork (including foul main round the inside of the house), tools, and implements; also covered coal store to contain four weeks' stock of coal calculated on the maximum day's consumption, with railway communication	11	2	3	55	10	0
4,190	<i>Ground Floor Retort House</i> and coal stores only, as above	6	13	3	33	5	0
2,810	<i>Retort Stack</i> , two dwarf chimneys, and retort settings, with iron mountings, complete	4	9	0	22	5	0

¹ The cost of an inclined retort house, with 20 ft. retorts, conveyors, and all brickwork and ironwork, complete, may be set down at £115 per mouthpiece, reckoning two mouthpieces to each retort.

Cost.	Description.	Cost reckoned on the Max. daily (24 hours') Gas Production per 1000 Cubic Feet.			Cost per Mouthpiece.		
		£	s.	d.	£	s.	d.
1,606	<i>Brickwork</i> of retort stack, two dwarf chimneys, retorts, and settings, but no ironwork	2	11	0	12	15	0
1,194	<i>Ironwork</i> only of stack, including hydraulic and foul mains	1	18	0	9	10	0
630	<i>Retorts</i> , including labour in setting and fire-clay materials (no ironwork)	1	0	0	5	0	0
2,000	<i>Railway Communication</i> with an adjoining line of railway. This is an uncertain item, but say as an average	3	2	6	16	0	0
460	<i>Condenser</i> . This may be of any form, vertical or horizontal (the respective cost will not vary to any great extent), with connections and by-pass mains and valves, complete	0	14	6	—		
					Cost per 1000 Cubic Feet of Gas (maximum) produced per Day.		
					£ s. d.		
535	<i>Boiler and Exhauster House</i> . Chimney and setting for two boilers		0	17	0		
300	<i>Steam Boilers</i> of the Cornish type, two in number, of steel and of ample size to supply steam for exhausters, scrubbers, washer-scrubber, pumps, sulphate apparatus, and any other purpose on the works, 18 ft. by 5 ft. 6 in., and all mountings and connections		0	9	6		
330	<i>Exhauster</i> . Capacity 40,000 cub. ft. per hour driven direct, with its own steam engine, with governor, connections, by-pass mains and flap-valve complete. Duplicate exhausters are desirable in case of a breakdown		0	10	6		
1,325	<i>Tower Scrubbers</i> , two in number, 9 ft. in diam. and 44 ft. high each, with pent-house in addition. Wood filling, liquor and water distributors, washer, at base of first		2	2	0		
570	<i>Washer-Scrubber</i> with steam engine, connections, by-pass mains and valves. Capacity, 700,000 cub. ft. per day		0	18	0		
500	<i>Tar and Ammoniacal Liquor Wells</i> , two in number or one divided in two. These are assumed to be underground, built of bricks in Portland cement mortar; capacity equal to four weeks' production of tar and liquor; with separator		0	16	0		
80	<i>Set of three Pumps</i> with steam engine		0	2	6		
					2	12	

Cost.	Description.	Cost per Square Foot of Purifying Area. £ s. d.	Cost per 1000 Cubic Feet of Gas (maximum) produced per Day. £ s. d.
3,780	<i>Purifying House.</i> Ground floor house with cellar and six purifiers 20 ft. square by 5 ft. deep, and lifting apparatus for purifier lids, wood grids, one centre valve, two 4-way change valves, and all connections 18 in. diam., complete	1 11 6	6 0 0
1,260	<i>House only</i> , as above	0 10 6	2 0 0
400	<i>Revivifying Floor</i> adjoining, for oxide of iron, covered by a roof supported on pillars	0 3 4	0 12 6
4,800	<i>Two-Storeyed Purifying House</i> , including six purifiers 20 ft. square and 5 ft. deep, placed on upper floor, supported on iron beams and columns; wood grids, one centre valve, and two 4-way change valves, all connections 18 in. diam.; lifting apparatus for purifier lids; revivifying space on ground floor, steam engine and elevating apparatus for oxide of iron and lime	2 0 0	7 12 6
1,780	<i>House only</i> , as above	0 16 6	3 3 0
300	<i>Oxide Elevating Apparatus</i> , with gearing, belting, and steam engine	0 2 6	0 9 6
2,520	<i>Purifiers.</i> Six vessels, 20 ft. square by 5 ft. deep in two sets. The first four with centre valve, and the last two with 4-way valves; with wood grids, lifting tackle for covers, and all connections	1 1 0	4 0 0
500	<i>Station Meter House</i> , with accommodation for two station meters and two station governors		0 16 0
425	<i>Station Meter.</i> Square, connections, with by-pass valves and mountings, complete; capacity, 40,000 cub. ft. per hour		0 13 6
		Cost per 1000 Cubic Feet Capacity. £ s. d.	
5,040	<i>Gasholder Tanks</i> , two in number, 122 ft. diam., 22½ ft. deep = 240,000 cub. ft. each, built with bricks laid in Portland cement mortar and puddled	10 10 0	8 0 0
7,040	<i>Gasholders</i> , two in number, two-lift, telescopic, 120 ft. diam., 40 ft. deep, capacity 430,000 cubic ft. each, together 860,000 cub. ft., equal to 32 hours' (1½ days') production; with stand pipes and valves	8 0 0	11 3 6
236	<i>Station Governors</i> , 16 in., two in number, with by-pass, connections, and valves		0 7 6
400	<i>Foundations of Apparatus</i> throughout the works		0 12 6

Cost. £	Description.	Cost per 1000 Cubic Feet of Gas (maximum) produced per Day		
		£	s.	d.
315	Connections, valves, and mains, throughout the works, 16 in. diam. Tar pipes, water pipes, etc.	0	10	0
65	Weighbridge at entrance	0	2	0
1,700	Offices, Workshops, Stores, testing room and laboratory, and furnishing	2	14	0
700	Boundary Wall, Drains, yard paving, and conveniences	1	2	0
21,000	Distributing Plant. Assuming that the outlay on mains, valves, syphons, and service pipes amounts to 30 per cent. of the total capital expenditure, which is a fair average, then the cost will be	33	6	8
500	Sulphate of Ammonia Apparatus, capacity 5 to 7 tons liquor per 24 hours and appurtenances; including two cast-iron purifiers, 10 ft. by 10 ft. by 5 ft., hydraulic change valve and wood roof on pillars, overhead liquor tank to hold 10 tons, lead-lined acid store tank, and acid supply tank with elevator, pipes, taps, etc.	0	16	0
150	Buildings and lead-lined store for ditto	0	12	6
140	Sulphur Recovery Apparatus	0	4	6
310	Tar Distilling Apparatus	0	10	0
280	Buildings for ditto	0	9	0

	Capital Amount. £	Per- centage.			
<i>The Capital of, say, £70,000 would be distributed as under.</i>					
Land, law, parliamentary, and engineering expenses	6,300	9	10	0	0
Floating capital	4,900	7	7	15	6
Buildings (including a stage floor house, the brickwork of the retort stack, the gasholder tanks, tar wells, and foundations of apparatus)	22,400	32	35	11	0
Apparatus and machinery (including the ironwork of retort stack, gasholders, and the apparatus generally)	15,400	22	24	9	0
Distributing plant, mains, service pipes, etc.	21,000	30	33	6	8
Total	£70,000	100	111	2	2

Dividing the £70,000 Capital under the Heads of the Different Departments.

Land, law, parliamentary, and engineering expenses	6,300	9	10	0	0
Floating capital	4,900	7	7	15	6
Manufacturing	16,100	23	25	11	0
Purifying (including condenser, scrubbers, washer-scrubber, purifiers, etc.)	9,100	13	14	9	0
Storing	12,600	18	20	0	0
Distributing	21,000	30	33	6	8
Total	£70,000	100	£111	2	2

MISCELLANEOUS.

BRICKS AND BRICKWORK.

Usual Dimensions of Bricks.

9 in. long ; $4\frac{1}{2}$ in. broad ; $2\frac{3}{4}$ in. thick.

Weight of 1000 common clay bricks, about $3\frac{1}{4}$ tons.

Weight of 1000 fire-clay bricks, about $3\frac{1}{2}$ tons.

305 common clay bricks weigh about 1 ton.

300 fire-clay bricks weigh about 1 ton.

32 bricks laid flat will pave one square yard.

52 bricks laid on edge will pave one square yard.

Number of bricks in a cubic yard, without mortar, 416.

Number of bricks in a cubic yard, with mortar, 384.

In England, brickwork is generally calculated by the square rod.

A rod of brickwork measures $16\frac{1}{2}$ ft. by $16\frac{1}{2}$ ft. by $1\frac{1}{8}$ ft. = 306 cub. ft., or $11\frac{1}{8}$ cub. yds.

A rod of brickwork = 272 superficial ft., $1\frac{1}{2}$ bricks, or $13\frac{1}{2}$ in. thick, which is called the *standard* thickness.

Number of bricks in a rod of brickwork, allowing for waste, 4500.

To reduce brickwork from superficial feet of 9 in. thick to the standard thickness of $13\frac{1}{2}$ in., deduct one-third.

To reduce brickwork from cubic feet to superficial feet of the standard thickness of $13\frac{1}{2}$ in., deduct one-ninth.

To reduce brickwork from cubic feet to rods, divide by 306.

To reduce brickwork of more than $1\frac{1}{2}$ bricks thick to superficial feet of the standard thickness of $13\frac{1}{2}$ in., multiply the area in feet by the number of half-bricks in thickness, and divide the product by 3.

To reduce brickwork footings to superficial feet of the standard thickness of $13\frac{1}{2}$ in., multiply the length by the height of the courses, in feet, and the product by the number of half-bricks in the *mean* breadth, and divide by 3. When the number of courses is odd, the number of half-bricks in the middle course is the mean. When the number of courses is even, the mean breadth is found by

taking half the sum of half-bricks in the upper and lower courses.

Bond in Brickwork.

English bond is the strongest, and is a course of stretchers and a course of headers alternately, or one course of headers and one course of stretchers.

Flemish bond is a header and stretcher laid alternately in the same course.

Hoop-iron, when used as bond, should be well tarred and sanded, and bedded in Portland cement.

A rod of brickwork in ordinary buildings requires about—

1 cub. yd. of lime.
2 $\frac{3}{4}$ cub. yds. of sand.

A rod of brickwork in a gasholder tank requires about—

1 $\frac{2}{5}$ cub. yds. of blue lias lime.
2 $\frac{4}{5}$ cub. yds. of sharp river sand.

A rod of brickwork requires about—

1 $\frac{3}{4}$ cub. yds. of Roman or Portland cement.
1 $\frac{3}{4}$ cub. yds. of sharp river sand.

A cubic yard of quicklime	.	.	weighs about	1460 lbs.
„	„	blue lias quicklime	„	„
„	„	Portland cement	.	„
„	„	Roman cement	.	„
„	„	dry sand	.	„
			„	„
				1470 „
				2416 „
				1700 „
				2430 „

The above materials, when made into mortar, lose about one third of their bulk.

Fire-Clay.

The value of fire-clay consists chiefly in the proportion of the alumina to the fusible matter (*viz.*, oxide of iron, and the alkalies of magnesia, potash, and soda, etc.) and to the silica; these being the principal ingredients of which it is composed. The larger the proportion of alumina to the fusible matter, the more refractory the clay. Of two clays containing alumina and fusible matter in the same proportions, that which contains the least silica is the more refractory.

The celebrated clays of Stourbridge, Newcastle-on-Tyne, different parts of Yorkshire, Scotland, and a few other places, are valuable in the manufacture of bricks, tiles, and retorts used in furnaces for the distillation of coal.

An important contribution on refractory materials, by Mr. F. J. Bywater of Birmingham, resulted in a Refractory Materials Committee being appointed to determine the value of different fire-clays.

A standard specification for all fire-clay materials has now been compiled by the Committee, and although it is subject to revision as experience and research may dictate, it will do much to raise the standard of English fire-clays.

TABLE
Exhibiting the usual Constituents of the Chief English and Foreign Fire-Clays.

Locality.	Silica.	Alumina.	Peroxide of Iron.	Peroxide of Manganese.	Phosphate of Iron.	Lime.	Magnesia.	Potassa.	Soda.	Titanic Acid.	Water, Organic Matter, &c.	Total.
Stourbridge	65·37	26·48	5·68	..	..	·28	·33	1·26	·30	·30	..	100
Plympton, Devonshire .	74·02	21·37	1·94	..	..	·40	·36	1·82	·09	..	..	100
Newcastle-on-Tyne . . .	64·63	29·78	3·23	..	..	·42	·41	1·09	·24	·20	..	100
Burton-on-Trent	55·05	36·09	3·06	..	..	·55	·14	·20	1·88	..	..	100
Wortley, near Leeds . . .	65·25	29·71	3·07	..	..	·40	·61	·43	1·12	·41	..	100
Derbyshire	43·08	36·89	2·26	..	..	..	..	1·88	..	..	10·89	100
Hedgerley, Bucks*	84·65	8·85	4·25	..	..	1·90	·36	..	..	..	..	100
Poole, Dorsetshire	59·35	34·32	2·35	..	..	·43	·22	3·33	..	..	..	100
Monmouthshire	75·30	16·80	1·00	..	..	·90	..	..	..	..	6·00	100
Pembrokeshire	88·43	6·90	1·50	..	..	3·17	..	..	..	..	..	100
Dinas, Glamorganshire . .	97·62	1·40	·49	..	..	·29	..	·10	·10	..	..	100
Kilmarnock, Scotland . .	58·92	35·65	2·49	..	..	·39	·35	1·14	1·06	..	..	100
Perceton, Sootland	62·50	35·00	·90	·20	·50	·60	·30	..	..	..	..	100
Govan, Sootland	60·20	37·70	1·10	..	..	1·00	..	..	..	..	..	100
France	66·10	19·80	..	..	..	..	..	..	..	..	14·10	100
Hesse	47·50	34·37	1·24	..	..	..	1·00	..	..	..	15·89	100
Bavaria	45·79	28·10	6·55	..	..	..	..	..	..	..	19·56	100

Authorities.—Berthier, Cowper, Salvetti, Muspratt, Richardson, Kitt, and Grover.

* Windsor bricks.

TABLES.

Showing the Number of Bricks in Walls of different Areas, from $\frac{1}{2}$ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 ft. super.), allowing for Waste.

TABLE I.—From 1 to 50 Superficial Feet.

Area of Wall. Sup. Feet.	$\frac{1}{2}$ Brick on Bed.	1 Brick thick.	$1\frac{1}{2}$ Bricks thick.	2 Bricks thick.	$2\frac{1}{2}$ Bricks thick.	3 Bricks thick.	$3\frac{1}{2}$ Bricks thick.	4 Bricks thick.
1	6	11	17	22	28	33	39	44
2	11	22	33	44	55	66	77	88
3	17	33	50	66	83	99	116	132
4	22	44	66	88	110	132	154	176
5	28	55	83	110	138	165	193	221
6	33	66	99	132	165	199	232	265
7	39	77	116	154	193	232	270	309
8	44	88	132	176	221	265	309	353
9	50	99	149	199	248	298	347	397
10	55	110	165	221	276	331	386	441
11	61	121	182	243	303	364	425	485
12	66	132	199	265	331	397	463	529
13	72	143	215	287	358	430	502	574
14	77	154	232	309	386	463	540	618
15	83	165	248	331	414	496	579	662
16	88	176	265	353	441	529	618	706
17	94	187	281	375	469	563	656	750
18	99	199	298	397	496	596	695	794
19	105	210	314	419	524	629	733	838
20	110	221	331	441	551	662	772	882
21	116	232	347	463	579	695	811	926
22	121	243	364	485	607	728	849	971
23	127	254	381	507	634	761	888	1015
24	132	265	397	529	662	794	926	1059
25	138	276	414	551	689	827	965	1103
26	143	287	430	574	717	860	1004	1147
27	149	298	447	596	744	893	1042	1191
28	154	309	463	618	772	926	1081	1235
29	160	320	480	640	800	960	1119	1279
30	165	331	496	662	827	993	1158	1324
31	171	342	513	684	855	1026	1197	1368
32	176	353	529	706	882	1059	1235	1412
33	182	364	546	728	910	1092	1274	1456
34	188	375	563	750	938	1125	1313	1500
35	193	386	579	772	965	1158	1351	1544
36	199	397	596	794	993	1191	1390	1588
37	204	408	612	816	1020	1224	1428	1632
38	210	419	629	838	1048	1257	1467	1676
39	215	430	645	860	1075	1290	1506	1721
40	221	441	662	882	1103	1324	1544	1765
41	226	452	678	904	1131	1357	1583	1809
42	232	463	695	926	1158	1390	1621	1853
43	237	474	711	949	1186	1423	1660	1897
44	243	485	728	971	1213	1456	1699	1941
45	248	496	744	993	1241	1489	1737	1985
46	254	507	761	1015	1268	1522	1776	2029
47	259	518	778	1037	1296	1555	1814	2074
48	265	529	794	1059	1324	1588	1853	2118
49	270	540	811	1081	1351	1621	1892	2162
50	276	551	827	1103	1379	1654	1930	2206

Showing the Number of Bricks in Walls of different Areas, from $\frac{1}{2}$ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to a Rod (272 feet super.), allowing for Waste.

TABLE II.—From 51 to 100 Superficial Feet.

Area of Wall. Sup. Feet.	$\frac{1}{2}$ Brick on Bed.	1 Brick thick.	$1\frac{1}{2}$ Bricks thick.	2 Bricks thick.	$2\frac{1}{2}$ Bricks thick.	3 Bricks thick.	$3\frac{1}{2}$ Bricks thick.	4 Bricks thick.
51	281	563	844	1125	1406	1688	1969	2250
52	287	574	860	1147	1434	1721	2007	2294
53	292	584	877	1169	1461	1754	2046	2338
54	298	596	893	1191	1489	1787	2085	2382
55	303	607	910	1213	1517	1820	2123	2426
56	309	618	926	1235	1544	1853	2162	2471
57	314	629	943	1257	1572	1886	2200	2515
58	320	640	960	1279	1599	1919	2239	2559
59	325	651	976	1301	1627	1952	2278	2603
60	331	662	993	1323	1654	1985	2316	2647
61	336	673	1009	1346	1682	2018	2355	2691
62	342	684	1026	1368	1710	2051	2393	2735
63	347	695	1042	1390	1737	2085	2432	2779
64	353	706	1059	1412	1765	2118	2471	2824
65	358	717	1075	1434	1792	2151	2509	2868
66	364	728	1092	1456	1820	2184	2548	2912
67	369	739	1108	1478	1847	2217	2586	2956
68	375	750	1125	1500	1875	2250	2625	3000
69	381	761	1142	1522	1903	2283	2664	3044
70	386	772	1158	1544	1939	2316	2702	3088
71	392	783	1175	1566	1958	2349	2741	3132
72	397	794	1191	1588	1985	2382	2779	3177
73	403	805	1208	1610	2013	2415	2818	3221
74	408	816	1224	1632	2040	2449	2857	3265
75	414	827	1241	1654	2068	2482	2895	3309
76	419	838	1257	1676	2096	2515	2934	3353
77	425	849	1274	1699	2123	2548	2972	3397
78	430	860	1290	1721	2151	2581	3011	3441
79	436	871	1307	1743	2178	2614	3050	3485
80	441	882	1324	1765	2206	2647	3088	3529
81	447	893	1340	1787	2233	2680	3127	3574
82	452	904	1357	1809	2261	2713	3165	3618
83	458	915	1373	1831	2289	2746	3204	3662
84	463	926	1390	1853	2316	2779	3243	3706
85	469	938	1406	1875	2344	2813	3281	3750
86	474	949	1423	1897	2371	2846	3320	3794
87	480	960	1439	1919	2399	2879	3358	3838
88	485	970	1456	1941	2426	2912	3397	3882
89	491	982	1472	1963	2454	2945	3436	3926
90	496	993	1489	1985	2482	2978	3474	3971
91	502	1004	1506	2007	2509	3011	3513	4015
92	507	1015	1522	2029	2537	3044	3551	4059
93	513	1026	1539	2051	2564	3077	3590	4103
94	518	1037	1555	2074	2592	3110	3629	4147
95	524	1048	1572	2096	2619	3143	3667	4191
96	529	1059	1588	2118	2647	3176	3706	4235
97	535	1070	1605	2140	2675	3210	3744	4279
98	540	1081	1621	2162	2702	3243	3783	4324
99	546	1092	1638	2184	2730	3276	3822	4368
100	551	1103	1654	2206	2757	3309	3860	4412

Showing the Number of Bricks in Walls, of different Areas, from $\frac{1}{2}$ Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE III.—From 110 to 600 Superficial Feet.

Area of Wall. Sup. Feet.	$\frac{1}{2}$ Brick on Bed.	1 Brick thick.	$1\frac{1}{2}$ Bricks thick.	2 Bricks thick.	$2\frac{1}{2}$ Bricks thick.	3 Bricks thick.	$3\frac{1}{2}$ Bricks thick.	4 Bricks thick.
110	607	1213	1820	2426	3033	3640	4246	4853
120	662	1324	1985	2647	3309	3971	4632	5294
130	717	1434	2151	2868	3585	4301	5018	5735
140	772	1544	2316	3088	3860	4632	5404	6176
150	827	1654	2482	3309	4136	4963	5790	6618
160	882	1765	2647	3529	4412	5294	6176	7059
170	938	1875	2813	3750	4688	5625	6563	7500
180	993	1985	2978	3971	4963	5956	6949	7941
190	1048	2096	3143	4191	5239	6287	7335	8382
200	1103	2206	3309	4412	5515	6618	7721	8824
210	1158	2316	3474	4632	5790	6949	8107	9265
220	1213	2426	3640	4853	6066	7279	8493	9706
230	1268	2537	3805	5074	6342	7610	8879	10,147
240	1324	2647	3971	5294	6618	7941	9265	10,588
250	1379	2757	4136	5515	6893	8272	9651	11,029
260	1434	2868	4301	5735	7169	8603	10,037	11,471
270	1489	2978	4467	5956	7445	8934	10,423	11,912
280	1544	3088	4632	6176	7721	9265	10,809	12,353
290	1599	3199	4798	6397	7996	9596	11,195	12,794
300	1654	3309	4963	6618	8272	9926	11,581	13,235
310	1710	3419	5129	6838	8548	10,257	11,967	13,676
320	1765	3529	5294	7059	8824	10,588	12,353	14,118
330	1820	3640	5460	7279	9099	10,919	12,739	14,559
340	1875	3750	5625	7500	9375	11,250	13,125	15,000
350	1930	3860	5790	7721	9651	11,581	13,511	15,441
360	1985	3971	5956	7941	9926	11,912	13,897	15,882
370	2040	4081	6121	8162	10,202	12,243	14,283	16,324
380	2096	4191	6287	8382	10,478	12,574	14,669	16,765
390	2151	4301	6452	8603	10,754	12,904	15,055	17,206
400	2206	4412	6618	8824	11,029	13,235	15,441	17,647
410	2261	4522	6783	9044	11,305	13,566	15,827	18,088
420	2316	4632	6949	9265	11,581	13,897	16,213	18,529
430	2371	4743	7114	9485	11,857	14,228	16,599	18,971
440	2426	4853	7279	9706	12,132	14,559	16,985	19,412
450	2482	4963	7445	9926	12,408	14,890	17,371	19,853
460	2537	5074	7610	10,147	12,684	15,221	17,757	20,294
470	2592	5184	7776	10,368	12,960	15,551	18,143	20,735
480	2647	5294	7941	10,588	13,235	15,882	18,529	21,176
490	2702	5404	8107	10,809	13,511	16,213	18,915	21,618
500	2757	5515	8272	11,029	13,787	16,544	19,301	22,059
510	2813	5625	8438	11,250	14,063	16,875	19,688	22,500
520	2868	5735	8603	11,471	14,338	17,206	20,074	22,941
530	2923	5846	8768	11,691	14,064	17,537	20,460	23,382
540	2978	5956	8934	11,912	14,890	17,868	20,846	23,824
550	3033	6066	9099	12,132	15,165	18,199	21,232	24,265
560	3088	6176	9265	12,353	15,441	18,529	21,618	24,706
570	3143	6287	9430	12,574	15,717	18,860	22,004	25,147
580	3199	6397	9596	12,794	15,993	19,191	22,390	25,588
590	3254	6507	9761	13,015	16,268	19,522	22,776	26,029
600	3309	6618	9926	13,235	16,544	19,853	23,162	26,471

Showing the Number of Bricks in Walls of different Areas, from $\frac{1}{2}$ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE IV.—From 610 to 2000 Superficial Feet.

Area of Wall Sup. Feet.	$\frac{1}{2}$ Brick on Bed.	1 Brick thick.	$1\frac{1}{2}$ Bricks thick.	2 Bricks thick.	$2\frac{1}{2}$ Bricks thick.	3 Bricks thick.	$3\frac{1}{2}$ Bricks thick.	4 Bricks thick.
610	3364	6728	10,092	13,456	16,820	20,184	23,548	26,912
620	3419	6838	10,257	13,676	17,096	20,515	23,934	27,353
630	3474	6949	10,423	13,897	17,371	20,846	24,320	27,794
640	3529	7059	10,588	14,118	17,647	21,176	24,706	28,235
650	3585	7169	10,754	14,338	17,923	21,507	25,092	28,676
660	3640	7279	10,919	14,559	18,199	21,838	25,478	29,118
670	3695	7390	11,085	14,779	18,474	22,169	25,864	29,559
680	3750	7500	11,250	15,000	18,750	22,500	26,250	30,000
690	3805	7610	11,415	15,221	19,026	22,831	26,636	30,441
700	3860	7721	11,581	15,441	19,301	23,162	27,022	30,882
710	3915	7831	11,746	15,662	19,577	23,493	27,408	31,324
720	3971	7941	11,912	15,882	19,853	23,824	27,794	31,765
730	4026	8051	12,077	16,103	20,129	24,154	28,180	32,206
740	4081	8162	12,243	16,324	20,404	24,485	28,566	32,647
750	4136	8272	12,408	16,544	20,680	24,816	28,952	33,088
760	4191	8382	12,574	16,765	20,956	25,147	29,338	33,529
770	4246	8493	12,739	16,985	21,232	25,478	29,724	33,971
780	4301	8603	12,904	17,206	21,507	25,809	30,110	34,412
790	4357	8713	13,070	17,426	21,783	26,140	30,496	34,853
800	4412	8824	13,235	17,647	22,059	26,471	30,882	35,294
810	4467	8934	13,401	17,868	22,335	26,801	31,268	35,735
820	4522	9044	13,566	18,088	22,610	27,132	31,654	36,176
830	4577	9154	13,732	18,309	22,886	27,463	32,040	36,618
840	4632	9265	13,897	18,529	23,162	27,794	32,426	37,059
850	4688	9375	14,063	18,750	23,438	28,125	32,813	37,500
860	4743	9485	14,228	18,971	23,713	28,456	33,199	37,941
870	4798	9596	14,393	19,191	23,989	28,787	33,585	38,382
880	4853	9706	14,559	19,412	24,265	29,118	33,971	38,824
890	4908	9816	14,724	19,632	24,540	29,449	34,357	39,265
900	4963	9926	14,890	19,853	24,816	29,779	34,743	39,706
910	5018	10,037	15,055	20,074	25,092	30,110	35,129	40,147
920	5074	10,147	15,221	20,294	25,368	30,441	35,515	40,588
930	5129	10,257	15,386	20,515	25,643	30,772	35,901	41,029
940	5184	10,368	15,551	20,735	25,919	31,103	36,287	41,471
950	5239	10,478	15,717	20,956	26,195	31,434	36,673	41,912
960	5294	10,588	15,882	21,176	26,471	31,765	37,059	42,353
970	5349	10,699	16,048	21,397	26,746	32,096	37,445	42,794
980	5404	10,809	16,213	21,618	27,022	32,426	37,831	43,235
990	5460	10,919	16,379	21,838	27,298	32,757	38,217	43,676
1000	5515	11,029	16,544	22,059	27,574	33,088	38,603	44,118
1100	6066	12,132	18,199	24,265	30,331	36,397	42,463	48,529
1200	6618	13,235	19,853	26,471	33,088	39,706	46,324	52,941
1300	7169	14,338	21,507	28,676	35,846	43,015	50,184	57,353
1400	7721	15,441	23,162	30,882	38,603	46,324	54,044	61,765
1500	8272	16,544	24,816	33,088	41,360	49,632	57,904	66,176
1600	8824	17,647	26,471	35,294	44,118	52,941	61,765	70,588
1700	9375	18,750	28,125	37,500	46,825	56,250	65,625	75,000
1800	9926	19,853	29,779	39,706	49,632	59,559	69,485	79,412
1900	10,478	20,956	31,434	41,912	52,390	62,868	73,346	83,824
2000	11,029	22,059	33,088	44,118	55,147	66,176	77,206	88,235

Showing the Number of Bricks in Walls of different Areas from $\frac{1}{2}$ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE V.—From 2100 to 250,000 Superficial Feet.

Area of Wall. Sup. Feet.	$\frac{1}{2}$ Brick on Bed.	1 Brick thick.	$1\frac{1}{2}$ Bricks thick.	2 Bricks thick.	$2\frac{1}{2}$ Bricks thick.	3 Bricks thick.	$3\frac{1}{2}$ Bricks thick.	4 Bricks thick.
2100	11,581	23,162	34,743	46,324	57,904	69,485	81,066	92,647
2200	12,132	24,265	36,397	48,529	60,662	72,794	84,926	97,059
2300	12,684	25,368	38,051	50,735	63,419	76,103	88,787	101,471
2400	13,235	26,471	39,706	52,941	66,176	79,412	92,647	105,882
2500	13,787	27,574	41,360	55,147	68,934	82,721	96,507	110,294
2600	14,338	28,676	43,015	57,353	71,691	86,029	100,368	114,705
2700	14,890	29,779	44,669	59,559	74,449	89,338	104,238	119,118
2800	15,441	30,882	46,324	61,765	77,206	92,647	108,088	123,529
2900	15,993	31,985	47,378	63,971	79,963	95,956	111,949	127,941
3000	16,544	33,088	49,632	66,176	82,721	99,265	115,809	132,353
3100	17,096	34,191	51,287	68,382	85,478	102,574	119,669	136,765
3200	17,647	35,294	52,541	70,588	88,235	105,882	123,529	141,176
3300	18,199	36,397	54,596	72,794	90,993	109,191	127,390	145,588
3400	18,750	37,500	56,250	75,000	93,750	112,500	131,250	150,000
3500	19,301	38,603	57,904	77,206	96,507	115,809	135,110	154,412
3600	19,853	39,706	59,559	79,412	99,265	119,118	138,971	158,824
3700	20,404	40,809	61,213	81,618	102,022	122,426	142,831	163,235
3800	20,956	41,912	62,868	83,824	104,779	125,735	146,691	167,647
3900	21,507	43,015	64,522	86,029	107,537	129,044	150,551	172,059
4000	22,059	44,118	66,176	88,235	110,294	132,353	154,412	176,471
4100	22,610	45,221	67,831	90,441	113,051	135,662	158,272	180,882
4200	23,162	46,324	69,485	92,647	115,809	138,971	162,132	185,294
4300	23,713	47,426	71,140	94,853	118,566	142,279	165,993	189,706
4400	24,265	48,529	72,794	97,059	121,324	145,588	169,853	194,118
4500	24,816	49,632	74,449	99,265	124,081	148,897	173,713	198,529
4600	24,368	50,735	76,103	101,471	126,838	152,206	177,574	202,941
4700	25,919	51,838	77,757	103,676	129,596	155,515	181,434	207,353
4800	26,471	52,941	79,412	105,882	132,353	158,824	185,294	211,765
4900	27,022	54,044	81,066	108,088	135,110	162,132	189,154	216,176
5000	27,574	55,147	82,721	110,294	137,868	165,441	193,015	220,588
10,000	55,147	110,294	165,441	220,588	275,735	330,882	386,029	441,176
15,000	82,721	165,441	248,162	330,882	418,603	496,324	579,044	661,765
20,000	110,294	220,588	330,882	441,176	551,471	661,765	772,059	882,353
25,000	137,868	275,735	418,603	551,471	689,338	827,206	965,074	1,102,941
30,000	165,441	330,882	496,324	661,765	802,206	992,647	1,158,088	1,323,529
35,000	193,015	386,029	579,044	772,059	965,074	1,158,088	1,351,103	1,544,118
40,000	220,588	441,176	661,765	882,353	1,102,941	1,323,529	1,544,118	1,764,706
45,000	248,162	496,324	744,485	992,647	1,240,809	1,488,971	1,737,132	1,985,294
50,000	275,735	551,471	827,206	1,102,941	1,378,676	1,654,412	1,930,147	2,205,882
55,000	303,309	606,618	909,926	1,213,235	1,516,544	1,819,753	2,123,162	2,426,471
60,000	330,882	661,765	992,647	1,323,529	1,654,412	1,985,294	2,316,176	2,647,059
65,000	358,456	716,912	1,075,368	1,433,824	1,792,279	2,150,735	2,509,191	2,867,647
70,000	386,029	772,059	1,158,088	1,544,118	1,930,147	2,316,176	2,702,206	3,088,235
75,000	413,603	827,206	1,240,809	1,654,412	2,068,015	2,481,618	2,895,221	3,308,824
80,000	441,176	882,353	1,323,529	1,764,706	2,205,882	2,647,059	3,088,235	3,529,412
85,000	468,750	937,500	1,406,250	1,875,000	2,343,750	2,812,500	3,281,250	3,750,000
90,000	496,324	992,647	1,488,971	1,965,294	2,481,618	2,977,941	3,474,265	3,970,588
95,000	523,897	1,047,794	1,571,791	2,095,588	2,619,485	3,143,382	3,667,279	4,191,176
100,000	551,471	1,102,941	1,654,412	2,205,882	2,757,353	3,308,824	3,860,294	4,411,765
150,100	827,206	1,654,412	2,481,618	3,308,824	4,136,029	4,963,235	5,790,441	6,617,647
200,000	1,102,941	2,205,882	3,308,824	4,411,765	5,514,706	6,617,647	7,720,588	8,823,529
250,000	1,378,676	2,757,353	4,136,029	5,514,706	6,893,382	8,272,059	9,650,735	11,029,412

MORTAR AND CONCRETE.

Mortar.

	By Measure.
Lime	1 part.
Sharp river sand	3 parts

Or,

Lime	1 part.
Sand	2 parts.
Blacksmith's ashes or clinker, ground	1 part.

Coarse Mortar.

Lime	1 part.
Coarse sand	4 parts.

Hydraulic Lime Mortar.

Best blue lias lime	1 part.
Clean sharp river sand	2½ parts.

Or,

Best blue lias lime	1 part.
Burnt clay	2 parts.

Or,

Best blue lias lime	1 part.
Puzzolana	1 part.
Clean sharp sand	6 parts.

Cement Mortar.

Cement, Portland	1 part.
Clean sharp sand	3 parts.

The lime should be fresh burnt, and not more than sufficient of the mortar for a day's work prepared at once. The cement mortar should only be made as it is being used.

Concrete.

	By Measure.
Blue lias lime concrete (for foundations)—	
Gravel, shingle, broken stone, bricks, or old retorts, 1½ to 2 in. cube	6 parts.

	By Measure.
Clean sharp sand	2 parts.
Blue lias or other hydraulic lime	1 part.
Portland cement concrete (for tank walls)—	
Gravel, shingle, broken stone, bricks, or old retorts $1\frac{1}{2}$ in. cube	7 parts.
Clean sharp sand	2 parts.
Portland cement	1 part.

Mastic Cement for Buildings.

1 part red lead.	1 part red lead.
5 parts ground lime.	5 parts whiting.
5 parts sharp sand.	10 parts sharp sand.
Mix with boiled linseed oil.	Mix with boiled linseed oil.

Clean sharp sand (not having its particles rounded by attrition) should always be used in the composition of mortar when it can be procured; but, otherwise, clean well-burnt ashes may be substituted.

In preparing ordinary mortar it is desirable to mix a small proportion of smithy ashes with the lime and sand. On this subject Mr. Graham Smith remarks (*Engineering Papers*, p. 20), "The importance of the admixture of ashes with mortar to be atmospherically dried will be shown by the following results: The bricklayers' mortar, with common bricks, after a lapse of eighty-four days, broke with 570 lbs.; when sand was substituted in place of ashes—that is, when the proportions were 1 slaked lime, 2 sand, and no ashes—it only required 257 lbs. to tear asunder the bricks. These are the averages of three experiments. This is no doubt attributable to the ashes being porous; they thus allow greater facilities for the absorption of carbonic acid from the atmosphere."

The more sand that can be incorporated with the lime, the better the mortar, provided the necessary degree of plasticity is preserved.

A load of mortar is equal to one cubic yard.

A hod of mortar measures 9 in. by 9 in. by 14 in.

Two hods of mortar are nearly equal to a bushel.

The mortar in a rod of brickwork (4500 bricks) is taken at $1\frac{1}{2}$ cwt. of chalk lime and 2 loads of sand, or 1 cwt. of stone lime and $2\frac{1}{2}$ loads of sand.

Handy Multiplier for Wrought-Iron.

If the area in square inches of the cross section of any specimen of wrought-iron be multiplied by 3.34, the product will be the weight in pounds of a lineal foot of such specimen.

FLAT BAR IRON.—*Weight in lbs. of a Lineal Foot.*

Breadth in Inches.	Thickness in Parts of an Inch.								
	1-4th.	5-16ths	3-8ths.	7-16ths	1-half.	5-8ths.	3-4ths.	7-8ths.	1
1	0'835	1'044	1'253	1'461	1'670	2'088	2'506	2'923	3'340
1 1/16	0'939	1'174	1'409	1'644	1'878	2'348	2'818	3'287	3'756
1 1/8	1'044	1'305	1'566	1'826	2'088	2'609	3'132	3'653	4'176
1 1/4	1'148	1'435	1'722	2'009	2'296	2'870	3'444	4'018	4'592
1 1/2	1'252	1'566	1'879	2'192	2'504	3'131	3'758	4'384	5'008
1 3/8	1'358	1'696	2'035	2'374	2'716	3'392	4'070	4'749	5'432
1 3/4	1'462	1'827	2'192	2'557	2'924	3'653	4'384	5'114	5'848
1 7/8	1'566	1'957	2'348	2'740	3'132	3'914	4'696	5'479	6'204
2	1'671	2'088	2'505	2'922	3'342	4'175	5'010	5'845	6'684
2 1/16	1'775	2'218	2'662	3'105	3'550	4'435	5'324	6'210	7'100
2 1/8	1'880	2'348	2'818	3'288	3'760	4'696	5'636	6'575	7'520
2 1/4	1'984	2'479	2'975	3'470	3'968	4'957	5'950	6'941	7'936
2 1/2	2'088	2'609	3'131	3'653	4'176	5'218	6'262	7'306	8'352
2 3/8	2'193	2'740	3'288	3'836	4'386	5'479	6'576	7'671	8'772
2 3/4	2'297	2'870	3'444	4'018	4'594	5'740	6'888	8'036	9'188
2 7/8	2'402	3'001	3'601	4'201	4'804	6'001	7'202	8'402	9'608
3	2'506	3'131	3'758	4'384	5'012	6'262	7'516	8'767	10'024
3 1/16	2'715	3'392	4'071	4'749	5'430	6'784	8'142	9'489	10'860
3 1/8	2'923	3'653	4'384	5'114	5'846	7'306	8'768	10'228	11'692
3 1/4	3'132	3'914	4'697	5'479	6'264	7'828	9'394	10'959	12'528
3 1/2	3'341	4'175	5'010	5'845	6'682	8'350	10'020	11'690	13'364
3 3/8	3'549	4'436	5'323	6'210	7'098	8'871	10'646	12'421	14'196
3 3/4	3'758	4'697	5'636	6'575	7'516	9'393	11'272	13'151	15'032
4	3'966	4'958	5'949	6'941	7'932	9'915	11'898	13'881	15'864
4 1/16	4'175	5'219	6'263	7'306	8'350	10'437	12'526	14'612	16'700
4 1/8	4'384	5'479	6'576	7'671	8'768	10'958	13'152	15'343	17'536
4 1/4	4'593	5'741	6'889	8'037	9'186	11'480	13'778	16'073	18'372
4 1/2	4'801	6'001	7'202	8'402	9'602	12'002	14'404	16'804	19'204
5	5'010	6'262	7'515	8'767	10'020	12'524	15'030	17'535	20'042

ROUND BAR IRON. *Weight in lbs. of a Lineal Foot.*

Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
1/16	0'040	1 1/16	6'870	3 1/16	25'400	4 1/16	55'640
1/8	0'163	1 1/8	7'970	3 1/8	27'475	4 1/8	58'688
3/16	0'363	1 3/16	9'150	3 3/16	29'625	4 3/16	61'820
1/4	0'650	2	10'406	3 1/4	31'870	5	65'040
5/16	1'006	2 1/16	11'750	3 5/16	34'175	5 1/16	68'330
3/8	1'456	2 1/8	13'106	3 3/8	36'575	5 1/8	71'700
1/2	1'990	2 1/4	14'670	3 1/2	39'056	5 1/4	75'150
5/8	2'590	2 3/8	16'256	4	41'620	5 3/8	78'700
3/4	3'300	2 1/2	17'925	4 1/4	44'260	5 1/2	82'300
7/8	4'070	2 3/4	19'600	4 1/2	46'990	5 3/4	86'006
1	4'920	3	21'500	4 3/4	49'790	5 7/8	89'800
1 1/16	5'860	3 1/16	23'406	4 1/2	52'675	6	93'650

FLAT ROLLED STEEL.

Weight in lbs. of a Lineal Foot.

Breadth in Inches.	Thickness in parts of an Inch.							
	1-16th.	1-8th.	3-16th.	1-4th.	5-16th.	3-8th.	7-16th.	1-half.
1	0'213	0'425	0'638	0'850	1'06	1'28	1'49	1'70
1 1/4	0'266	0'531	0'797	1'06	1'33	1'59	1'86	2'13
1 1/2	0'319	0'638	0'956	1'28	1'59	1'91	2'23	2'55
1 3/4	0'372	0'744	1'12	1'49	1'86	2'23	2'60	2'98
2	0'425	0'850	1'28	1'70	2'13	2'55	2'98	3'40
2 1/4	0'478	0'956	1'43	1'91	2'39	2'87	3'35	3'83
2 1/2	0'531	1'06	1'59	2'13	2'66	3'19	3'72	4'25
2 3/4	0'584	1'17	1'75	2'34	2'92	3'51	4'09	4'68
3	0'638	1'28	1'91	2'55	3'19	3'83	4'46	5'10
3 1/4	0'691	1'38	2'07	2'76	3'45	4'14	4'83	5'53
3 1/2	0'744	1'49	2'23	2'98	3'72	4'46	5'21	5'95
3 3/4	0'797	1'59	2'39	3'19	3'98	4'78	5'58	6'38
4	0'850	1'70	2'55	3'40	4'25	5'10	5'95	6'80
4 1/4	0'903	1'81	2'71	3'61	4'52	5'42	6'32	7'23
4 1/2	0'956	1'91	2'87	3'83	4'78	5'74	6'69	7'65
4 3/4	1'01	2'02	3'03	4'04	5'05	6'06	7'07	8'08
5	1'06	2'13	3'19	4'25	5'31	6'38	7'44	8'50
5 1/4	1'12	2'23	3'35	4'46	5'58	6'69	7'81	8'93
5 1/2	1'17	2'34	3'51	4'68	5'84	7'01	8'18	9'35
5 3/4	1'22	2'44	3'67	4'89	6'11	7'33	8'55	9'78
6	1'28	2'55	3'83	5'10	6'38	7'65	8'93	10'20
6 1/4	1'33	2'66	3'98	5'31	6'64	7'97	9'30	10'63
6 1/2	1'38	2'76	4'14	5'53	6'91	8'29	9'67	11'05
6 3/4	1'43	2'87	4'30	5'74	7'17	8'61	10'04	11'48
7	1'49	2'98	4'46	5'95	7'44	8'93	10'41	11'90
7 1/4	1'54	3'08	4'62	6'16	7'70	9'24	10'78	12'33
7 1/2	1'59	3'19	4'78	6'38	7'97	9'56	11'16	12'75
7 3/4	1'65	3'29	4'94	6'59	8'23	9'88	11'53	13'18
8	1'70	3'40	5'10	6'80	8'50	10'20	11'90	13'60
8 1/4	1'75	3'51	5'26	7'01	8'77	10'52	12'27	14'03
8 1/2	1'81	3'61	5'42	7'23	9'03	10'84	12'64	14'45
8 3/4	1'86	3'72	5'58	7'44	9'30	11'16	13'02	14'88
9	1'91	3'83	5'74	7'65	9'56	11'48	13'39	15'30
9 1/4	1'97	3'93	5'90	7'86	9'83	11'80	13'76	15'73
9 1/2	2'02	4'04	6'06	8'08	10'09	12'11	14'13	16'15
9 3/4	2'07	4'14	6'22	8'29	10'36	12'43	14'50	16'58
10	2'13	4'25	6'38	8'50	10'63	12'75	14'88	17'00
10 1/4	2'18	4'36	6'53	8'71	10'89	13'07	15'25	17'43
10 1/2	2'23	4'46	6'70	8'93	11'16	13'39	15'62	17'85
10 3/4	2'28	4'57	6'85	9'14	11'42	13'71	15'99	18'28
11	2'34	4'68	7'01	9'35	11'69	14'03	16'36	18'70
11 1/4	2'39	4'78	7'17	9'56	11'95	14'34	16'73	19'13
11 1/2	2'44	4'89	7'33	9'78	12'22	14'66	17'11	19'55
11 3/4	2'50	5'00	7'49	9'99	12'48	14'98	17'48	19'98
12	2'55	5'10	7'65	10'20	12'75	15'30	17'85	20'40

FLAT ROLLED STEEL.

Weight in lbs. of a Lineal Foot.

Breadth in Inches.	Thickness in parts of an Inch.							
	9-16th.	5-8th.	11-16th.	3-4th.	13-16th.	7-8th.	15-16th.	1 inch.
1	1'91	2'13	2'34	2'55	2'76	2'98	3'19	3'40
1 1/4	2'39	2'66	2'92	3'19	3'45	3'72	3'98	4'25
1 1/2	2'87	3'19	3'51	3'83	4'14	4'46	4'78	5'10
1 3/4	3'35	3'72	4'09	4'46	4'83	5'21	5'58	5'95
2	3'83	4'25	4'68	5'10	5'53	5'95	6'38	6'80
2 1/4	4'30	4'78	5'26	5'74	6'22	6'69	7'17	7'65
2 1/2	4'78	5'31	5'84	6'38	6'91	7'44	7'97	8'50
2 3/4	5'26	5'84	6'43	7'01	7'60	8'18	8'77	9'35
3	5'74	6'38	7'01	7'65	8'29	8'93	9'56	10'20
3 1/4	6'22	6'91	7'60	8'29	8'98	9'67	10'36	11'05
3 1/2	6'70	7'44	8'18	8'93	9'67	10'41	11'16	11'90
3 3/4	7'17	7'97	8'77	9'56	10'36	11'16	11'95	12'75
4	7'65	8'50	9'35	10'20	11'05	11'90	12'75	13'60
4 1/4	8'13	9'03	9'93	10'84	11'74	12'64	13'55	14'45
4 1/2	8'61	9'56	10'52	11'48	12'43	13'39	14'34	15'30
4 3/4	9'08	10'09	11'10	12'11	13'12	14'13	15'14	16'15
5	9'56	10'63	11'69	12'75	13'81	14'88	15'94	17'00
5 1/4	10'04	11'16	12'27	13'39	14'50	15'62	16'73	17'85
5 1/2	10'52	11'69	12'86	14'03	15'19	16'36	17'53	18'70
5 3/4	11'00	12'22	13'44	14'66	15'88	17'11	18'33	19'55
6	11'48	12'75	14'03	15'30	16'58	17'85	19'13	20'40
6 1/4	11'95	13'28	14'61	15'94	17'27	18'59	19'92	21'45
6 1/2	12'43	13'81	15'19	16'58	17'96	19'34	20'72	22'10
6 3/4	12'91	14'34	15'78	17'21	18'65	20'08	21'52	22'95
7	13'39	14'88	16'36	17'85	19'34	20'83	22'31	23'80
7 1/4	13'87	15'41	16'95	18'49	20'03	21'57	23'11	24'65
7 1/2	14'34	15'94	17'53	19'13	20'72	22'31	23'91	25'50
7 3/4	14'82	16'47	18'12	19'76	21'41	23'06	24'70	26'35
8	15'30	17'00	18'70	20'40	22'10	23'80	25'50	27'20
8 1/4	15'78	17'53	19'28	21'04	22'79	24'54	26'30	28'05
8 1/2	16'26	18'06	19'87	21'68	23'48	25'29	27'10	28'90
8 3/4	16'73	18'59	20'45	22'31	24'17	26'03	27'89	29'75
9	17'21	19'13	21'04	22'95	24'86	26'78	28'69	30'60
9 1/4	17'69	19'66	21'62	23'59	25'55	27'52	29'48	31'45
9 1/2	18'17	20'19	22'21	24'23	26'24	28'26	30'28	32'30
9 3/4	18'65	20'72	22'79	24'86	26'93	29'01	31'08	33'15
10	19'13	21'25	23'38	25'50	27'63	29'75	31'88	34'00
10 1/4	19'60	21'78	23'96	26'14	28'32	30'49	32'67	34'85
10 1/2	20'08	22'31	24'54	26'78	29'01	31'24	33'47	35'70
10 3/4	20'56	22'84	25'13	27'41	29'70	31'98	34'27	36'55
11	21'04	23'38	25'71	28'05	30'39	32'73	35'06	37'40
11 1/4	21'52	23'91	26'30	28'69	31'08	33'47	35'86	38'25
11 1/2	22'00	24'44	26'88	29'33	31'77	34'21	36'66	39'10
11 3/4	22'47	24'97	27'47	29'96	32'46	34'96	37'45	39'95
12	22'95	25'50	28'05	30'60	33'15	35'70	38'25	40'80

SQUARE BAR IRON.

Weight in lbs. of a Lineal Foot.

Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.
$\frac{1}{8}$	.052	$1\frac{1}{8}$	8.82	$3\frac{1}{8}$	32.72	$4\frac{1}{8}$	71.60
$\frac{1}{4}$	.208	$1\frac{3}{8}$	10.23	$3\frac{3}{8}$	35.23	$4\frac{3}{8}$	75.86
$\frac{3}{8}$	.469	$1\frac{5}{8}$	11.74	$3\frac{5}{8}$	38.16	$4\frac{5}{8}$	79.54
$\frac{1}{2}$	.832	2	13.36	$3\frac{7}{8}$	40.92	5	83.44
$\frac{5}{8}$	1.304	$2\frac{1}{8}$	15.08	$3\frac{9}{8}$	44.01	$5\frac{1}{8}$	87.90
$\frac{3}{4}$	1.876	$2\frac{3}{8}$	16.91	$3\frac{11}{8}$	46.96	$5\frac{3}{8}$	92.40
$\frac{7}{8}$	2.557	$2\frac{5}{8}$	18.84	$3\frac{13}{8}$	50.38	$5\frac{5}{8}$	96.67
1	3.340	$2\frac{7}{8}$	20.86	4	53.44	$5\frac{7}{8}$	101.04
$1\frac{1}{8}$	4.227	$2\frac{9}{8}$	23.10	$4\frac{1}{8}$	56.97	$5\frac{9}{8}$	105.87
$1\frac{1}{4}$	5.216	$2\frac{11}{8}$	25.25	$4\frac{3}{8}$	60.32	$5\frac{11}{8}$	110.80
$1\frac{3}{8}$	6.314	$2\frac{13}{8}$	27.70	$4\frac{5}{8}$	64.08	$5\frac{13}{8}$	115.48
$1\frac{1}{2}$	7.504	3	30.02	$4\frac{7}{8}$	67.64	6	120.08

SHEET IRON AND STEEL.

Weight of a Superficial Foot in Pounds and Fractions, with Corresponding Number and Thickness of Birmingham Wire Gauge.

No. of Birmingham Wire Gauge.	Thickness in Parts of an Inch. Board of Trade Standard.	Weight per Square Foot in lbs.		No. of Birmingham Wire Gauge.	Thickness in Parts of an Inch. Board of Trade Standard.	Weight per Square Foot in lbs.	
		Iron.	Steel.			Iron.	Steel.
1	.300	12.00	12.240	19	.041	1.64	1.673
2	.234	11.36	11.557	20	.035	1.40	1.423
3	.260	10.40	10.608	21	.032	1.28	1.306
4	.238	9.52	9.710	22	.028	1.12	1.142
5	.220	8.80	8.976	23	.025	1.00	1.020
6	.203	8.12	8.232	24	.022	0.88	0.898
7	.180	7.20	7.344	25	.020	0.80	0.816
8	.165	6.60	6.732	26	.018	0.72	0.734
9	.148	5.92	6.038	27	.016	0.64	0.653
10	.135	5.40	5.508	28	.014	0.56	0.571
11	.120	4.80	4.896	29	.013	0.52	0.530
12	.109	4.36	4.447	30	.012	0.48	0.490
13	.095	3.80	3.876	31	.010	0.40	0.408
14	.083	3.32	3.386	32	.009	0.36	0.367
15	.072	2.88	2.938	33	.008	0.32	0.326
16	.065	2.60	2.652	34	.007	0.28	0.286
17	.058	2.32	2.366	35	.005	0.20	0.240
18	.050	2.00	2.040	36	.004	0.16	0.168

ROLLED STEEL JOISTS.

Weight in lbs. of a Lineal Foot.

Size in Inches.	Weight per Foot.	Size in Inches.	Weight per Foot.	Size in Inches.	Weight per Foot.
3 × 1½	4	6 × 5	25	12 × 5	32
3½ × 1½	6	7 × 4	16	12 × 5	39
3 × 3	8.5	8 × 4	18	12 × 6	44
4 × 1½	8	8 × 4	25	12 × 6	54
4 × 3	9.5	8 × 5	28	14 × 6	46
4½ × 1½	6.5	8 × 6	35	14 × 6	57
4½ × 1½	10	9 × 4	21	15 × 5	42
5 × 3	11	9½ × 3½	21.5	15 × 6	59
5 × 4½	18	9 × 7	58	16 × 6	62
5 × 5	24	10 × 5	30	18 × 7	75
6 × 3	12	10 × 5	35	20 × 7½	89
6 × 3	16	10 × 6	42	24 × 7½	100
6 × 4½	20	10 × 8	70		

STEEL.

Weight of One Foot of Round Steel.

Diameter in Inches.	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	1⅝	1⅞	1⅞	2	
Weight per Foot in lbs.	.167	.373	.669	1.04	1.05	2.05	2.67	3.38	4.18	5.06	6.02	7.07	8.2	9.41	11.71

WEIGHT IN POUNDS OF A SUPERFICIAL FOOT OF IRON, COPPER, AND BRASS.

Thickness by the Birmingham Wire Gauge.	Iron.	Copper.	Brass.	Thickness by the Birmingham Wire Gauge.	Iron.	Copper.	Brass.
	lbs.	lbs.	lbs.		lbs.	lbs.	lbs.
1	12.50	14.50	13.75	16	2.50	2.90	2.75
2	12.00	13.99	13.20	17	2.18	2.52	2.40
3	11.00	12.75	12.10	18	1.86	2.15	2.04
4	10.00	11.60	11.00	19	1.70	1.97	1.87
5	8.74	10.10	9.61	20	1.54	1.78	1.69
6	8.12	9.40	8.93	21	1.40	1.62	1.54
7	7.50	8.70	8.25	22	1.25	1.45	1.37
8	6.86	7.90	7.54	23	1.12	1.30	1.23
9	6.24	7.20	6.86	24	1.00	1.16	1.10
10	5.62	6.50	6.18	25	.90	1.04	.99
11	5.00	5.80	5.50	26	.80	.92	.88
12	4.38	5.08	4.81	27	.72	.83	.79
13	3.75	4.34	4.12	28	.64	.74	.70
14	3.12	3.60	3.43	29	.56	.64	.61
15	2.82	3.27	3.10	30	.50	.58	.55

IMPERIAL WIRE GAUGE.

Number of Wire Gauge.	Thickness in Inches.	Number of Wire Gauge.	Thickness in Inches.
7 0	0'500	18	0'048
6 0	0'464	19	0'040
5 0	0'432	20	0'036
4 0	0'400	21	0'032
3 0	0'372	22	0'028
2 0	0'348	23	0'024
0	0'324	24	0'022
1	0'300	25	0'020
2	0'276	26	0'018
3	0'252	27	0'0164
4	0'232	28	0'0149
5	0'212	29	0'0136
6	0'192	30	0'0124
7	0'176	31	0'0116
8	0'160	32	0'0108
9	0'144	33	0'0100
10	0'128	34	0'0092
11	0'116	35	0'0084
12	0'104	36	0'0076
13	0'092	37	0'0068
14	0'080	38	0'0060
15	0'072	39	0'0052
16	0'064	40	0'0048
17	0'056		

WEIGHT OF A SUPERFICIAL FOOT OF VARIOUS METALS.

Thickness in Inches.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.	Zinc.	Thickness in Inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1-16th.	2'526	2'344	2'552	2'891	2'374	3'708	2'344	1-16th.
1-8th.	5'052	4'687	5'104	5'781	5'469	7'417	4'687	1-8th.
3-16ths.	7'578	7'031	7'656	8'672	8'203	11'125	7'031	3-16ths.
1-4th.	10'104	9'375	10'208	11'563	10'938	14'883	9'375	1-4th.
5-16ths.	12'630	11'719	12'760	14'453	13'672	18'542	11'719	5-16ths.
3-8ths.	15'156	14'062	15'312	17'344	16'406	22'250	14'062	3-8ths.
7-16ths.	17'682	16'406	17'865	20'234	19'141	25'958	16'406	7-16ths.
1-half.	20'208	18'750	20'417	23'125	21'875	29'667	18'750	1-half.
9-16ths.	22'734	21'094	22'969	26'016	24'609	33'375	21'094	9-16ths.
5-8ths.	25'260	23'437	25'521	28'906	27'344	37'083	23'437	5-8ths.
11-16ths.	27'786	25'718	28'073	31'797	30'078	40'792	25'718	11-16ths.
3-4ths.	30'312	28'125	30'625	34'688	32'813	44'500	28'125	3-4ths.
13-16ths.	32'839	30'469	33'177	37'578	35'547	48'208	30'469	13-16ths.
7-8ths.	35'365	32'812	35'729	40'469	38'281	51'917	32'812	7-8ths.
15-16ths.	37'891	35'156	38'281	43'359	41'016	55'625	35'156	15-16ths.
1 inch	40'417	37'500	40'883	46'250	43'750	59'333	37'500	1 inch.

WEIGHT IN PARTS OF A POUND OF A SPHERE
1 IN. DIAM. OF VARIOUS METALS.

Brass Cast.	Bronze.	Copper Hammered.	Iron Cast.	Iron Wrought.	Steel.	Lead.	Tin.	Zinc.
0'156	0'159	0'167	0'135	0'145	0'147	0'214	0'139	0'133

HOOP IRON.

Weight of 10 Lineal Feet.

Width in Inches and Parts.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
No. of Gauge	21	20	19	18	17	16	15	15	14	13	13	12	11	11
Weight in lbs. and Decimal Parts.	685	885	1'24	1'60	2'05	2'73	3'40	3'72	4'72	6'06	6'83	8'96	10'85	

ANGLE IRON OF EQUAL SIDES.

Length of Sides in Inches.	Thickness of Edges.	Thickness of Root.	Weight of One Lineal Foot in lbs. and Decimal Parts.
4	$\frac{1}{2}$ in.	$\frac{1}{4}$ in.	14'0
3	$\frac{3}{8}$	$\frac{1}{8}$	10'375
$2\frac{3}{4}$	$\frac{7}{16}$	$\frac{1}{16}$	8'25
$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{8}$	6'5
$2\frac{1}{4}$	$\frac{1}{2}$ full	$\frac{1}{8}$	5'0
2	$\frac{1}{4}$ full	$\frac{1}{16}$ full	3'875
$1\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	3'25
$1\frac{1}{2}$	$\frac{1}{4}$ bare	$\frac{1}{8}$ bare	2'625

ANGLE STEEL.

Weight in lbs. of a Lineal Foot.

Sum of Flanges in Inches.	Thickness of Angle in parts of an Inch.											
	$\frac{1}{16}$ th.	$\frac{1}{8}$ th.	$\frac{3}{16}$ th.	$\frac{1}{4}$ th.	$\frac{5}{16}$ th.	$\frac{1}{2}$	$\frac{3}{8}$ th.	$\frac{7}{16}$ th.	$\frac{1}{2}$ th.	$\frac{3}{4}$ th.	$\frac{7}{8}$ th.	1 inch.
2½	1'47	1'91	—	—	—	—	—	—	—	—	—	—
3	1'79	2'33	2'85	—	—	—	—	—	—	—	—	—
3½	2'11	2'77	3'39	—	—	—	—	—	—	—	—	—
4	2'43	3'19	3'92	4'62	—	—	—	—	—	—	—	—
4½	2'75	3'61	4'45	5'26	6'05	—	—	—	—	—	—	—
5	—	4'04	4'98	5'89	6'78	7'65	—	—	—	—	—	—
5½	—	4'46	5'51	6'53	7'53	8'50	9'44	—	—	—	—	—
6	—	4'90	6'05	7'18	8'28	9'36	10'41	11'43	—	—	—	—
6½	—	—	6'58	7'81	9'02	10'20	11'36	12'49	—	—	—	—
7	—	—	7'11	8'45	9'76	11'05	12'31	13'55	14'76	—	—	—
7½	—	—	7'64	9'08	10'50	11'90	13'27	14'61	15'92	—	—	—
8	—	—	8'17	9'72	11'25	12'75	14'22	15'67	17'09	18'49	—	—
8½	—	—	—	10'37	12'01	13'61	15'19	16'74	18'27	19'77	—	—
9	—	—	—	11'00	12'74	14'46	16'14	17'80	19'44	21'04	24'18	—
9½	—	—	—	11'64	13'49	15'31	17'10	18'87	20'61	22'32	25'67	—
10	—	—	—	12'27	14'23	16'15	18'05	19'92	21'77	23'59	27'15	30'60
10½	—	—	—	—	14'97	17'00	19'01	20'98	22'94	24'86	28'63	32'30
11	—	—	—	—	15'70	17'84	19'95	22'04	24'10	26'13	30'11	33'99
12	—	—	—	—	17'21	19'56	20'89	24'18	26'45	28'70	33'11	37'41

TEE IRON.

Width of Top Table in Inches.	Total Depth in Inches.	Thickness of Top Table at Root.	Thickness of Top Table at Edges.	Uniform Thickness of Rib.	Weight of One Lineal Foot in lbs.
3	3½	$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	$\frac{7}{16}$ in.	8.0
3	2½	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	8.0
2	3	$\frac{7}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	5.25
2½	2½	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$ full	6.5
2	1½	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	3.5
2	1½	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	2.875

TEE STEEL.

Weight in Pounds of a Lineal Foot.

Size and Thickness.	Weight per Foot.	Size and Thickness.	Weight per Foot.	Size and Thickness.	Weight per Foot.
1½" × 1½" × ¼"	2.35	2½" × 2½" × 1/16"	5.92	4" × 4" × 3/16"	9.77
1½" × 1½" × 1/16"	1.81	" " × 1/16"	5.01	5" × 3" × 1/16"	12.79
1½" × 1½" × 1/8"	3.40	" " × 1/8"	4.07	" " × 1/8"	9.78
" " × " " × 1/8"	2.79	3" × 2½" × 1/16"	8.52	5" × 4" × 1/16"	14.51
1½" × 2" × 1/16"	3.41	" " × " " × 1/16"	6.56	" " × " " × 1/16"	11.07
" " × " " × 1/8"	2.79	3" × 3" × 1/16"	9.38	6" × 3" × 1/16"	17.87
2" × 1½" × 1/16"	4.01	" " × " " × 1/8"	7.21	" " × " " × 1/8"	14.53
" " × " " × 1/8"	2.79	3½" × 3½" × 1/16"	11.08	" " × " " × 1/8"	11.08
2" × 2" × 1/16"	4.64	" " × " " × 1/8"	8.49	6" × 4" × 1/16"	19.99
" " × " " × 1/8"	3.22	4" × 3" × 1/16"	11.08	" " × " " × 1/8"	16.22
2½" × 2½" × 1/16"	5.28	" " × " " × 1/8"	8.49	" " × " " × 1/8"	12.36
" " × " " × 1/8"	3.64	4" × 4" × 1/16"	12.78		

WEIGHT OF CORRUGATED IRON ROOFING.

B. W. Gauge.	Size of Sheets.	Per Square.	Super. Feet per ton.
16 ..	6 feet × 2 feet to 8 feet	× 3 feet × 3½ cwt.	.. 800
18 ..	6 " × 2 " 8 "	× 3 " × 2½ "	.. 1000
20 ..	6 " × 2 " 8 "	× 3 " × 1¾ "	.. 1250
22 ..	6 " × 2 " 7 "	× 2½ " × 1½ "	.. 1550
24 ..	6 " × 2 " 7 "	× 2½ " × 1¼ "	.. 1880
26 ..	6 " × 2 " 7 "	× 2½ " × 1 "	.. 2170

WEIGHT IN POUNDS OF NUTS AND BOLT-HEADS.

Diameter of Bolt in Inches.	¼	⅜	½	¾	1	1¼	1½	1¾	2	2½	3		
Weight of Hexagon Nut and Head.	.017	.057	.128	.267	.430	.730	1.10	2.14	3.77	5.62	8.75	17.28	28.8
Weight of Square Nut and Head.	.021	.070	.164	.321	.553	.882	1.31	2.56	4.42	7.00	10.50	21.0	36.4

WHITWORTH SCREWS WITH ANGULAR THREADS.

Diameter in Inches.	Number of Threads per Inch.	Diameter in Inches.	Number of Threads per Inch.	Diameter in Inches.	Number of Threads per Inch.
1/8	40	3/8	6	3	3 1/2
1/8	24	1/2	6	3 1/4	3 1/4
1/4	20	5/8	5	3 3/8	3 1/4
1/4	18	3/4	5	3 1/2	3
3/8	16	7/8	4 1/2	4	3
3/8	14	1	4 1/2	4 1/4	2 3/4
1/2	12	1 1/8	4 1/2	4 3/8	2 3/4
1/2	11	1 1/4	4	4 1/2	2 3/4
5/8	10	1 3/8	4	5	2 3/4
5/8	9	1 1/2	4	5 1/4	2 3/8
3/4	8	1 3/4	4	5 1/2	2 3/8
1	7	2	3 1/2	5 3/4	2 1/2
1 1/8	7	2 1/8	3 1/2	6	2 1/2
1 1/4	7	2 1/4	3 1/2		2 3/8

Angle of threads 55° in every instance.

The threads do not intersect at their sides, but are rounded off $\frac{1}{8}$ both at top and bottom, making their depth equal to $\frac{2}{3}$ of the pitch.

The number of threads to the inch in square-threaded screws is generally half the number of those in angular-threaded screws, and the depth equal to the space between the threads.

WEIGHT OF CHAINS.

Diameter of Link in Inches.	Weight per Lineal Foot in lbs.	Diameter of Link in Inches.	Weight per Lineal Foot in lbs.	Diameter of Link in Inches.	Weight per Lineal Foot in lbs.
3/8	0'33	3/4	5'33	1 5/8	16'00
1/2	0'63	7/8	6'16	1 3/4	17'66
5/8	0'91	1	7'16	1 7/8	19'25
3/4	1'33	1 1/8	8'16	1 7/8	20'83
7/8	1'50	1	9'33	1 3/4	24'17
1	2'33	1 1/8	10'50	1 3/4	28'33
1 1/8	3'00	1 1/4	11'83	1 3/4	32'50
1 1/4	3'67	1 3/8	13'16	2	38'33
1 3/8	4'50	1 1/2	14'50		

To Find the Safe Load on Chains.

$$\frac{(\text{Diam. of link in eighths of an inch})^2}{8} = \text{safe load in tons.}$$

$$\sqrt{(8 \times \text{weight to be raised})} = \text{diam. of link in eighths of an inch.}$$

WEIGHT AND STRENGTH OF ROUND ROPES OF HEMP AND WIRE.

Hemp.			Iron Wire.			Steel Wire.		
Girth or Circumference in Inches.	Weight per Fathom of Six Feet in lbs.	Breaking Weight in Tons.	Girth or Circumference in Inches.	Weight per Fathom of Six Feet in lbs.	Breaking Weight in Tons.	Girth or Circumference in Inches.	Weight per Fathom of Six Feet in lbs.	Breaking Weight in Tons.
1	0'15	1	1	0'56	7	1	1	2
1 1/2	0'26	1 1/2	1 1/2	1	1 1/2	1 1/2	1 1/2	3
2	0'59	2	2	1 1/2	3 1/2	2	2	4
2 1/2	1'04	2 1/2	2 1/2	2	4	2 1/2	2 1/2	5
3	1'70	3	3	2 1/2	4 1/2	3	3	6
3 1/2	2'00	3 1/2	3 1/2	3	5 1/2	3 1/2	3 1/2	7
4	2'34	4	4	3 1/2	6	4	4	8
4 1/2	3'19	4 1/2	4 1/2	4	6 1/2	4 1/2	4 1/2	10
5	3'66	5	5	4 1/2	7 1/2	5	5	11
5 1/2	4'16	5 1/2	5 1/2	5	8 1/2	5 1/2	5 1/2	12
6	5'27	6	6	5 1/2	9 1/2	6	6	14
6 1/2	6'50	6 1/2	6 1/2	6	10 1/2	6 1/2	6 1/2	15
7	7'86	7	7	6 1/2	11 1/2	7	7	17
7 1/2	9'36	7 1/2	7 1/2	7	12 1/2	7 1/2	7 1/2	19
8	11'00	8	8	7 1/2	13 1/2	8	8	20
8 1/2	12'74	8 1/2	8 1/2	8	14 1/2	8 1/2	8 1/2	22
9	14'63	9	9	8 1/2	16	9	9	24
9 1/2	16'64	9 1/2	9 1/2	9	17	9 1/2	9 1/2	26
10	18'78	10	10	10	18 1/2	10	10	28
10 1/2	21'06	10 1/2	10 1/2	11	19 1/2	10 1/2	10 1/2	30
11	23'46	11	11	12	21	11	11	35
11 1/2	26'00	11 1/2	11 1/2	13	22 1/2	11 1/2	11 1/2	40
12	28'66	12	12	14	24	12	12	
	31'46	12 1/2	12 1/2	15	27			
	34'38	13	13	16	28 1/2			
	37'44	14	14	18	30 1/2			
		15	15	20	32			
		16	16	25	38			
			17	32	45 1/2			
			18	38	54			

To find the Breaking Weight of Round Ropes of Hemp, Iron Wire, and Steel Wire.

Hemp $\frac{(\text{circum. in.})^2}{5} = \text{breaking weight in tons.}$

Iron wire $(\text{circum. in.})^2 \times 1.5 = \text{breaking weight in tons.}$

Steel wire $(\text{circum. in.})^2 \times 2.5 = \text{breaking weight in tons.}$

Factor of safety for hemp, iron, and steel ropes = $\frac{1}{6}$.

To find the Weight of Hemp Ropes.

(Circum. in.)² × 26 = weight in lbs. per fathom.

ALLOYS OF METALS.

Yellow brass, 2 parts copper, 1 zinc.

Rolled brass, 32 parts copper, 10 zinc, 1.5 tin.

Brass casting, common, 25 parts copper, 2 zinc, 4.5 tin.

Gun metal, 8 parts copper, 1 tin.

Copper flanges for pipes, 9 parts copper, 1 zinc, 0.26 tin.

Bell metal, 3 parts copper, 1 tin.

IRON TO RESIST THE ACTION OF FIRE.

The following mixture of iron is recommended for fire bars, furnace plates, gas retorts (iron), and any other ironwork required to resist the action of fire :—

80 per cent. Ridsdale.

20 per cent. Siemens steel scrap.

This is said to make a kind of pyrostatic iron, the high fusion point being due to the small percentage of carbon present in the mixture.

TABLE
Of the Velocity and Force of the Wind.

Miles per Hour.	Feet per Second.	Pressure in lbs. per Square Foot.	Description.
1	1.47	0.005	Hardly perceptible.
2	2.93	0.020	Just perceptible.
3	4.4	0.044	
4	5.87	0.079	Gentle breeze.
5	7.33	0.123	
10	14.67	0.492	Pleasant breeze.
15	22.0	1.107	
20	29.34	1.968	Brisk gale.
25	35.67	3.076	
30	44.01	4.429	High wind.
35	51.34	6.027	
40	58.68	7.873	Very high wind.
45	66.01	9.996	
50	73.35	12.300	Storm or tempest.
60	88.02	17.718	
70	102.71	24.153	Great storm.
80	117.36	31.490	
100	146.7	49.200	Hurricane.

The pressure or force of the wind is as the square of its velocity.

The square of the velocity of the wind in feet per second \times 0.002288 = pressure in lbs. per square foot.

The wind pressure upon a cylindrical surface is one-half, and on a spherical surface one-fourth that which is exerted on a flat surface.

SPECIFIC GRAVITY AND WEIGHT OF VARIOUS SUBSTANCES.

Name of Substance.	Specific Gravity and Weight per Cb. Ft. in Ounces.	Weight per Cub. Ft. in lbs. Avoirdupois.	Name of Substance.	Specific Gravity and Weight per Cb. Ft. in Ounces.	Weight per Cub. Ft. in lbs. Avoirdupois.
Alcohol, pure	790	49'38	Gold, pure	19,360	1,210
Ash (timber)	752	47	" standard	17,728	1,108
Asphalt, prepared	2,496	156	Granite	2,688	168
Basalt	2,992	187	Gravel	1,840	115
Bath stone	1,792	112	Grindstone	2,096	131
Beech	688	43	Gun metal	8,784	549
Birch	704	44	Gypsum	2,304	144
Bitumen	992	62	Ice	908	56'75
Boxwood	960	60	Iron, cast	7,168	448
Brass, cast	8,240	515	" wrought	7,680	480
" wire	8,180	530	Lead	11,392	712
Brick	2,080	130	" white	3,168	198
Brickwork	1,792	112	Limestone, lias	2,496	156
Cement, Portland	3,000	187'5	" magnesian	2,848	178
" Roman	960	60	Lime, quick	864	54
Chalk	2,368	148	Mahogany, Honduras	640	40
Charcoal, oak	336	21	" Spanish	720	45
Clay	1,920	120	Maple	784	49
Clay puddle	2,560	160	Marble	2,720	170
Coal, anthracite, solid	1,280	80	Marl	1,728	108
" bituminous	1,200	75	Masonry	2,240	140
" cannel, Scotch	1,248	78	Mercury	13,584	849
" " Wigan	1,280	80	Mortar	1,760	110
" " N'castle	1,312	82	Mud	1,600	100
" stored in usual way	832	52	Naphtha	848	53
Coke from coking ovens	800	50	Oak, English	800	50
" from gas-works slaked	515	32'2	" American, red	864	54
" from gas-works unslaked	448	28	Oil, linseed	944	59
Concrete	1,920	120	" olive	912	57
Copper, cast	8,640	540	" whale (train)	928	58
" sheet and wire	8,800	550	" sperm	880	55
Cork	240	15	" tallow	896	56
Earth, loam	1,600	100	" colza	912	57
Ebony	1,200	75	Paving	2,560	160
Elm	560	35	Peat	1,280	80
Fir, red pine and spruce	560	35	Pebble stone	2,704	169
" American	464	29	Petroleum	880	55
" larch	544	34	Pitch	1,152	72
Fire-clay, natural	2,400	150	Platinum, pure	19,520	1,220
" burned in blocks	2,080	130	" hammered	20,480	1,280
Flag, Yorkshire	2,288	143	" wire	20,800	1,300
Flint	2,624	164	Portland stone	2,096	131
Freestone	2,240	140	Quartz	2,640	165
Glass, crown	2,496	156	Sand, damp	1,888	118
" plate	2,880	180	" dry	1,440	90
" flint	2,992	187	Sandstone	2,528	158
			Shale	2,592	162
			Shingle	1,520	95
			Silver, pure	10,480	655
			" standard	10,528	658

SPECIFIC GRAVITY AND WEIGHT OF VARIOUS SUBSTANCES—*Continued.*

Name of Substance.	Sp. Gr. and Weight per Cb. Ft. in Ounces.	Weight per Cub. Foot in lbs. Avoirdupois.	Name of Substance.	Sp. Gr. and Weight per Cb. Ft. in Ounces.	Weight per Cub. Foot in lbs. Avoirdupois.
Slate	2,880	180	Trap	2,720	170
Snow	128	8	Water, pure	1,000	62·5
Steel	7,840	490	„ sea	1,024·8	64·05
Sulphur	2,000	125	Whinstone	2,752	172
Sycamore	592	37	Willow	448	28
Tar	1,040	65	Yew	800	50
Tile	1,792	112	Yorkshire flag	2,288	143
Tin	7,360	460	Zinc	7,040	440
	Mean of the whole earth			5,664	354

MISCELLANEOUS ARTICLES.

Bale of flax (Russia)	5 to 6 cwt.
Barrel bulk	5 cub. ft.
Barrel of tar	26 $\frac{1}{4}$ gals.
Battens	Boards 7 in. wide.
Bushel of coal	80 lbs.
Bushel of coke	45 „
Cable's length	240 yds.
Cask of black lead	11 $\frac{1}{2}$ cwt.
Chaldron of coal	25 $\frac{1}{2}$ „
„ coke	12 $\frac{1}{2}$ to 15 cwt.
Cord of wood	128 cub. ft.
Deals	Boards 9 in. wide.
Dozen	12 articles.
Faggot of steel	120 lbs.
Fodder of lead	19 $\frac{1}{2}$ cwt.
Gross	12 doz.
Hundred of deals	120 in number.
„ nails	120 „

Keel of coals	21 tons 4 cwt.
Load of bricks	500 bricks.
„ inch boards	600 sq. ft.
„ 2-inch planks	300 „
„ lime	32 bushels.
„ new hay	19 cwt. 32 lbs.
„ old hay	18 „
„ straw	11 „ 64 „
„ sand	36 bushels
„ squared timber	50 cub. ft.
„ unhewn „	40 „
„ tiles	1000 tiles.
Mat of flax (Dutch)	126 lbs.
Pig of ballast	56 „
Planks	Boards 12 in. wide.
Quire of paper	24 sheets.
Ream of paper	20 quires (480 sheets).
Roll of parchment	60 skins.
Sack of coals	224 lbs.
Score	20 articles.

Sheet of paper folded into—

2 leaves is termed	folio size.
4 „ „	4to, or quarto.
8 „ „	8vo, or octavo.
12 „ „	12mo, or duodecimo.
16 „ „	16mo.
18 „ „	18mo.
24 „ „	24mo.
48 „ „	48mo.
Square of planking	100 superficial ft.
Thousand of nails	1200 nails.
Ton shipping	40 cub. ft.
Truss of old hay	56 lbs.
„ new hay	60 „
„ straw.	36 „

OFFICE MEMORANDA.

Books Required in the Keeping of a Gas Company's Accounts.

1. Ledger (general).
2. Cash Book (general).
3. Gas Register, or Ledger, sometimes called "The Consumers' Ledger."
4. Mill Register, or Ledger.

This book is devoted to the accounts of all the largest consumers, such as mill-owners and the proprietors of other large establishments of any kind where the consumption of gas is heavy. They are handier classed together by themselves than mixed up with smaller consumers.

5. Removals Book.

In this book is kept an account of all changes of residence that have taken place amongst consumers during each quarter, the substitution of meters, and the consumption of gas by temporary consumers, etc. It is a most useful record, and prevents confusion by interlineations in the regular register.

6. Quarterly Summary.

The several pages in the three foregoing books are added up and then brought together here, quarterly, in order to ascertain the total consumption, amount due, etc. By means of this book it is easy to compare the totals of the different quarters during a number of years.

7. Journal.

Containing entries of all goods sold from the works, with the exception of gas. Separate columns should be arranged for "Fittings, etc.," "Residual Products," "Miscellaneous," and "Total." At the end of each quarter the separate amounts of all accounts remaining unpaid are transferred to the

8. Arrears Fittings, etc., Book,

Which is entered up at the end of every quarter, and

shows the amount remaining due (arrears included) for Fittings, Residual Products, and Miscellaneous.

9. Daily Receipt (Cash) Book.

In which is entered the amount of each separate payment made to the company on account of "Gas," "Meter Rents," "Fittings, etc.," "Residual Products," and other miscellaneous items.

10. Stock-Taking Books.

For taking the quarterly stock of gas consumed through each meter. Two or more are always required, according to the number of consumers. The one used (we will suppose) on Monday is left at the office that night to be entered up into the Register by the clerk on the day following; and so on alternately.

11. Black Book.

In which a record of all bad debts is kept.

12. Collector's Book.

In some cases checks only are used with counterfoil.

13. Receiving Book.

In which all delivery notes for goods received by the company are copied daily. The regular invoice, when received, is checked by this book.

14. Wages and Time Book.

Containing, in separate columns, a daily account of the number of hours worked by each man, the kind of work, and the place where employed, with the amount due as wages at the end of each week.

15. Stores Book, A.

16. Stores Book, B.

In the one is kept a record of goods *sold* out of stock, and in the other of goods *used* out of stock for *repairs and extension of plant*. The one may be said to relate to *revenue*, the other chiefly to *capital*.

17. Stores Ledger.

Into which the entries in the previous two books are

posted to the *credit* of the several accounts (such as "Meters," "Lead Pipe," "Wrought-Iron Fittings," etc.), and the items from the several invoices are posted to the *debit* of the several accounts. At the end of each half year the balance of each account represents the stock on hand. This latter is proved to be correct or otherwise by the actual stock-taking.

18. Carbonizing Book—Daily and Weekly Statements.

Containing a record of the state of the station meter taken twice in the twenty-four hours (in large works the state of the meter is recorded every hour); the quantity of coal and cannel used daily, the production of gas per ton, and the total daily production; the number of benches at work, stokers, etc. Each page serves for a week, and is then added up; an additional line is left at the foot of the page, on which is entered, for comparison, the particulars of the total of the corresponding week of the previous year.

19. Public Lamp Register.

Gives particulars of the number of lamps lighted each night; the hours of lighting and extinguishing; the hours burning per lamp, the total hours burning; a column into which the number of hours, weekly, can be added, and another for remarks.

20. Test Register.

For noting the results of the different tests of the illuminating power and purity of the gas.

21. Shareholders' Register and Address Book.

22. Seal Register and Dividend List.

23. Register of Calls.

24. Register of Transfers.

25. Transfer Certificate Book.

Containing certificates of the registration of shares, to be torn out, leaving counterfoil behind.

26. Invoice Book.

With blank leaves, into which are gummed all invoices for goods received.

27. Minute Book.

A lettered index at the beginning of this book is handy.

A few other account books of a less important character may be useful, but the above are indispensable.

Discount for Early Payment of Gas Bills.

The custom of allowing discount to consumers on gas bills paid either during the first month after the expiration of a quarter or within a period of twenty-one or thirty days from the date of the delivery of the account, is very general amongst gas companies.

The most common allowance is at the rate of 10 per cent. on the amount due for gas consumed (excluding the meter rent), but the premium varies throughout the country from 5 to 20 per cent.; some companies adopting a graduated scale of discounts according to the quarterly consumption.

The practice has been found highly beneficial, saving labour in collecting, and reducing the percentage of bad debts.

FORMS.*Renouncement of Proposed New Issue on the Transfer of Old Shares.*

I, John Thompson, of Tipping Street, Newcastle, hereby renounce my right to any of the new Shares about to be issued by the ——— Gas Company, in favour of William Jones, of Broad Street, Manchester.

(Signed) JOHN THOMPSON.

To the Secretary
of the ——— Gas Company.

Jan. 1, 19—

Renunciation of Shares Newly Allotted.

I, John Wilson, of Birmingham, being the holder [or proprietor] of ——— Shares in the ——— Gas Company, do hereby renounce the same to and in favour of William Jackson, of Bristol.

And I, the said William Jackson, hereby agree to accept and take the said Shares, subject to the conditions on which they are allotted. Dated this — day of —, One thousand nine hundred and —.

Signed by the said
John Wilson in the
presence of }

JOHN WILSON.

(Here Witness signs.)

Signed by the said
William Jackson
in the presence of }

WILLIAM JACKSON.

(Here Witness signs.)

Declaration for Loss of Sealed Share Certificates.

I, —, of —, do hereby solemnly and sincerely declare that I am possessed of and entitled to — in the — Company, —, and that the said — are *bona fide* my property, and that they are not pledged or assigned to any person or persons whomsoever for money advanced thereon, or for any consideration whatever. And I further declare that I have made diligent search for the —, and can nowhere find the same. And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of an Act made and passed in the fifth and sixth years of the reign of His late Majesty King William the Fourth, intituled "An act to repeal an Act of the present Session of Parliament, intituled 'An Act for the more effectual abolition of Oaths and Affirmations taken and made in various departments of the state, and to substitute declarations in lieu thereof,' and for the more entire suppression of voluntary and extra judicial Oaths and Affidavits, and to make other provisions for the abolition of unnecessary Oaths."

Declared at —, this — day of —, One thousand nine hundred and —, before me.

[The above Declaration is to be made before a Commissioner to administer Oaths in Chancery in England. Any person making a false Declaration is declared guilty of a misdemeanour.]

Indemnity for Loss of Share Certificates or Dividend Warrant.

———— Company.

Whereas ———, in the Company called the ———, numbered ———, being the property of ———, the undersigned, h— by accident been lost or destroyed, and the said Company have consented to give ———, on being indemnified for so doing. Now, in consideration of the said Company so granting to me, the said ———, a ———, we the undersigned ——— and ——— do hereby severally and respectively undertake and agree to save harmless and keep indemnified the Directors for the time being of the said Company of and from all losses, damages, and expenses which they, any or either of them, may sustain, incur, or be put unto, for or in consequence of their so granting such new ———; and also from and against all claim or claims to be at any time hereafter made upon the said Company for or in respect of the original ——— by any person or persons whomsoever.

Dated this ——— day of ———, One thousand nine hundred and ———.

Authority to Pay Dividends.

———— Company,

—————19—.

Payment of Dividends.

I, the undersigned, ———, of ———, being a shareholder of and in the undertaking called the ——— Company, do hereby request that all Dividends and Interest due to me on the Stock or Shares now registered, or that may hereafter be registered in my name may be paid to ———, of ———, until further notice, whose receipt shall be a sufficient discharge to the Company for the payment of the same.

Signature _____

Date _____

Certificate Showing that Income-Tax has been Deducted.

This is to certify that on paying to John Brown the sum of £45, being the amount of one year's Dividend [or one half year's

Dividend, as the case may be] on Shares [or Stock] to December 31st, 19—, I deducted for Income-Tax the sum of 18s. 9d.

Pro the A ——— B ——— Gas Company,

WILLIAM JONES,
Secretary.

Form of Proxy.

A. B., one of the proprietors of "The ——— Company," doth hereby appoint C. D., of ———, to be the proxy of the said A. B., in his absence to vote in his name upon any matter relating to the undertaking proposed at the meeting of the proprietors of the said Company, to be held on the ——— day of ——— next, in such manner as he the said C. D. doth think proper. In witness whereof the said A. B. hath hereunto set his hand [or, if a corporation, say, the common seal of the corporation], the ——— day of ———, One thousand nine hundred and ———.

TERMS FOR LEASES, ETC.

England and Ireland.

Lady Day . . . March 25th.
Midsummer . . . June 24th.
Michaelmas . . . Sept. 29th.
Christmas . . . Dec. 25th.

Scotland.

Candlemas . . . Feb. 2nd.
Whitsunday . . . May 15th.
Lammas . . . August 1st.
Martinmas . . . Nov. 11th.

When a Scottish term falls on Sunday, the Monday following is considered term day.

LAW TERMS.

England and Ireland.

Hilary or Lent . . . Begins, Jan. 11th . . . Ends, Jan. 31st.
Easter " April 15th . . . " May 8th.
Trinity " May 22nd . . . " June 12th.
Michaelmas " Nov. 2nd . . . " Nov. 25th.

Scotland.

Candlemas . . . Begins, Jan. 15th . . . Ends, Feb. 3rd.
Whitsunday " May 12th . . . " June 2nd.
Lammas " June 17th . . . " July 5th.
Martinmas " Nov. 24th . . . " Dec. 20th.

SIZES OF DRAWING PAPER.

	Ft. In.	Ft. In.		Ft. In.	Ft. In.
Antiquarian	4	4 × 2	7	Double Crown	3 6 × 1 8
„ extra	4	8 × 3	4	Imperial	2 6 × 1 10
Double Elephant	3	4 × 2	3	Super Royal	2 3 × 1 7
Atlas	2	10 × 2	2	Royal	2 0 × 1 7
Columbia	2	10 × 1	11	Medium	1 10 × 1 5
Elephant	2	3 $\frac{3}{4}$ × 1	10 $\frac{1}{4}$	Demy	1 8 × 1 3

TABLE OF COLOURS.

Used in Mechanical and Architectural Drawing.

Work.	Colour.
Brickwork in plan or section	Carmine or crimson lake.
Brickwork in elevation	Venetian red or crimson lake mixed with burnt sienna.
Brickwork to be removed by alterations	Burnt umber.
Concrete work	Sepia with darker markings.
Clay	Burnt umber.
Earth	Burnt umber.
Flintwork	Prussian blue.
Granite	Purple madder or pale Indian ink.
Stone generally	Yellow ochre or pale sepia.
Slate	Indigo and lake or Prussian blue.
English timber (oak excepted)	Raw sienna.
Oak	Burnt sienna or Vandyke brown.
Fir and other light timber	Indian yellow or raw sienna.
Mahogany	Indian red.
Cast-iron	Payne's grey or neutral tint.
Wrought-iron	Prussian blue.
Steel, bright	Indigo with a little lake.
Brass	Gamboge or Roman ochre.
Gun metal	Dark cadmium.
Lead	Pale Indian ink, tinged with indigo.
Meadow land	Hooker's green.
Sky effects	Cobalt blue.

The presence of any slight greasiness, preventing the laying on of the colours evenly, may be counteracted in its effects by dissolving a little prepared ox-gall in the water with which the

colours are mixed. The brush should always be used in mixing colours, the latter being rubbed in separate divisions of the slab.

EPITOME OF MENSURATION

Of the Circle, Cylinder, and Sphere.

The areas of circles are to each other as the squares of their diameters.

The diameter of a circle being 1, its circumference equals 3·1416.

The diameter of a circle multiplied by 3·1416 equals its circumference.

The diameter of a circle is equal to 0·31831 of its circumference.

The square of the diameter of a circle being 1, its area equals 0·7854.

The diameter of a circle squared and multiplied by 0·7854 equals its area.

The internal circumference of a cylinder multiplied by its length or height equals its concave surface.

The area of the end of a cylinder multiplied by its length equals its solid contents.

The area of the internal diameter of a cylinder multiplied by its depth equals its cubical capacity.

The square of the diameter of a sphere multiplied by 3·1416 equals its convex surface.

The cube of the diameter of a sphere multiplied by 0·5236 equals its solid contents.

The capacity of a cylinder 1 ft. in diameter and 1 ft. in length equals 4·895 imperial gallons.

The capacity of a cylinder 1 in. in diameter and 1 ft. in length equals 0·034 of an imperial gallon.

The capacity of a cylinder 1 in. in diameter and 1 in. in length equals 0·002832 of an imperial gallon. Hence—

The capacity of any other cylinder in imperial gallons is obtained by multiplying the square of its diameter by its length, and by the number of imperial gallons contained in the unity of its measurement.

The capacity of a sphere 1 ft. in diameter equals 3·263 imperial gallons.

The capacity of a sphere 1 in. in diameter equals 0·001888 of an imperial gallon. Hence—

The capacity of any other sphere in imperial gallons is obtained by multiplying the cube of its diameter by the number of imperial gallons contained in the unity of its measurement.

Of the Square, Rectangle, and Cube.

The side of a square equals the square root of its area.

The area of a square equals the square of one of its sides.

The diagonal of a square equals the square root of twice the square of its side.

The side of a square is equal to the square root of half the square of its diagonal.

A square, the side of which is equal to the diagonal of a given square, contains double the area of the given square.

The area of a rectangle equals its length multiplied by its breadth.

The length of a rectangle equals the area divided by the breadth, or the breadth equals the area divided by the length.

The side or end of a rectangle equals the square root of the sum of the diagonal and opposite side to that required, multiplied by their difference.

The diagonal in a rectangle equals the square root of the sum of the squares of the base and perpendicular.

The solidity of a cube equals the area of one of its sides multiplied by the length or breadth of one of its sides.

The length or breadth of a side of a cube equals the cube root of its solidity.

The capacity of a 12-in. cube equals 6·232 imperial gallons.

Of Triangles and Polygons.

The sum of the squares of the two given sides of a right-angled triangle is equal to the square of the hypotenuse.

The difference between the squares of the hypotenuse and given side of a right-angled triangle is equal to the square of the required side.

The area of a triangle equals half the product of the base multiplied by the perpendicular height.

The side of any regular polygon multiplied by its apothegm,

or perpendicular, and by the number of its sides, equals twice the area.

Of Ellipses, Cones, and Frustums.

The square root of half the sum of the squares of the two diameters of an ellipse, multiplied by 3·1416, equals its circumference.

The product of the two axes of an ellipse, multiplied by 0·7854, equals its area.

The solidity of a cone equals one-third of the product of its base multiplied by its altitude or height.

The squares of the diameters of the two ends of the frustum of a cone added to the product of the two diameters, and that sum multiplied by its height and by 0·2618, equal its solidity.

Table of Common Fractional Parts and Equivalent Decimals.

Common Fractional Parts.	Decimals.	Common Fractional Parts.	Decimals.	Common Fractional Parts.	Decimals.
1-100th	·01	9-14ths	·6428	7-10ths	·7
1-90th	·0111	11-14ths	·7857	9-10ths	·9
1-80th	·0125	13-14ths	·9285	1-9th	·1111
1-70th	·0143	1-13th	·077	2-9ths	·2222
1-60th	·0166	2-13ths	·1538	4-9ths	·4444
1-50th	·02	3-13ths	·2307	5-9ths	·5555
1-40th	·025	4-13ths	·3076	7-9ths	·7777
1-30th	·0333	5-13ths	·3846	8-9ths	·8888
1-20th	·05	6-13ths	·4615	1-8th	·125
1-19th	·0526	7-13ths	·5384	3-8ths	·375
1-18th	·0555	8-13ths	·6153	5-8ths	·625
1-17th	·0588	9-13ths	·6923	7-8ths	·875
1-16th	·0625	10-13ths	·7692	1-7th	·143
3-16ths	·1875	11-13ths	·8461	2-7ths	·2857
5-16ths	·3125	12-13ths	·923	3-7ths	·4285
7-16ths	·4375	1-12th	·0833	4-7ths	·5714
9-16ths	·5625	5-12ths	·4166	5-7ths	·7142
11-16ths	·9875	7-12ths	·5833	6-7ths	·8571
13-16ths	·8125	11-12ths	·9166	1-6th	·1666
15-16ths	·9375	1-11th	·0909	5-6ths	·833
1-15th	·0666	2-11ths	·1818	1-5th	·2
2-15ths	·1333	3-11ths	·2727	2-5ths	·4
4-15ths	·2666	4-11ths	·3636	3-5ths	·6
7-15ths	·4666	5-11ths	·4545	4-5ths	·8
8-15ths	·5333	6-11ths	·5454	1-4th	·25
11-15ths	·7333	7-11ths	·6363	3-4ths	·75
13-15ths	·8666	8-11ths	·7272	1-3rd	·3333
14-15ths	·9333	9-11ths	·8181	2-3rds	·6666
1-14th	·0714	10-11ths	·909	1-half	·5
3-14ths	·2142	1-10th	·1	1	1
4-14ths	·2857	3-10ths	·3		

ARITHMETICAL AND ALGEBRAICAL SIGNS.

=	The sign of Equality, and signifies <i>equal to</i> , as 2 added to 3 = 5.
+	„ Addition „ <i>plus</i> or <i>more</i> , as 4 + 6 = 10.
-	„ Subtraction „ <i>minus</i> or <i>less</i> , as 6 - 4 = 2.
×	„ Multiplication „ <i>multiplied by</i> , as 5 × 3 = 15.
÷	„ Division „ <i>divided by</i> , as 8 ÷ 4 = 2.

$$\text{or } \frac{8}{4} = 2.$$

: :: : „ Proportion, : signifies *is to*, or *to*, :: signifies *so is*.
Thus, 2 : 3 :: 4 : 6 signifies that as 2 is to 3 so is 4 to 6.

Evolution, or the Extraction of Roots.

√	The sign of the Square Root (termed the Radical sign), as √16 = 4, <i>i.e.</i> the square root of 16 is equal to 4.
∛	„ Cube Root, as ∛64 = 4, <i>i.e.</i> the cube root of 64 is equal to 4.
∜	„ Bi-quadrate, or Fourth Root, ∜16 = 2.

Involution, or the Raising of Powers.

4² signifies to be squared, as 4² = 16. The small figure is termed the Index or Exponent.

4³ „ to be cubed, as 4³ = 64.

—A vinculum placed over two or more figures, thus 3 + 5, signifies that they are to be taken as one quantity.
Thus :

$\overline{3 + 5} \times 4 = 32$, signifies that 3 plus 5 multiplied by 4 = 32, and
 $\sqrt{5^2 - 3^2} = 4$, signifies that 5 squared, minus 3 squared, and the square root of the remainder = 4, and

$\sqrt[3]{\frac{20 \times 12}{30}} = 2$, signifies that 20 multiplied by 12, divided by 30, and the cube root of the quotient = 2, and

$\frac{24 \times 6 + 12 \times 3 \times 4}{12} = 60$, signifies that 24 multiplied by 6, and 12 multiplied by 3, added together, multiplied by 4 and divided by 12, the quotient = 60.

[] () Brackets ; *e.g.* 12 - [3 + (4 × 2)] = 1, signify that the product of 4 multiplied by 2, added to 3, and the total subtracted from 12, leaves 1.

∴ is used to signify the word *therefore*.

∵ is used to signify the word *because* or *since*.

? is used in the Chain Rule to signify *how many*.

APPROXIMATE MULTIPLIERS FOR FACILITATING CALCULATIONS.

Square inches $\times 0\cdot007 =$ square feet.

Square feet $\times 0\cdot111 =$ square yards.

Square yards $\times 0\cdot0002067 =$ statute acres.

Square yards $\times 0\cdot000000323 =$ square miles.

Statute acres $\times 0\cdot0015625 =$ square miles.

Square links $\times 0\cdot4356 =$ square feet.

Square feet $\times 2\cdot3 =$ square links.

Square feet $\times 183\cdot346 =$ circular inches.

Circular inches $\times 0\cdot00456 =$ square feet.

Links $\times 0\cdot22 =$ yards.

Links $\times 0\cdot66 =$ feet.

Feet $\times 1\cdot5 =$ links.

Cubic inches $\times 0\cdot00058 =$ cubic feet.

Cubic inches $\times 0\cdot01638 =$ litres.

Cubic feet $\times 0\cdot037 =$ cubic yards.

Cubic feet $\times 2200 =$ cylindrical inches.

Cylindrical inches $\times 0\cdot0004546 =$ cubic yards.

Cylindrical feet $\times 0\cdot02909 =$ cubic yards.

Cubic feet $\times 6\cdot232 =$ imperial gallons.

Imperial gallons $\times 0\cdot1604 =$ cubic feet.

Cubic inches $\times 0\cdot003607 =$ imperial gallons.

Imperial gallons $\times 277\cdot3 =$ cubic inches.

Imperial gallons $\times 4\cdot541 =$ litres.

Cubic feet $\times 0\cdot779 =$ bushels.

Cubic inches $\times 0\cdot00045 =$ bushels.

Bushels $\times 0\cdot0476 =$ cubic yards.

Bushels $\times 1\cdot284 =$ cubic feet.

Bushels $\times 2218\cdot2 =$ cubic inches.

Lineal feet $\times 0\cdot00019 =$ statute miles.

Lineal yards $\times 0\cdot0006 =$ statute miles.

Statute miles $\times 0\cdot869 =$ mean geographical miles.

Mean geographical miles $\times 1\cdot151 =$ statute miles.

Pounds avoirdupois $\times 7000 =$ grains.

- Pounds avoirdupois $\times 0.82286 =$ pounds troy.
 Pounds troy $\times 1.2153 =$ pounds avoirdupois.
 Grains $\times 0.0001429 =$ pounds avoirdupois.
 Pounds avoirdupois $\times 0.009 =$ cwts.
 Pounds avoirdupois $\times 0.00045 =$ tons.
 Pounds on square inch $\times 1.44 =$ pounds on square foot.
 Pounds on square foot $\times 0.007 =$ pounds on square inch.
 Miles per hour $\times 1.467 =$ feet per second.
 Feet per second $\times 0.682 =$ miles per hour.
 Diameter of circle $\times 3.1416 =$ circumference.
 Circumference of circle $\times 0.31831 =$ diameter.
 Diameter of circle $\times 0.8862 =$ side of equal square.
 Circumference of circle $\times 0.2821 =$ side of equal square.
 Diameter of circle $\times 0.7071 =$ side of inscribed square.
 Circumference of circle $\times 0.2251 =$ side of inscribed square.
 Area of circle $\times 0.6366 =$ side of inscribed square.
 Side of square $\times 1.128 =$ diameter of equal circle.
 Side of square $\times 3.545 =$ circumference of equal circle.
 Side of square $\times 1.414 =$ diameter of circumscribing circle.
 Side of square $\times 4.443 =$ circumference of circumscribing circle.
 Square of diameter $\times 0.7854 =$ area of circle.
 Square root of area $\times 1.12837 =$ diameter of equal circle.
 Square of diameter of sphere $\times 3.1416 =$ convex surface.
 Cube of diameter of sphere $\times 0.5236 =$ solidity.
 Diameter of sphere $\times 0.806 =$ dimensions of equal cube.
 Diameter of sphere $\times 0.6667 =$ length of equal cylinder.
 One atmosphere = 14.7 pounds on square inch.
 „ = 2116 pounds on square foot.
 „ = 29.922 inches of mercury.
 „ = 33.9 feet of water.
 Each 1000 cubic feet of coal gas in a holder $\times 37 =$ (approximate)
 weight of gas in pounds.
 The atomic weight of an *elementary* gas $\times 0.0691 =$ its specific
 gravity.¹
 Half the molecular weight of a *compound* gas or vapour
 $\times 0.0691 =$ its specific gravity.

¹ Exceptions to this rule occur in the case of the vapours of phosphorus and arsenic, whose atomic weights must be doubled, and in those of mercury, zinc, and cadmium, the atomic weights of which must be halved.

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND SIDES OF EQUAL SQUARES.

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
$\frac{1}{2}$	·7854	·0490	·2215	18 $\frac{1}{2}$	43·197	148·489	12·185
$\frac{3}{4}$	1·5708	·1963	·4431	14	43·982	153·938	12·406
$\frac{1}{1}$	2·3562	·4417	·6646	14 $\frac{1}{2}$	44·767	159·485	12·628
1	3·1416	·7854	·8862	14 $\frac{3}{4}$	45·553	165·130	12·850
1 $\frac{1}{4}$	3·9270	1·2271	1·1077	14 $\frac{1}{2}$	46·338	170·873	13·071
1 $\frac{1}{2}$	4·7124	1·7671	1·3293	15	47·124	176·715	13·293
1 $\frac{3}{4}$	5·4978	2·4052	1·5508	15 $\frac{1}{4}$	47·909	182·654	13·514
2	6·2832	3·1416	1·7724	15 $\frac{1}{2}$	48·694	188·692	13·736
2 $\frac{1}{4}$	7·0686	3·9760	1·9939	15 $\frac{3}{4}$	49·480	194·828	13·957
2 $\frac{1}{2}$	7·8540	4·9087	2·2155	16	50·265	201·062	14·174
2 $\frac{3}{4}$	8·6394	5·9395	2·4370	16 $\frac{1}{4}$	51·051	207·394	14·400
3	9·4248	7·0686	2·6586	16 $\frac{1}{2}$	51·836	213·825	14·622
3 $\frac{1}{4}$	10·210	8·2957	2·8801	16 $\frac{3}{4}$	52·621	220·353	14·843
3 $\frac{1}{2}$	10·995	9·6211	3·1017	17	53·407	226·980	15·065
3 $\frac{3}{4}$	11·781	11·044	3·3232	17 $\frac{1}{4}$	54·192	233·705	15·286
4	12·566	12·566	3·5448	17 $\frac{1}{2}$	54·978	240·528	15·508
4 $\frac{1}{4}$	13·351	14·186	3·7663	17 $\frac{3}{4}$	55·763	247·450	15·730
4 $\frac{1}{2}$	14·137	15·904	3·9880	18	56·548	254·469	15·951
4 $\frac{3}{4}$	14·922	17·720	4·2095	18 $\frac{1}{4}$	57·334	261·587	16·173
5	15·708	19·635	4·4310	18 $\frac{1}{2}$	58·119	268·808	16·394
5 $\frac{1}{4}$	16·493	21·647	4·6525	18 $\frac{3}{4}$	58·905	276·117	16·616
5 $\frac{1}{2}$	17·278	23·758	4·8741	19	59·690	283·529	16·837
5 $\frac{3}{4}$	18·064	25·967	5·0956	19 $\frac{1}{4}$	60·475	291·039	17·060
6	18·849	28·274	5·3172	19 $\frac{1}{2}$	61·261	298·648	17·280
6 $\frac{1}{4}$	19·635	30·679	5·5388	19 $\frac{3}{4}$	62·046	306·355	17·502
6 $\frac{1}{2}$	20·420	33·183	5·7603	20	62·832	314·160	17·724
6 $\frac{3}{4}$	21·205	35·784	5·9819	20 $\frac{1}{4}$	63·617	322·063	17·945
7	21·991	38·484	6·2034	20 $\frac{1}{2}$	64·402	330·064	18·167
7 $\frac{1}{4}$	22·776	41·282	6·4250	20 $\frac{3}{4}$	65·188	338·163	18·388
7 $\frac{1}{2}$	23·562	44·178	6·6465	21	65·973	346·361	18·610
7 $\frac{3}{4}$	24·347	47·173	6·8681	21 $\frac{1}{4}$	66·759	354·657	18·831
8	25·132	50·265	7·0897	21 $\frac{1}{2}$	67·544	363·051	19·053
8 $\frac{1}{4}$	25·918	53·456	7·3112	21 $\frac{3}{4}$	68·329	371·543	19·274
8 $\frac{1}{2}$	26·703	56·745	7·5328	22	69·115	380·133	19·496
8 $\frac{3}{4}$	27·489	60·132	7·7544	22 $\frac{1}{4}$	69·900	388·822	19·718
9	28·274	63·617	7·9760	22 $\frac{1}{2}$	70·686	397·608	19·939
9 $\frac{1}{4}$	29·059	67·200	8·1974	22 $\frac{3}{4}$	71·471	406·493	20·161
9 $\frac{1}{2}$	29·845	70·882	8·4190	23	72·256	415·476	20·382
9 $\frac{3}{4}$	30·630	74·662	8·6405	23 $\frac{1}{4}$	73·042	424·557	20·604
10	31·416	78·540	8·8620	23 $\frac{1}{2}$	73·827	433·731	20·825
10 $\frac{1}{4}$	32·201	82·516	9·0836	23 $\frac{3}{4}$	74·613	443·014	21·047
10 $\frac{1}{2}$	32·986	86·590	9·3051	24	75·398	452·390	21·268
10 $\frac{3}{4}$	33·772	90·762	9·5267	24 $\frac{1}{4}$	76·183	461·864	21·490
11	34·557	95·033	9·7482	24 $\frac{1}{2}$	76·969	471·436	21·712
11 $\frac{1}{4}$	35·343	99·402	9·9698	24 $\frac{3}{4}$	77·754	481·106	21·933
11 $\frac{1}{2}$	36·128	103·869	10·191	25	78·540	490·875	22·155
11 $\frac{3}{4}$	36·913	108·434	10·413	25 $\frac{1}{4}$	79·325	500·741	22·376
12	37·699	113·097	10·634	25 $\frac{1}{2}$	80·110	510·706	22·598
12 $\frac{1}{4}$	38·484	117·859	10·856	25 $\frac{3}{4}$	80·896	520·769	22·819
12 $\frac{1}{2}$	39·270	122·718	11·077	26	81·681	530·930	23·041
12 $\frac{3}{4}$	40·055	127·676	11·299	26 $\frac{1}{4}$	82·467	541·189	23·262
13	40·840	132·732	11·520	26 $\frac{1}{2}$	83·252	551·547	23·484
13 $\frac{1}{4}$	41·626	137·886	11·742	26 $\frac{3}{4}$	84·037	562·002	23·708
13 $\frac{1}{2}$	42·411	143·139	11·963	27	84·823	572·556	23·927

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
27½	85·608	583·208	24·149	41½	131·161	1369·00	36·999
27½	86·894	593·958	24·370	42	131·947	1385·44	37·220
27½	87·179	604·807	24·592	42½	132·732	1401·98	37·442
28	87·964	615·753	24·813	42½	133·518	1418·62	37·663
28½	88·750	626·798	25·035	42¾	134·303	1435·36	37·885
28½	89·535	637·941	25·256	43	135·088	1452·20	38·106
28½	90·321	649·182	25·478	43½	135·874	1469·13	38·328
29	91·106	660·521	25·699	43½	136·659	1486·17	38·549
29½	91·891	671·958	25·921	43¾	137·445	1503·30	38·771
29½	92·677	683·494	26·143	44	138·230	1520·53	38·993
29½	93·462	695·128	26·364	44½	139·015	1537·86	39·214
30	94·248	706·860	26·586	44½	139·801	1555·28	39·436
30½	95·033	718·690	26·807	44¾	140·586	1572·81	39·657
30½	95·818	730·618	27·029	45	141·372	1590·43	39·879
30½	96·604	742·644	27·250	45½	142·157	1608·15	40·110
31	97·389	754·769	27·472	45½	142·943	1625·97	40·322
31½	98·175	766·992	27·693	45¾	143·728	1643·89	40·543
31½	98·968	779·313	27·915	46	144·513	1661·90	40·765
31½	99·745	791·732	28·136	46½	145·299	1680·01	40·986
32	100·531	804·249	28·358	46½	146·084	1698·23	41·208
32½	101·316	816·865	28·580	46¾	146·869	1716·54	41·429
32½	102·102	829·578	28·801	47	147·655	1734·94	41·651
32½	102·887	842·390	29·023	47½	148·440	1753·45	41·873
33	103·672	855·300	29·244	47½	149·226	1772·05	42·094
33½	104·458	868·308	29·466	47¾	150·011	1790·76	42·316
33½	105·243	881·415	29·687	48	150·796	1809·56	42·537
33½	106·029	894·619	29·909	48½	151·582	1828·46	42·759
34	106·814	907·922	30·131	48½	152·367	1847·45	42·980
34½	107·599	921·323	30·352	48¾	153·153	1866·55	43·202
34½	108·385	934·822	30·574	49	153·938	1885·74	43·423
34½	109·170	948·419	30·795	49½	154·723	1905·03	43·645
35	104·956	962·115	31·017	49½	155·509	1924·42	43·867
35½	110·741	975·908	31·238	49¾	156·294	1943·91	44·088
35½	111·526	989·800	31·460	50	157·080	1963·50	44·310
35½	112·312	1003·79	31·681	50½	157·865	1983·18	44·531
36	113·097	1017·87	31·903	50½	158·650	2002·96	44·753
36½	113·883	1032·06	32·124	50¾	159·436	2022·84	44·974
36½	114·668	1046·39	32·349	51	160·221	2042·82	45·196
36½	115·453	1060·78	32·567	51½	161·007	2062·90	45·417
37	116·239	1075·21	32·789	51½	161·792	2083·07	45·639
37½	117·024	1089·79	33·011	51¾	162·577	2103·35	45·861
37½	117·810	1104·46	33·232	52	163·363	2123·72	46·082
37½	118·595	1119·24	33·454	52½	164·148	2144·19	46·304
38	119·380	1134·11	33·675	52½	164·934	2164·75	46·525
38½	120·166	1149·08	33·897	52¾	165·719	2185·42	46·747
38½	120·951	1164·15	34·118	53	166·504	2206·18	46·968
38½	121·737	1179·32	34·340	53½	167·290	2227·05	47·190
39	122·522	1194·59	34·561	53½	168·075	2248·01	47·411
39½	123·307	1209·95	34·783	53¾	168·861	2269·06	47·633
39½	124·093	1225·42	35·005	54	169·646	2290·22	47·854
39½	124·878	1240·98	35·226	54½	170·431	2311·48	48·076
40	125·664	1256·64	35·448	54½	171·217	2332·83	48·298
40½	126·449	1272·39	35·669	54¾	172·002	2354·28	48·519
40½	127·234	1288·25	35·891	55	172·788	2375·83	48·741
40½	128·020	1304·20	36·112	55½	173·573	2397·48	48·962
41	128·805	1320·25	36·334	55½	174·358	2419·22	49·184
41½	129·591	1336·40	36·555	55¾	175·144	2441·07	49·405
41½	130·376	1352·65	36·777	56	175·929	2463·01	49·627

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
56½	176·715	2485·05	49·848	71	223·053	9959·20	62·920
56¾	177·500	2507·19	50·070	71½	223·839	9987·18	63·141
56⅞	178·285	2529·42	50·291	71¾	224·624	4015·16	63·363
57	179·071	2551·76	50·513	71⅞	225·409	4043·28	63·545
57½	179·856	2574·19	50·735	72	226·195	4071·51	63·806
57¾	180·642	2596·72	50·956	72½	226·980	4099·83	64·028
57⅞	181·427	2619·35	51·178	72¾	227·766	4128·25	64·249
58	182·212	2642·03	51·399	72⅞	228·551	4156·77	64·471
58½	182·998	2664·91	51·621	73	229·336	4185·39	64·692
58¾	183·783	2687·83	51·842	73½	230·122	4214·11	64·914
58⅞	184·569	2710·85	52·064	73¾	230·907	4242·92	65·135
59	185·354	2733·97	52·285	73⅞	231·693	4271·83	65·357
59½	186·139	2757·19	52·507	74	232·478	4300·85	65·578
59¾	186·925	2780·51	52·729	74½	233·263	4329·95	65·800
59⅞	187·710	2803·92	52·950	74¾	234·049	4359·16	66·022
60	188·496	2827·44	53·172	74⅞	234·834	4388·47	66·243
60½	189·281	2851·05	53·393	75	235·620	4417·87	66·465
60¾	190·066	2874·76	53·615	75½	236·405	4447·37	66·686
60⅞	190·852	2898·56	53·836	75¾	237·190	4476·97	66·908
61	191·637	2922·47	54·048	75⅞	237·976	4506·67	67·129
61½	192·423	2946·47	54·279	76	238·761	4536·47	67·351
61¾	193·208	2970·57	54·501	76½	239·547	4566·36	67·572
61⅞	193·993	2994·77	54·723	76¾	240·332	4596·35	67·794
62	194·779	3019·07	54·944	76⅞	241·117	4626·44	68·016
62½	195·564	3043·47	55·166	77	241·903	4656·63	68·237
62¾	196·350	3067·96	55·387	77½	242·688	4686·92	68·459
62⅞	197·135	3092·56	55·609	77¾	243·474	4717·30	68·680
63	197·920	3117·25	55·830	77⅞	244·259	4747·79	68·902
63½	198·706	3142·04	56·052	78	245·044	4778·37	69·123
63¾	199·491	3166·92	56·273	78½	245·830	4809·05	69·345
63⅞	200·277	3191·91	56·495	78¾	246·615	4839·83	69·566
64	201·062	3216·99	56·716	78⅞	247·401	4870·70	69·788
64½	201·847	3242·17	56·938	79	248·186	4901·68	70·009
64¾	202·633	3267·46	57·159	79½	248·971	4932·75	70·231
64⅞	203·418	3292·83	57·381	79¾	249·757	4963·92	70·453
65	204·204	3318·31	57·603	79⅞	250·542	4995·19	70·674
65½	204·989	3343·88	57·824	80	251·328	5026·56	70·896
65¾	205·774	3369·56	58·046	80½	252·113	5058·01	71·119
65⅞	206·560	3395·33	58·267	80¾	252·898	5089·58	71·339
66	207·345	3421·20	58·489	80⅞	253·684	5121·24	71·562
66½	208·131	3447·16	58·710	81	254·469	5153·00	71·782
66¾	208·916	3473·23	58·932	81½	255·255	5184·86	72·005
66⅞	209·701	3499·39	59·154	81¾	256·040	5216·82	72·225
67	210·487	3525·66	59·375	81⅞	256·825	5248·87	72·449
67½	211·272	3552·01	59·597	82	257·611	5281·02	72·668
67¾	212·058	3578·47	59·818	82½	258·396	5313·27	72·892
67⅞	212·843	3605·03	60·040	82¾	259·182	5345·62	73·111
68	213·628	3631·68	60·261	82⅞	259·967	5377·07	73·335
68½	214·414	3658·44	60·483	83	260·752	5410·62	73·554
68¾	215·199	3685·29	60·704	83½	261·538	5443·26	73·778
68⅞	215·985	3712·24	60·926	83¾	262·323	5476·00	73·997
69	216·770	3739·28	61·147	83⅞	263·109	5508·84	74·221
69½	217·555	3766·43	61·369	84	263·894	5541·78	74·440
69¾	218·341	3793·67	61·591	84½	264·679	5574·81	74·664
69⅞	219·126	3821·02	61·812	84¾	265·465	5607·95	74·884
70	219·912	3848·46	62·034	84⅞	266·250	5641·18	75·107
70½	220·697	3875·99	62·255	85	267·036	5674·51	75·327
70¾	221·482	3903·63	62·477	85½	267·821	5707·94	75·550
70⅞	222·268	3931·36	62·698	85¾	268·606	5741·47	75·770

TABLE OF DIAMETERS, CIRCUMFERENCES, ETC.

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
85½	269·392	5775·09	75·994	100½	315·730	7932·73	89·065
86	270·177	5808·81	76·218	100¾	316·516	7972·21	89·287
86½	270·963	5842·63	76·437	101	317·301	8011·86	89·508
86¾	271·748	5876·55	76·656	101¼	318·087	8051·57	89·730
87	272·533	5910·57	76·880	101½	318·872	8091·38	89·952
87½	273·319	5944·69	77·099	101¾	319·657	8131·29	90·173
87¾	274·104	5978·90	77·323	102	320·443	8171·30	90·395
88	274·890	6013·21	77·542	102½	321·228	8211·40	90·616
88½	275·675	6047·62	77·766	102¾	322·014	8251·60	90·838
88¾	276·460	6082·13	77·985	103	322·799	8291·86	91·059
89	277·246	6116·74	78·209	103½	323·584	8332·30	91·281
89½	278·031	6151·44	78·428	103¾	324·370	8372·80	91·502
89¾	278·817	6186·25	78·652	104	325·155	8413·40	91·724
90	279·602	6221·15	78·871	104½	325·941	8454·09	91·946
90½	280·387	6256·15	79·095	104¾	326·726	8494·83	92·167
90¾	281·173	6291·25	79·315	105	327·511	8535·77	92·389
91	281·958	6326·44	79·538	105½	328·297	8576·76	92·610
91½	282·744	6361·74	79·758	105¾	329·082	8617·85	92·832
91¾	283·529	6397·13	79·982	106	329·868	8659·03	93·053
92	284·314	6432·62	80·201	106½	330·653	8700·31	93·275
92½	285·100	6468·21	80·425	106¾	331·438	8741·69	93·496
92¾	285·885	6503·89	80·644	107	332·224	8783·17	93·718
93	286·671	6539·68	80·868	107½	333·009	8824·75	93·940
93½	287·456	6575·56	81·087	107¾	333·794	8866·42	94·161
93¾	288·241	6611·54	81·311	108	334·580	8908·20	94·383
94	289·027	6647·62	81·530	108½	335·365	8950·07	94·604
94½	289·812	6683·80	81·754	108¾	336·151	8992·04	94·826
94¾	290·598	6720·07	81·973	109	336·936	9034·11	95·047
95	291·383	6756·45	82·197	109½	337·722	9076·27	95·269
95½	292·168	6792·92	82·416	109¾	338·506	9118·54	95·491
96	292·954	6829·49	82·640	110	339·292	9160·90	95·712
96½	293·739	6866·16	82·859	110½	340·077	9203·36	95·934
96¾	294·525	6902·92	83·083	110¾	340·863	9245·92	96·155
97	295·310	6939·79	83·302	111	341·648	9288·58	96·377
97½	296·095	6976·75	83·526	111½	342·434	9331·33	96·598
97¾	296·881	7013·81	83·746	111¾	343·219	9374·18	96·820
98	297·666	7050·97	83·970	112	344·005	9417·14	97·041
98½	298·452	7088·23	84·189	112½	344·789	9460·19	97·263
98¾	299·237	7125·58	84·413	113	345·575	9503·34	97·485
99	300·022	7163·04	84·632	113½	346·360	9546·59	97·707
99½	300·808	7200·59	84·856	113¾	347·146	9589·93	97·928
99¾	301·593	7238·24	85·077	114	347·931	9633·37	98·150
100	302·379	7275·99	85·299	114½	348·716	9676·91	98·371
100½	303·164	7313·84	85·520	114¾	349·502	9720·55	98·593
101	303·949	7351·78	85·742	115	350·287	9764·29	98·814
101½	304·735	7389·82	85·964	115½	351·073	9808·12	99·036
101¾	305·520	7427·96	86·185	115¾	351·858	9852·06	99·258
102	306·306	7466·20	86·407	116	352·643	9896·09	99·479
102½	307·091	7504·54	86·628	116½	353·429	9940·22	99·701
102¾	307·876	7542·98	86·850	116¾	354·214	9984·45	99·922
103	308·662	7581·51	87·071	117	355·000	10028·77	100·144
103½	309·447	7620·14	87·293	117½	355·785	10073·20	100·365
103¾	310·233	7658·87	87·514	117¾	356·570	10117·72	100·587
104	311·018	7697·70	87·736	118	357·356	10162·34	100·808
104½	311·803	7736·62	87·958	118½	358·141	10207·06	101·030
104¾	312·589	7775·65	88·179	118¾	358·927	10251·88	101·252
105	313·374	7814·79	88·401	119	359·712	10296·79	101·473
105½	314·160	7854·00	88·622	119½	360·497	10341·80	101·695
105¾	314·945	7893·31	88·844	119¾	361·283	10386·92	101·916

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
115 $\frac{1}{2}$	362-068	10432-12	102-138	129 $\frac{3}{4}$	407-621	13222-26	114-988
115 $\frac{3}{4}$	362-864	10477-43	102-369	130	409-407	13273-26	115-210
115 $\frac{7}{8}$	363-639	10522-84	102-581	130 $\frac{1}{2}$	409-192	13324-36	115-431
116	364-424	10568-34	102-802	130 $\frac{3}{4}$	409-977	13375-56	115-653
116 $\frac{1}{4}$	365-210	10613-94	103-024	130 $\frac{7}{8}$	410-763	13426-85	115-874
116 $\frac{1}{2}$	365-995	10659-65	103-246	131	411-548	13478-25	116-096
116 $\frac{3}{4}$	366-780	10705-44	103-467	131 $\frac{1}{4}$	412-334	13529-74	116-317
117	367-566	10751-34	103-689	131 $\frac{1}{2}$	413-119	13581-33	116-539
117 $\frac{1}{4}$	368-351	10797-34	103-910	131 $\frac{3}{4}$	413-904	13633-02	116-761
117 $\frac{1}{2}$	369-137	10843-43	104-132	132	414-690	13684-81	116-982
117 $\frac{3}{4}$	369-922	10889-62	104-353	132 $\frac{1}{4}$	415-475	13736-70	117-204
118	370-708	10935-91	104-575	132 $\frac{1}{2}$	416-260	13788-68	117-425
118 $\frac{1}{4}$	371-493	10982-30	104-796	132 $\frac{3}{4}$	417-046	13840-76	117-647
118 $\frac{1}{2}$	372-278	11028-78	105-018	133	417-831	13892-94	117-868
118 $\frac{3}{4}$	373-064	11075-37	105-240	133 $\frac{1}{4}$	418-617	13945-22	118-090
119	373-849	11122-05	105-461	133 $\frac{1}{2}$	419-402	13997-90	118-311
119 $\frac{1}{4}$	374-635	11168-83	105-683	133 $\frac{3}{4}$	420-188	14050-07	118-533
119 $\frac{1}{2}$	375-420	11215-71	105-904	134	420-973	14102-64	118-755
119 $\frac{3}{4}$	376-205	11262-69	106-126	134 $\frac{1}{4}$	421-758	14155-31	118-976
120	376-991	11309-76	106-347	134 $\frac{1}{2}$	422-544	14208-08	119-198
120 $\frac{1}{4}$	377-776	11356-93	106-569	134 $\frac{3}{4}$	423-329	14260-95	119-419
120 $\frac{1}{2}$	378-562	11404-20	106-790	135	424-115	14313-92	119-641
120 $\frac{3}{4}$	379-347	11451-57	107-012	135 $\frac{1}{4}$	424-900	14366-98	119-862
121	380-132	11499-04	107-234	135 $\frac{1}{2}$	425-685	14420-14	120-084
121 $\frac{1}{4}$	380-918	11546-61	107-455	135 $\frac{3}{4}$	426-470	14473-40	120-305
121 $\frac{1}{2}$	381-703	11594-27	107-677	136	427-256	14526-76	120-527
121 $\frac{3}{4}$	382-489	11642-03	107-898	136 $\frac{1}{4}$	428-042	14580-21	120-749
122	383-274	11689-89	108-120	136 $\frac{1}{2}$	428-827	14633-77	120-970
122 $\frac{1}{4}$	384-059	11737-85	108-341	136 $\frac{3}{4}$	429-612	14687-42	121-192
122 $\frac{1}{2}$	384-845	11785-91	108-563	137	430-398	14741-12	121-413
122 $\frac{3}{4}$	385-630	11834-06	108-784	137 $\frac{1}{4}$	431-183	14795-02	121-635
123	386-416	11882-32	109-006	137 $\frac{1}{2}$	431-969	14848-97	121-856
123 $\frac{1}{4}$	387-201	11930-67	109-228	137 $\frac{3}{4}$	432-754	14903-11	122-078
123 $\frac{1}{2}$	387-986	11979-12	109-449	138	433-539	14957-16	122-299
123 $\frac{3}{4}$	388-772	12027-66	109-671	138 $\frac{1}{4}$	434-325	15011-40	122-521
124	389-557	12076-31	109-892	138 $\frac{1}{2}$	435-110	15065-74	122-743
124 $\frac{1}{4}$	390-343	12125-05	110-114	138 $\frac{3}{4}$	435-896	15120-18	122-964
124 $\frac{1}{2}$	391-128	12173-90	110-335	139	436-681	15174-71	123-186
124 $\frac{3}{4}$	391-913	12222-84	110-557	139 $\frac{1}{4}$	437-466	15229-35	123-407
125	392-699	12271-88	110-778	139 $\frac{1}{2}$	438-252	15284-08	123-629
125 $\frac{1}{4}$	393-484	12321-01	111-000	139 $\frac{3}{4}$	439-037	15338-91	123-850
125 $\frac{1}{2}$	394-270	12370-25	111-222	140	439-823	15393-84	124-072
125 $\frac{3}{4}$	395-055	12419-58	111-443	140 $\frac{1}{4}$	440-608	15448-87	124-293
126	395-840	12469-01	111-665	140 $\frac{1}{2}$	441-393	15503-99	124-515
126 $\frac{1}{4}$	396-626	12518-54	111-886	140 $\frac{3}{4}$	442-179	15559-22	124-737
126 $\frac{1}{2}$	397-411	12568-17	112-108	141	442-964	15614-54	124-958
126 $\frac{3}{4}$	398-197	12617-89	112-329	141 $\frac{1}{4}$	443-750	15669-96	125-180
127	398-982	12667-72	112-551	141 $\frac{1}{2}$	444-535	15725-48	125-401
127 $\frac{1}{4}$	399-767	12717-64	112-772	141 $\frac{3}{4}$	445-320	15781-09	125-623
127 $\frac{1}{2}$	400-553	12767-66	112-994	142	446-106	15836-81	125-844
127 $\frac{3}{4}$	401-338	12817-78	113-216	142 $\frac{1}{4}$	446-891	15892-62	126-066
128	402-124	12868-00	113-437	142 $\frac{1}{2}$	447-677	15948-53	126-287
128 $\frac{1}{4}$	402-909	12918-31	113-659	142 $\frac{3}{4}$	448-462	16004-54	126-509
128 $\frac{1}{2}$	403-694	12968-72	113-880	143	449-247	16060-64	126-731
128 $\frac{3}{4}$	404-480	13019-23	114-102	143 $\frac{1}{4}$	450-033	16116-85	126-952
129	405-265	13069-84	114-323	143 $\frac{1}{2}$	450-818	16173-15	127-174
129 $\frac{1}{4}$	406-051	13120-55	114-545	143 $\frac{3}{4}$	451-604	16229-55	127-395
129 $\frac{1}{2}$	406-836	13171-35	114-767	144	452-389	16286-05	127-617

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
144 $\frac{1}{2}$	453-174	16334-66	127-838	158 $\frac{3}{4}$	498-727	19793-31	140-689
144 $\frac{1}{4}$	453-960	16399-35	128-060	159	499-513	19855-70	140-910
144 $\frac{3}{8}$	454-745	16456-14	128-281	159 $\frac{1}{4}$	500-298	19918-19	141-132
145	455-531	16513-04	128-503	159 $\frac{1}{2}$	501-084	19980-77	141-353
145 $\frac{1}{4}$	456-316	16570-03	128-725	159 $\frac{3}{8}$	501-869	20043-46	141-575
145 $\frac{1}{2}$	457-101	16627-11	128-946	160	502-654	20106-24	141-796
145 $\frac{3}{8}$	457-887	16684-30	129-168	160 $\frac{1}{4}$	503-440	20169-12	142-018
146	458-672	16741-59	129-389	160 $\frac{1}{2}$	504-225	20232-10	142-240
146 $\frac{1}{4}$	459-458	16798-97	129-611	160 $\frac{3}{8}$	505-011	20295-18	142-461
146 $\frac{1}{2}$	460-243	16856-45	129-832	161	505-796	20358-35	142-683
146 $\frac{3}{8}$	461-028	16914-03	130-054	161 $\frac{1}{4}$	506-581	20421-63	142-904
147	461-814	16971-71	130-276	161 $\frac{1}{2}$	507-367	20485-00	143-126
147 $\frac{1}{4}$	462-599	17029-48	130-497	161 $\frac{3}{8}$	508-152	20548-47	143-347
147 $\frac{1}{2}$	463-385	17087-36	130-719	162	508-938	20612-04	143-569
147 $\frac{3}{8}$	464-170	17145-33	130-940	162 $\frac{1}{4}$	509-723	20675-70	143-790
148	464-955	17203-40	131-162	162 $\frac{1}{2}$	510-508	20739-47	144-012
148 $\frac{1}{4}$	465-741	17261-57	131-383	162 $\frac{3}{8}$	511-294	20803-33	144-234
148 $\frac{1}{2}$	466-526	17319-84	131-605	163	512-079	20867-29	144-455
148 $\frac{3}{8}$	467-312	17378-20	131-826	163 $\frac{1}{4}$	512-865	20931-35	144-677
149	468-097	17436-67	132-048	163 $\frac{1}{2}$	513-650	20995-51	144-898
149 $\frac{1}{4}$	468-882	17495-22	132-270	163 $\frac{3}{8}$	514-435	21059-76	145-120
149 $\frac{1}{2}$	469-668	17553-89	132-491	164	515-221	21124-12	145-341
149 $\frac{3}{8}$	470-453	17612-64	132-713	164 $\frac{1}{4}$	516-006	21188-57	145-563
150	471-239	17671-50	132-934	164 $\frac{1}{2}$	516-792	21253-12	145-784
150 $\frac{1}{4}$	472-024	17730-45	133-156	164 $\frac{3}{8}$	517-577	21317-77	146-006
150 $\frac{1}{2}$	472-809	17789-51	133-377	165	518-362	21382-32	146-228
150 $\frac{3}{8}$	473-595	17848-66	133-599	165 $\frac{1}{4}$	519-148	21447-36	146-449
151	474-380	17907-91	133-820	165 $\frac{1}{2}$	519-933	21512-30	146-671
151 $\frac{1}{4}$	475-165	17967-25	134-042	165 $\frac{3}{8}$	520-719	21577-34	146-892
151 $\frac{1}{2}$	475-951	18026-70	134-264	166	521-504	21642-48	147-114
151 $\frac{3}{8}$	476-736	18086-24	134-485	166 $\frac{1}{4}$	522-290	21707-72	147-335
152	477-522	18145-88	134-707	166 $\frac{1}{2}$	523-075	21773-06	147-557
152 $\frac{1}{4}$	478-307	18205-62	134-928	166 $\frac{3}{8}$	523-860	21838-49	147-779
152 $\frac{1}{2}$	479-092	18265-46	135-150	167	524-646	21904-02	148-000
152 $\frac{3}{8}$	479-878	18325-39	135-371	167 $\frac{1}{4}$	525-431	21969-65	148-222
153	480-663	18385-43	135-593	167 $\frac{1}{2}$	526-216	22035-38	148-443
153 $\frac{1}{4}$	481-449	18445-56	135-814	167 $\frac{3}{8}$	527-002	22101-21	148-665
153 $\frac{1}{2}$	482-234	18505-79	136-036	168	527-787	22167-13	148-886
153 $\frac{3}{8}$	483-019	18566-12	136-258	168 $\frac{1}{4}$	528-573	22233-15	149-108
154	483-805	18626-55	136-479	168 $\frac{1}{2}$	529-358	22299-27	149-329
154 $\frac{1}{4}$	484-590	18687-07	136-701	168 $\frac{3}{8}$	530-143	22365-49	149-551
154 $\frac{1}{2}$	485-376	18747-69	136-922	169	530-929	22431-81	149-773
154 $\frac{3}{8}$	486-161	18808-42	137-144	169 $\frac{1}{4}$	531-714	22498-22	149-994
155	486-946	18869-24	137-365	169 $\frac{1}{2}$	532-500	22564-74	150-216
155 $\frac{1}{4}$	487-732	18930-15	137-587	169 $\frac{3}{8}$	533-285	22631-35	150-437
155 $\frac{1}{2}$	488-517	18991-17	137-808	170	534-070	22698-06	150-659
155 $\frac{3}{8}$	489-303	19052-28	138-030	170 $\frac{1}{4}$	534-856	22764-87	150-880
156	490-088	19113-49	138-252	170 $\frac{1}{2}$	535-641	22831-77	151-102
156 $\frac{1}{4}$	490-873	19174-80	138-473	170 $\frac{3}{8}$	536-426	22898-79	151-323
156 $\frac{1}{2}$	491-659	19236-21	138-695	171	537-212	22965-88	151-545
156 $\frac{3}{8}$	492-444	19297-72	138-916	171 $\frac{1}{4}$	537-997	23033-08	151-767
157	493-230	19359-32	139-138	171 $\frac{1}{2}$	538-783	23100-38	151-988
157 $\frac{1}{4}$	494-015	19421-03	139-359	171 $\frac{3}{8}$	539-568	23167-78	152-210
157 $\frac{1}{2}$	494-800	19482-83	139-581	172	540-353	23235-27	152-431
157 $\frac{3}{8}$	495-586	19544-73	139-802	172 $\frac{1}{4}$	541-139	23302-87	152-653
158	496-371	19606-73	140-024	172 $\frac{1}{2}$	541-924	23370-56	152-874
158 $\frac{1}{4}$	497-157	19668-82	140-246	172 $\frac{3}{8}$	542-710	23438-35	153-096
158 $\frac{1}{2}$	497-942	19731-02	140-467	173	543-495	23506-24	153-317

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
173 $\frac{1}{4}$	544-280	23574-22	153-539	186 $\frac{1}{4}$	586-692	27391-27	165-503
173 $\frac{1}{2}$	545-066	23642-31	153-761	187	587-477	27464-65	165-725
173 $\frac{3}{4}$	545-851	23710-49	153-982	187 $\frac{1}{2}$	588-263	27538-14	165-946
174	546-637	23778-77	154-204	187 $\frac{3}{4}$	589-048	27611-72	166-168
174 $\frac{1}{4}$	547-422	23847-15	154-425	187 $\frac{1}{2}$	589-834	27685-40	166-389
174 $\frac{1}{2}$	548-207	23915-63	154-647	188	590-619	27759-18	166-611
174 $\frac{3}{4}$	548-993	23984-20	154-868	188 $\frac{1}{2}$	591-404	27833-05	166-832
175	549-778	24052-88	155-090	188 $\frac{3}{4}$	592-190	27907-03	167-054
175 $\frac{1}{4}$	550-564	24121-65	155-311	188 $\frac{1}{2}$	592-975	27981-10	167-276
175 $\frac{1}{2}$	551-349	24190-52	155-533	189	593-761	28055-27	167-497
175 $\frac{3}{4}$	552-134	24259-48	155-755	189 $\frac{1}{2}$	594-546	28129-54	167-719
176	552-920	24328-55	155-976	189 $\frac{3}{4}$	595-331	28203-91	167-940
176 $\frac{1}{4}$	553-705	24397-71	156-198	189 $\frac{1}{2}$	596-117	28278-38	168-162
176 $\frac{1}{2}$	554-491	24466-98	156-419	190	596-902	28352-94	168-383
176 $\frac{3}{4}$	555-276	24536-34	156-641	190 $\frac{1}{4}$	597-687	28427-60	168-605
177	556-061	24605-80	156-862	190 $\frac{1}{2}$	598-473	28502-36	168-826
177 $\frac{1}{4}$	556-847	24675-35	157-084	190 $\frac{3}{4}$	599-258	28577-22	169-048
177 $\frac{1}{2}$	557-632	24745-01	157-305	191	600-044	28652-18	169-270
177 $\frac{3}{4}$	558-418	24814-76	157-527	191 $\frac{1}{4}$	600-829	28727-23	169-491
178	559-203	24884-61	157-749	191 $\frac{1}{2}$	601-614	28802-39	169-713
178 $\frac{1}{4}$	559-988	24954-56	157-970	191 $\frac{3}{4}$	602-400	28877-64	169-934
178 $\frac{1}{2}$	560-774	25024-61	158-192	192	603-185	28952-99	170-156
178 $\frac{3}{4}$	561-559	25094-76	158-413	192 $\frac{1}{4}$	603-971	29028-43	170-377
179	562-345	25165-00	158-635	192 $\frac{1}{2}$	604-756	29103-98	170-599
179 $\frac{1}{4}$	563-130	25235-34	158-856	192 $\frac{3}{4}$	605-541	29179-62	170-820
179 $\frac{1}{2}$	563-915	25305-78	159-078	193	606-327	29255-37	171-042
179 $\frac{3}{4}$	564-701	25376-32	159-299	193 $\frac{1}{4}$	607-112	29331-21	171-264
180	565-486	25446-96	159-521	193 $\frac{1}{2}$	607-898	29407-14	171-485
180 $\frac{1}{4}$	566-272	25517-70	159-743	193 $\frac{3}{4}$	608-683	29483-18	171-707
180 $\frac{1}{2}$	567-057	25588-53	159-964	194	609-468	29559-32	171-928
180 $\frac{3}{4}$	567-842	25659-46	160-186	194 $\frac{1}{4}$	610-254	29635-55	172-150
181	568-628	25730-49	160-407	194 $\frac{1}{2}$	611-039	29711-88	172-371
181 $\frac{1}{4}$	569-413	25801-62	160-629	194 $\frac{3}{4}$	611-825	29788-31	172-593
181 $\frac{1}{2}$	570-199	25872-84	160-850	195	612-610	29864-84	172-814
181 $\frac{3}{4}$	570-984	25944-17	161-072	195 $\frac{1}{4}$	613-395	29941-46	173-036
182	571-769	26015-59	161-293	195 $\frac{1}{2}$	614-181	30018-19	173-258
182 $\frac{1}{4}$	572-555	26087-11	161-515	195 $\frac{3}{4}$	614-966	30095-01	173-479
182 $\frac{1}{2}$	573-340	26158-73	161-737	196	615-752	30171-93	173-701
182 $\frac{3}{4}$	574-126	26230-45	161-958	196 $\frac{1}{4}$	616-537	30248-95	173-922
183	574-911	26302-26	162-180	196 $\frac{1}{2}$	617-322	30326-06	174-144
183 $\frac{1}{4}$	575-696	26374-17	162-401	196 $\frac{3}{4}$	618-108	30403-28	174-365
183 $\frac{1}{2}$	576-482	26446-19	162-623	197	618-893	30480-59	174-587
183 $\frac{3}{4}$	577-267	26519-29	162-844	197 $\frac{1}{4}$	619-679	30558-00	174-808
184	578-053	26590-50	163-066	197 $\frac{1}{2}$	620-464	30635-51	175-030
184 $\frac{1}{4}$	578-838	26662-81	163-287	197 $\frac{3}{4}$	621-249	30713-12	175-252
184 $\frac{1}{2}$	579-623	26735-21	163-509	198	622-035	30790-82	175-473
184 $\frac{3}{4}$	580-409	26807-71	163-731	198 $\frac{1}{4}$	622-820	30868-63	175-695
185	581-194	26880-32	163-952	198 $\frac{1}{2}$	623-606	30946-53	175-916
185 $\frac{1}{4}$	581-980	26953-01	164-174	198 $\frac{3}{4}$	624-391	31024-53	176-138
185 $\frac{1}{2}$	582-765	27025-81	164-395	199	625-176	31102-63	176-359
185 $\frac{3}{4}$	583-550	27098-71	164-617	199 $\frac{1}{4}$	625-962	31180-82	176-581
186	584-336	27171-70	164-838	199 $\frac{1}{2}$	626-747	31259-12	176-802
186 $\frac{1}{4}$	585-121	27244-79	165-060	199 $\frac{3}{4}$	627-533	31337-49	177-024
186 $\frac{1}{2}$	585-907	27317-98	165-282	200	628-318	31415-98	177-246

WEIGHTS AND MEASURES.

Troy Weight.

	Ounces.	Pennyweights.	Grains.	gr.	dwt.
Pound.	1	= 20	= 24		
	1	= 20	= 240	= 480	oz.
1	= 12	= 240	= 5760		lb.

A carat = 4 grains.

437.5 grs. troy = 1 oz. avoirdupois.

7000 „ „ = 1 lb. „

100 oz. troy = 109 $\frac{5}{7}$ oz. „

3.2 grs. „ = 4 diamond grs.

1 oz. „ = 150 „

The pound troy is the weight of 22.815 cub. in. of distilled water at the temperature of 62° Fahr., the height of the barometer being 30 in.

Troy weight is used in philosophical experiments, and in weighing gold, silver, and jewels. The fineness of gold and silver coins means the proportion of the precious metal which they contain. This is expressed in $\frac{1}{1000}$ ths of their total weight, or in carats: 24ths of their total weight. British gold coins are 22 carats fine, or 0.916 $\frac{2}{3}$; silver coins, 0.925. Gold, if pure, is said to be 24 carats fine; if there be one of alloy with 23 carats of pure gold, it is 23 carats fine, and so on downwards. The alloy in gold and silver coins consists of copper. The true weight of a sovereign is 123.274 grains, consisting of: Pure gold, 11 parts or 113.001 grs.; copper, 1 part or 10.273 grs. Silver coin consists of: Pure silver, 222 parts; copper, 18 parts. The weight of a shilling is 87 $\frac{1}{4}$ grs. 24 pence are made from an avoirdupois pound of copper.

Septem and Decigallon.

The word *septem* (seven) is descriptive of the weight of the $\frac{1}{1000}$ part of a decigallon of distilled water at 62° Fahr. and under a barometric pressure of 30 in.

A decigallon of water is the $\frac{1}{10}$ part of a gallon, and as a gallon of water at the above temperature and pressure weighs 70,000 grs. (10 lbs. avoirdupois), it follows that the $\frac{1}{10}$ part, or a decigallon, must weigh 7000 grs. (1 lb.).

Each decigallon is divided into 1000 septems; and therefore the septem of pure water weighs 7 grs.

Apothecaries Weight.

		Drams.		Scruples.		Grains.		gr.	
		or Drachms.		1 =		20		scr.	
Ounces.		1 =		3 =		60		dr.	
Pound.	1 =	8 =	24 =	480 =	oz.				
1	= 12 =	96 =	288 =	5760 =	lb.				

The sign of the scruple is ϑ ; the dram, ζ ; the ounce, ζ .

This weight, which is now abolished, was formerly used for *compounding* medicines. The grain, ounce, and pound are equal to those of troy weight. Drugs are bought and sold by avoirdupois weight.

Avoirdupois Weight.

		Pounds.		Ounces.		Drams.		dr.	
		1 =		16 =		16 =		oz.	
Stones.		1 =		14 =		224 =		256 lb.	
Quarters.	1 =	2 =	28 =	448 =	7168	qr.			
Cwts.	1 =	4 =	8 =	112 =	1792 =	28672	cwt.		
Ton.	1 =	20 =	40 =	80 =	160 =	2240 =	35840 =	573440	ton.
		1 lb. avoirdupois =		7000		grs. troy.			
		1 oz.		,,		=437.5		,,	
		100 ,,		,,		=91 $\frac{7}{8}$		oz. troy.	

The imperial pound avoirdupois is the standard unit by means of which all commodities, except gold, silver, and precious stones, are weighed, and is equal to the weight of $\frac{1}{10}$ of an imperial gallon, or of 27.7274 cub. in. of distilled water at the temperature of 62° Fahr. and when the barometer stands at 30 in. A certain piece of platinum of this standard weight is kept in the Exchequer Office at Westminster.

Lineal or Long Measure.

		Rods,		Feet.		Inches.		
		Perches, or		1 =		12		
		Poles.		1 =		3 =		
Chains.		1 =		5 $\frac{1}{2}$ =		16 $\frac{1}{2}$ =		198
Furlongs.	1 =	4 =	22 =	66 =	792			
Mile.	1 =	10 =	40 =	220 =	660 =	7920		
1	= 8 =	80 =	320 =	1760 =	5280 =	63360		

- 1 link = 7.92 in.
 100 links = 1 chain, or 66 feet, or 22 yards.
 1 league = 3 geographical or nautical miles.
 1 hand = 4 inches.
 1 fathom = 6 feet.
 1 military pace = $2\frac{1}{2}$ feet.
 1 geometrical pace = 5 feet.
 1 geographical or nautical mile = 1.15 statute miles.
 1 geographical degree = 60 geographical or nautical miles.
 1 Admiralty knot = 6080 feet.

The yard is the imperial standard measure of length, and is the distance, at the temperature of 62° Fahr., between two marks on a certain bar kept in the Exchequer Office, Westminster.

Cloth Measure.

		Quarters.		Nails.		Inches.		
		1	=	4	=	2 $\frac{1}{4}$		
Ell.	Yards.	1	=	4	=	9		
	1	=	4	=	16	=	36	
1	=	1 $\frac{1}{4}$	=	5	=	20	=	45

The yard is the same as in long measure, but differs in its divisions and subdivisions.

Yarn Measure—Cotton.

		Hanks.		Skeins.		Yards.	
		1	=	7	=	120	
Spindle.	1	=	7	=	840		
1	=	18	=	126	=	15120	

Yarn Measure—Linen.

		Hears.		Cuts.		Yards.		
		1	=	2	=	300		
		1	=	2	=	600		
Spindle.	Hasps.	1	=	6	=	12	=	3600
1	=	4	=	24	=	48	=	14400

Square Measure.

		Sq. Poles or Sq. Yards.		Sq. Feet.		Sq. Inches.	
		1 =		1	=	144	
		Perches.		1	=	9	= 1296
Statute Sq.	Roods.	1	= 30 $\frac{1}{4}$	=	272 $\frac{1}{4}$	=	39204
Acre.	1	= 40	= 1210	= 10890	=	1568160	
	1 = 4	= 160	= 4840	= 43560	=	6272640	

1 square mile = 640 statute acres.

In round numbers, $\frac{1}{2}$ d. per square yard is £10 per statute acre (actually, £10. rs. 8d.).

		4,840	square yards	make 1	statute acre.
{	<i>Customary Measure.</i>	6,150	4	"	Scotch acre.
		7,840	"	"	Irish acre.
		4,000	"	"	Devonshire acre.
		4,000	"	"	Somersetshire acre.
		5,760	"	"	Cornwall acre.
		7,840	"	"	Lancashire acre.
		10,240	"	"	Cheshire acre.
		10,240	"	"	Staffordshire acre.

To Reduce Statute Measure to Customary.

Multiply the number of perches statute measure by the square feet in a square perch statute measure; divide the product by the square feet in a square perch customary measure, and the quotient will be the answer in square perches *customary*.

To Reduce Customary Measure to Statute.

Multiply the number of perches customary measure by the square feet in a square perch customary measure; divide the product by the square feet in a square perch statute measure, and the quotient will be the answer in square perches *statute*.

Square Measure—Land.

		Sq. Chains.		Sq. Perch.		Sq. Links.	
		1 =		16	=	625	
Acre.	1	= 2.5	= 40	=	25000		
	1 = 4	= 10	= 160	=	100000		

The chain with which land is measured is 22 yards long.

Solid or Cubic Measure.

Cubic Yard.	Cubic Feet.	Cubic Inches.
	1	= 1728
1	= 27	= 46656

Liquid Measure.

Gallon.	Quarts.	Pints.	Gills.
	1	= 2	= 4
1	= 4	= 8	= 32

The standard measure of capacity, both for liquids and dry goods, is the imperial gallon, being equal to a volume of distilled water of 277.274 cub. in., weighing 10 lbs. avoirdupois, at the temperature of 62° Fahr. and 30 in. atmospheric pressure.

Liquid Measures used by Apothecaries.

1 fluid minim	= 0.0045 cubic inch.	(M)
60 „ minims	= 1 dram.	(3)
8 drams	= 1 oz.	(3)
20 oz.	= 1 pint.	(c)

Wine Measure.

		Gallons.	Quarts.	Pints.
	Tierces.	1	= 4	= 8
	Hhds.	1	= 42	= 168
	Punch.	1	= 1½	= 63
	Pipes.	1	= 1¼	= 2
Tun.	1	= 1½	= 2	= 3
1	= 2	= 3	= 4	= 6
		126	= 504	= 1008
		252	= 1008	= 2016

Ale and Beer Measure.

		Gallons.	Quarts.	Pints.
	Firkins.	1	= 4	= 8
	Kildkns.	1	= 9	= 36
	Barrels.	1	= 2	= 18
	Hhds.	1	= 2	= 4
	Punch.	1	= 1½	= 3
Butt.	1	= 1¼	= 2	= 4
1	= 1½	= 2	= 3	= 6
		12	= 108	= 432
		108	= 432	= 864

Dry Measure.

				Gallons.		Pints.	
		Pecks.	1 =	8			
		Bushels.	1 =	2 =	16		
		Quarters.	1 =	4 =	8 = 64		
Loads or Weys.		1 =	8 =	32 =	64 =	512	
Last.	1 =	5 =	40 =	160 =	320 =	2560	
	1 =	2 =	10 =	80 =	320 =	640 =	5120
3 bushels = 1 sack = 3.85 cubic feet.							
12 sacks = 1 chaldron = 46.2 cubic feet.							

The imperial bushel contains 80 lbs. avoirdupois of distilled water, and its content is 2218.192 cubic inches, or 1.283 cubic feet.

Table of Time.

		Minutes.		Seconds.	
		Hours.	1 =	60	
Days.		1 =	60 =	3600	
Week.	1 =	24 =	1440 =	86400	
	1 =	7 =	168 =	10080 = 604800	

28 days = 1 lunar month.

28, 29, 30, or 31 days = 1 calendar month.

1 common year = 365 days, or 52 weeks 1 day.

1 leap year = 366 days, or 52 weeks 2 days.

1 Julian year = 365 days 6 hours.

1 solar year = 365 days, 5 hours, 48 minutes, 49 seconds.

30 degrees = 1 sign.

12 signs = 1 circle of the zodiac.

CIRCULAR AND ANGULAR SPACE.

60'' (seconds) = 1' (minute).

60' = 1° (degree).

30° = 1 sign.

45° = 1 octant.

60° = 1 sextant.

90° = { 1 quadrant.

{ 1 right angle.

360° = A circle.

The earth moves through 360° in 24 hours, therefore 15° = 1 hour, and 1° = 4 minutes.

TIME IN WHICH ANY SUM DOUBLES ITSELF,
AT RATES OF INTEREST BOTH SIMPLE
AND COMPOUND.

Rate of Interest per cent.	Years in which the sum is doubled, at		Rate of Interest per cent.	Years in which the sum is doubled, at	
	Simple Interest.	Compound Interest.		Simple Interest.	Compound Interest.
1	100	69'6603	5	20	14'2067
2	50	35'0028	6	16 $\frac{2}{3}$	11'8957
2 $\frac{1}{2}$	40	28'0701	7	14 $\frac{1}{2}$	10'2448
3	33 $\frac{1}{3}$	23'4498	8	12 $\frac{1}{2}$	9'00646
3 $\frac{1}{2}$	28 $\frac{1}{2}$	20'1488	9	11 $\frac{1}{2}$	8'04323
4	25	17'67303	10	10	7'27254
4 $\frac{1}{2}$	22 $\frac{2}{3}$	15'7473	11	9 $\frac{1}{2}$	6'64189
			12	8 $\frac{1}{2}$	6'11626

FRENCH WEIGHTS AND MEASURES—
DECIMAL SYSTEM.

Weights.

	French.		English.
Milligramme	= $\frac{1}{1000}$	or 0'001 gramme	= 0'01543 grains.
Centigramme	= $\frac{1}{100}$	or 0'01 „	= 0'1543 „
Décigramme	= $\frac{1}{10}$	or 0'1 „	= 1'5432 „
GRAMME	= 1	„	= { 15'432349 „ 0'643 dwt. 0'03215 oz. troy. 0'03527 oz. avoird. 0'0022 lb. „ 0'0000197 cwt.
Décagramme	= 10	grammes	= { 154'32 grains. 0'3527 oz. avoird. 0'022 lb. „
Hectogramme	= 100	„	= { 1,543'23 grains. 3'527 oz. avoird. 0'22046 lb. „

French.	.	English.
Kilogramme = 1,000 grammes =	=	15,432'349 grains.
		32'15 oz. troy.
		35'2739 „ avoir.
		2'2046 lbs. „
		2'679 „ troy.
		0'01968 cwt.
Myriagramme = 10,000 „ =	=	0'00098 ton.
		22'046 lbs. avoir.
		0'1968 cwt.
Quintal = 100,000 grms. =	=	0'00984 ton.
		220'46 lbs. or 1 cwt. 3 qrs.
Millier or bar = 1,000,000 „ =	=	24½ lbs.
		2,204'62 lbs. or 19 cwt. 2 qrs.
		20¾ lbs.

The Gramme is the unit of measures of weight, and is the weight of a cubic centimètre of distilled water at its maximum density (39'2° Fahr.) *in vacuo*, at sea-level in the latitude of Paris, barometer 29'922 inches.

English.	=	French:
Grain	=	0'064799 grammes.
Dwt.	=	1'555 „
Dram	=	1'771846 „
Ounce, troy	=	31'1035 „
Ounce, avoirdupois	=	28'3496 „
Pound „	= {	453'59 „
		0'454 kilogramme.
Pound, troy	= {	373'226 grammes.
		0'373226 kilogramme.
Cwt.	=	50'8 kilogrammes.
Ton	= {	1,016'05 „
		1'01605 tonnes.
		1 tonne × 0'984.

Lineal or Long Measure.

French.	=	English.
Millimètre = $\frac{1}{1000}$ or 0'001 mètre =	=	{ 0'03937 inch.
		{ 0'00328 foot.
		{ 0'00109 yard.

French.		English.	
Centimètre	= $\frac{1}{100}$ or 0'01 mètre	= {	0'3937 inch. 0'0328 foot. 0'0109 yard.
Décimètre	= $\frac{1}{10}$ or 0'1 „	= {	3'9371 inches. 0'3281 foot. 0'1093 yard.
MÈTRE	= 1 „	= {	39'37079 inches. 3'2808992 feet. 1'093633056 yards. 0'00062 mile.
Décamètre	= 10 mètres	= {	393'7079 inches. 32'809 feet. 10'936 yards. 0'0062 mile.
Hectomètre	= 100 „	= {	3,937'079 inches. 328'09 feet. 109'36 yards. 0'06214 mile.
Kilomètre	= 1,000 „	= {	39,370'79 inches. 3,280'9 feet. 1,093'63 yards. 0'62138 mile.
Myriamètre	= 10,000 „	= {	393,707'9 inches. 32,809'0 feet. 10,936'3 yards. 6'21382 miles.
Ligne or line	.	=	0'088819 inch.
Pouce or inch	= 12 lines	=	1'06583 inches.
Piéd or foot	= 12 pouces	=	12'78996 „
Toise	= 6 French feet	=	76'74 „

The Mètre is the unit of lineal measure, and is the ten-millionth part of 90° of the meridian.

English.		French.	
Inch	.	= {	25'39954 millimètres. 2'54 centimètres 0'254 décimètre. 0'0254 mètre.
Foot	.	=	0'3048 „

	English.		French.
Yard	=	0'9144	mètre.
Fathom	=	1'8287	mètres.
Pole	=	5'0291	"
Chain	=	20'116	"
Furlong	=	{ 201'16	"
		{ 0'20116	kilomètre.
Mile	=	{ 1,609'315	mètres.
		{ 1'609315	kilomètres.

Square Measure.

	French.		English.
Milliare	= { $\frac{1}{10000}$ or 0'001 are } =	{	155'00 sq. in.
	{ or sq. décamètre }	{	1'0764 " feet.
		{	0'1196 " yard.
Centiare } or sq. } mètre. }	= { $\frac{1}{100}$ or 0'01 sq. } =	{	1,550'0 " in.
	{ décamètre }	{	10'764 " feet.
		{	1'196033292, " yards.
		{	0'03954 " perch.
		{	0'00099 " rood.
		{	0'00025 " acre.
Déciare	= { $\frac{1}{10}$ or 0'1 sq. } =	{	15,501'0 sq. in.
	{ décamètre }	{	107'64 " feet.
		{	11'96033 " yards.
		{	0'3954 " perch.
		{	0'0099 " rood.
		{	0'0025 " acre.
ARE or sq. } décamètre }	= 1 sq. décamètre =	{	1,076'4 " feet.
		{	119'6033 " yards.
		{	3'954 " perches.
		{	0'099 " rood.
		{	0'0247 " acre.
Décare	= { 10 ares or sq. } =	{	1,196'033 " yards.
	{ décamètres }	{	39'54 " perches.
		{	0'99 " rood.
		{	0'2471 " acre.

	French.	English.
Hectare	= { 100 ares or sq. } { décamètres }	= { 11,960'3 sq. yards. 395'4 „ perches. 9'89 „ roods. 2'4712 „ acres.

The Are, which is a square décamètre, is the unit of square measure.

English.	French.
Square inch	= { 645'137 sq. millimètres. 0'000645 „ mètre.
Square foot	= 0'0929 „ „
Square yard	= 0'8361 „ „
Square perch	= 25'292 „ mètres.
Square rood	= 1,011'7 „ „
Square acre	= 4,046'7 „ „
Square mile	= 2'59 „ kilomètres.

Solid Measure.

	French.	English.
Millistère	= { $\frac{1}{1000}$ or 0'001 stère } = { 61'028 cubic inches. 0'035317 „ foot.	
Centistère	= { $\frac{1}{100}$ or 0'01 stère } = { 610'28 „ inches. 0'35317 „ foot.	
Décistère	= { $\frac{1}{10}$ or 0'1 stère } = { 6,102'8 „ inches. 3'5317 „ feet. 0'1308 „ yard.	
STÈRE OR cubic mètre. }	= { 1 stère or cubic mètre }	= { 61,028'0 „ inches. 35'317 „ feet. 1'308 „ yards.
Décastère = 10 stères or cubic mètres	= { 353'17 „ feet. 13'0802 „ yards.	
Hectostère = 100 „	= { 3,531'7 „ feet. 130'802 „ yards.	
Kilostère = 1,000 „	= { 35,317'0 „ feet. 1,308'02 „ yards.	
Myriastère = 10,000 „	= 13,080'224 „ „	

The Stère, which is a cubic mètre, is the unit of solid measure.

English.	=	{	0'000016386	stère or cubic mètre.
Cubic inch . . .	=	{	16,386'0	cubic millimètres.
Cubic foot . . .	=	{	0'028315	stère or cubic mètre.
1000 cubic feet . . .	=	{	28'315	stères or cubic mètres.
Cubic yard . . .	=	{	0'7645131	stère or cubic mètre.

Dry and Fluid Measure (Capacity).

French.	=	{	English.
Millilitre = {	$\frac{1}{1000}$ or 0'001 litre	}	0'0610 cubic inch.
	or cubic décimètre	}	0'00022 imperial bushel.
Centilitre = {	$\frac{1}{100}$ or 0'01 litre or	}	0'61028 cubic inch.
	cubic décimètre . . }	}	0'0022 imperial bushel.
Décilitre = {	$\frac{1}{10}$ or 0'1 litre or	}	6'1028 cubic inches.
	cubic décimètre . . }	}	0'022 imperial bushel.
LITRE or	} = { 1 litre or cubic	} = {	61'028 cubic inches.
cubic dé-			0'0353 „ foot.
cimètre }			1'76172 imperial pints.
			0'220215 „ gallon.
			0'0275 „ bushel.
Décalitre = {	10 litres or cubic	}	610'28 cubic inches.
	décimètres . . }	}	0'353 „ foot.
		}	2'2 imperial gallons.
		}	0'275 „ bushel.
Hectolitre = {	100 litres or cubic	}	6,102'8 cubic inches.
	décimètres . . }	}	3'53171 „ feet.
		}	22'0 imperial gallons.
		}	2'751 „ bushels.
Kilolitre = {	1000 litres or	}	35'3171 cubic feet.
	cubic décimètres }	}	220'02 imperial gallons.
		}	27'512 „ bushels.
Myrialitre = {	10,000 litres or	}	353'171 „ cubic feet.
	cubic décimètres }	}	2,202'15 imperial gallons.
		}	275'121 „ bushels.

The Litre, which is a cubic décimètre, is the unit of measures of capacity.

	English.		French.
Cubic inch		0·016386 litre.
Cubic foot	=	28·315 litres.
1000 cubic feet	=	28,315·0 „
Imperial pint	=	0·5676 litre.
Imperial gallon	=	4·541 litres.
Imperial bushel	=	36·328 „

MONEY TABLES.

France.

Name.		English Value.
Centime	=	$\frac{1}{200}$ or 0·005d.
Franc = 100 centimes	=	9½d.
Sou = 5 „	=	$\frac{1}{40}$ or 0·475d
Napoléon = 20 francs	=	15s. 10d.

Accounts are kept in francs and centimes. For convenience in reckoning, a sou may be taken as equal to ½d., a franc as 10d., and 25 francs as 20s.

Belgium.

The Belgian currency is in centimes and francs, having the same English money-value as those of France.

To convert centimes per cubic metre into pence per 1000 cubic feet, and vice versa.

Centimes per cubic metre $\times 2\cdot7$ = pence per 1000 cubic feet.

Pence per 1000 cubic feet $\times 0\cdot37$ = centimes per cubic metre.

To convert centimes per litre into pence per 1000 cubic feet, and vice versa.

Centimes per litre $\times 2700$ = pence per 1000 cubic feet.

Pence per 1000 cubic feet $\times 0\cdot00037$ = centimes per litre.

UNITED STATES OF AMERICA.

Name.	English Value.
Cent	= $\frac{1}{2}$ d.
Dollar = 100 cents.	= 4s. 2d.
$4\frac{4}{5}$, or 4·8 dollars, or 4 dollars 80 cents	= £1
Dollars \times 0·2084	= £1

To convert dollars and cents per 1000 cubic feet into pence per 1000 cubic feet, and vice versa.

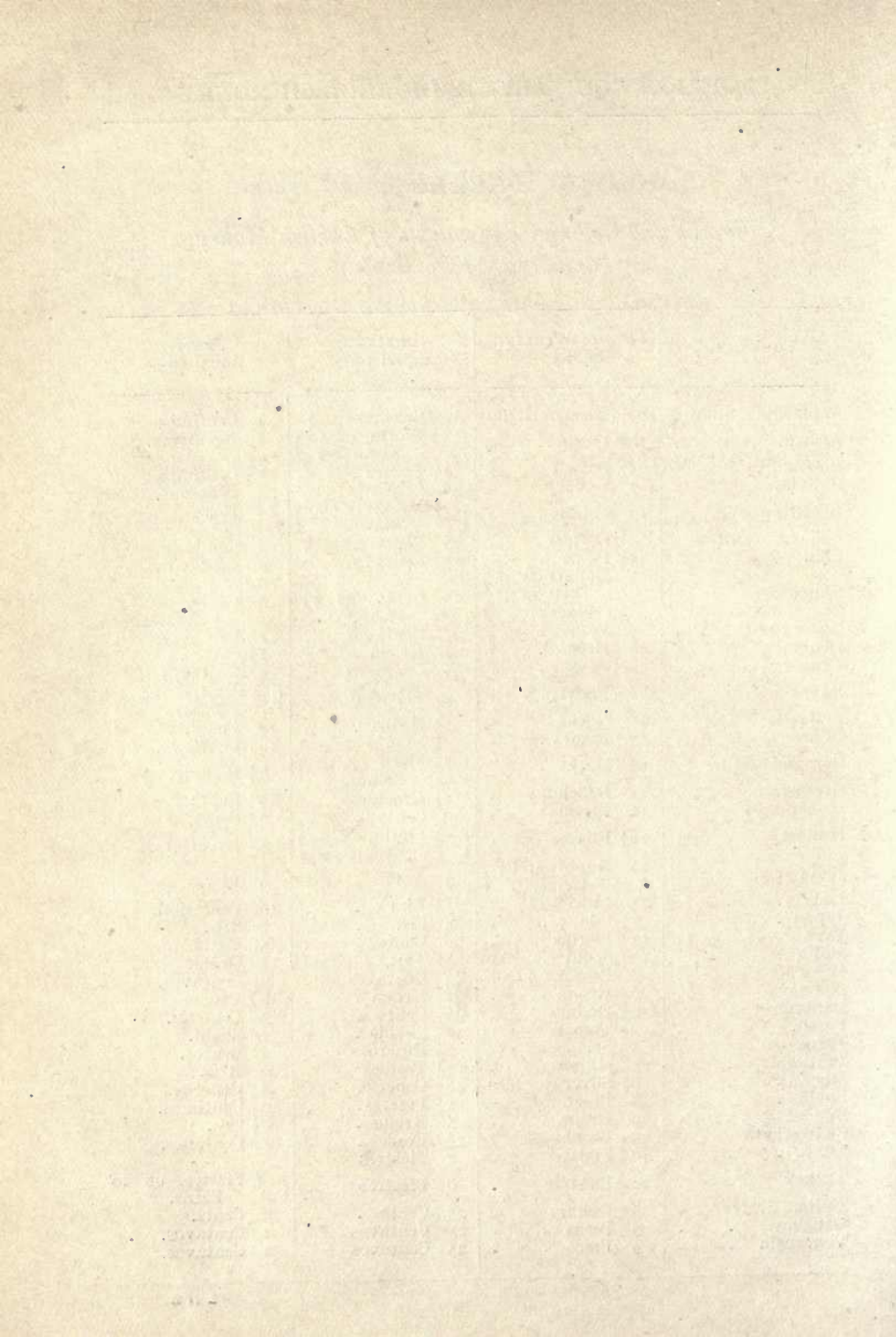
Dollars and cents per 1000 cubic feet \times 50 = pence per 1000 cubic feet.

Pence per 1000 cubic feet \times 0·02 = dollars and cents per 1000 cubic feet.

TABLE.

*Foreign and Colonial Equivalents of English Money.
(Actual or Approximate.)*

COUNTRY.	POUND STERLING, Equal to—	SHILLING, Equal to—	PENNY, Equal to—
Argentine Republic	10 Patacon or Dollars	50 Centimos . . .	4 Centimos.
Austria	10½ Florins . . .	{ ½ Florin, or 50 } Kreutzers	4 Kreutzers.
Belgium	25 Francs	1¼ Francs	10 Centimes.
Bolivia.	7 Dollars	36 Centenas	3 Centenas.
Brazil	10 Milreis	{ ½ Milreis or 500 } Reis	40 Reis.
Canada	4½ Dollars	25 Cents	2 Cents.
Chili	5½ Pesos	25 Centavos	2 Centavos.
China	{ 5 Dollars, or 3½ } Tael, or 35 } Mace.	25 Cents, or 1¼ } Mace.	2 Cents, or 1½ } Candareen.
Columbia	5 Pesos	25 Centavos	2 Centavos.
Denmark	20 Krona	1 Krona	8½ Ore.
Ecuador	5 Pesos	25 Centavos	2 Centavos.
Egypt	100 Piastres	5 Piastres	{ ½ Piastre, or 20 } Paras.
Finland	25 Marks	1¼ Marks	10 Penni.
France	25 Francs	1¼ Francs	10 Centimes.
German Empire	20 Marks	{ 1 Mark or 100 } Pfennig	8½ Pfennig.
Greece	25 Drachmæ	1¼ Drachmæ	10 Lepta.
Holland	12 Florius	60 Cents	5 Cents.
Hungary	10½ Florins	{ ½ Florin, or 50 } Kreutzers	4 Kreutzers.
India	{ 10 Rupees and 4 } Annas.	9 Annas	8 Pies.
Italy	25 Lira	1¼ Lira	10 Centesimi.
Japan	5 Yen	25 Sen	2 Sen.
Java	12 Florins	60 Cents	5 Cents.
Malta	12 Scudi	7 Tari, 4 Grani	12 Grani.
Mexico	5 Pesos or 5 Dols.	25 Centavos	2 Centavos.
Norway	20 Krona	1 Krona	8½ Ore.
Paraguay	6½ Dollars	36 Centena	3 Centena.
Persia	2½ Toman	12 Shahis	1 Shahi.
Peru	5 Sol	2½ Dineros	2 Centos.
Portugal	5 Milreis	2½ Testoes	20 Reis.
Russia	6½ Silver Roubles	48 Copecks	4 Copecks.
Spain	26 Pesetas	1¼ Pesetas	10 Centimos.
Sweden	20 Krona	1 Krona	8½ Ore.
Switzerland	25 Francs	1¼ Francs	10 Centimes.
Tunis	40 Piastres	2 Piastres	—
Turkey	120 Piastres	6 Piastres	{ ½ Piastre, or 20 } Paras.
United States	4½ Dollars	25 Cents	2 Cents.
Uruguay	5 Pesos	25 Centavos	2 Centavos.
Venezuela	5 Pesos	25 Centavos	2 Centavos.



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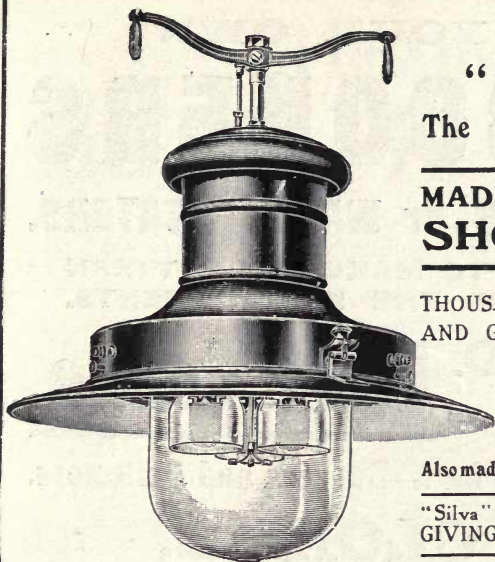
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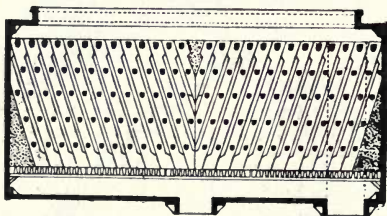
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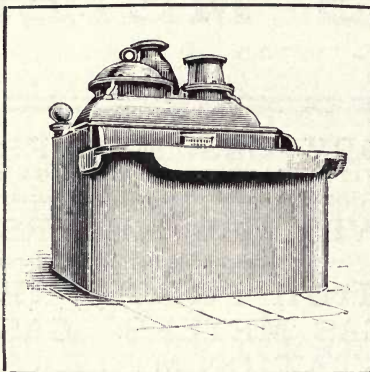
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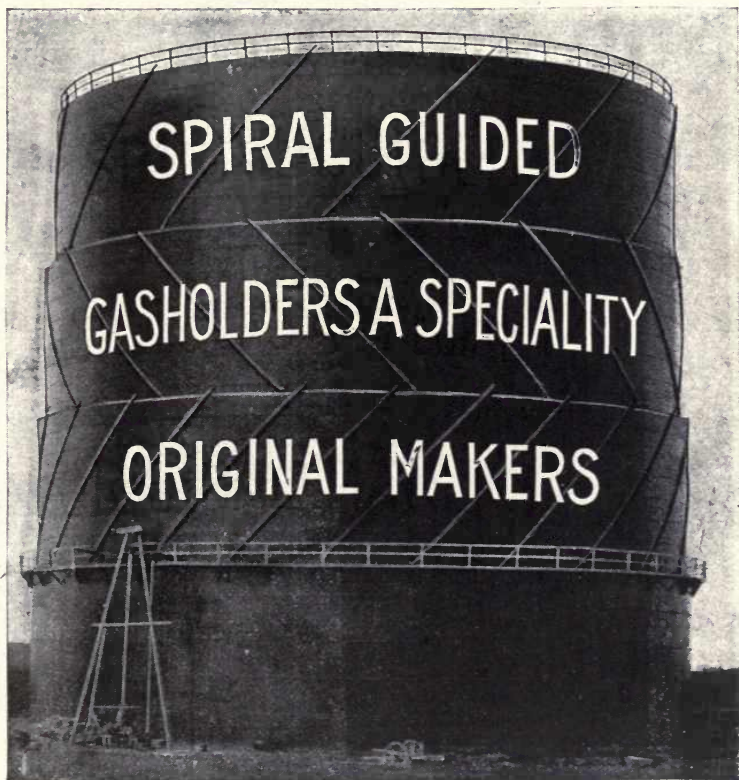
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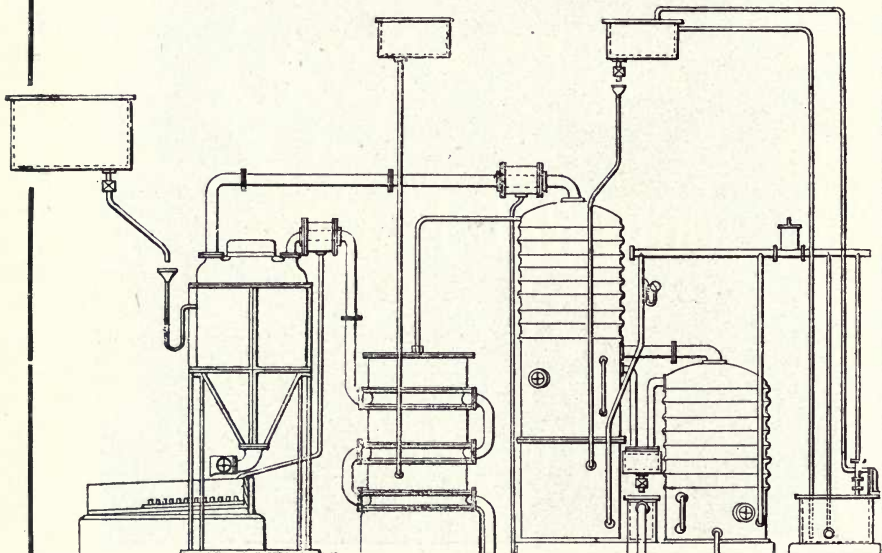
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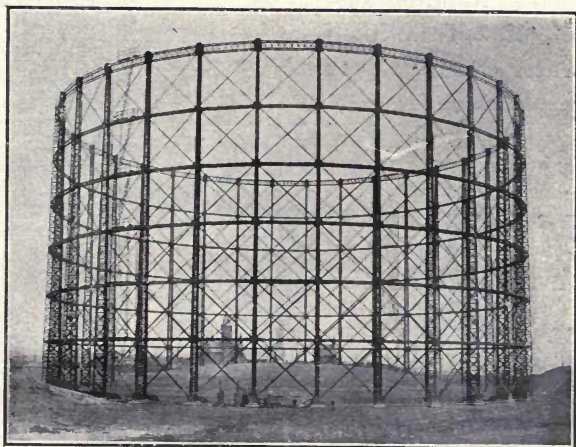
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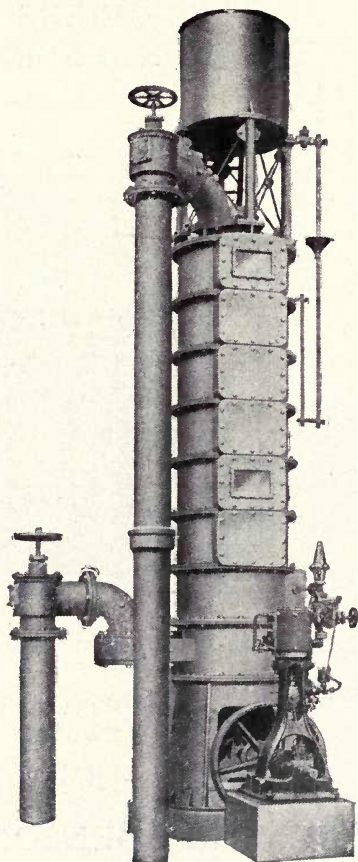
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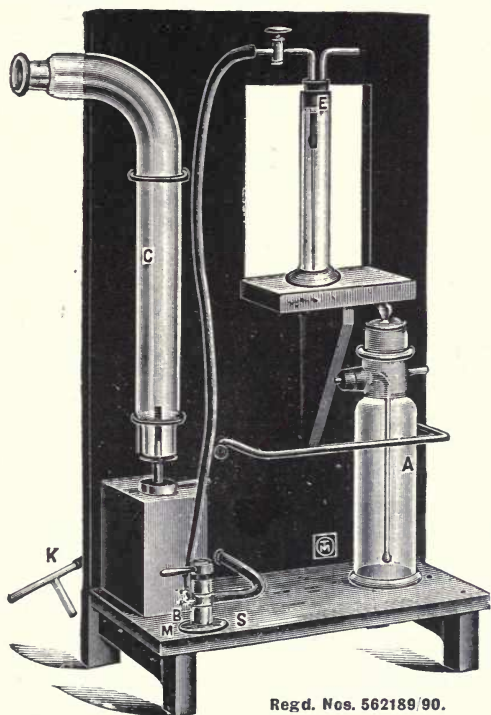
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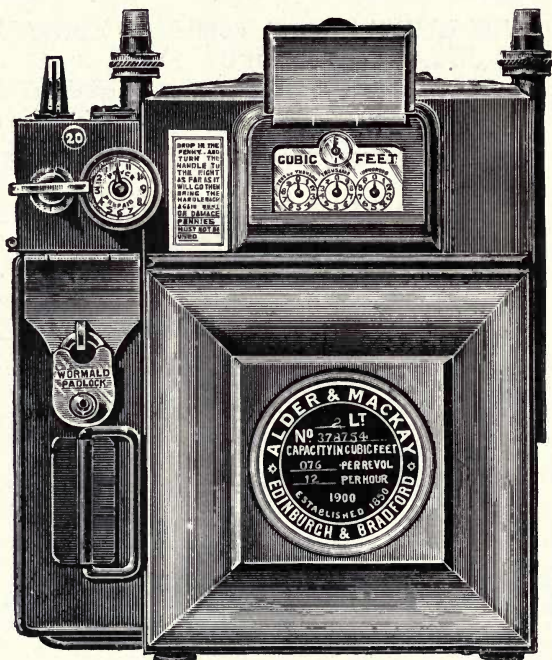
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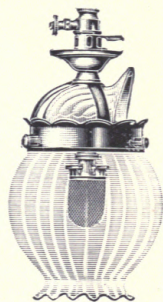
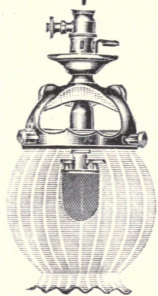
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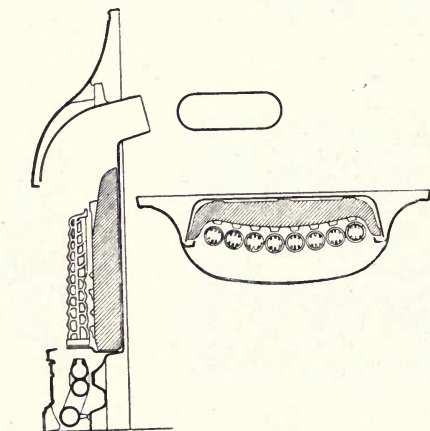
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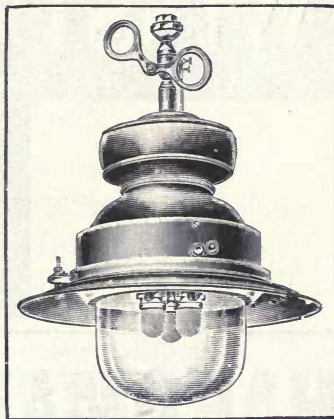
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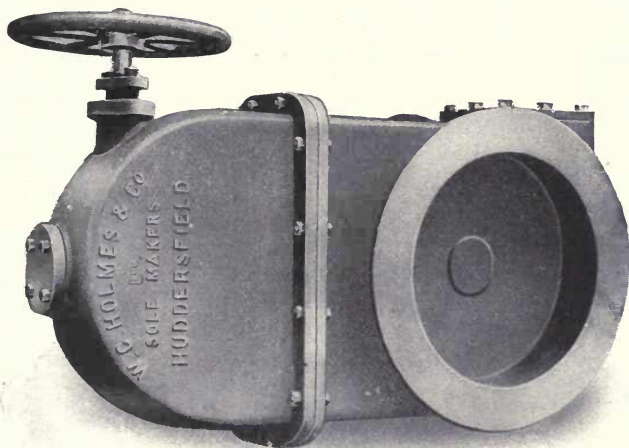
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U.G.I. CO., U.S.A.	690,600,000
Total ...	<u>994,500,000</u>

COMPARE with figures
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Newbigging's Handbook,
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	Cu. Ft. Daily
H. & G. Ltd. ...	145,980,000
U.G.I. CO. ...	381,000,000
Total...	<u>526,980,000</u>

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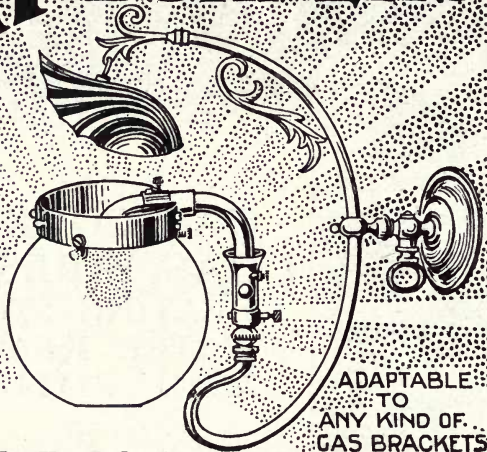
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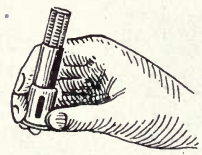
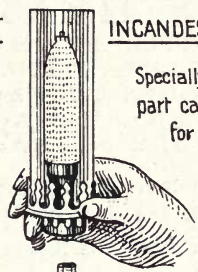
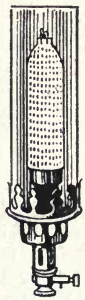
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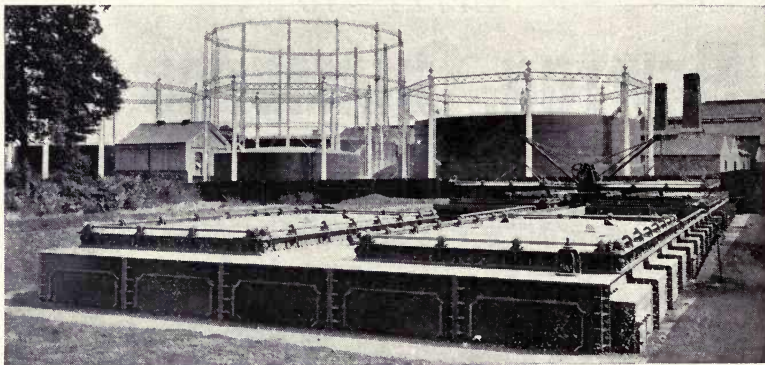
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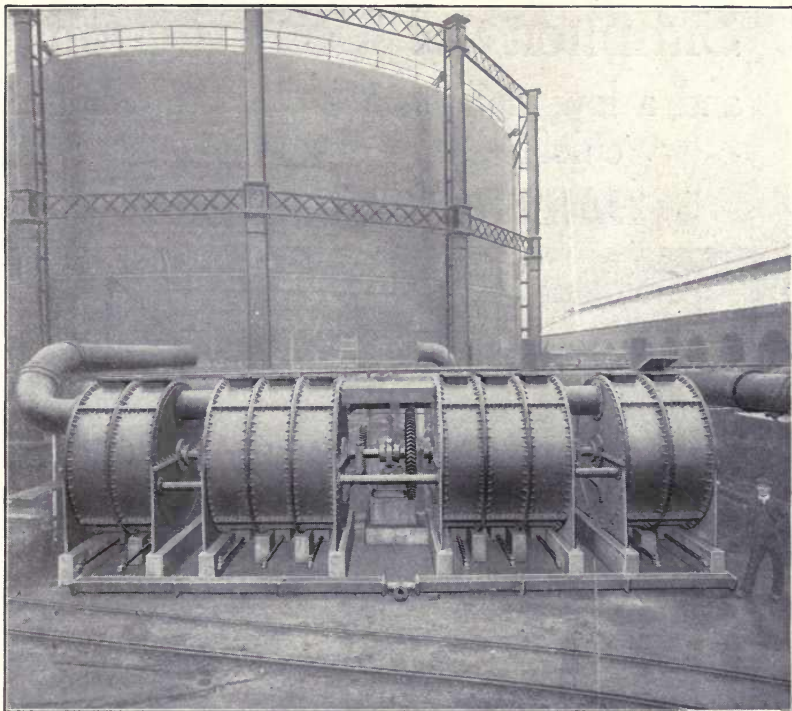
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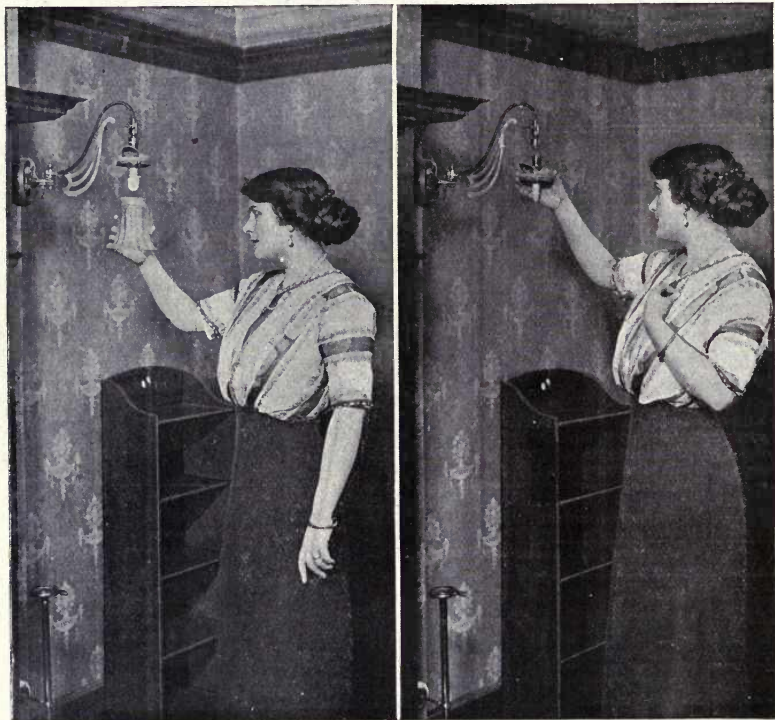
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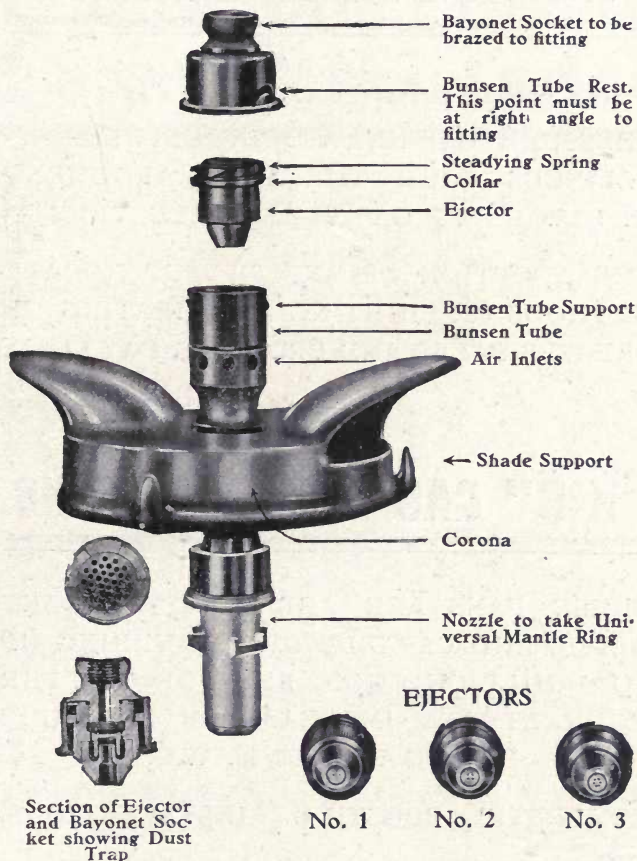
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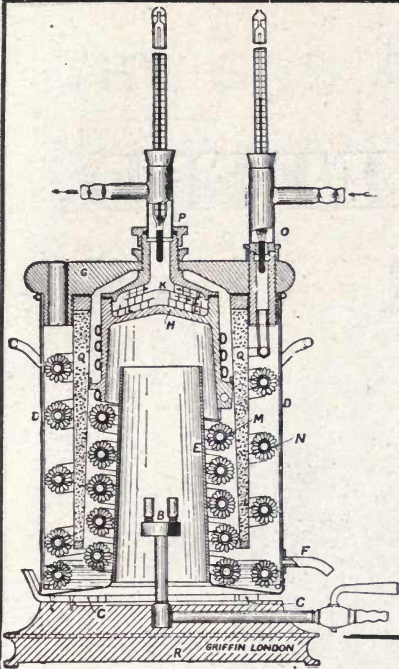
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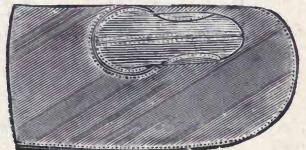
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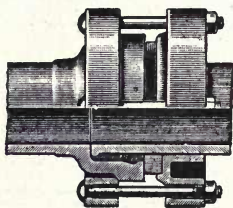
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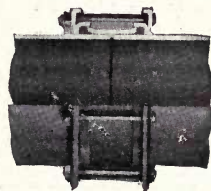
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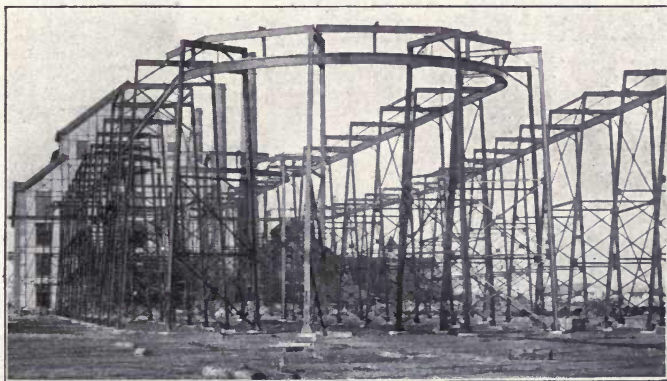


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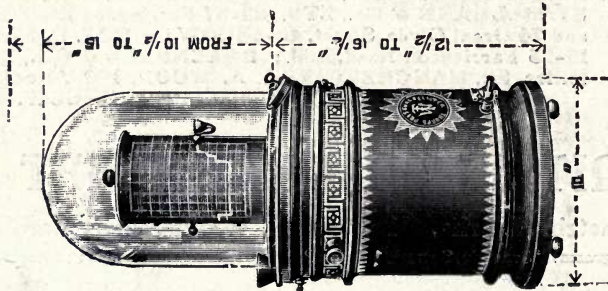
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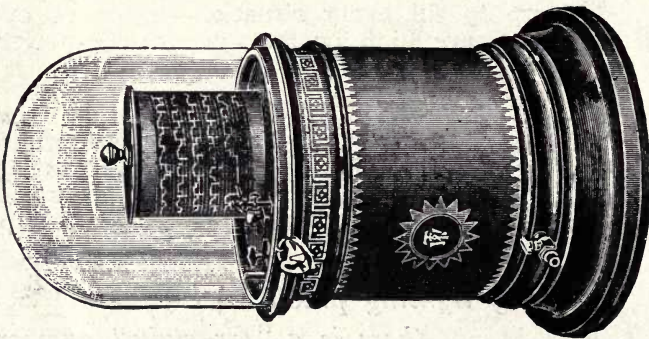
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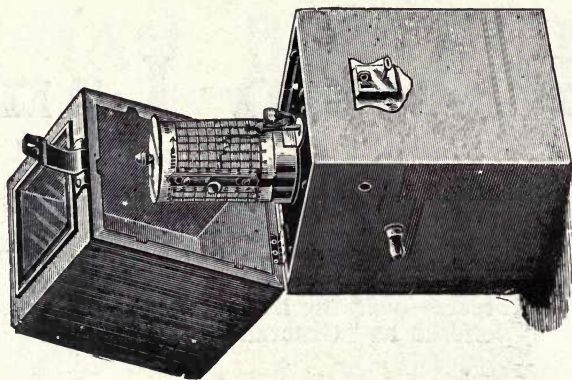
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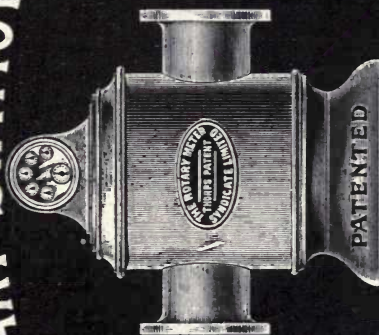


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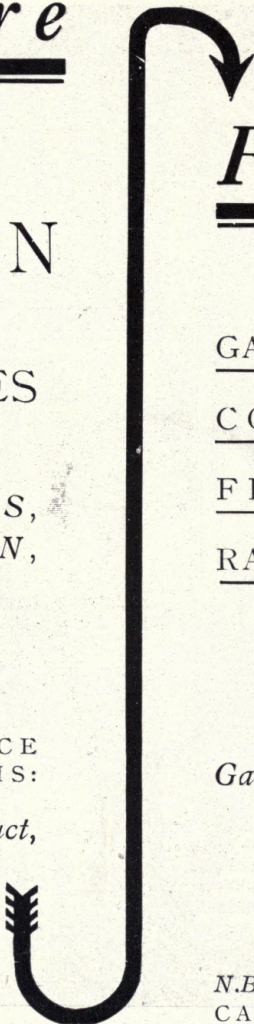
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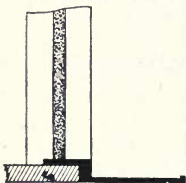


FIG. 1.

Dick's
Antithermic Cement
between Brickwork.

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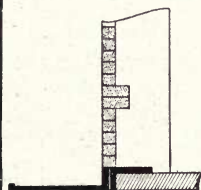


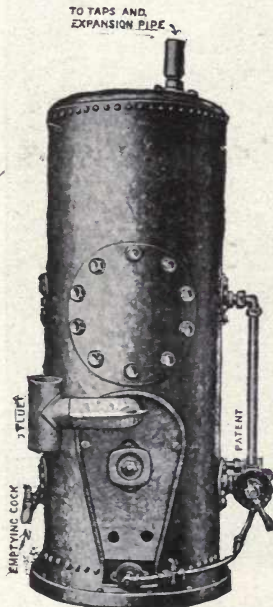
FIG. 2.

Dick's
Antithermic Bricks
on face of Brickwork
showing bonding.

GAS HEATED HOT WATER SUPPLY

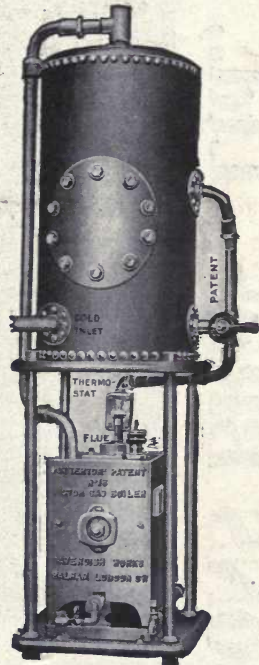
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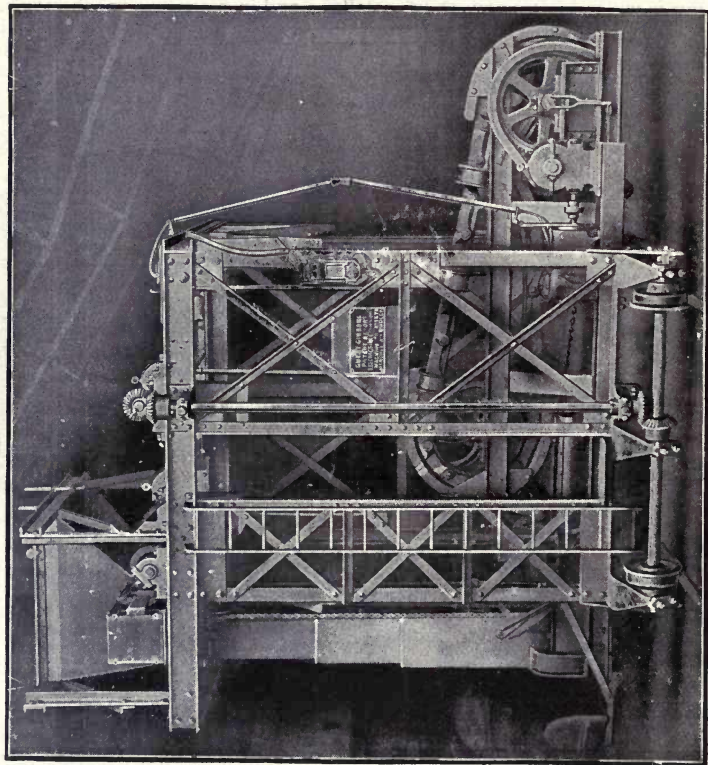
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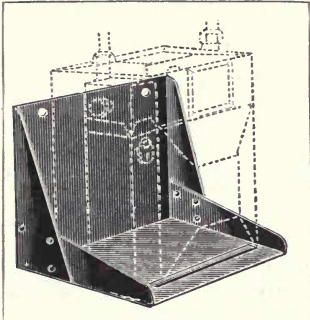
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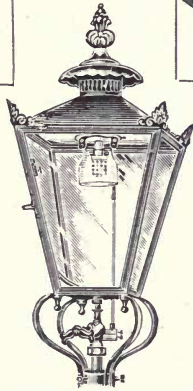
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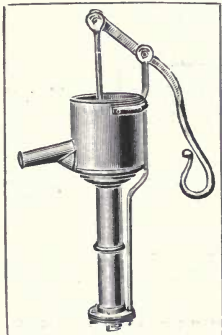
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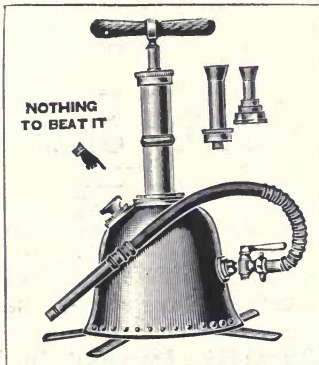
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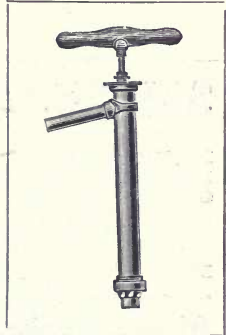
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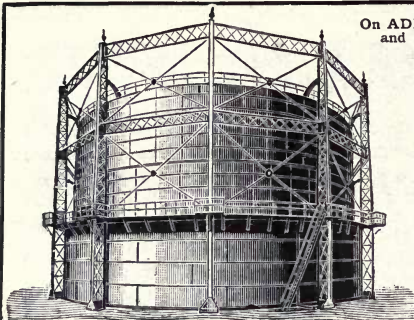
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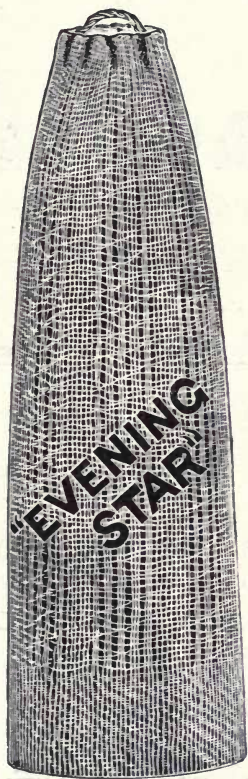
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